Characterisation of Agricultural Soils in Cascape Intervention Woredas in Southern Tigray, Ethiopia

Mekelle, March, 2015

Preface

The main goal of this is to identify, characterise and understand the qualities and behaviour of the major agricultural soils occurring in the 5 CASCAPE intervention woredas in the southern zone of the Tigray region. The soil survey will be the basis for developing site specific and functional soil information that would guide soil fertility management decisions by smallholder farmers. Moreover, it will help in scaling up and extrapolating soil-based results of experiments. The study also contributes to the development of the national/regional soil information database under EthioSIS by the generated locally specific soil information.

The work has been done from December 2013 to November 2014. We are greatly indebted to Dr. Eyasu Elias, Arie van Kekem (Alterra), Johan Leenaars (ISRIC) and Koos Dijkshoorn (ISRIC) for providing the initial concept of the survey. Their continuous support and guidance was invaluable during the whole process of the survey, and their very helpful comments and suggestions on the first draft of this report. Moreover, we sincerely wish to thank the CASCAPE Kebelle Agricultural development agents and farmers for providing information and for all round support they render during the course of the survey.

Amanuel Zenebe (PhD), Girmay Gebresamuel (PhD) and Atkilt Girma (PhD), March 2015

Acronyms and Abbreviations

CASCAPE	Capacity Building for Scaling up of Evidence-Based Best Practices in Ethiopia
CSO	Central Statistical Office
DTM	Digital Terrain Model
ISRIC	International Soil Reference and Information Centre
MCE	Metaferia Consulting Engineers
NCU	National CASCAPECoordination Unit
NEDECO	Netherlands Engineering Consultants
PRA	Participatory Rural Appraisal
NGOs	Non Governmental Organizations
SRTM	Shuttle Radar Topographic Mission
RVIADP	Raya Valley Integrated Agricultural Development Project
WUR	Wageningen University Research

Table of Contents

List of Figures

List of Tables

List of Appendices

1 Introduction

CASCAPE has entered into a collaboration agreement with the Government of Ethiopia (MoA/ATA) to assist *the Ethiopian Soils Information System (EthioSIS*) in various ways including soil characterisation study through conducting detailed soil profile studies and classification of agricultural soils in all 30 CASCAPE intervention woredas. This report presents results from five woredas of Tigray.

Objective

The goal of the conducted study is to characterise and understand the qualities and behaviour of the major agricultural soils occurring in the 30 CASCAPE intervention woredas based on properly observed and measured soil morphologic, physical and chemical properties.This will be the basis for developing site specific and functional soil information that would guide soil fertility management decisions by smallholder farmers. Moreover, this will help in scaling up and extrapolating soil-based results of experiments. The study also contributes to the development of the national/regional soil information database under EthioSIS by the generated locally specific soil information.

Specific objectives are:

- To survey soil variability and to identify major soil types in each woreda (4 kebeles per woreda) through auger observations (based on the outcome of preparatory base mapping including, the PRA results, farmers soil mapping) in relation todelineated major landforms.

- To characterise and classify the identified major agricultural soils by describing their morphological, physical and chemical properties through observations in soil pits, sampling and laboratory measurements.

- To develop general management recommendations (such as but not limited to fertilizer application, soil and water conservation, liming, etc., based on the above study and other available and/or recently collected soil data).

Scope

The study was conducted on the agricultural lands of 20 kebeles in 5 CASCAPE intervention woredas (4 kebeles per woreda) in Tigray region (Figure 1). Study has been carried out by Amanuel Zenebe, Girmay Gebresamuel and Atkilt Girma.

The scope of this report was on soil characterisation of five woredas Alaje, Enda Mokeni, Ofla, Raya Alamata and Raya Azebo of the regional cluster of Tigray as conducted by Mekelle University.

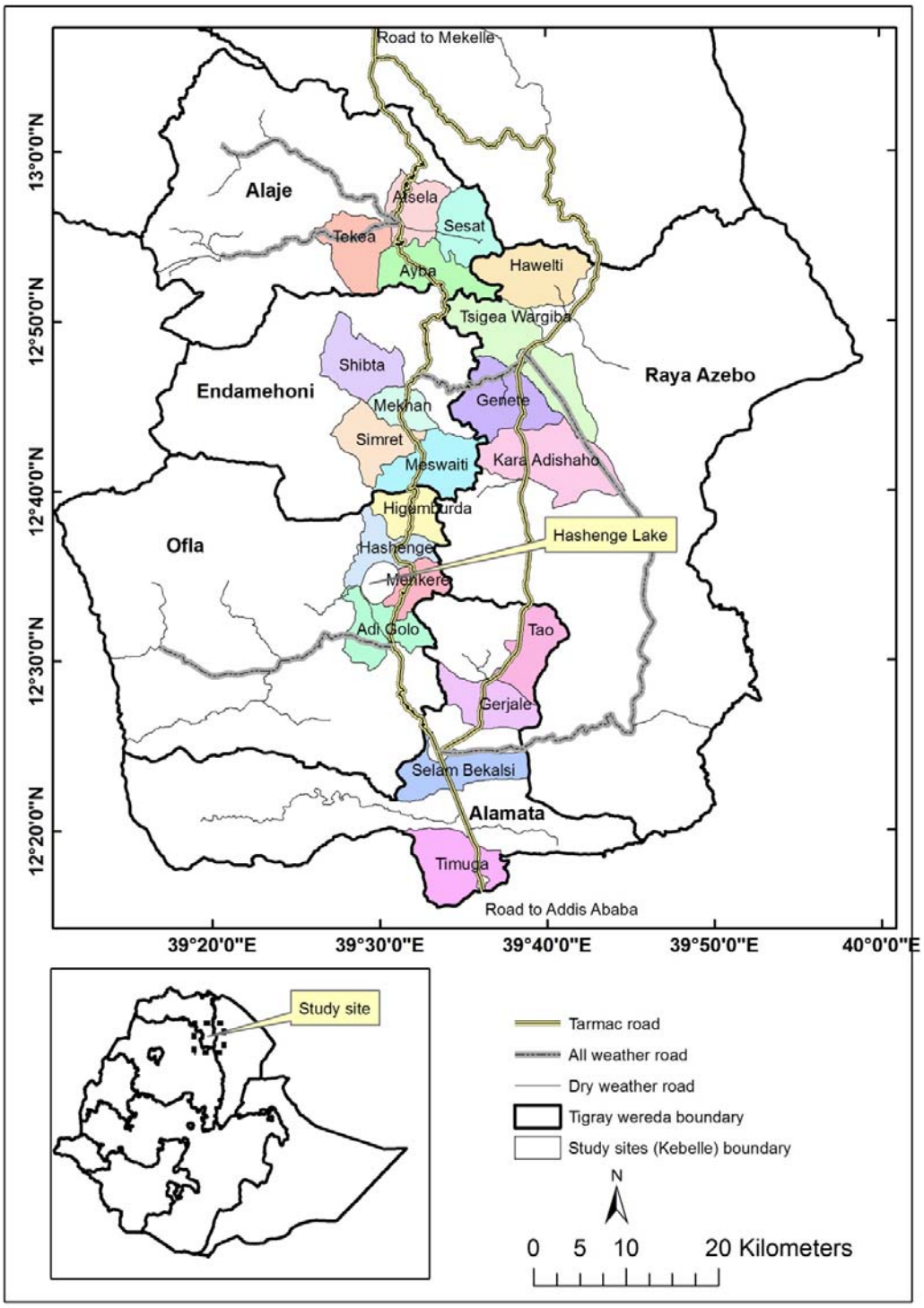


Figure 1: Location map of the 5 CASCAPE intervention woredas Alaje, Enda Mokeni, Ofla, Raya Alamata and Raya Azebo in the regional cluster of Tigray, including 20 Kebeles.

2 Materials and methods

The study involved the research elements and activities as described hereafter.

2.1 Preparation

- Secondary data collection

Existing secondary data were collected from various sources and compiled to produce the base map, geological map, and soil maps of the 20 keebelles of 5 woredas

- The woredas and the 4 kebeles per woreda;
- The location of the CASCAPE trial sites
- Topography and landforms (Google Earth, Shuttle Radar Topographic Mission (SRTM)) and ASTER GDEM 30m)
- Land cover / land use (agricultural lands)
- Geology from Hunting (1976) & Tefera etal.(1995)
- PRA results 2011 (participatory soil maps); obtained (shapefiles) with regional CASCAPE coordinators
- Regional soil maps (1:250,000); soil map obtained from BoPED's, with attribute data tables and profile data
- SoTer (Soil and Terrain) of IGAD (FAO, 1998) at 1: 1 mln and original Soil and Geomorphology map of Ethiopia (FAO, 1984) at 1:1 mln; shared by ISRIC.

ISRIC provided shapefiles (and kmz files for for use in Google Earth) of the woredas in combination with the 1998 SoTer files (including mapping units with information about the major landform, geology and others and the proportions of occurring soil types, at 1: 1 mln, together with scanned (not GIS files) of the corresponding original 1984 soil map, and an extract out of the Africa Soil Profiles database (Leenaars, 2013). Additional data and information sources included the Ministry of Water Resources (river basin studies), Ministry of Agriculture, Agricultural Transformation Agency (ATA), EthioGIS (Water and Land Resources Center), Atlas of Ethiopia (IFPRI); assessed centrally, and universities and the ISRIC library. Johan Leenaars and Koos Dijkshoorn from ISRIC assisted and gave guidance when needed.

- **Base map preparation**

The major landforms of the study sites including their surrounding areas were mapped according to the FAO (2006) legend (Table 1), and the manual of Dobos et. al (2005) and ISRIC report (2008/04) using SRTM 90 meters resolution. The freely available ASTER GDEM 30 meters resolution was not of good quality and resulted to have several stripping after processing for slope as well as relief intensity. Thus, it was not used for analysis but for 3D display only (Figure 2). According to the manual and FAO (2006), Slope gradient, Relief Intensity and Potential Drainage Density (PDD) map was generated.Drainage density map was first derived,from the SRTM 90 m, using ArcGIS ArcHydro tool or extension to a visual reasonable detail that match google earth drainage was considered. The DEM (SRTM) image was

reconditioned using a manually digitized drainage (major) lines from Google earth. Second the slope gradient (%) map was generated using ArcGIS and reclassified to 4 classes (<10 %, 10 to 15 %, 15 to 30 %, and > 30 %). The second class (10-15%) was generated to specifically find out Sloping areas with medium- gradient slopes (SM). Because this class is not in the Table 1 description but exists implicitly when 10-30 % and 15-30% classes are mentioned. FOCAL MAJORITY function with a 4 cells radius circle was applied to the slope because the resulting grid still had some salt and pepper effect, having a mixture of stand-alone cells or small contiguous areas.These slope classes were re-coded as 10, 20, 30 and 40.

Table 1: Hierarchy of major landforms (FAO, 2006)

1st level	2nd level	Gradient	Relief intensity	Potential drainage density
		(%)	(m km-1)	
L level land	LP plain	< 10	< 50	0–25
	LL plateau	< 10	< 50	0–25
	LD depression	< 10	< 50	16–25
	LV valley floor	< 10	< 50	6–15
S sloping land	SE medium-gradient escarpment zone	10–30	50–100	< 6
	SH medium-gradient hill	10–30	100–150	0–15
	SM medium-gradient mountain	15–30	150–300	0–15
	SP dissected plain	10–30	50–100	0–15
	SV medium-gradient valley	10–30	100–150	6–15
T steep land	TE high-gradient escarpment zone	> 30	150–300	< 6
	TH high-gradient hill	> 30	150–300	0–15
	TM high-gradient mountain	> 30	> 300	0–15
	TV high-gradient valley	> 30	> 150	6–15

Next, the Relief intensity (meter per Km) map was generated under ArcGIS environment using Focal Range with circular neighborhood with a radius of approximately 1 Km. An average statistics was computed for each pixel to derive the Relief Intensity map. To obtain a per km relief intensity map the SRTM was resampled to a block size of 990 meters (approximately a km; 5 cells radius or 11 cells diameter = 990 metres diameter circle). The RI map was resampled before it is classified to smoothout the map. The relief intensity map was later classified in to 5 classes (<50, 50-100,100-150,150-300, and >300). These five classes were re-coded to 1, 2, 3, 4, and 5. Adding the two steps code resulted in the first level categories of the major landforms. For example adding <10% slope (coded 10) with relief intensity <50 m/km (coded 1) would result in 11. Thus, 11 is now under the category of level land (1st level). To find the second level it is a little bit tricky because LP and LL has the same, gradient, relief intensity as well as potential

drainage, description according to the FAO (2006) (Table 1). The combined map above was overlayed on to the potential drainage density map and visually assessed. The output from these was manually digitized to avoid automatic individual pixel classes rather than the eliminating them. Level plain and high gradient mountains were the easiest automated results. Moreover, choosing a radius for the circle to count drainage cells as well as choosing class limits for the reclassification of the continuous with automatic procidures will be subjective still. Thus, given the size of the study area and differences in the complexity of PDD we opted to visually decide on the potential drainage density.

Defined and delineated 'major mapping units' (based on major landforms and geology) and 'minor mapping units' (based on the positions on the typical topo-sequence of the major landforms and on auxiliary information as soil maps, PRA study, land use, location of trial sites, etc.), together with the anticipated soil types per hypothesised mapping units, projected upon the topographic map. The results are given in sections 3.4, 3.5, 3.6, 3.7 and 3.8.

- **Soil map preparation**

To prepare the soil map first the auger hole locations with their soil and related attributes, soil profile locations and their attributes, the prepared base map, the woreda and the Kebelle boundaries were converted in to KML (Google earth file format) and superimposed on the 3D view of google earth image.The soil naming (description) for the test pits was finalized after soil laboratory analysis result.Taking into account our field experience, auger and test pit locations, a soil boundary was digitized for each study area. The digitized map was improved after additional field work and augering. Soil map was created by manually digitizing polygons in Google earth. This was later imported in to ArcGIS and topology was built and attributes filled including area of each polygons. Final summary statistics was generated using pivot table function under Micro-soft Excel.

2.2 Field work

An exploratory soil survey (reconnaissance) is conducted in the 4 CASCAPE kebelesfor each woreda through road cuts, other visible means (soil surface colour; rock outcrops/stoniness) and soil auger descriptions. Following the base map, point locations for soil observation were identified, georeferenced by GPS and augered. Augers were described according to the standard description form following the guidelines for soil profile description (FAO, 2006), to a depth of at least 120 cm (bedrock permitting) with a minimum of 8 augers per kebele (also near trial sites). Auger description forms were provided by ISRIC. The exploratory soil survey led to the identification of the different major soil types, and their respective proportions, in each kebele and woreda and on each topo-sequential position of each major landform.

Detailed characterization of soil profiles (soil pits) that are representative for the distinguished major soil types were collected as follows:

- Following the exploratory soil survey and the identified major soil types, representative point locations for detailed observation were identified, georeferenced by GPS and opened as soil pits. The opened soil profiles were described in detail according to the standard description form provided by WUR following the guidelines for soil profile description (FAO, 2006), designating master horizons with subordinate characteristics to a depth of at least 180 cm (bedrock permitting), for on average 6 soil pits per woreda (minimally 4, maximally 8). The locations of the soil pits are not necessarily evenly distributed over all 4 kebeles but over all major soil types.
- The designated soil horizons of the soil pits were sampled (at least 1 kg per sample) for soil analysis, with on average 4 (2-10) samples per profile; bewaring of cross-contamination. Two samples were taken from thick horizons (sample area should never extend more than 30 cm). The 128 samples were properly labeled and taken to soil laboratory of Mekelle University and prepared for physico-chemical analysis by Mr. Asay Kidanu under close supervision of the consultant.

2.3 Back to office

- **Soil laboratory analysis**

128 soil samples were submitted to Mr. Yohanes Belete a soil laboratory expert in Water Works Design and Supervision Enterprise, Addis Ababa-lab service sub process, soil fertility section (domestically identified by Dr Eyasu of the NCU). Physico-chemical analysis was done by Key soil parameters including soil texture, gravel content, pH H2O, EC, organic C, total N, available (Olsen)-P, CEC and exchangeable bases (K, Ca, Mg, Na) were analyzed in this laboratory. The consultant collected the results from the lab, and shared the results with NCU and in this report. The results are given in Annex 2 and the statistical summary of the major soils is also shown in Figure 3A for Vertisol (n=16), 3B for Cambisol (n=8), 3C for Fluvisol (n=3) and 4D for Regosol (n=1).

- **Data processing**

The profile data collected from augers and soil pits (site data and morphological, chemical and physical horizon data) were compiled in a database. The format of the data base was provided by ISRIC (tailored adaptation of the Africa Soil Profiles database). Data compilation was followed by data analysis including error checking. Preliminary soil classifications were verified against analytical data and the profiles are classified according to WRB2006. The results are given in Annex 2.

- **Report writing**

A report was written per woreda and includes:

- A synthesis (of the cluster and the woreda)
- A description of the soil-landscape, including distinguished major landforms & geology, topo-sequential positions per major landforms and the major soil types, including proportions, per topo-sequential position. Included with this section are a soil-landscape map and sketches of the typical topo-sequences with associated soil types.

- A full characterization of the representative soil profiles (soil pits), including a summary of the whole profile, a description of the profile site and morphology and tables of morphologic and analytical data, with reference to the classified major soil type and soil-landscape unit.
- Auger profile descriptions, including GPS readings, were annexed with reference to the corresponding major soil type, and possibly soil-landscape unit.
- Agronomic observations and main management implications of the soil properties were discussed for each soil type, with emphasis on the relevance for making soil type specific soil fertility management recommendations.
- The match/mismatch between farmers' perceptions and classification of soils with scientific classification was explored and discussed in order to recommend appropriate management strategies.

- **Sharing of results**
  - Before and at the beginning of the fieldwork, the regional CASCAPE team made available one agronomist/natural resources specialist to assist the consultant in obtaining the results of the PRA, to introduce the consultant to the woreda officials and to accompany the consultant during fieldwork. In that way at least one innovator of the regional team learned about soil – landform – crop performance relationships.
  - Workshop with field excursion for regional CASCAPE teams
    - This workshop will take place after the draft reports have been written and commented upon by WUR (ALTERRA-ISRIC).
  - Nationally; to be determined (not part of this TOR).

The data and information collected, compiled and reported will also serve to support the other EthioSIS objectives and soil fertilizer recommendations as set out in the beginning of this document.

3 Results

3.1 Description of the environment

- **Location, infrastructure, elevation and population**

The CASCAPE project area is located in Southern zone of Tigray National Regional State. Its western and eastern boundaries are geographically located at 39°25'52"E and 39°44'50"E longitudes, respectively and its northern and southern boundaries at 12°15'28" N and 12°59'21" N latitudes respectively. The study area consists of 20 kebeles in 5 woredas.

The project area (Figure 1 & 2) can be accessed in two ways from Addis Ababa or Alamata town to Mekelle through the rugged mountains of Ofla, Endamekoni and Alaje woredas, and the second way is through the lowlands of Raya Alamata and Mohoni town of Raya Azebo woredas along the Western marginal escarpment of the Rift valley of Ethiopia.

The Tigray population mainly belongs to the Semetic ethnic group. 95.5, 4.1 and 0.4% of the rural population of Tigray are Orthodox, Catholic and Muslims, respectively (CSO, 1995). The population density of Tigray, with a population of 4.5 million and an area of 54,000 square kms, is 84 individuals per square kilometers.

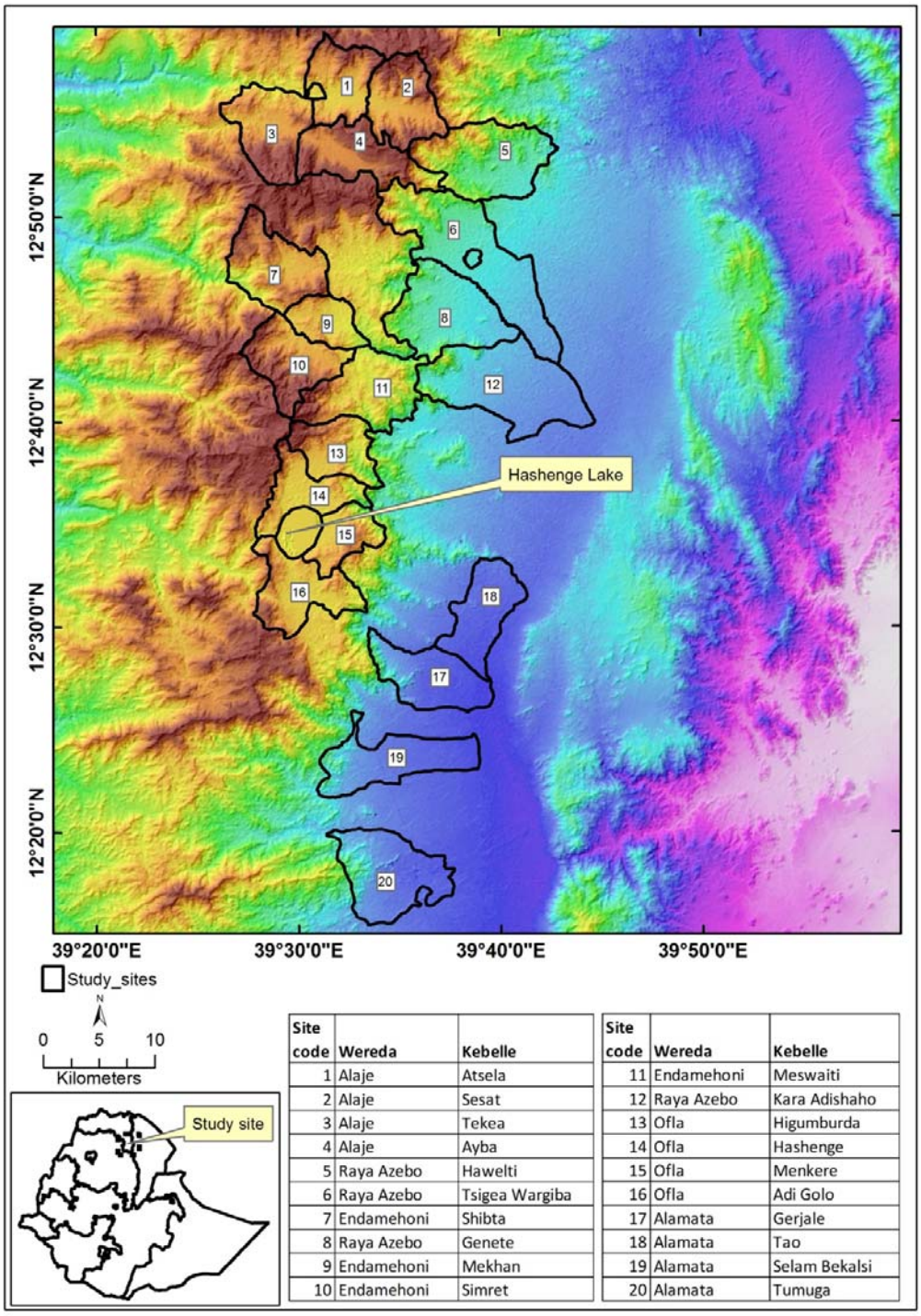
- **Elevation**

The elevation of the study area is given per kebele in Table 2 and ranges between 1404 and 3924 m.a.s.l and is on average 2284 m.The study area in general is not level land except for the eastern part. The highest elevation (3924m) is found at Tekaa Kebele of Alaje woreda and the lowest is found at Gerjele kebele of Raya Alamata woreda (1404 m). The study area is located at the head waters of the Denakil River basin.

Table 2: The elevation per woreda and Kebele

Woreda	Kebele	Elevation (m above sea level)		
		Min	Max	Mean
Alaje	Atsela	2408	3545	2704
	Ayba	2130	3848	2889
	Sesat	2509	3488	2826
	Tekea	2270	3924	2846
		2130	3924	2824
Endamekhoni	Mekhan	2142	2932	2504
	Meswaiti	1781	3693	2475
	Shibta	2146	3350	2688
	Simret	2303	3688	2895
		1781	3693	2647
Ofla	Adi Golo	1932	3066	2572
	Hashenge	1917	3394	2511
	Higumburda	1955	3608	2584
	Menkere	1942	2869	2529
		1917	**3608**	**2548**
Raya Alamata	Gerjele	1404	2208	1518
	Selam Bekalsi	1409	2012	1551
	Tao	1411	1611	1455
	Tumuga	1426	2129	1565
		1404	**2208**	**1527**
Raya Azebo	Ebo	1702	3217	2120
	Genete	1642	2475	1858
	Kara Adishaho	1517	2360	1669
	Tsigea Wargiba	1582	2982	1895
		1517	**3217**	**1873**
Study Area		**1404**	**3924**	**2284**

Figure 2 gives a map of the elevation in the kebeles of the study area; it clearly shows a pattern of high elevation with sloping to steep land in the west and low elevation with more level land in the east. More or less N-S runs the escarpment, part of the main valley, separating the high and lower areas. The maximum difference in altitude between E and W is about 2500m.



Site code	Wereda	Kebelle
1	Alaje	Atsela
2	Alaje	Sesat
3	Alaje	Tekea
4	Alaje	Ayba
5	Raya Azebo	Hawelti
6	Raya Azebo	Tsigea Wargiba
7	Endamehoni	Shibta
8	Raya Azebo	Genete
9	Endamehoni	Mekhan
10	Endamehoni	Simret

Site code	Wereda	Kebelle
11	Endamehoni	Meswaiti
12	Raya Azebo	Kara Adishaho
13	Ofla	Higumburda
14	Ofla	Hashenge
15	Ofla	Menkere
16	Ofla	Adi Golo
17	Alamata	Gerjale
18	Alamata	Tao
19	Alamata	Selam Bekalsi
20	Alamata	Tumuga

Figure 2: Elevation map of the study area

- **Climatic characteristics and data**

Tigray belongs to the African dry lands, called the Sudano-Sahelian region (Warren and Khogali, 1992). The climate of Tigray may be described as a sub-tropical continental type with extended dry period of nine to ten months and a maximum effective rainy season of 50 to 60 days (Hunting, 1975). The Southern Tigray has generally a bimodal rainfall.

The climatic data used for this study is obtained from the FAO-NewLocClim database. Maychew and Alamata stations were selected to represent the highlands and lowlands respectively. The highlands constitute a large part of Alaje, Endamehoni and Ofla woredas, whereas the lowland includes the Raya Alamata and Raya Azebo woredas.

Rainfall

The project area has a bimodal rainfall pattern. The short rain comes in March-May and the main rain is July-September and the two periods are connected by little rain in June in the highlands represented by Maychew climatic data. April is the peak period of the small rain (92 mm) and August is the peak for Kiremt (main rain) rain, which amounts 211mm for the highlands (Figure 3).

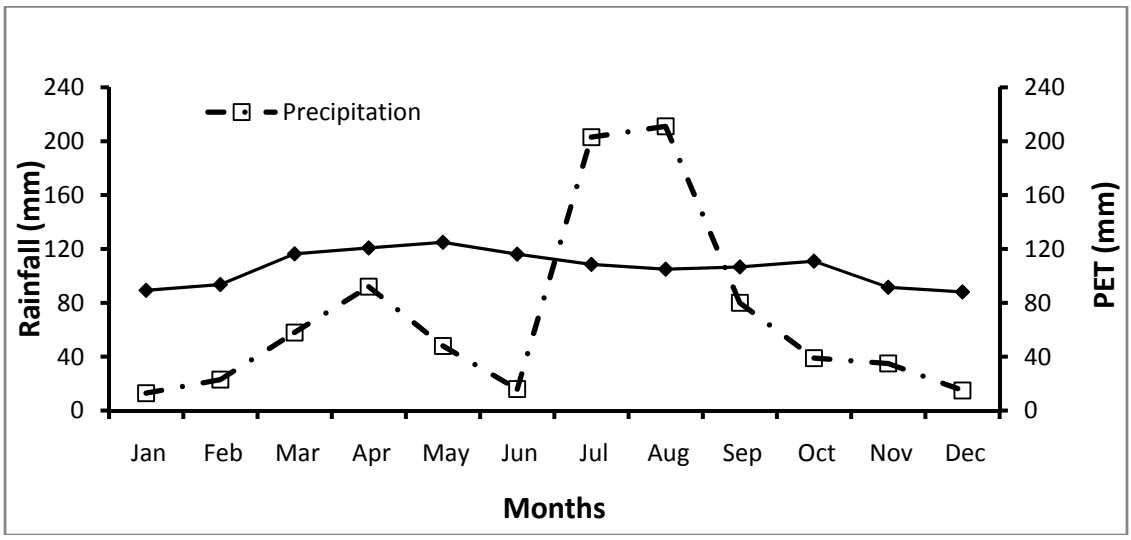


Figure 3. Monthly rainfall and potential evapotranspiration (PET) of Maychew Climatic station from LocClim database (own processing)

Whereas in the lowland woreda (Raya Alamata and Azebo woredas), which represented by Alamata station March is the peak period of the small rain (195 mm) and August is the peak for Kiremt (main rain) rain, which amounts 180 mm for the highlands.
The bimodal pattern is reflected in one growing season for the highlands & two growing seasons for the lowlands (Figure 4). Information from locClim analysis

revealed that there is only one rainy season for the highlands and two rainy seasons for the lowlands. However, farmers believe that there were two seasons in the study area, and are being changed to one season nowadays.

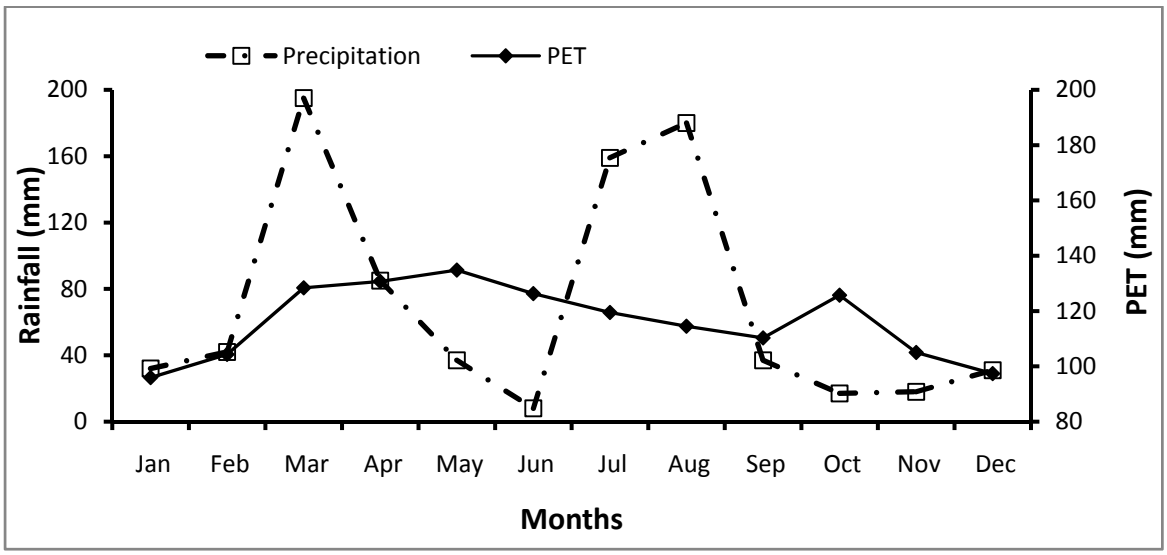


Figure 4. Monthly rainfall and potential evapotranspiration (PET) of Alamata Climatic station from LocClim database (own processing)

The long-term meteorological data indicated that: the highlands represented by Climatic Maychew station receives mean annual rainfall of 833mm with annual potential evapotranspiration (PET) of 1272mm, and the annual net water balance (rainfall minus PET) amounts 439mm, whereas, the annual rainfall and PET for the lowlands is 841mm, and 1393mm respectively, and the annual net water balance is 552mm.

Temperature

The mean annual monthly temperature of Maychew staton (Alaje, Endamehoni & Ofla woredas) ranges between 8 and 25 ^{o}C. Raya Alamata and Raya Azebo woredas have a mean monthly temperature that ranges between 14 to 30^{o}C (Figure 5).

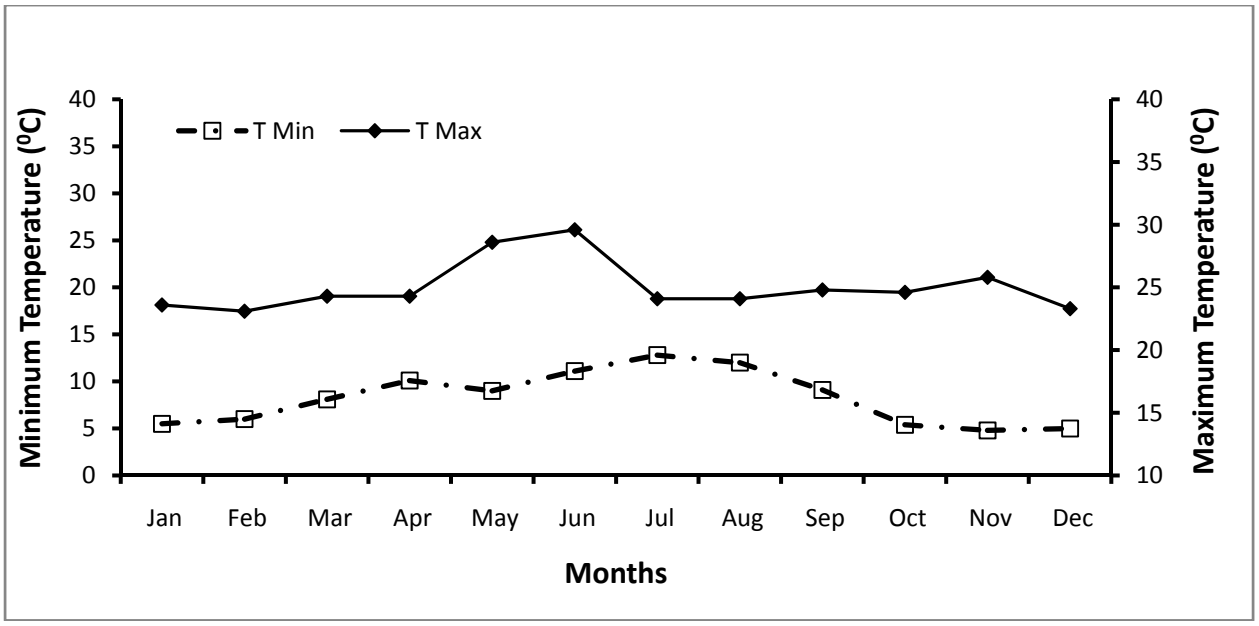


Figure 5. Monthly minimum and maximum temperature of Maychew climatic station from LocClim database (own processing)

In Raya Alamata and Raya Azebo valley woredas the lowest temperature occurs during January (11.5°C) and the highest temperature in June (35°C). Whereas, the minimum and maximum temperatures are 5.5 and 29.6°C in January and June respectively. Mean annual minimum and maximum temperature is 8 and 25°C respectively (Figure 6).

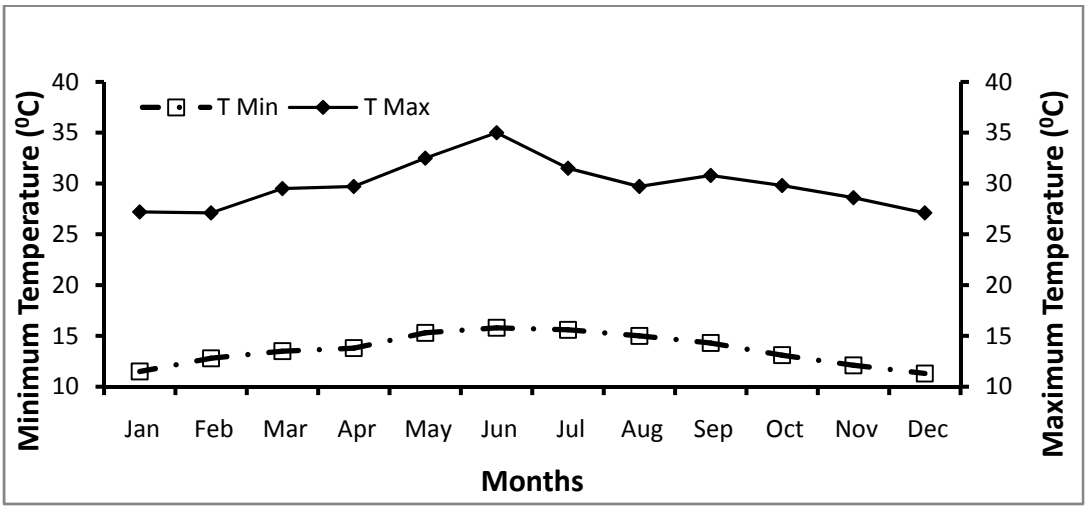


Figure 6. Monthly minimum and maximum temperature of Alamata climatic station from LocClim database (own processing)

- **Hydrology**

A number of large and small streams draining from the mountains and hills of southern Tigray flow to the low-lying flat to undulating plain. Most of the streams are intermittent and flow only during the rainy season. Indigenous and recently introduced small-scale flood irrigation schemes are widely introduced in the plains of the Raya Alamata and Raya Azebo valley woredas. Irrigation from groundwater is also practiced in some parts (the graben valley) of the Raya area. Perennial springs are also used in the whole parts of the escarpment for maturing cereals such as maize.

- **Overall land use and vegetation**

The present land uses are generally rainfed agriculture, and livestock (grazing) (Figure 7 and Table 3).The rainfed cultivation is the main land use in Southern Tigray and flood irrigation is also practised in many parts of the Graben Valley by diverting flood from the stream during the rainy season and from dams or ponds during the dry season. According to the RVIADP (1998), mostly flood irrigation is used for late maturing crops such as sorghum in the Raya Valley. Perennial springs are also used in the whole parts of the escarpment for maturing cereals such as maize.

Alaje woreda is dominated by degraded shrubland, followed by rainfed agriculture. Endamoheni is dominated by rainfed agriculture followed by degraded shrubland and shrubland. The Ofla wereda is dominated by rainfed agriculture, degraded shrubland and shrubland with more or less the same proportions. The Raya Alamata and Raya Azebo woreda are dominated by rainfed agriculture and the former is followed by degraded grass land, and the later is followed by degraded shrubland.

Table 3: The Land cover of the study area

Woreda	land_use	Area (ha)	Percent
Alaje	Built-up Areas	171	1
	Degraded Shrub land	11106	62
	Homestead	1026	6
	Rainfed arable cultivation	5435	30
	Shrub land	150	1
Total		**17889**	**100**
Endamehoni	Built-up Areas	62	0
	Degraded Shrub land	4069	23
	Grass land	135	1
	Homestead	800	5
	Rainfed arable cultivation	8291	47
	Shrub land	4118	24
Total		**17475**	**100**
Ofla	Degraded Shrub land	3870	25
	Grass land	1273	8
	Homestead	1088	7
	Lake	1381	9
	Rainfed arable cultivation	4158	26
	Shrub land	3942	25
Total		**15712**	**100**
Raya Alamata	Built-up Areas	72	0
	Degraded Grass land	4454	22
	Grass land	530	3
	Homestead	1620	8
	Rainfed arable cultivation	12684	64
	Shrub land	516	3
Total		**19876**	**100**
Raya Azebo	Built-up Areas	178	1
	Degraded Shrub land	6244	20
	Homestead	3148	10
	Rainfed arable cultivation	16143	52
	Shrub land	5139	17
Total		**30852**	**100**

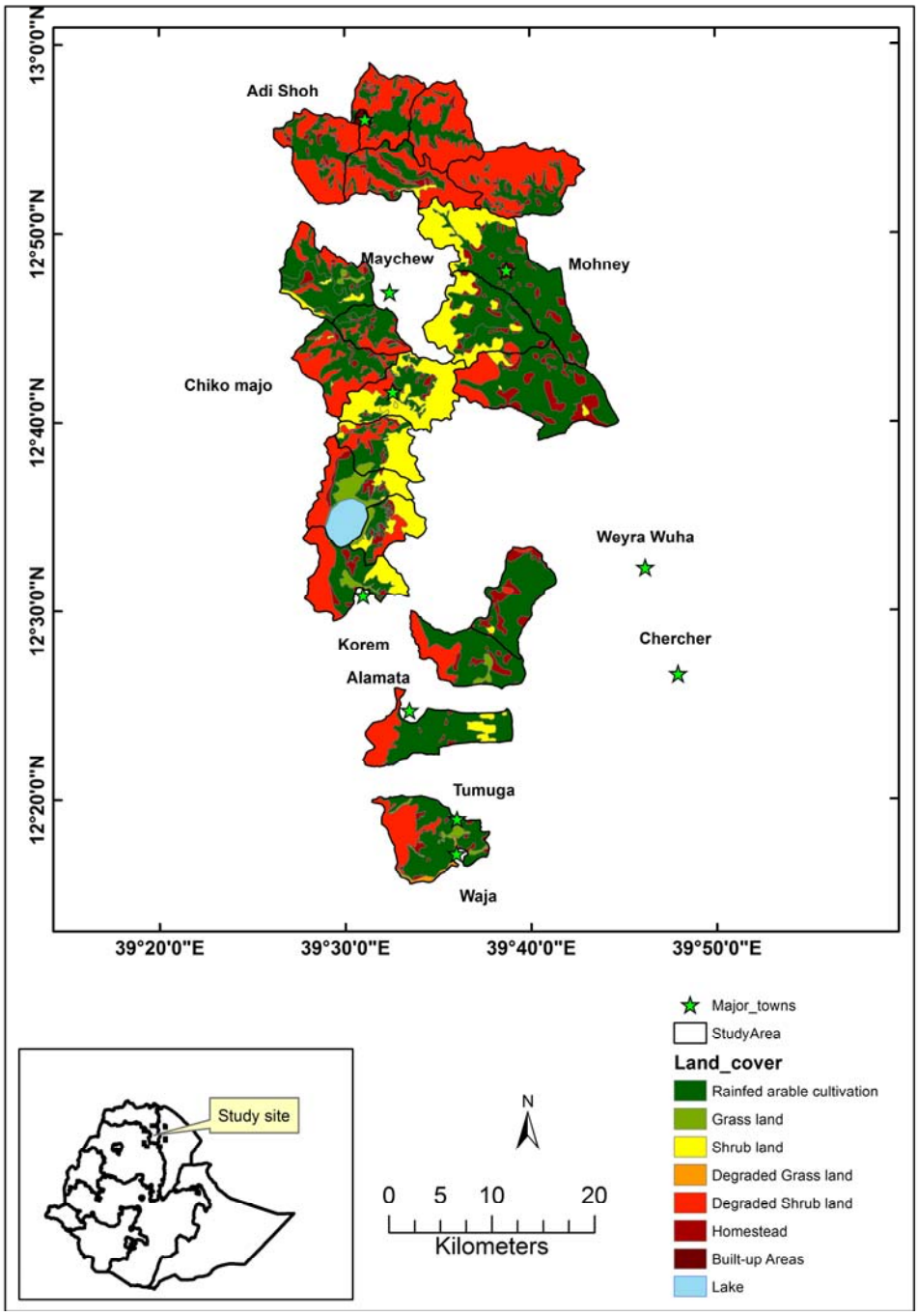


Figure 7. Land cover map of the study area

- **Geology**

The major geological formations occurring in the area can be broadly grouped into the trap volcanic and the alluvium (Figure 8 and Table 4). The geological structure to the east of the escarpment is complicated by north/south trending grabens separated by horsts (Hunting, 1976).

a) **Trap volcanic rocks:** The volcanic rocksconsist of thick basalt flowsof Tertiary age, which are deeply weathered, and which form dissected plateaux occupying most of the upland western part of the study area (mainly in Alaje, Endamokeni and Ofla woredas). Alluvial deposites are also found in these woredas, but they are not mappable at the mentioned scale.

b) **Alluvium:** Alluvium occurs as restricted fluvial terraces along the major rivers and depressional areas on dissected plateaus of the highlands, and as sheet flood deposits in the lowland plains of the graben valley in the east. Their texture is fairly coarse, with both sands and gravels occurring. Sheet flood alluvium consists of deposits of silt and occasional thin sands and occurs in the graben plains of Mohoni and Alamata plains.

Woreda	Geology	Area (ha)	Percent
Alaje	Trap volcanic rocks	17889	100
Endamehoni	Trap volcanic rocks	17475	100
Ofla	Trap volcanic rocks	15712	100
Raya Alamata	Alluvium	15703	79
	Trap volcanic rocks	4173	21
		19876	100
Raya Azebo	Alluvium	21276	69
	Trap volcanic rocks	9576	31
		30852	100

Table 4: The geology of the study area

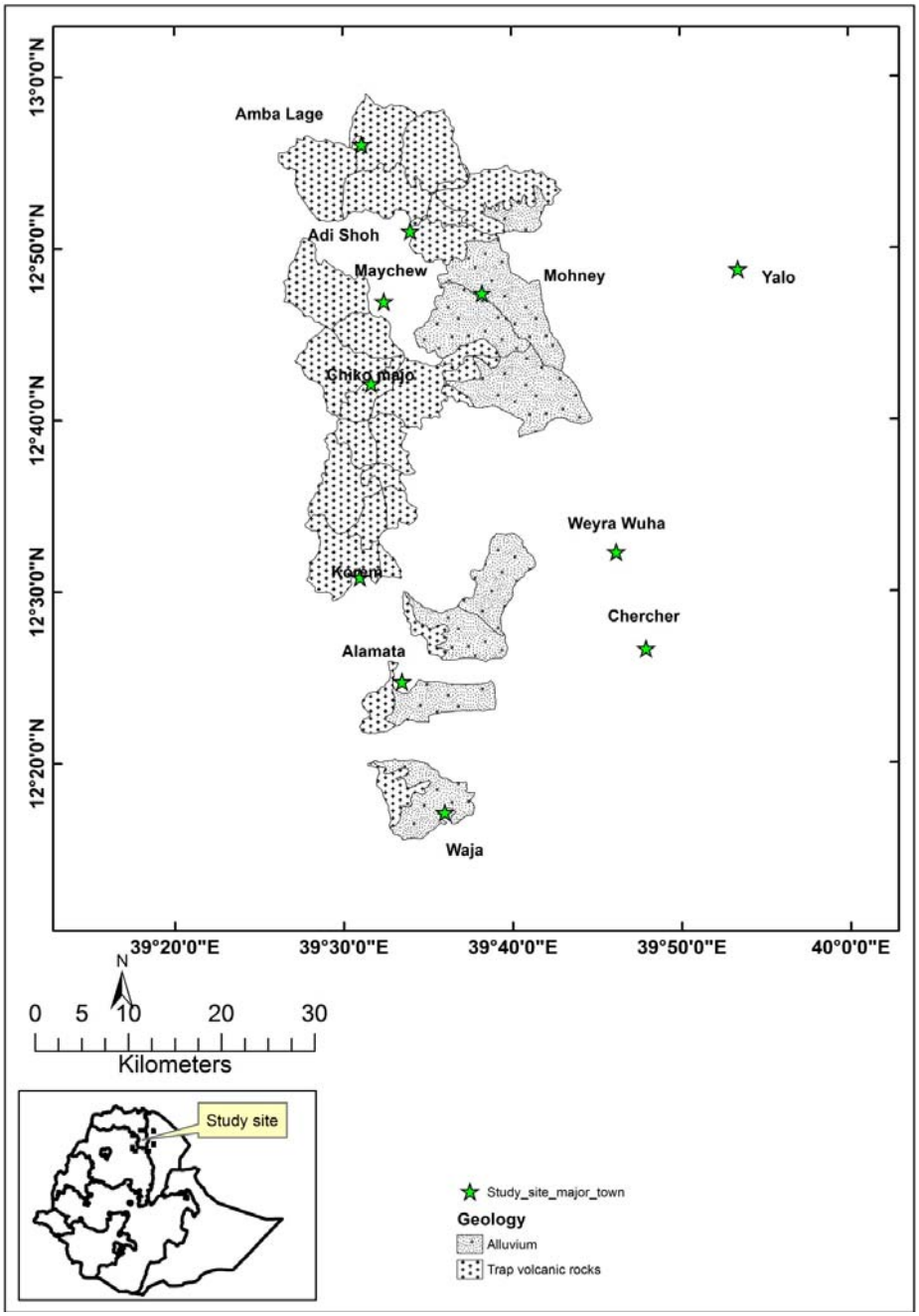


Figure 8: Geology map of the 5 CASCAPE intervention woredas Alaje, Enda Mokeni, Ofla, Raya Alamata and Raya Azebo in the regional cluster of Tigray, including 20 Kebeles.

3.2 Results of preparation and review of existing information

- **Preparation**

Previous studies in soil survey were reviewed (see section 2.1) and available information in geoogy, landforms and land cover were produced based on satellite imagery, maps and field observations. Finally a base map was produced based on the geological and landform maps (Figure 9 and Table 5).

The dominant land mapping unit is steep land,High-gradient mountain (TTM)-Trap volcanic rocks (TVR) (51%) and the scond dominant is sloping land,Medium-gradient escarpment zone (SSE)-Trap volcanic rocks (TVR) (30%) in Alaje woreda.

Endamehoni woreda is dominated by a land mapping unit steep land,High-gradient mountain (TTM)-Trap volcanic rocks (TVR) (49 %), followed by sloping land,Medium-gradient escarpment zone (SSE)-Trap volcanic rocks (TVR) (30%)

The dominant land mapping unit in Ofla woreda is steep land,High-gradient mountain TTM)-Trap volcanic rocks (TVR) (34%) and the second dominant unit is steep land,High-gradient hill (TTH)-Trap volcanic rocks (TVR) (12%) and Hashenge Lake accounts 9% of the woreda.

Raya Alamata and Raya Azebo woredas are dominted by Level land, Plain (LLP)-Alluvium (ALL), which accounts 64 and 43% respectively.

Table 5: Base (Land) mapping units of the study area

Woreda	Land Mapping Unit	Area (ha)	Percent
Alaje	Sloping land,Dissected plain(SSP)-Trap volcanic rocks(TVR)	285	2
	Sloping land,Medium-gradient escarpment zone(SSE)-Trap volcanic rocks(TVR)	5410	30
	Sloping land,Medium-gradient valley(SSV)-Trap volcanic rocks(TVR)	2662	15
	Steep land,High-gradient hill(TTH)-Trap volcanic rocks(TVR)	212	1
	Steep land,High-gradient mountain(TTM)-Trap volcanic rocks(TVR)	9081	51
	Steep land,High-gradient valley(TTV)-Trap volcanic rocks(TVR)	239	1
Total		**17889**	**100**
Endamehoni	Level land,Plateau(LLL)-Trap volcanic rocks(TVR)	48	0
	Sloping land,Dissected plain(SSP)-Trap volcanic rocks(TVR)	663	4
	Sloping land,Medium-gradient escarpment zone(SSE)-Trap volcanic rocks(TVR)	5169	30
	Sloping land,Medium-gradient hill(SSH)-Trap volcanic rocks(TVR)	600	3
	Sloping land,Medium-gradient valley(SSV)-Trap volcanic rocks(TVR)	1533	9
	Steep land,High-gradient escarpment zone(TTE)-Trap volcanic rocks(TVR)	640	4
	Steep land,High-gradient hill(TTH)-Trap volcanic rocks(TVR)	248	1
	Steep land,High-gradient mountain(TTM)-Trap volcanic rocks(TVR)	8572	49
Total		**17475**	**100**
Ofla	Lake	1371	9
	Level land,Depression(LLD)-Trap volcanic rocks(TVR)	1163	7
	Sloping land,Dissected plain(SSP)-Trap volcanic rocks(TVR)	772	5
	Sloping land,Medium-gradient escarpment zone(SSE)-Trap volcanic rocks(TVR)	1408	9
	Sloping land,Medium-gradient hill(SSH)-Trap volcanic rocks(TVR)	90	1
	Sloping land,Medium-gradient valley(SSV)-Trap volcanic rocks(TVR)	1615	10
	Steep land,High-gradient escarpment zone(TTE)-Trap volcanic rocks(TVR)	1230	8
	Steep land,High-gradient hill(TTH)-Trap volcanic rocks(TVR)	1892	12
	Steep land,High-gradient mountain(TTM)-Trap volcanic rocks(TVR)	5406	34
	Steep land,High-gradient valley(TTV)-Trap volcanic rocks(TVR)	765	5
Total		**15712**	**100**

Woreda	Land Mapping Unit	Area (ha)	Percent
Raya Alamata	Level land,Plain(LLP)-Alluvium(ALL)	12723	64
	Level land,Plain(LLP)-Trap volcanic rocks(TVR)	48	0
	Sloping land,Dissected plain(SSP)-Alluvium(ALL)	99	0
	Sloping land,Dissected plain(SSP)-Trap volcanic rocks(TVR)	287	1
	Sloping land,Medium-gradient escarpment zone(SSE)-Alluvium(ALL)	312	2
	Sloping land,Medium-gradient escarpment zone(SSE)-Trap volcanic rocks(TVR)	1761	9
	Sloping land,Medium-gradient hill(SSH)-Alluvium(ALL)	2502	13
	Sloping land,Medium-gradient hill(SSH)-Trap volcanic rocks(TVR)	458	2
	Steep land,High-gradient hill(TTH)-Alluvium(ALL)	24	0
	Steep land,High-gradient hill(TTH)-Trap volcanic rocks(TVR)	149	1
	Steep land,High-gradient mountain(TTM)-Alluvium(ALL)	41	0
	Steep land,High-gradient mountain(TTM)-Trap volcanic rocks(TVR)	1348	7
	Steep land,High-gradient valley(TTV)-Alluvium(ALL)	1	0
	Steep land,High-gradient valley(TTV)-Trap volcanic rocks(TVR)	122	1
Total		**19876**	**100**
Raya Azebo	Level land,Plain(LLP)-Alluvium(ALL)	13362	43
	Sloping land,Dissected plain(SSP)-Alluvium(ALL)	244	1
	Sloping land,Dissected plain(SSP)-Trap volcanic rocks(TVR)	569	2
	Sloping land,Medium-gradient escarpment zone(SSE)-Alluvium(ALL)	1860	6
	Sloping land,Medium-gradient escarpment zone(SSE)-Trap volcanic rocks(TVR)	2641	9
	Sloping land,Medium-gradient hill(SSH)-Alluvium(ALL)	4822	16
	Sloping land,Medium-gradient hill(SSH)-Trap volcanic rocks(TVR)	333	1
	Steep land,High-gradient escarpment zone(TTE)-Alluvium(ALL)	7	0
	Steep land,High-gradient escarpment zone(TTE)-Trap volcanic rocks(TVR)	127	0
	Steep land,High-gradient hill(TTH)-Alluvium(ALL)	191	1
	Steep land,High-gradient hill(TTH)-Trap volcanic rocks(TVR)	253	1
	Steep land,High-gradient mountain(TTM)-Alluvium(ALL)	790	3
	Steep land,High-gradient mountain(TTM)-Trap volcanic rocks(TVR)	5586	18
	Steep land,High-gradient valley(TTV)-Trap volcanic rocks(TVR)	67	0
Total		**30852**	**100**

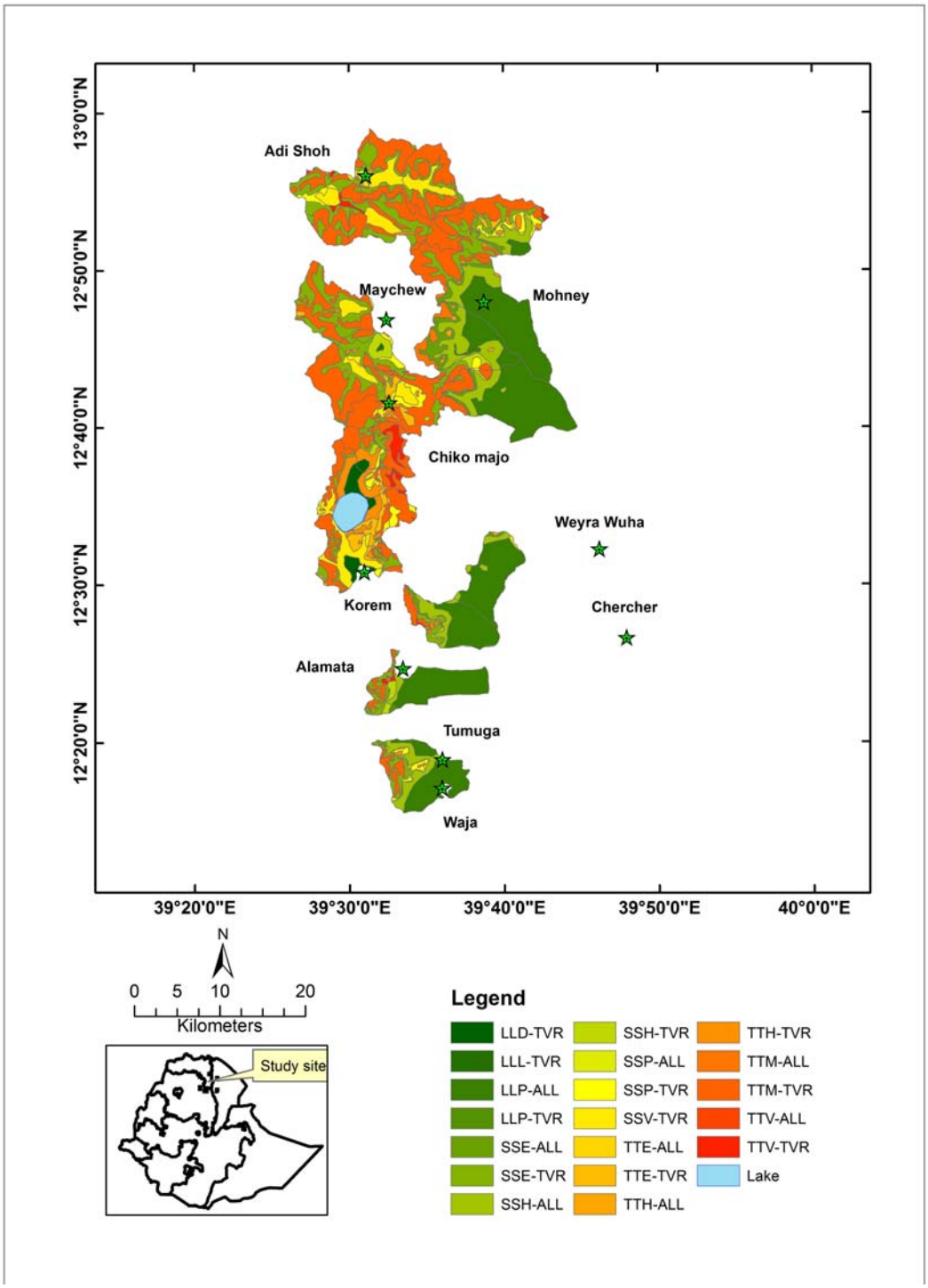


Figure 9: The base map of the 5 CASCAPE intervention woredas Alaje, Enda Mokeni, Ofla, Raya Alamata and Raya Azebo in the regional cluster of Tigray

3.3 Results of field work and data processing

The exploratory soil survey (reconnaissance) was carried out to verify the preliminary mapping units indicated on the base map of Figure 9. In general a maximum of 8 augers per kebele was described and the soil observations were classified according to WRB (2006) and grouped as so-called major soil types. Soil profiles representative for the major soil types per landform (soil-landscape unit), as distinguished during the exploratory auger survey, were characterised in detail by describing and sampling soil pits (4-8 per woreda).

The locations of the soil auger and soil pit observations are visualised in Figure 10. The auger and profile pit ID's, with coordinates and reference to the corresponding major soil type and soil-landscape (mapping) unit, are provided in table format in Annex 1 and the observed site and layer data for the representative soil pits are compiled in data tables as given in Annex 2.

The delineations of the mapping units were adapted where necessary and the different major soil types, and their respective proportions, were identified per mapping unit and per kebele, as summarized in section 3.4, 3.5, 3.6, 3.7 and 3.8 and shown in detail in Annex 4.

The study area is built up by the dissected upland plateau in the west and the escarpment leading towards to the graben (Raya lowland) in the Denakil Depression in the east. The escarpment forms a natural division between the upland and the lowland by a sharp change in altitude of 500 meters over a short horizontal distance (Hunting 1976).

The Tigray upland plateau in the east (of the southern zone of the region) is of moderate to predominantly steep relief and is composed of steeply dipping volcanic rocks (basalt; see section on geology). The plateau is sharply incised by rivers (Figure 1, 2 and figure 8).

The eastern escarpment of Tigray lies astride the fault linewith the main Ethiopian Rift valley. The main escarpment forms a belt of rugged mountainous terrain, varying in width from 2 to 20 kms with eastern-facing scarps of 500 to 1,000m in height (Hunting, 1976). The rugged escarpment forms the eastern boundary of the plateau near the town of Chinke Majo of Meswati kebelle at Enda mokoni woreda and falls steeply from plateau at 1000 to the Rift (graben) valley, e.g. at Kara Adishabo kebelle of Raya Azobo woreda (Figure 2 & 9). Similar physiography was also observed in the transect from Ofla to Alamata woreda, as well as from Maychew town of Endamokeni woreda to Mohoni town of Raya Azebo. The lowlands of the Raya Valley located at the bottom of the eastern escarpment extend from the border of Raya Azebo woreda in the north to the village Waja in the south of the study area. This valley comprises sheet flood terraces and alluvial plains with flat to undulating relief. Rivers are actively cutting down in the main part of the escarpment, but the lowlands are relatively stable geomorphologically (Hunting, 1976).

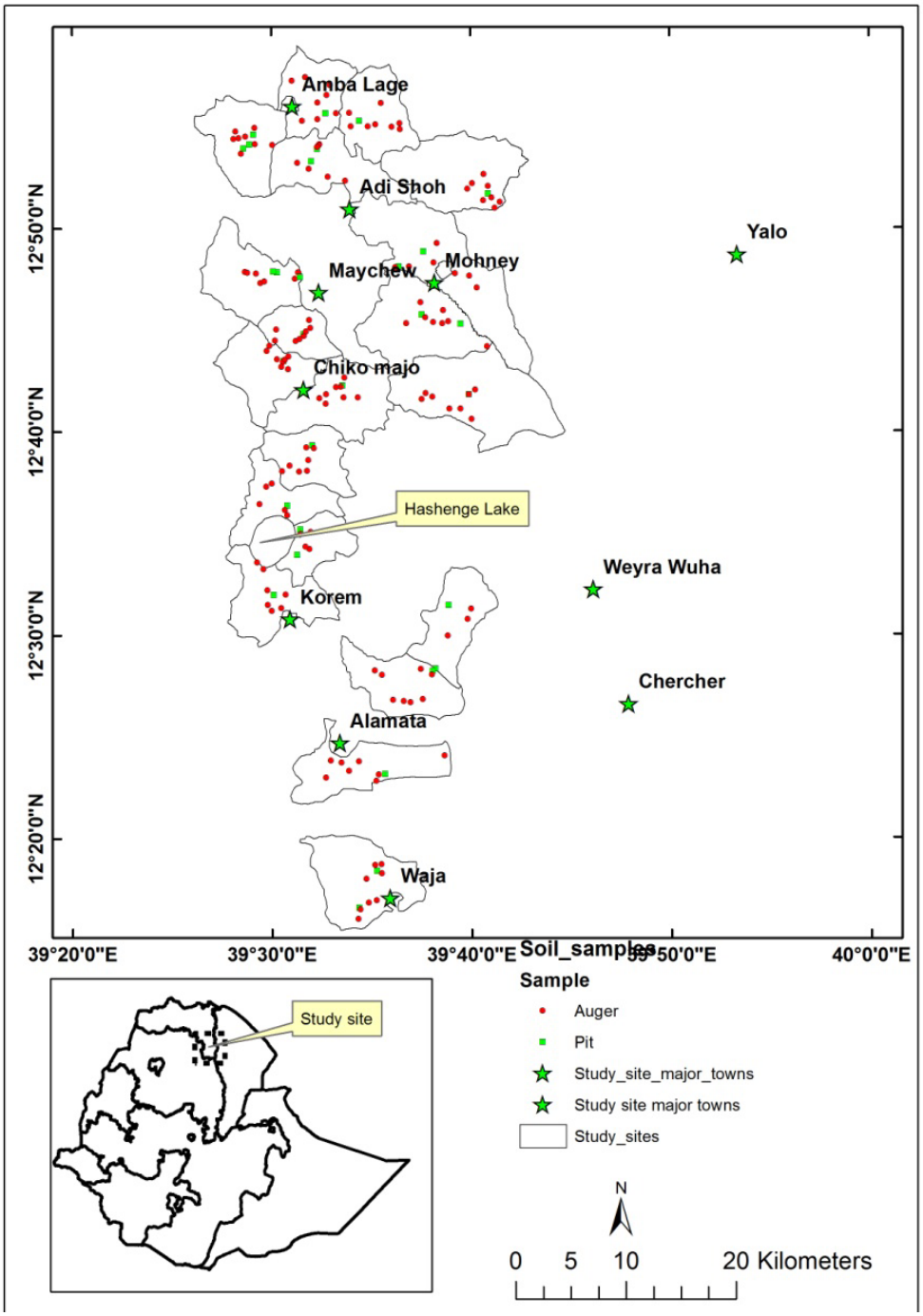


Figure 10: The observed auger and pit locations

Regosols and Leptosols dominate the dissected upland plateau of the study area on the hill and mountain slopes and Cambisols on foot slopes of the mountains, and Vertisols on the valley bottom and Fluvisols near the confined gorges, and areas surrounding Lake Hashenge. In the eastern escarpment part the soils are mostly

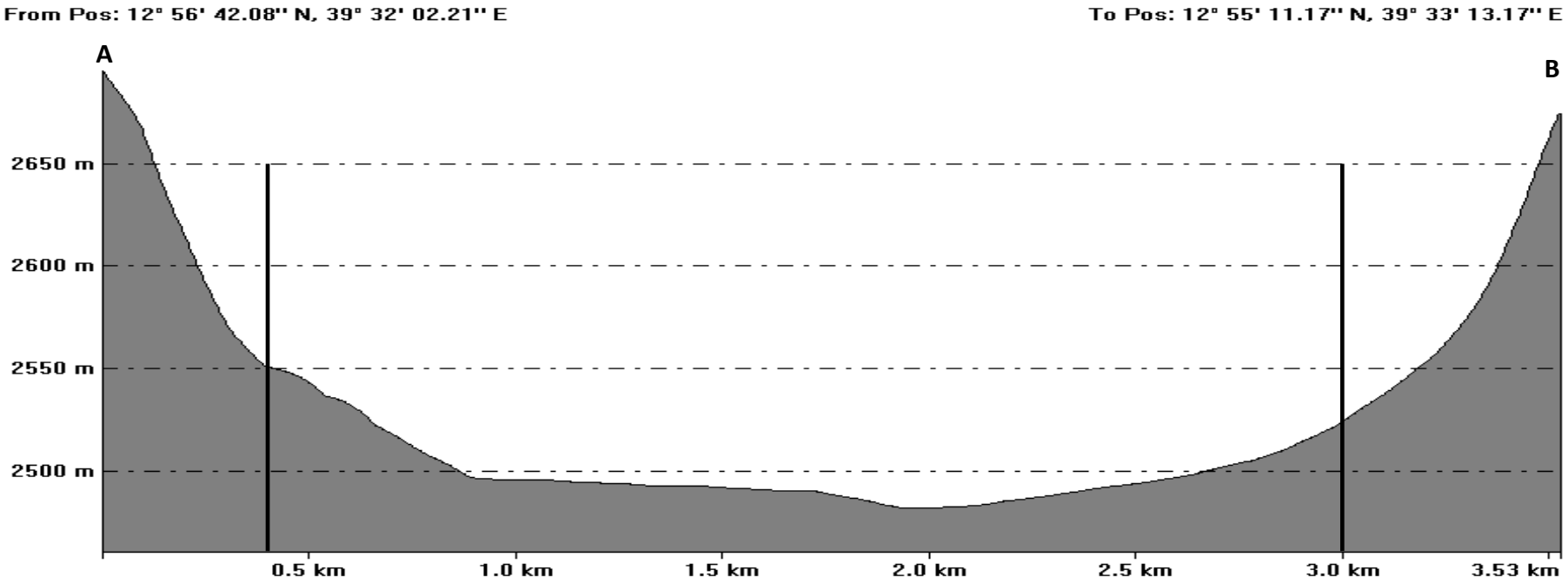
developed under semi-arid condition where the weathering process is slow as a result shallow Leptosols are dominant on steep slopes, where as the graben valley is dominated by Vertisols and Cambisols (buried Vertisols). Fluvisols are also found near the braided rivers in the graben (rift) valley.

3.4 Soils of the Alaje woredas

3.4.1. The soil-landscape of Alaje woreda

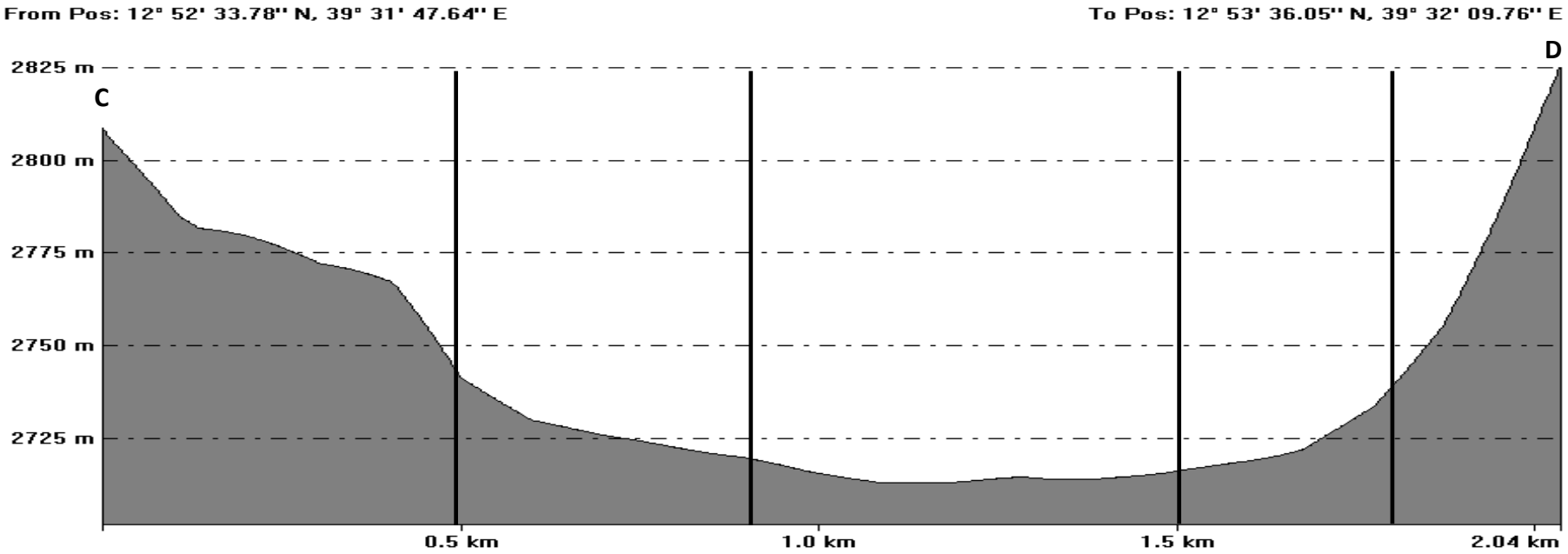
Landforms in Alaje woreda are characterized by sloping (S) and steep (T) land with medium and high gradient slopes, respectively, consisting of valleys (SV, TV), hills (SH, TH) and mountains (SM, TM). No level land (L) has been distinguished as major landform. The medium-gradient sloping land (escarpment) occupies about 30% of the surveyed kebeles and the high-gradient mountain steep land, at a higher elevation, consist of about 51% (Annex 5.1). Lands of high and medium altitude are strongly dissected. Steep land high-gradient mountain(TM) has shallow soils (Leptosol) on the mountaineous side, and deep soils on the valley bottom (Cambisols) developed from basalt or alluvium of basalt origin.

On sloping land with dissected plain and medium gradient valley landforms, Cambisols are the dominant soils covering 38% and 25% respectively (Table 6). On the other hand, on sloping land-medium gradient escarpment zone, Leptosols covers 34% of the land unit. On sloping land with medium gradient valley landform, Vertisols account 52% of the landform. With 29% and 27% area coverage, Regosols is the second important soil on sloping land with dissected plain and medium gradient escarpment zone landform respectively. On steep landscape with high gradient hill and mountain landform Leptosols are the major soils that dominate the area (57 & 56%). Regosols are the second important soils in both landforms. With 68% area coverage, Cambisols are the dominant soils in steep land-high gradient valley. Other soil types such as Regosols, Cambisol, Leptosols and Fluvisols exists in all landform categories covering limited area usually less than10%. Cross profile taken from dissected plateau at Atsela and Ayba Kebele of Alaje woreda (Figures 11, 12 &13) indicate that Leptosols and Regosols are found on steep land-high gradient mountain, while Vertisols are present on sloping land-medium gradient escarpment zone where alluvial materials are deposited from the surrounding mountain areas (Figure 11 and 13). Simialrly cross profile taken from dissected plateau at Ayba Kebele of Alaje woreda shows that Regosols and Leptosols are dominately found on steep land-high gradient mountain areas but on the valley of sloping land-medium gradient areas vertic epileptic Cambisols and Thapto-Vertisolic are present (Figure 12 and 13).



Steep land , High-gradient mountain	Sloping land Medium-gradient escarpment zone(SE)	Steep land , High-gradient mountain
Trap volcanic rocks	Alluvium	Trap volcanic rocks
Leptic Regosol (Eutric)	Haplic Vertisol (Eutric, Pellic)	Haplic Leptosol (Eutric, Skeletic)

Figure 11: Cross profile AB dissected plateau at Atsela Kebele of Alaje woreda



Steep land , High-gradient mountain	Sloping land Medium-gradient valley(SV)	Sloping land Medium-gradient valley(SV)	Sloping land Medium-gradient valley(SV)	Steep land High-gradient mountain(TM)
Trap volcanic rocks	Trap volcanic rocks	Alluvium	Trap volcanic rocks	Trap volcanic rocks
Leptic Regosol (Eutric)	Vertic Epileptic Cambisol (Eutric)	Endogleyic Cambisol (Eutric) (Thapto-Vertisolic)	Vertic Epileptic Cambisol (Eutric)	Haplic Leptosol (Eutric, Skeletic)

Figure 12: Cross profile CD dissected plateau at Ayba Kebele of Alaje woreda

		
TENM-AYB-A1: Haplic Leptosol (Eutric, Skeletic)	TENM-AYB-P1: Calcic Vertisol (Eutric, Pellic)	TENM-Ayb-P2: Endogleyic Cambisol (Eutric) (Thapto-Vertisolic)

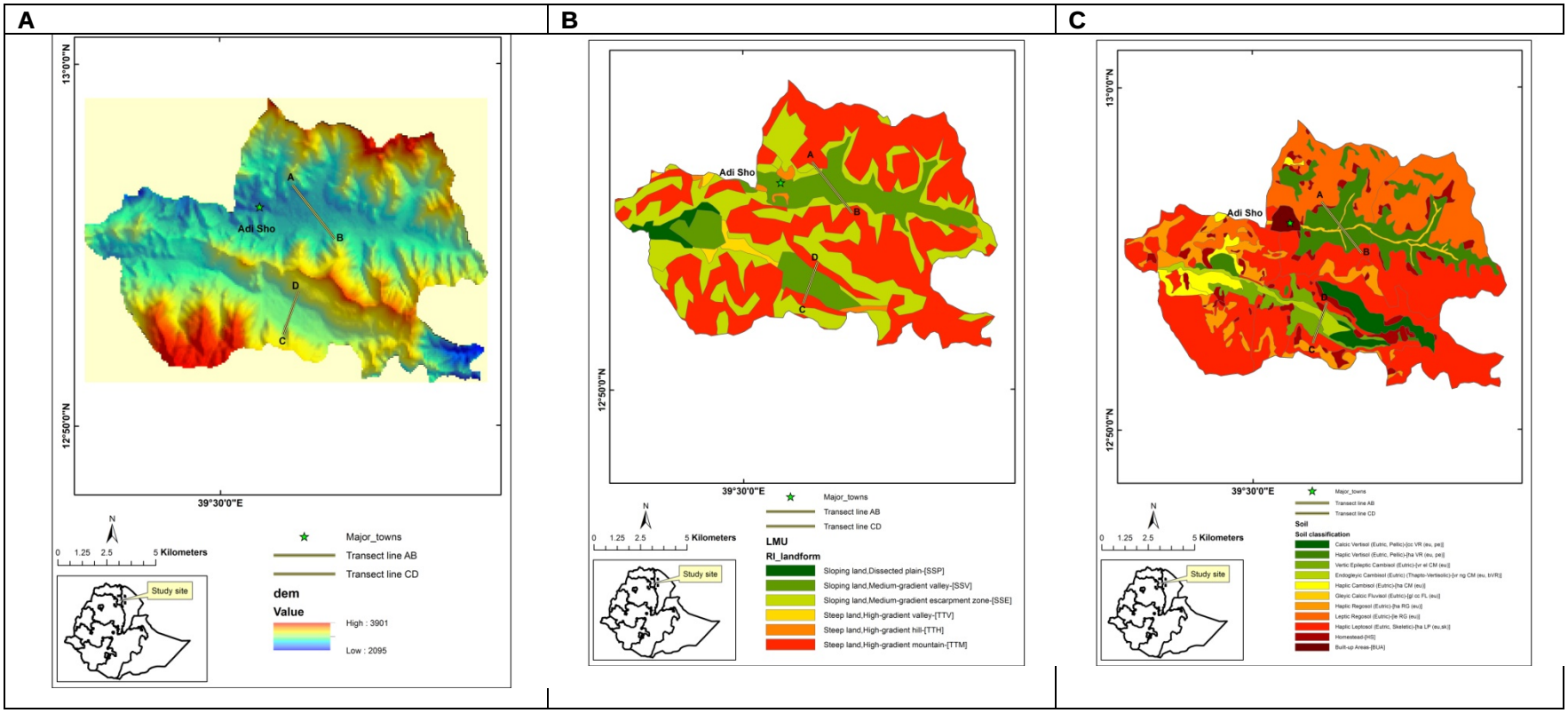


Figure 13: A,B,C. Elevation, major landform and major soils distribution in Alaje woreda

Table 6: Proportion major soils per land mapping unit of Alaje Woreda

Soils per landform and geology	Area (ha)	Per cent
Sloping land-Dissected plain,Trap volcanic rocks [SSP-TVR]	**285**	100
Cambisol (CM)	109	38
Homestead (HS)	27	10
Leptosol (LP)	61	21
Regosol (RG)	84	29
Vertisol (VR)	4	1
Sloping land-Medium-gradient escarpment zone,Trap volcanic rocks [SSE- TVR]	**5410**	100
Built-up Areas (BUA)	21	0
Cambisol (CM)	389	7
Fluvisol (FL)	6	0
Homestead (HS)	602	11
Leptosol (LP)	1827	34
Regosol (RG)	1455	27
Vertisol (VR)	1110	21
Sloping land-Medium-gradient valley,Trap volcanic rocks [SSV- TVR]	**2662**	**100**
Built-up Areas (BUA)	121	5
Cambisol (CM)	663	25
Fluvisol (FL)	179	7
Homestead (HS)	90	3
Leptosol (LP)	188	7
Regosol (RG)	50	2
Vertisol (VR)	1371	52
Steep land-High-gradient hill,Trap volcanic rocks [TTH- TVR]	**212**	100
Built-up Areas (BUA)	29	14
Cambisol (CM)	10	5
Fluvisol (FL)	0	0
Homestead (HS)	1	1
Leptosol (LP)	121	57
Regosol (RG)	45	21
Vertisol (VR)	6	3
Steep land-High-gradient mountain,Trap volcanic rocks [TTM- TVR]	**9081**	100
Cambisol (CM)	107	1
Homestead (HS)	281	3
Leptosol (LP)	5054	56
Regosol (RG)	3287	36
Vertisol (VR)	353	4

Soils per landform and geology	Area (ha)	Per cent
Steep land-High-gradient valley,Trap volcanic rocks [TTV- TVR]	**239**	100
Cambisol (CM)	162	68
Homestead (HS)	26	11
Leptosol (LP)	20	8
Regosol (RG)	13	5
Vertisol (VR)	18	8

3.4.2 Soil profile descriptions with analytical data

The soil profile descriptions are organized per soil-landscape (Annex 2). The characteristics of the major soil types of each major soil-landscape (landform) are synthesised in the next paragraph.

3.4.3 Synthesis for Alaje woreda

Based on the soil survey of the four Kebelles in Alaje Woreda, Cambisols, Fluvisols, Leptosols, Vertisols and Regosols are the major soils that exist in the area. Of these soils Leptosols, Regosols and Vertisols are the dominat soils covering 40.6%, 27.6% and 16% of the surveyed Kebeles respectively. On the other hand, Cambisols and Fluvisols exist in limited area and account about 8% and 1% respectively. Built-up area and homestead area, different soils exists with area coverage of 6.7%.

Vertisols are characterized by very dark grey and dark greyish brown color when moist, dry clay; angular to sub-angular blocky structure, clay to sandy silty clay in texture with no clear clay content pattern with depth. Top soil depth is generally deep (< 150%). The soils are dominately found in medium-gradient valley sloping land. Vertisols dominate in valley bottom and flat topography. Fluvisols are mostly found on footslopes. Deep to moderately deep, dark brown to brown color, sand clay loam texture, weak, fine to medium sub-angluar blocky structure characterize Cambisols. Cambisols have 5-15% stone cover with different size. In terms of drainage, Cambisols are well drained soils. Regosols have deep to very deep soil depth, well drainage, dark reddish brown color, clay loam; strong, fine to medium granular structure.

All the soils are derived from basalt (basic igneous rock) or its derivative unconsolidated sedimentary alluvial materials.

For Vertisols and Cambisols farmers perceptions matched with the soil classification. Farmer's soils classification is based on depth, color and fertility, and

farmers classify walka soils with deep and high fertility as Vertisols and baekel with reddish and medium depth as Cambisols.

In terms of soil physical properties, the soils have high clay content and well structured soils. Organic matter content of the soils varies between very low to low and often declines with depth. Low organic matter and shallow depth may constrain water-holding capacity of the soil, which have implication on agricultural productivity.

Chemically Vertisols are inherently fertile but due to poor soil management, the fertility is declining over time. Accordingly the soil has low to medium nitrogen content, low OC, very high available P content, very high CEC (> 40 cmol (+)/kg). Higher CEC shows high nutrient reserve which can be available in future to plant. Soil pH of the Vertisols is moderately alkaline which may limit availability of some nutrients. Simialry Cambisols have low nitrogen content, low OC, moderate to high available P and high CEC. It has clay to sandy clay loam texture and netural to moderately alkaline soil. Clay content is higher on the top and decline with depth.

Improving organic matter content and soil nitrogen through organic matter supply (manure, crop residue) with proper agronomic measure could improve productivity of the soils. In addition to applying organic matter, use of sulphur containing fertilizers may help to reduce soil pH of alkaline soils. Cereal legume rotation should be widely practiced to avoid nutrient depletion and increase nitrogen stock in soils.

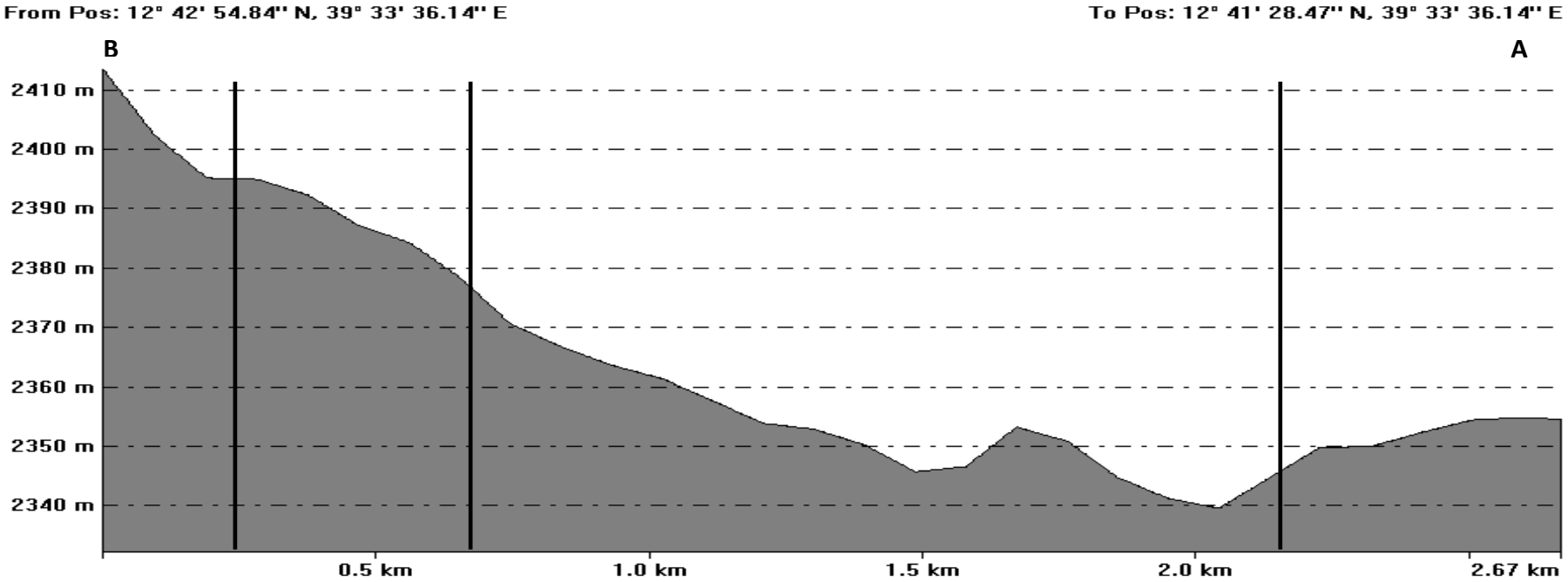
3.5 Soils of Enda Mehoni woreda

3.5.1 Soil-landscape of Endamoheni woreda

About 30% and 49% of Endamohoni landform is medium gradient escarpment sloping land and high gradient mountain steep land respectively. The rest are medium and high gradient hilly and valley lands, which all together account about 20% (Annex 5.2).

On the medium gradient escarpment sloping land, Leptosol account 55% of the area. Cambisol covers 20% while other soil types such as Fluvisols, Regosols, and Vertisols consistute 2-6% of the land unit (Table 7). Simiarly pattern exist in the high gradient mountain steep land where Leptosol account 59% of the area followed by Cambisol covering 10%. On steep land with high-gradient mountain, Leptosol covers 89% of the area. Regosol is the second most important soil type in steep land –with high graidnet escarpment, high gradient hill and high gradient mountain are covering 28%, 18% and 5% respectively. Leptosols are also fairly distributed in sloping land. For example, sloping land –medium gradient escarpment, Leptosols covers 55% of the area. On the other hand, Vertisols are dominant soil types in sloping land with medium gradient hill and with medium gradient valley area covering 75% and 54% of the respective land forms.

Distributions of soils along a catena taken from Meswaeti area on basalt lithology shows that on steep land-high gradient mountain Leptosols are found while on sloping land with dissected plain and medium-gradient valley landform Cambisols with vertic properties are mainly available (Figure 14 & 15). Leptosols are developed from trap volcanic rocks while in the vertic Cambisols are developed from transported unconsolidated materials.



Steep land , High-gradient mountain	Sloping land Dissected plain(SP)	Sloping land Medium-gradient valley (SV)	Sloping land Dissected plain(SP)
Trap volcanic rocks	Trap volcanic rocks	Alluvium	Trap volcanic rocks
Haplic Leptosol (Eutric, Skeletic)	Vertic Cambisol (Eutric)	Vertic Cambisol (Eutric)	Vertic Cambisol (Eutric)

Figure 14 A: Cross profile CD dissected plateau at Meswaeti Kebele of Endamoheni woreda

TENM- TENM-MES: -P1: Calcic Vertisol (Eutric, Pellic)

Figure 14 B: Cross profile CD dissected plateau at Meswaeti Kebele of Endamoheni woreda

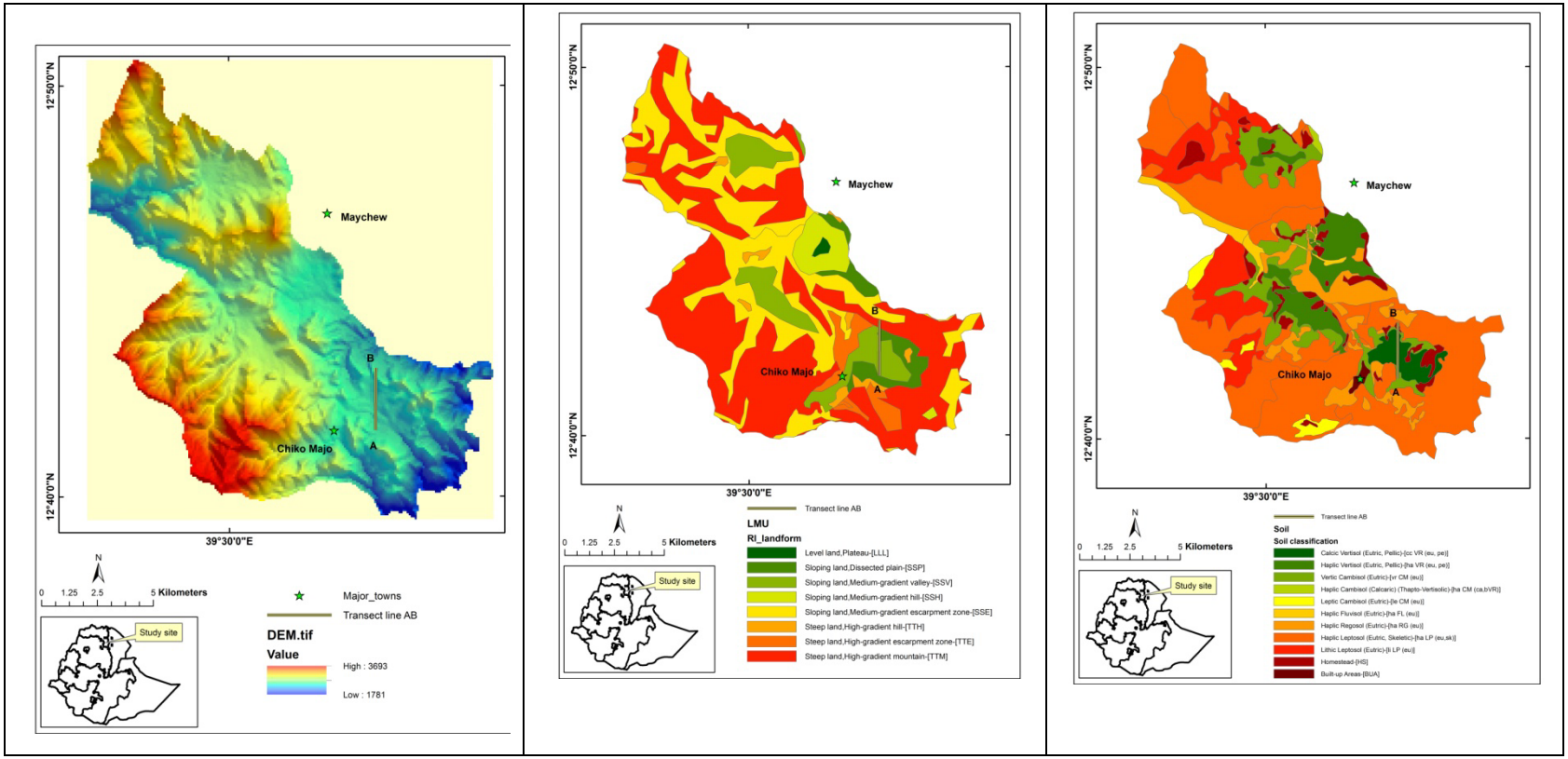


Figure 15: Elevation (A), major landform (B) and major soils distribution (C) in Endamoheni woreda

Table 7: Proportion major soils per land mapping unit of Endamoheni Woreda

Soils per landform and geology	Area (ha)	Per cent
Level land-Plateau,Trap volcanic rocks [LLL- TVR]	**48**	100
Vertisol (VR)	48	100
Sloping land-Dissected plain,Trap volcanic rocks [SSP- TVR]	**663**	100
Built-up Areas (BUA)	0	0
Cambisol (CM)	109	16
Homestead (HS)	151	23
Leptosol (LP)	135	20
Regosol (RG)	115	17
Vertisol (VR)	154	23
Sloping land-Medium-gradient escarpment zone,Trap volcanic rocks [SSE- TVR]	**5169**	100
Cambisol (CM)	1043	20
Fluvisol (FL)	283	5
Homestead (HS)	333	6
Leptosol (LP)	2853	55
Regosol (RG)	424	8
Vertisol (VR)	232	4
Sloping land-Medium-gradient hill,Trap volcanic rocks [SSH- TVR]	**600**	100
Fluvisol (FL)	32	5
Homestead (HS)	54	9
Leptosol (LP)	26	4
Regosol (RG)	37	6
Vertisol (VR)	451	75
Sloping land-Medium-gradient valley,Trap volcanic rocks [SSV- TVR]	**1533**	100
Built-up Areas (BUA)	39	3
Cambisol (CM)	426	28
Fluvisol (FL)	12	1
Homestead (HS)	88	6
Leptosol (LP)	51	3
Regosol (RG)	96	6
Vertisol (VR)	821	54
Steep land-High-gradient escarpment zone,Trap volcanic rocks [TTE-TVR]	**640**	100
Built-up Areas (BUA)	22	3
Cambisol (CM)	71	11
Homestead (HS)	7	1
Leptosol (LP)	354	55
Regosol (RG)	179	28
Vertisol (VR)	8	1

Soils per landform and geology	Area (ha)	Per cent
Steep land-High-gradient hill,Trap volcanic rocks [TTH- TVR]	**248**	100
Cambisol (CM)	24	10
Fluvisol (FL)	3	1
Homestead (HS)	20	8
Leptosol (LP)	147	59
Regosol (RG)	45	18
Vertisol (VR)	11	4
Steep land-High-gradient mountain,Trap volcanic rocks [TTM- TVR]	**8572**	100
Cambisol (CM)	304	4
Fluvisol (FL)	82	1
Homestead (HS)	136	2
Leptosol (LP)	7605	89
Regosol (RG)	390	5
Vertisol (VR)	55	1

3.5.2. The soil descriptions with analytical data

The soil profile descriptions are organized per soil-landscape (Annex 2). The characteristics of the major soil types of each major soil-landscape (landform) are synthesised in the next paragraph.

3.5.3 Synthesis for Endamoheni woreda

- **Endamehoni Woreda**

Fluvisols, Leptosols, Regosols, Vertisols, and Cambisols are major soils available in the woreda. Leptosols, Cambisols and Vertisols cover 63.9%, 11.3% and 10.2% respectively. On the other hand, Regosols and Fluvisols exist in a limited area.

On sloping land with medium-gradient hilly cultivated areas, Vertisols with dark color when moist and dark grey when dry are found extensively. On other hand, on steep land with high-gradient mountains, Leptosol are commonly found. Vertisols in EndaMehoni woreda is characterized by angular to sub-anguar soil structure, very deep, well drained, higher clay content in top soils and lower in subsoils. On the other hand, on areas with Cambisols, the soils are dark reddish brown on top and very dusty red color on subsoils with corresponding soil structure of granular and sub-angular. The soils have sandy clay loam, well drained, deep soil, and many rock outcrops. The soils are developed from basalt rock and are being used for cultivation.

The physical properties of the Vertisols and Cambisols soils are good as they are well structured with low to medium soil organic content and thick soils. Organic matter content is higher on surface of the soils and decline with depth. This shows

that the current management practices used by farmers may be contributing to maintain organic matter content of top soil although the rate is insufficient given the limited resources and higher competition of organic manure for domestic energy sources. During dry periods, workability could be a problem for the Vertisols. The soils are expected to have moderate to high water holding capacity. With high drainage and deep ground water, flooding will not be a challenge for both soil types.

Vertisols are chemically fertile and are favourable for agriculture. The total nitrogen content is rated mostly as medium with some exceptions (low and high). Available P is generally high while CEC is high to very high implying that the soil is potentially fertile. However there could be nutrient imbalance due high pH content in some cases. In case of Cambisols, it has low to medium nitrogen content and OC content, moderate to high available P and CEC. The soil has neutral soil pH. Except for Cu, micronutrients are deficient in both soils (S, Zn, and Fe).

Crop rotation using legume crops and trees, and application of organic matters in the form of mulch, manure could not not only improve nitrogent content of the soil but also improve workability and waterholding capacity of the soil. Given higher P and lower/medium N content of the soils, the rate of DAP and Urea being recommended by the extension system (100kg/ha each) should be revised taking the soil type and its nutrient content, and crop needs. This will lead to use of lower P and higher N rate than what has been practices for the last 40 years. Higher N application is important to balance N/P availability. However, timing for application of urea should be adjusted with moisture availability. The need for micronutrients should be addressed using blended fertilizers containing S, Zn, and Fe. The exact rate should be formulated taking the micronutrient content of the soils and crop need.

3.6 Soils of Ofla woreda

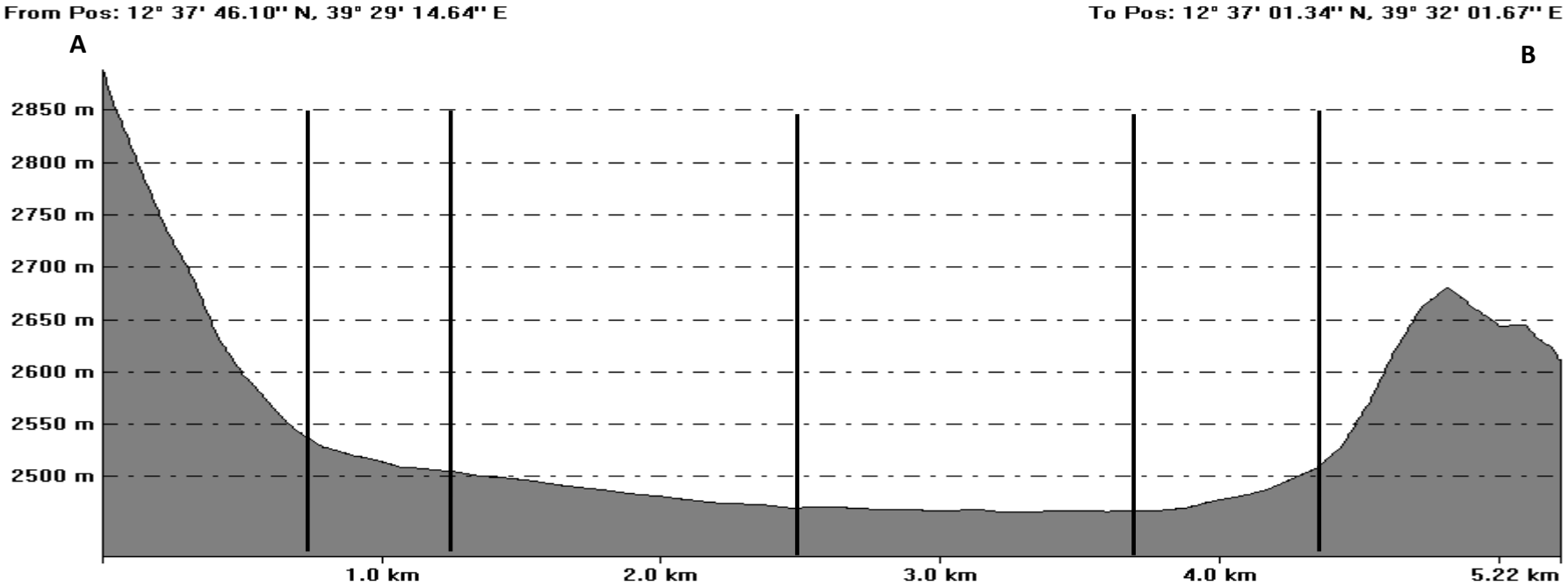
3.6.1. The soil-landscape of Ofla woreda

The landform of Ofla is mainly characterized by steep land with high gradient mountain and steep land with high gradient hill landforms. Steep land with high gradient mountain landform consistute 34% of the area while the steep land-high gradient hill landform accounts 12% (Annex 5.3). The level pleatux, on the other hand, accounts about 16.1% of the total area. Other landforms cover lessthan 10%.

On level land depression Fluvisol and Vertisols are the major soil types dominately found in the area while on sloping land with dissected plain and medium gradient escarpment land Leptosols are more dominant covering 56% and 66% of the resepectively landforms (Table 8). Cambisol also exists in these landforms but with lesser area coverage. However, on sloping land-medium gradient hill landfrom Cambisols covers 60% of the area. On steep land-high gradient Mountain and steep land-high gradient valley, Leptosols are the major soil types covering 90% and

88% of the respective land unit. This shows Leptosols are mostly found at high altitude, with strongly dissected topography due to high rate of erosion. Vertisols dominaetly occurred on sloping land- medium gradient valley and on steep land-high gradient hill where it covers 45% and 53% respectively. Other soil types also exists in all landform category but with small area coverage usually less than 10%.

The soil distribution on typical catena taken from Menkere area with basalt lithology is usually Leptosols on mountain and high altitude, Cambisol on the foot slope, Vertisols on level land plain and Fluvisols on level land depression where there is periodically flooding (Figue 16 & 17).



Steep land High-gradient mountain(TM)	Sloping land , Medium-gradient escarpment zone	Level land Plain(LP)	Level land Depression(LD)	Sloping land , Medium-gradient escarpment zone	Steep land High-gradient mountain(TM)
Trap volcanic rocks	Trap volcanic rocks	Alluvium	Alluvium	Trap volcanic rocks	Trap volcanic rocks
Haplic Leptosol (Eutric, Skeletic)	Vertic Epileptic Cambisol (Eutric)	Haplic Vertisol (Calcaric)	Gleyic Calcic Fluvisol (Eutric)	Vertic Epileptic Cambisol (Eutric)	Haplic Leptosol (Eutric, Skeletic)

Figure 16 A: Cross profile AB dissected plateau at Menkere Kebele of Ofla woreda

TOFL-AGO-P1:Haplic Vertisol (Eutric) SV(ha VR (eu, pe))

Figure 16 B: Soils of Adi Golo Kebele of Ofla woreda

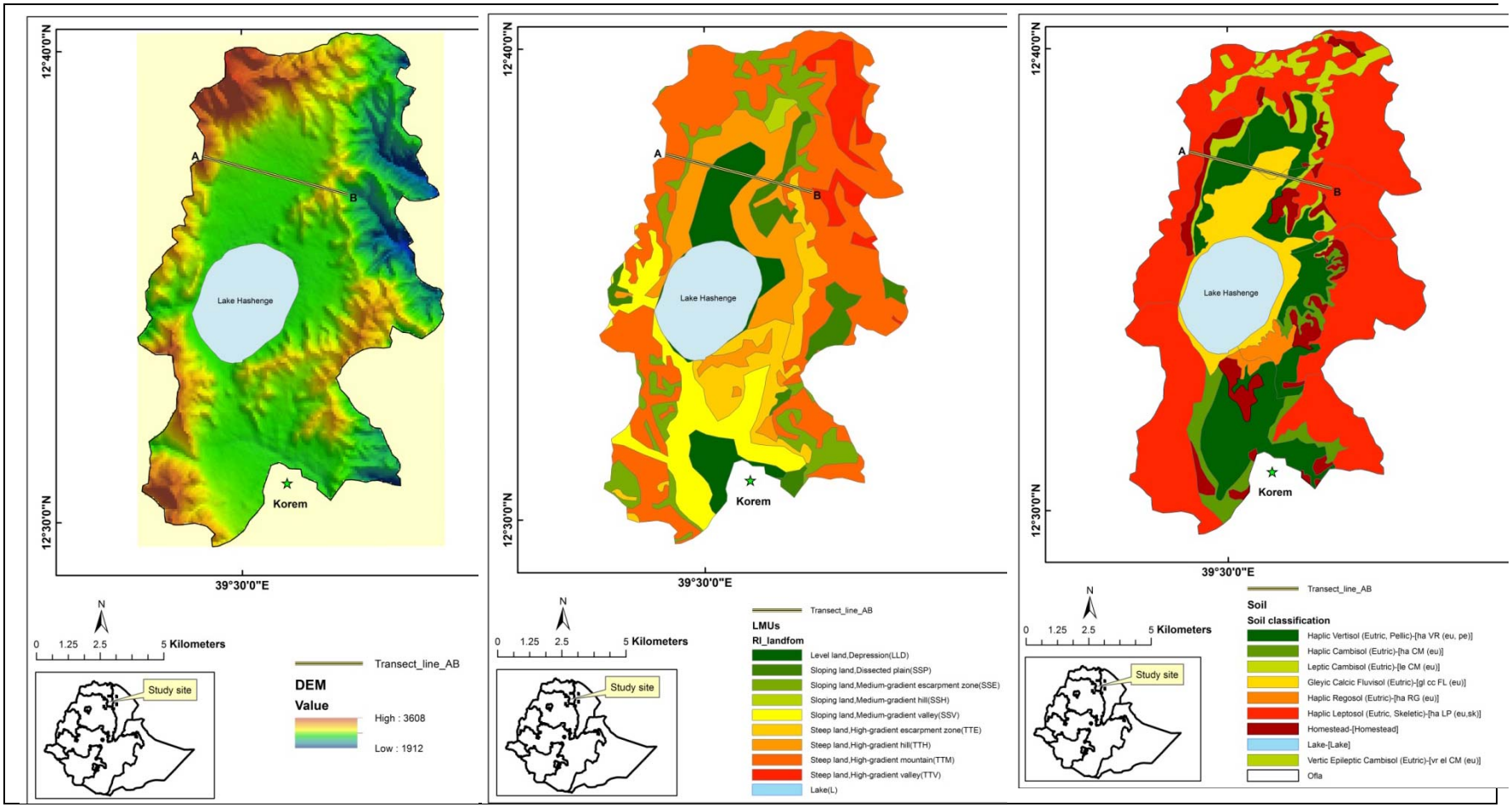


Figure 17: A,B,C. Elevation, major landform and major soils distribution in Ofla woreda

Table 8: Proportion major soils per land mapping unit of Ofla Woreda

Soils per landform and geology	Area (ha)	Per cent
Level land-Depression,Trap volcanic rocks [LLD-TVR]	**2534**	100
Cambisol (CM)	46	2
Fluvisol (FL)	605	24
Homestead (HS)	32	1
Lake (L)	1368	54
Vertisol (VR)	483	19
Sloping land-Dissected plain,Trap volcanic rocks [SSP- TVR]	**772**	100
Cambisol (CM)	88	11
Fluvisol (FL)	1	0
Homestead (HS)	154	20
Leptosol (LP)	429	56
Vertisol (VR)	100	13
Sloping land-Medium-gradient escarpment zone,Trap volcanic rocks [SSE-TVR]	**1408**	100
Cambisol (CM)	325	23
Homestead (HS)	130	9
Leptosol (LP)	931	66
Vertisol (VR)	21	1
Sloping land-Medium-gradient hill,Trap volcanic rocks [SSH- TVR]	**90**	100
Cambisol (CM)	54	60
Homestead (HS)	16	18
Vertisol (VR)	20	22
Sloping land-Medium-gradient valley,Trap volcanic rocks [SSV- TVR]	**1615**	100
Cambisol (CM)	305	19
Fluvisol (FL)	74	5
Homestead (HS)	87	5
Lake (L)	1	0
Leptosol (LP)	417	26
Regosol (RG)	1	0
Vertisol (VR)	729	45
Steep land-High-gradient escarpment zone,Trap volcanic rocks [TTE- TVR]	**1230**	100
Cambisol (CM)	251	20
Fluvisol (FL)	67	5
Homestead (HS)	338	27
Lake (L)	4	0
Leptosol (LP)	171	14
Regosol (RG)	122	10
Vertisol (VR)	277	23

Soils per landform and geology	Area (ha)	Per cent
Steep land-High-gradient hill,Trap volcanic rocks [TTH- TVR]	**1892**	100
Cambisol (CM)	171	9
Fluvisol (FL)	387	20
Homestead (HS)	86	5
Lake (L)	7	0
Leptosol (LP)	115	6
Regosol (RG)	122	6
Vertisol (VR)	1004	53
Steep land-High-gradient mountain,Trap volcanic rocks [TTM- TVR]	**5406**	100
Cambisol (CM)	296	5
Fluvisol (FL)	4	0
Homestead (HS)	225	4
Leptosol (LP)	4875	90
Vertisol (VR)	6	0
Steep land-High-gradient valley,Trap volcanic rocks [TTV- TVR]	**765**	100
Cambisol (CM)	70	9
Homestead (HS)	19	2
Leptosol (LP)	677	88

3.6.2. The soil descriptions with analytical data

The soil profile descriptions are organized per soil-landscape (Annex 2). The characteristics of the major soil types of each major soil-landscape (landform) are synthesised in the next paragraph.

3.6.3 Synthesis for Ofla woreda

Fluvisols, Leptosols, Regosols, Vertisols, and Cambisols are the dominant soils in Ofla woreda. Large area is covered by Leptosols (48.5%) followed by Vertisols (16.8%), and Cambisols (10.2%), all together accounts 75% of the total area. Calcaric Fluvisols are widely available around Lake Hashenge, covering 7.2% of the area. The remained area is covered by Lake Hashenge (8.8%) and homestead.

Vertisols, Cambisols and Fluvisols are the major soil types identified in the cultivated area in Ofla woreda. Vertisols in Ofla are characterized by very deep, black soil, well structured, well drained, clayey with no clear pattern along soil depth. The Cambisols are dark brown, very deep, well drained, well structured, sandy clay loam on top and clay (clay loam) on subsoil but with no clear trend. Vertisols are developed from alluvial basalt materials and often exists on lower and toe slopes. Cambisols also developed from basalt and exists on middle to upper slope of hilly landscape. Fluvisols predominantely exists on lower slope closer to Lake Hasgenge and have brown and/or grey color, moderate structure, imperfect

drainage, very deep soil; sandy clay to sandy clay loam in texture that vary with depth. Fluvisols are characterized with sedimentation and wetness having strong stratified sediment layers.

Dry Vertisols have a very hard consistence; and they are very plastic and sticky when wet. This has physical limitation including workability and root growth. Under optimum condition, the soils have good structure, well drained. Cambisols have medium textured with good structural stability, a high porosity, and good water holding capacity and good internal drainage and as such have no major physical limitation. However, both Vertisols and Cambisol of the area have deep soils with corresponding low and very low organic matter content. Organic matter content declines with depth in both soil types. Fluvisols are soft and unripe, have medium N and OC content, low bearing capacity, low to medium hydraulic characteristics. Such soils pose problems for agricultural use and require drainage. Except for Cu, all the soils are deficient in micronutrients (Fe, Zn, S) and is worst at Hugunberda Kebele.

All the three soils have medium to high nitrogen content, P content and CEC, which makes the soils to be chemically fertile. Fertility is higher on Vertisol and decline with the order of Vertisol, Fluvisol and Cambisol. pH of the top soils are neutral except for Fluvial soils where moderately alkaline pH value was recorded. Higher pH on Fluvisol may create nutrient imbalance and drainage is also another problem on this soil.

Problems of Vertisols in the area are physical soil characteristics and water management where reclamation can be made using contour cultivation, contour bunding, mulching, applying soil and water conservation using broad bed and furrow system. Cambisols are less fertile with good infilitration and workability. Integrated soil fertility management should be applied to address fertility problem of the soil. On steep area, the soil should be kept under forest or permanent fruit plantation. High pH and poor drainage may impair productive potential of Fluvisols in the study area. Draining the soil using shallow ditches and maintaining high water table could create favourable condition. Addition of organic materials such as manure, crop residue and S containing fertilizer can reduce the pH to acceptable level. Use of blended fertilizer along with organic amendement may help to improve micronutrient content.

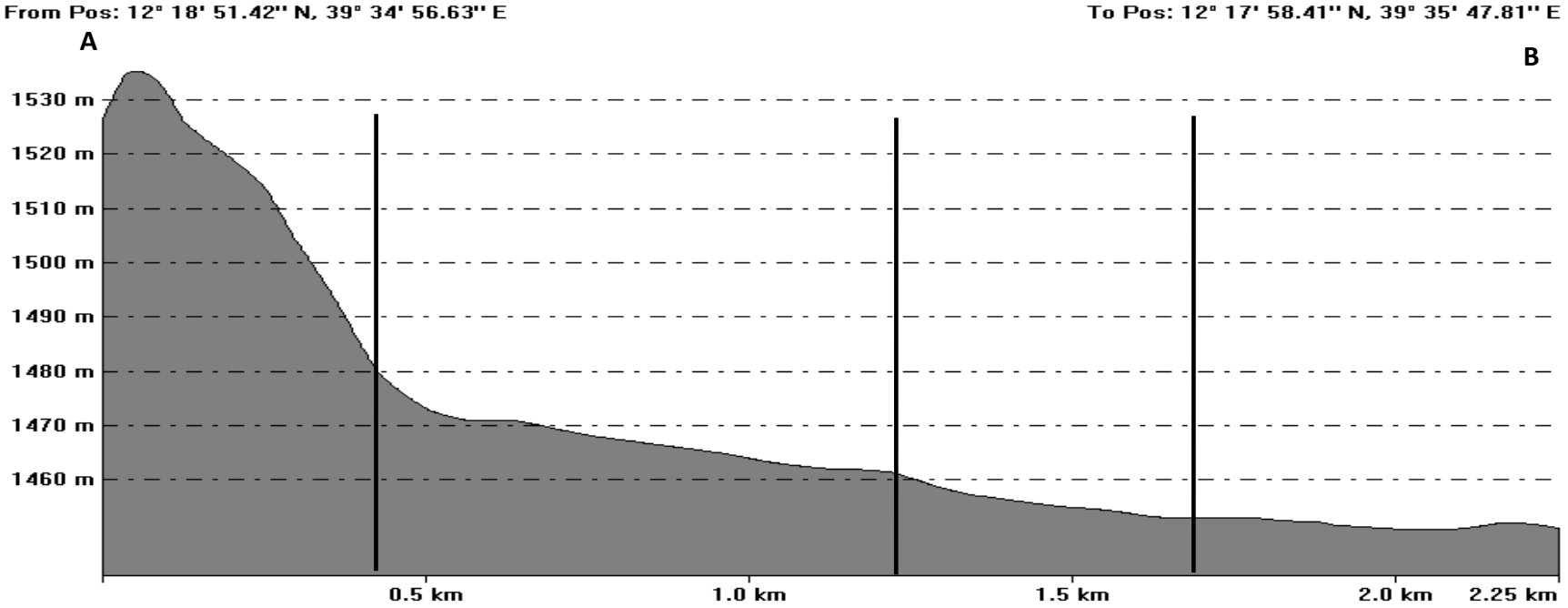
Except for steep and highly degraded areas, large part of the area is brought under cultivation. Unattractive soils such as Leptosols with limited potential for cultivation are partly kept under cultivation. About 60-70% of the total area is being cultivated. Wheat, barley, sorghum, maize, faba bean are major crops grown in the area.

3.7 Soils of Raya Alamata woreda

3.7.1. The soil-landscape of Raya Alamata woreda

The landform of Alamata woreda is largely level plain (64%). Medium gradient escarpment and hill sloping land accounts 10% and 15% of the area respectively (Annex 5.4). Soil distribution follows the landscape configuration where on the level land plain, Vertisols (41%) and Fluvisols (29%) are the dominant soils. On most of the landforms, Leptosols is the major soil type covering more area, particularly on steep land-high gradient hill, high gradient mountain and high gradient valley, Leptosols cover more than 90% each landform (Table 9). Also on sloping land with dissected plain and sloping land-medium escarpment zone, Leptosols is the major soil covering the larger portion of the area. Exceptional to this, Cambisols (60%) cover larger area on sloping land with medium gradient hill. Due to the influence of minor landforms, Fluvisols, Vertisols and Cambisols also exist in medium and high gradient slopes with limited coverage. The typical catena found on basalt lithology is usually Leptosols on the backslope of mountain and hill area which are developed mainly from trapped volcanic rocks (Figure 18). On the footslope with medium gradient sloping lanform, Cambisols derived from alluvium are found. Further down on level land plain Vertisols and Fulvisols are present, both of them are developed from alluvial deposits (Figure 19).

The existence of diverse soil types on level plain and medium slope area could be due to deposition of sediment material with different origins coming from the upland areas. These areas are mostly under cultivation, growing teff and sorghum.



Sloping land Dissected plain(SP)	Sloping land Medium-gradient hill(SH)	Level land Plain(LP)	Level land Plain(LP)
Trap volcanic rocks	Alluvium	Alluvium	Alluvium
Haplic Leptosol (Eutric, Skeletic)	Haplic Cambisol (Calcaric) (Thapto-Vertisolic)	Calcic Vertisol (Eutric)	Gleyic Calcic Fluvisol (Eutric)

Figure 18A: Cross profile AB Graben valley at Tumuga Kebele of Raya Alamata woreda

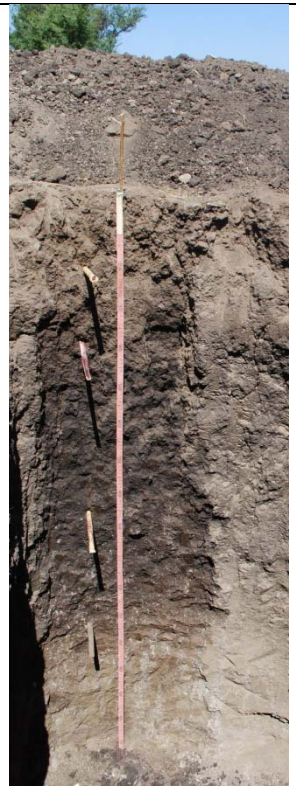
		
TRAL-TIM-P1: Haplic Cambisol (Calcaric) (Thapto-Vertisolic)	TRAL-TIM-P1: Calcic Vertisol (Eutric)	TRAL-SBK-P1: Gleyic Calcic Fluvisol (Eutric)

Figure 18 A: Soils of Tumuga and Selam Bikalsi Kebele of Raya Alamata woreda

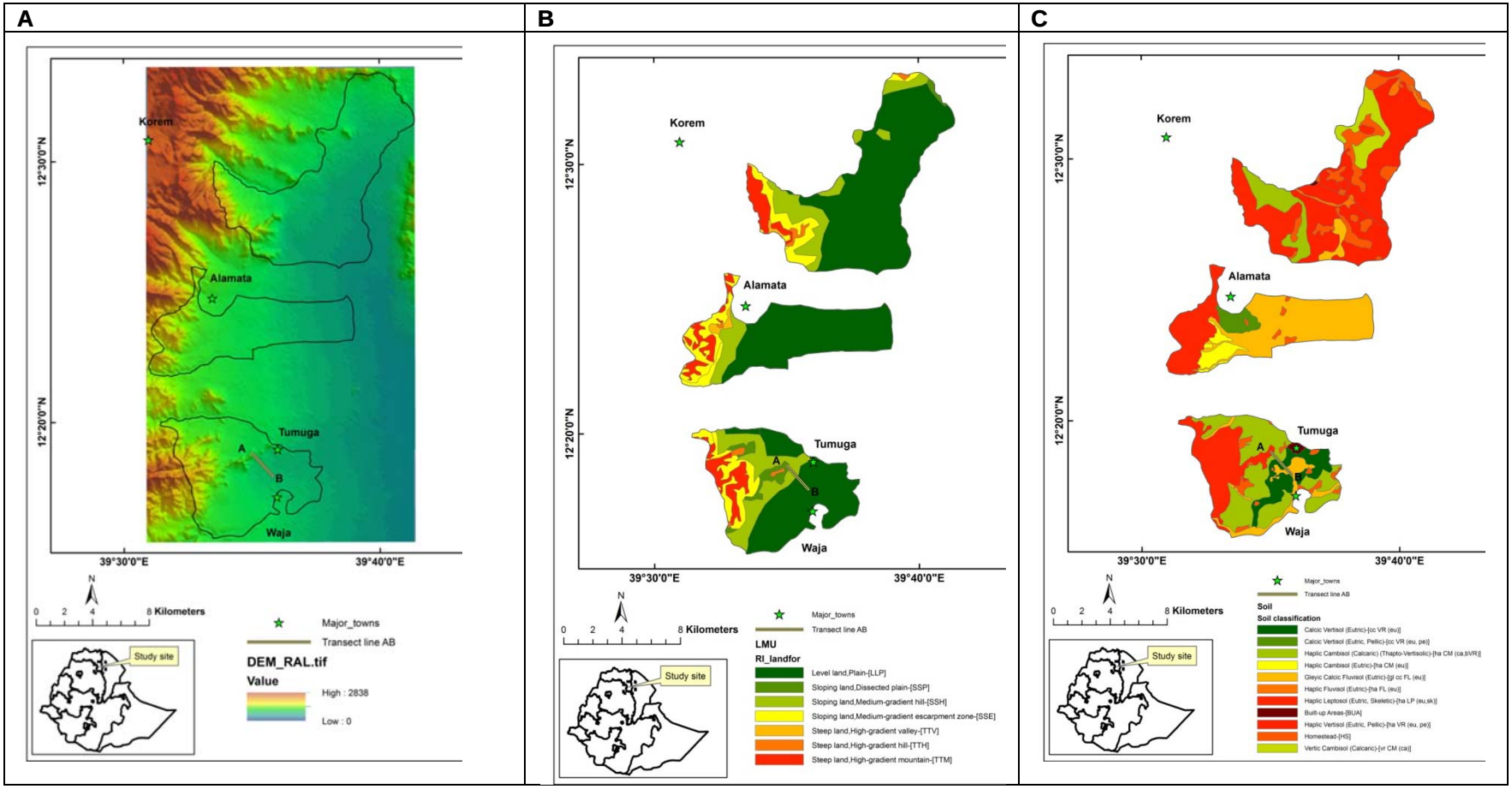


Figure 19: A,B,C. Elevation, major landform and major soils distribution in Raya Alamata woreda

Table 9: Proportion major soils per land mapping unit of Raya Alamat Woreda

Soils per landform and geology	Area (ha)	Per cent
Level land-Plain,Alluvium [LLP-ALL]	**12723**	100
Built-up Areas (BUA)	51	0
Cambisol (CM)	2490	20
Fluvisol (FL)	3739	29
Homestead (HS)	1173	9
Leptosol (LP)	11	0
Vertisol (VR)	5259	41
Level land-Plain,Trap volcanic rocks [LLP-TVR]	**48**	100
Cambisol (CM)	38	79
Fluvisol (FL)	10	21
Sloping land-Dissected plain,Alluvium [SSP-ALL]	**99**	100
Cambisol (CM)	23	23
Fluvisol (FL)	9	9
Homestead (HS)	49	49
Leptosol (LP)	19	19
Sloping land-Dissected plain,Trap volcanic rocks [SSP- TVR]	**287**	100
Cambisol (CM)	35	12
Fluvisol (FL)	2	1
Homestead (HS)	20	7
Leptosol (LP)	230	80
Sloping land-Medium-gradient escarpment zone,Alluvium [SSE-ALL]	**312**	100
Cambisol (CM)	118	38
Homestead (HS)	31	10
Leptosol (LP)	163	52
Sloping land-Medium-gradient escarpment zone,Trap volcanic rocks [SSE-TVR]	**1761**	100
Cambisol (CM)	28	2
Fluvisol (FL)	6	0
Homestead (HS)	19	1
Leptosol (LP)	1707	97
Sloping land-Medium-gradient hill,Alluvium [SSH-ALL]	**2502**	100
Built-up Areas (BUA)	21	1
Cambisol (CM)	1500	60
Fluvisol (FL)	124	5
Homestead (HS)	307	12
Leptosol (LP)	248	10
Vertisol (VR)	302	12

Soils per landform and geology	Area (ha)	Per cent
Sloping land-Medium-gradient hill,Trap volcanic rocks [SSH-TVR]	**458**	100
Cambisol (CM)	209	46
Fluvisol (FL)	51	11
Homestead (HS)	27	6
Leptosol (LP)	171	37
Vertisol (VR)	0	0
Steep land-High-gradient hill,Alluvium [TTH-ALL]	**24**	100
Homestead (HS)	0	1
Leptosol (LP)	24	99
Steep land-High-gradient hill,Trap volcanic rocks [TTH-TVR]	**149**	100
Leptosol (LP)	149	100
Steep land-High-gradient mountain,Alluvium [TTM-ALL]	**41**	100
Cambisol (CM)	3	7
Leptosol (LP)	38	93
Steep land-High-gradient mountain,Trap volcanic rocks [TTM-TVR]	**1348**	100
Leptosol (LP)	1348	100
Steep land-High-gradient valley,Alluvium [TTV-ALL]	**1**	100
Leptosol (LP)	1	85
Vertisol (VR)	0	15
Steep land-High-gradient valley,Trap volcanic rocks [TTV-TVR]	**122**	100
Fluvisol (FL)	3	2
Leptosol (LP)	119	98

3.7.2 Soil profile descriptions with analytical data

The soil profile descriptions are organized per soil-landscape (Annex 2). The characteristics of the major soil types of each major soil-landscape (landform) are synthesised in the next paragraph.

3.7.3 Synthesis for Alamata woreda

Cambisols, Fluvisols, Leptosols, and Vertisols are the major soil types found at Alamata woreda. Each of these soils covered 22.4%, 19.8%, 21.3% and 28.0% area respectively.

Cultivated lands in Alamata woreda are located in level plain land and bottom lands having slope < 10%. The dominant soils in the cultivated land of Raya Alamata woreda are Fluvisols, Vertisols, and Cambisol. Fluvisols and Vertisols are found extensively in farmland of the study area. Both soils have developed from unconsolidated sediments of fluvial or colluvial basalt-derived material. The soils

are deep, moderate to well drained, and have black and dark brown color, clay, clay loam or silt clay texture with irregular clay distribution within soil depth.

The physical properties of the soils are characterized by good structure with thick soil depth. The soils have low organic matter content associated with low organic matter inputs and high degree of mineralization. They have good soil workability and infiltration. Water holding capacity of the soils is generally good but actual availability of soil moisture is low due to high evaporation and low amount of rainfall in the area. Limitation due to unfavourable climate is a challenge in the area and therefore the moisture availability in the soil is a key issue determining the difference between crop failure and crop success.

The soils are generally fertile and suitable for agriculture. Total nitrogen content is medium in the top soil (plough layer) and declines with depth (to low content). Available P and CEC are rated as high. Soil pH of the soil is largely moderately to strong alkaline and this may have effect on nutrient availability. In all soils except for Cu, which is optimum rate, other micro nutrients are deficient (S, Zn, Fe), and the deficieny of micronutrients is higher in Cambisols compared to Fluvisols and Vertisols.

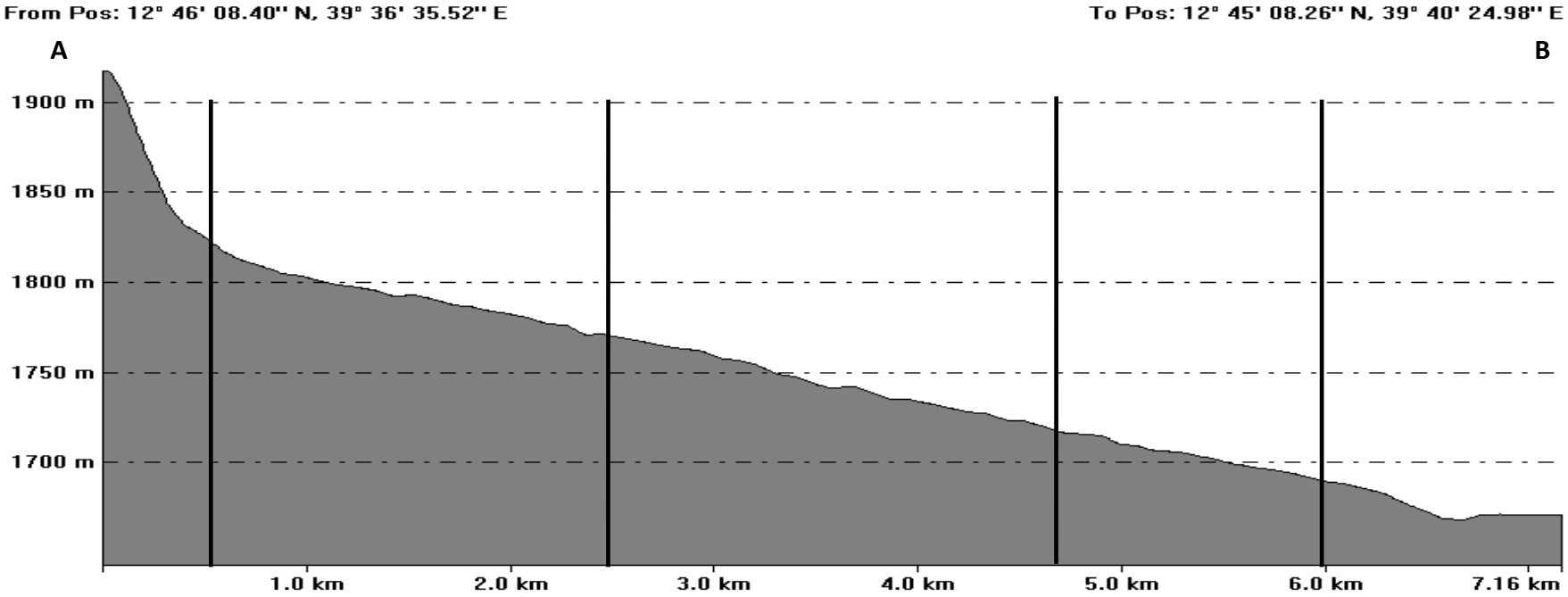
In the absence of enough moisture, use of chemical fertilizer is not an appropriate solution. Preferably, the use of organic fertilizer as organic amendement is suitable to the area. This practice can increase the organic content of the soil as well as provide nutrients such as nitrogen and organic carbon. In addition, the organic amendment is useful to reduce soil pH to neutral level. Application of S-containing fertilizer may also be beneficiary to reduce high soil pH if desired. But in time of good rainfall distribution or when irrigation water is available, use of chemical fertilizer prefereable the blended type of feritlizer are important to reduce further mining of soil nutreints and at the same time increase crop yield.

In general the area is suitable for irrigated agriculture given that 64% of the area is flat (< 10% slope) with potentially good productive land. Soil moisture is often the constraint and this has to be addressed, e.g. by using irrigation water be it from surface or subsurface water sources. Otherwise, dependency on rainfall is not reliable as it is highly variable and erratic in nature. The climate change is also posing clear negative effect on agricultural productivity in the area. Major crops grown in the area are Teff and Sorghum.

3.8 Soils of Raya Azebo woreda

3.8.1. The soil-landscape of Raya Azebo woreda

Raya Azebo has level land plain with 43% surface area coverage (Annex 5.5). On the west escarpment it has high gradient mountain steep land that covers 21% of the area. The area has also medium gradient escarpment and hill sloping area covering 15% and 17% respectively. Soil distribution also varies with the landform where on the level land plain Vertisols with calcic and haplic nature are the dominant soil types covering 77% of the land unit (Figure 20 & 21). Also on medium gradient sloping hill land, Vertisol and Fluvisols are the major soils covering 54% and 12% of the land unit respectively. Except on the two landforms (level land plain and slopingland-medium gradient hill), Leptosols are the major soils widely found in the other landform. Particularly on steep land with all landform categories, Leptosols covers 90-100% of the each landform. Fluvisol also exists on level land plain but has limited area coverage (4%). The typical catena found on 'trap volcanic rock-alluvium' lithology is usually Leptosols on steep land-high gradient hill and Vertisols on sloping land-medium gradient hill and level land plain. On the flatter area Fluvisols are also found (Figure 21).



Steep land High-gradient hill(TH)	Sloping land Medium-gradient hill(SH)	Level land Plain(LP)	Level land Plain(LP)	Level land Plain(LP)
Trap volcanic rocks	Alluvium	Alluvium	Alluvium	Alluvium
Haplic Leptosol (Eutric, Skeletic)	Calcic Vertisol (Eutric, Pellic)	Calcic Vertisol (Eutric)	Haplic Vertisol (Calcaric)	Gleyic Calcic Fluvisol (Eutric)

Figure 20A: Cross profile AB Graben valley at Genete Kebele of Raya Azebo woreda

	
TRAZ-GEN-P2: Calcic Vertisol (Eutric, Pellic) [LP(cc VR (eu, pe))]	TRAZ-GEN-P1: Haplic Vertisol (Calcaric) [SH(ha VR (ca))]

Figure 20B: Soils of Genete Kebele of Raya Azebo woreda

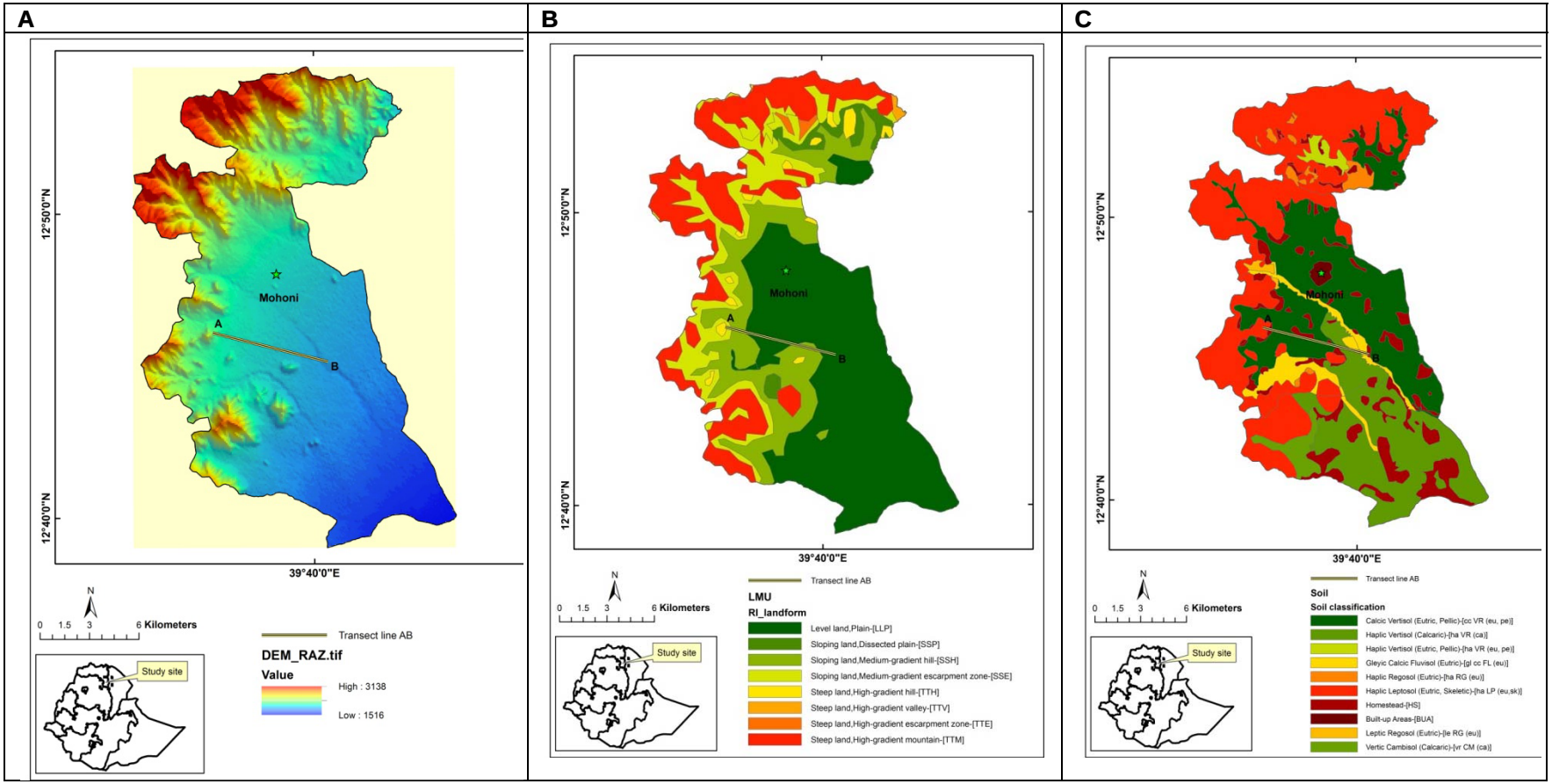


Figure 21: A,B,C. Elevation, major landform and major soils distribution in Raya Azebo woreda

Table 10: Proportion soils per land mapping unit of Raya Azebo Woreda

Soils per landform and geology	Area (ha)	Per cent
Level land-Plain,Alluvium [LLP-ALL]	**13362**	**100**
Built-up Areas (BUA)	178	1
Cambisol (CM)	112	1
Fluvisol (FL)	541	4
Homestead (HS)	2171	16
Regosol (RG)	22	0
Vertisol (VR)	10338	77
Sloping land-Dissected plain,Alluvium [SSP- ALL]	**244**	**100**
Homestead (HS)	22	9
Leptosol (LP)	136	56
Vertisol (VR)	87	36
Sloping land-Dissected plain,Trap volcanic rocks [SSP-B]	**569**	**100**
Fluvisol (FL)	6	1
Homestead (HS)	41	7
Leptosol (LP)	416	73
Regosol (RG)	2	0
Vertisol (VR)	104	18
Sloping land-Medium-gradient escarpment zone,Alluvium [SSE- ALL]	**1860**	**100**
Cambisol (CM)	33	2
Fluvisol (FL)	25	1
Homestead (HS)	223	12
Leptosol (LP)	1196	64
Regosol (RG)	91	5
Vertisol (VR)	292	16
Sloping land-Medium-gradient escarpment zone,Trap volcanic rocks [SSE-B]	**2641**	**100**
Cambisol (CM)	0	0
Fluvisol (FL)	45	2
Homestead (HS)	125	5
Leptosol (LP)	2045	77
Regosol (RG)	156	6
Vertisol (VR)	270	10
Sloping land-Medium-gradient hill,Alluvium [SSH- ALL]	**4822**	**100**
Cambisol (CM)	449	9
Fluvisol (FL)	440	9
Homestead (HS)	526	11
Leptosol (LP)	469	10
Regosol (RG)	218	5
Vertisol (VR)	2719	56

Soils per landform and geology	Area (ha)	Per cent
Sloping land-Medium-gradient hill,Trap volcanic rocks [SSH- TVR]	**333**	**100**
Fluvisol (FL)	159	48
Homestead (HS)	5	1
Leptosol (LP)	77	23
Regosol (RG)	32	10
Vertisol (VR)	61	18
Steep land-High-gradient escarpment zone,Alluvium [TTE- ALL]	**7**	**100**
Leptosol (LP)	7	100
Steep land-High-gradient escarpment zone,Trap volcanic rocks [TTE-TVR]	**127**	**100**
Leptosol (LP)	126	99
Vertisol (VR)	1	1
Steep land-High-gradient hill,Alluvium [TTH- ALL]	**191**	**100**
Homestead (HS)	15	8
Leptosol (LP)	163	86
Vertisol (VR)	12	6
Steep land-High-gradient hill,Trap volcanic rocks [TTH- TVR]	**253**	**100**
Homestead (HS)	8	3
Leptosol (LP)	239	94
Vertisol (VR)	6	2
Steep land-High-gradient mountain,Alluvium [TTM- ALL]	**790**	**100**
Fluvisol (FL)	1	0
Homestead (HS)	1	0
Leptosol (LP)	773	98
Regosol (RG)	13	2
Vertisol (VR)	2	0
Steep land-High-gradient mountain,Trap volcanic rocks [TTM- TVR]	**5586**	**100**
Fluvisol (FL)	10	0
Homestead (HS)	17	0
Leptosol (LP)	5471	98
Regosol (RG)	44	1
Vertisol (VR)	43	1
Steep land-High-gradient valley,Trap volcanic rocks [TTV-TVR]	**67**	**100**
Leptosol (LP)	67	100

3.8.2 Soil profile descriptions with analytical data

The soil profile descriptions are organized per soil-landscape (Annex 2). The characteristics of the major soil types of each major soil-landscape (landform) are synthesised in the next paragraph.

3.8.3 Synthesis for Raya Azebo woreda

Cambisols, Fluvisols, Leptosols, Regosols, and Vertisols are the major soils available in the woreda. Vertisol covers 45% of the area, and is the dominant soil. Leptosol is the second dominant soils covering 36% of the area. With 4% area coverage, Fluvisol is the third important soils in the area.

Vertisols are the dominant soil in cultivated land of Raya Azebo woreda. Regosols also exist in some areas. Vertisols are moderately well drained, very deep, very to dark brown when mosit and dark greyish brown when dry, angular and subangular structured, clay texture soils with a general increase in clay content from top to sub-soils. Higher clay content on lower horizon shows translocation of clay from the surface to the depth of illuviation. The soils are developed from a wide variety of unconsolidated materials including alluvial and colluvial deposits. The soils are located on upper, medium and lower slope. Regosols are well drained, very deep, dark reddis brown, granular structure, sandy clay texture soils with higher clay content on top soils and lower on the subsoil.

Soil physical properties of the soils are generally good as they are well structured and deep soil. They have good drainage condition with deep ground water. Infilitration rate and water holding capacity of the soils are good. However the soil physical properties may have some degree of limitation especially workability when it is dry especially on Vertisols. Organic matter content of the soils is rated as low to medium, and decline with depth.

These soils have favourable chemical properties except for alkalinity in all Kebeles and high exchangeable sodium percentage at Kara Adishu Kebele. The soils have medium to high total nutrient content. But in some cases very high rate was recorded. Available P is mostly with high rate except in Kara Adishabo where medium rate was recorded. CEC value is rated as high to very high showing the overall potential fertility of the soil. pH of the soils is moderate to strong alkaline, and this will have effect on nutrient availability. Both soils have low micronutrient contents except Cu in Vertisols. But the magnitude is higher in Regosols including Cu which is low.

High available P in the soils implies there is low demand for P containing fertilizer. On the other hand, there is more demand for nitrogen sources. Particularly low to medium level of organic matter implies high demand for organic matter supply to sustain nutrient availability and improve physical soil conditions. Therefore use of crop residues or with weeds as well as other aspects of organic farming such as with use of compost should be used to provide continunous N-supply by mineralization. Farmers should be encouraged to leave certain amount of crop residue in the field to serve as sources of organic matter. This effort must be support with zero grazing practices and immediate ploughing of the fields after harvest. When conditions are favourable, use of blended fertilizers (which contain the macro and micro nutrients including S, Zn, Fe) with the right dose and time of

application is important to supply plant nutrients and reduce further nutrient mining.

Soils of the area are generally potential for agriculture, and more than 80% of the area is being cultivated, mainly for teff and sorghum. However climate limitation is a challenge. The challenge can be addressed with expansion of irrigated agriculture. Soils of the cultivated area are highly suitable for surface irrigation. All development activities in the area related to agricultural should be supported by availability of irrigation water and improved water management.

4 Conclusions and recommendations

4.1 Conclusion

This soil survey focused on 20 kebeles of five woredas in southern zone of Tigray upon demand of the CASCAPE project. The main objective of this soil survey is to characterise and understand the qualities and behaviour of the major agricultural soils occurring in the five CASCAPE intervention woredas of Tigray based on properly observed and measured soil morphologic, physical and chemical properties. The outputs of this research can be the basis for developing site specific and functional soil information that would guide soil fertility management decisions by smallholder farmers. Moreover, this will help in scaling up and extrapolating soil-based results of experiments. The study also contributes to the development of the national/regional soil information database under EthioSIS by the generated locally specific soil information for this study observed, measured and digitally compiled according to previously agreed standards. The standards include the data model adapted from the Africa Soil Profiles database and the data conventions of the FAO 2006 guidelines for soil description, with the soil profiles classified and presented according to the terrain (landform & geology) following SOTER procedures.

The study area is split in two overall landforms, knowing the highlands in the west and the lowlansd in the east, separated by a steep escarpment. The major landforms of Alaje, Enda Mehoni and Ofla woredas in the highlands of the study area are dominantly characterized by rugged topography with the valleys confined in gorges. Whereas the landforms of Raya Alamata and Raya Azebo woredas in the lowlands are dominated by level plains. Vertisols, Cambisols (buried Vertisols), Cambisols, Fluvisols, Regosols and Leptosols are found in the study area. Despite variation in area coverage most soil types exist across all major landforms though confined to specific minor landforms.

The soils in the highlands grow cereals (wheat, barley, maize, sorghum) and pulses (faba bean, lentil). Graben Valley soils (lowlands) are dominated by Vertisols, which is good for crop cultivation; however it suited for irrigated agriculture due to rainfall deficiency. The main crops in the lowlands are cereals including maize and sorghum, with chickpeas on the heavy Vertisols.

The main physical limitation in the study area is the soil workability for particularly the Vertisols due to the swelling and shrinking characteristics of such soils. Soil erosion is one of the most important land degradation processes in the area and is the major threat for sustainable agricultural production in the study area. It is severe in the steeper slopes of the escarpment and mountains. The soils of the study area are generally susceptible to erosion due to the very low organic matter of the soils resulting from the use of dung for fuel wood, and free stubble grazing in cultivated land. This has reduced organic matter content of the soils leading to the higher erodibility of the soils, consequently lower productivity. Moreover, moisture is the most limiting factor in the Graben area.Generally, the water holding capacity of the soil in Raya Alamata and Raya Azobo woredas is good but availability of soil

moisture is low due high evaporation and low amount of rainfall. Limitation due to unfavourable climate is a challenge in the area. Drainage and alkalinity is another important limitation in Vertisols soils.

4.2 Recommendation

Improving organic matter content and soil nitrogen through organic matter supply (manure, crop residue) with proper agronomic measure could improve productivity of the soil. In addition to applying organic matter, use of sulphur containing fertilizers may help to reduce soil pH provided that the cost is affordable. Cereal legume rotation should be widely practiced to avoid nutrient depletion and increase nitrogen stock in soils.

Mountainous, escarpments and hills should be retained for catchment protection forests in an effort to reduce the present severe erosion of the steep slopes. The valley

in the dissected mountains are dominated by Vertisols and they can be used for cultivation provided that proper irrigation is practiced and the irrigation chanel are well managed and the soils well drained.In the absence of enough moisture use of chemical fertililzer is not appropriate solution, particularly in Raya Alamata and Raya Azebo woredas. Preferably, the use of organic fertilizer as organic amendment is suitable to the area. This practice can increase the organic content of the soil as well as provide nutrients such as nitrogen and phosphorus while increasing CEC values of the soil. In addition the organic amendment is useful to reduce soil pH to neutral level. Application of S-containing fertilizer is also beneficiary to reduce higher soil pH.

References

Dobos E, Daroussin J and Montanarella L (2005).An SRTM-based procedure to delineate SOTER Terrain Units on 1:1 and 1:5 million scales. EUR21571 EN, Office for Official Publications of the European Communities, Luxembourg

FAO (1984), Geomorphology and soils. Ethiopia (including maps).http://library.wur.nl/WebQuery/isric/5322

FAO (1998**),**The Soil and Terrain Database for Northeastern Africa.http://library.wur.nl/WebQuery/isric/15033

FAO (2006), World Reference Base for Soil Resources 2006. A Framework for International Classification, Correlation and Communication. http://library.wur.nl/WebQuery/isric/23598

FAO(2006),Guidelines for soil description. 4th ed. Food and Agricultural Organization of the United Nations (FAO), Rome.97p.

Hunting (1976), Central Tigray Development Study, Working papers, Hunting Technical Service Limited, London, England.

ISRIC (2008).Global Assessment of Land Degradation.GIS-procedures for mapping SOTER landformfor the LADA partner countries(Argentina, China, Cuba, Senegal and The Gambia,South Africa and Tunisia). Jan Huting, Koos Dijkshoorn, and Vincent van Engelen. Augest 2008

Leenaars et al. (2014), Africa Soil Profiles Database. http://library.wur.nl/WebQuery/isric/34023

MCE (1996), Sheraro and Tahtay Adiabo Agricultural Development Project, Addis Ababa, Ethiopia.

NEDECO (1997), Mereb River Basin Master Plan Integrated Project, Vol 1, Amersfoort, The Netherlands.

RVIADP (1998), Soil and Water Conservation Feasibility Study, Mekelle, Tigray.

Tefera,M., Tadlwos Chernet, T., Haro, W., 1995. Explanation of the Geological map of Ethiopia, at the Scale 1:2,000,000, Bulletin no.3 the Federal Democratic Republic of Ehiopia Ministry of Mines and Energy Ethiopian Institute of Geological Surveys, 2nd edition, Addis Ababa, Ethiopia

Annex 1:Auger observations

1.1 Auger obsrvation for Alaje Atsela

Auger ID	TALJ-ATS-A1	TALJ-ATS-A2
Soil unit	SV(ha VR (eu, pe))	SE(ha VR (eu, pe))
Elevation (m.)	2493	2532
Coordinates (Deg, Min, Sec)	39°31'37",12°55'21"	39°32'23",12°55'26"
Soil taxonomic classification (WRB 2006)	Haplic Vertisol (Eutric, Pellic)	Haplic Vertisol (Eutric, Pellic)
Local soil name	Walka	Walka
Topography	10-30	10-30
Landform	Sloping land,Medium-gradient valley	Sloping land,Medium-gradient escarpment zone
Position	Lower Slope (foot slope)	Lower Slope (foot slope)
Slope	Straight slope, 2%	Straight slope, 2%
Micro-topography	Gigai	Gigai
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Fluvial sediments derived from Trap volcanic rocks	Fluvial sediments derived from Trap volcanic rocks
Soil depth	120 cm+	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Few (2-5%)	Few (2-5%)
Erosion status	Slight sheet erosion	Slight sheet erosion
Surface sealing	None	None
Surface cracks	Wide cracks (2-5cm), very deep (>30cm)	Wide cracks (2-5cm), very deep (>30cm)
Internal drainage	Imperfectly	Imperfectly
External drainage	Slow	Slow
Flooding	None	None
Groundwater	None observed	None observed

Auger ID	TALJ-ATS-A3	TALJ-ATS-A4
Soil unit	SE(ha VR (eu, pe))	SV(ha VR (eu, pe))
Elevation (m.)	2648	2592
Coordinates (Deg, Min, Sec)	39°31'48",12°57'30"	39°33'1",12°57'7"
Soil taxonomic classification (WRB 2006)	Haplic Vertisol (Eutric, Pellic)	Haplic Vertisol (Eutric, Pellic)
Local soil name	Walka	Walka
Topography	10-30	10-30
Landform	Sloping land,Medium-gradient escarpment zone	Sloping land,Medium-gradient valley
Position	Lower Slope (foot slope)	Lower Slope (foot slope)
Slope	Straight slope, 2%	Straight slope, 2%
Micro-topography	Gigai	Gigai
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Fluvial sediments derived from Trap volcanic rocks	Fluvial sediments derived from Trap volcanic rocks
Soil depth	120 cm+	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Few (2-5%)	Few (2-5%)
Erosion status	Slight sheet erosion	Slight sheet erosion
Surface sealing	None	None
Surface cracks	Wide cracks (2-5cm), very deep (>30cm)	Wide cracks (2-5cm), very deep (>30cm)
Internal drainage	Imperfectly	Imperfectly
External drainage	Slow	Slow
Flooding	None	None
Groundwater	None observed	None observed

Auger ID	TALJ-ATS-A5	TALJ-ATS-A6
Soil unit	SV(ha VR (eu, pe))	SV(ha VR (eu, pe))
Elevation (m.)	2534	2493
Coordinates (Deg, Min, Sec)	39°32'52",12°56'37"	39°32'24",12°56'15"
Soil taxonomic classification (WRB 2006)	Haplic Vertisol (Eutric, Pellic)	Haplic Vertisol (Eutric, Pellic)
Local soil name	Walka	Walka
Topography	10-30	10-30
Landform	Sloping land,Medium-gradient valley	Sloping land,Medium-gradient valley
Position	Toe slope	Lower Slope (foot slope)
Slope	Straight slope, 2%	Straight slope, 2%
Micro-topography	Gigai	Gigai
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Fluvial sediments derived from Trap volcanic rocks	Fluvial sediments derived from Trap volcanic rocks
Soil depth	120 cm+	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Few (2-5%)	Few (2-5%)
Erosion status	Slight sheet erosion	Slight sheet erosion
Surface sealing	None	None
Surface cracks	Wide cracks (2-5cm), very deep (>30cm)	Wide cracks (2-5cm), very deep (>30cm)
Internal drainage	Imperfectly	Imperfectly
External drainage	Slow	Slow
Flooding	None	None
Groundwater	None observed	None observed

Auger ID	**TALJ-ATS-A7**	**TALJ-ATS-A8**
Soil unit	SV(ha VR (eu, pe))	SE(ha VR (eu, pe))
Elevation (m.)	2509	2642
Coordinates (Deg, Min, Sec)	39°33'20",12°55'43"	39°31'7",12°57'19"
Soil taxonomic classification (WRB 2006)	Haplic Vertisol (Eutric, Pellic)	Haplic Vertisol (Eutric, Pellic)
Local soil name	Walka	Walka
Topography	10-30	10-30
Landform	Sloping land,Medium-gradient valley	Sloping land,Medium-gradient escarpment zone
Position	Toe slope	Lower Slope (foot slope)
Slope	Straight slope, 2%	Straight slope, 2%
Micro-topography	Gigai	Gigai
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Fluvial sediments derived from Trap volcanic rocks	Fluvial sediments derived from Trap volcanic rocks
Soil depth	120 cm+	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Few (2-5%)	Few (2-5%)
Erosion status	Slight sheet erosion	Slight sheet erosion
Surface sealing	None	None
Surface cracks	Wide cracks (2-5cm), very deep (>30cm)	Wide cracks (2-5cm), very deep (>30cm)
Internal drainage	Imperfectly	Imperfectly
External drainage	Slow	Slow
Flooding	None	None
Groundwater	None observed	None observed

1.2 Auger obsrvation for Alaje Ayba

Auger ID	**TALJ-AYB-A1**	**TALJ-AYB-A2**
Soil unit	TM(cc VR (eu, pe))	TM(cc VR (eu, pe))
Elevation (m.)	3095	3069
Coordinates (Deg, Min, Sec)	39°32'30",12°54'12"	39°32'27",12°54'10"
Soil taxonomic classification (WRB 2006)	Calcic Vertisol (Eutric, Pellic)	Calcic Vertisol (Eutric, Pellic)
Local soil name	Walka	Walka
Topography	> 30	> 30
Landform	Steep land,High-gradient mountain	Steep land,High-gradient mountain
Position	Upper slope (shoulder)	Summit
Slope	Straight slope, 2%	Straight slope, 2%
Micro-topography	Gilgai	Gilgai
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Fluvial sediments derived from Trap volcanic rocks	Fluvial sediments derived from Trap volcanic rocks
Soil depth	120 cm+	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Few (2-5%)	Few (2-5%)
Erosion status	Slight sheet erosion	Slight sheet erosion
Surface sealing	None	None
Surface cracks	Wide cracks (2-5cm), very deep (>30cm)	Wide cracks (2-5cm), very deep (>30cm)
Internal drainage	Imperfectly	Imperfectly
External drainage	Well	Well
Flooding	None	None
Groundwater	None observed	None observed

Auger ID	**TALJ-AYB-A5**	**TALJ-AYB-A6**
Soil unit	SE(cc VR (eu, pe))	SV(cc VR (eu, pe))
Location (admin.)	Tigray, Alaje woreda, Ayba Kebele	Tigray, Alaje woreda, Ayba Kebele
Elevation (m.)	3031	2743
Coordinates (Deg, Min, Sec)	39°32'26",12°54'7"	39°32'54",12°52'36"
Soil taxonomic classification (WRB 2006)	Calcic Vertisol (Eutric, Pellic)	Calcic Vertisol (Eutric, Pellic)
Local soil name	Walka	Walka
Topography	10-30	10-30
Landform	Sloping land,Medium-gradient escarpment zone	Sloping land,Medium-gradient valley
Position	Middle slope (Back slope)	Lower slope (foot slope)
Slope	Straight slope, 2%	Concave slope, 2 %
Micro-topography	Gilgai	Gilgai
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Fluvial sediments derived from Trap volcanic rocks	Fluvial sediments derived from Trap volcanic rocks
Soil depth	120 cm+	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Few (2-5%)	Many (15-40%)
Erosion status	Slight sheet erosion	Slight sheet erosion
Surface sealing	None	None
Surface cracks	Wide cracks (2-5cm), very deep (>30cm)	Cracks can not be seen due to plough obliteration
Internal drainage	Imperfectly	Imperfectly
External drainage	Well	Slow
Flooding	None	about 3 times a year for a duration of a week
Groundwater	None observed	None observed

Auger ID	TALJ-AYB-A7	TALJ-AYB-A8
Soil unit	SV(vr el CM (eu))	SV(vr el CM (eu))
Location (admin.)	Tigray, Alaje woreda, Ayba Kebele	Tigray, Alaje woreda, Ayba Kebele
Elevation (m.)	2724	2725
Coordinates (Deg, Min, Sec)	39°31'58",12°52'60"	39°31'23",12°53'17"
Soil taxonomic classification (WRB 2006)	Vertic Epileptic Cambisol (Eutric)	Vertic Epileptic Cambisol (Eutric)
Local soil name	Walka	Walka
Topography	10-30	10-30
Landform	Sloping land,Medium-gradient valley	Sloping land,Medium-gradient valley
Position	Middle slope (Back slope)	Middle slope (Back slope)
Slope	Concave slope, 2 %	Concave slope, 2 %
Micro-topography	Gilgai	Gilgai
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Fluvial sediments derived from Trap volcanic rocks	Fluvial sediments derived from Trap volcanic rocks
Soil depth	120 cm+	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Many (15-40%)	Many (15-40%)
Erosion status	Slight sheet erosion	Slight sheet erosion
Surface sealing	None	None
Surface cracks	Cracks can not be seen due to plough obliteration	Cracks can not be seen due to plough obliteration
Internal drainage	Imperfectly	Imperfectly
External drainage	Slow	Slow
Flooding	about 3 times a year for a duration of a week	about 3 times a year for a duration of a week
Groundwater	None observed	None observed

1.3 Auger obsrvation for Alaje Sesat

Auger ID	**TALJ-SES-A1**	**TALJ-SES-A2**
Soil unit	SE(ha LP (eu,sk))	SE(ha LP (eu,sk))
Location (admin.)	Tigray, Alaje woreda, Sesat Kebele	Tigray, Alaje woreda, Sesat Kebele
Elevation (m.)	2581	2623
Coordinates (Deg, Min, Sec)	39°34'4",12°55'5"	39°34'55",12°55'4"
Soil taxonomic classification (WRB 2006)	Haplic Leptosol (Eutric, Skeletic)	Haplic Leptosol (Eutric, Skeletic)
Local soil name	Hamed Qoriya	Hamed Qoriya
Topography	10-30	10-30
Landform	Sloping land,Medium-gradient escarpment zone	Sloping land,Medium-gradient escarpment zone
Position	Middle Slope (Back slope)	Middle Slope (Back slope)
Slope	Straight slope, 30%	Straight slope, 30%
Micro-topography	None	None
Land Use	Degraded Shrub land	Degraded Shrub land
Human influence	Overgrazing	Overgrazing
Vegetation	Grasses and shrubs	Grasses and shrubs
Parent material	Trap volcanic rocks (Basic igneos rock basalt)	Trap volcanic rocks (Basic igneos rock basalt)
Soil depth	40 cm	35 cm
Land Use	Degraded Shrub land	Degraded Shrub land
Rock outcrops	few	few
Surface coarse fragments	Many (15-40%)	Many (15-40%)
Erosion status	Slight sheet erosion	Slight sheet erosion
Surface sealing	None	None
Surface cracks	Cracks can not be seen due to plough obliteration	Cracks can not be seen due to plough obliteration
Internal drainage	Imperfectly	Imperfectly
External drainage	Slow	Slow
Flooding	about 3 times a year for a duration of a week	about 3 times a year for a duration of a week
Groundwater	None observed	None observed

Auger ID	TALJ-SES-A3	TALJ-SES-A4
Soil unit	SE(ha VR (eu, pe))	SV(le RG (eu))
Location (admin.)	Tigray, Alaje woreda, Sesat Kebele	Tigray, Alaje woreda, Sesat Kebele
Elevation (m.)	2683	2692
Coordinates (Deg, Min, Sec)	39°35'35",12°56'13"	39°36'31",12°55'13"
Soil taxonomic classification (WRB 2006)	Haplic Vertisol (Eutric, Pellic)	Leptic Regosol (Eutric)
Local soil name	Walka	Walka
Topography	10-30	10-30
Landform	Sloping land,Medium-gradient escarpment zone	Sloping land,Medium-gradient valley
Position	Lower Slope (foot slope)	Middle Slope (Back slope)
Slope	Straight slope, 2%	Straight slope, 2%
Micro-topography	Gilgai	None
Land Use	Rainfed arable cultivation	Degraded Shrub land
Human influence	DAP and Urea fertilizer	Overgrazing
Vegetation	None	Grasses and shrubs
Parent material	Fluvial sediments derived from Trap volcanic rocks	Fluvial sediments derived from Trap volcanic rocks
Soil depth	120 cm+	85 cm
Land Use	Cultivated land	Degraded Shrub land
Rock outcrops	None	few
Surface coarse fragments	Few (2-5%)	Common (5-15%)
Erosion status	Slight sheet erosion	Severe sheet erosion
Surface sealing	thin crusts (<2mm)	None
Surface cracks	Wide cracks (4cm), very deep (>30cm)	None
Internal drainage	Poor	Well
External drainage	Slow	Rapid
Flooding	Once a year for a duration of a week	None
Groundwater	None observed	None observed

Auger ID	**TALJ-SES-A5**	**TALJ-SES-A6**
Soil unit	SV(ha VR (eu, pe))	SV(ha VR (eu, pe))
Location (admin.)	Tigray, Alaje woreda, Sesat Kebele	Tigray, Alaje woreda, Sesat Kebele
Elevation (m.)	2663	2645
Coordinates (Deg, Min, Sec)	39°36'32",12°54'56"	39°36'7",12°55'3"
Soil taxonomic classification (WRB 2006)	Haplic Vertisol (Eutric, Pellic)	Haplic Vertisol (Eutric, Pellic)
Local soil name	Walka	Walka
Topography	10-30	10-30
Landform	Sloping land,Medium-gradient valley	Sloping land,Medium-gradient valley
Position	Lower Slope (foot slope)	Lower Slope (foot slope)
Slope	Straight slope, 2%	Straight slope, 2%
Micro-topography	Gilgai	Gilgai
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Fluvial sediments derived from Trap volcanic rocks	Fluvial sediments derived from Trap volcanic rocks
Soil depth	120 cm+	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Few (2-5%)	Few (2-5%)
Erosion status	Slight sheet erosion	Slight sheet erosion
Surface sealing	thin crusts (<2mm)	thin crusts (<2mm)
Surface cracks	Wide cracks (4cm), very deep (>30cm)	Wide cracks (4cm), very deep (>30cm)
Internal drainage	Poor	Poor
External drainage	Slow	Slow
Flooding	Once a year for a duration of a week	Once a year for a duration of a week
Groundwater	None observed	None observed

Auger ID	TALJ-SES-A7	TALJ-SES-A8
Soil unit	SV(ha VR (eu, pe))	SV(ha VR (eu, pe))
Location (admin.)	Tigray, Alaje woreda, Sesat Kebele	Tigray, Alaje woreda, Sesat Kebele
Elevation (m.)	2598	2535
Coordinates (Deg, Min, Sec)	39°35'18",12°55'10"	39°33'60",12°55'44"
Soil taxonomic classification (WRB 2006)	Haplic Vertisol (Eutric, Pellic)	Haplic Vertisol (Eutric, Pellic)
Local soil name	Walka	Walka
Topography	10-30	10-30
Landform	Sloping land,Medium-gradient valley	Sloping land,Medium-gradient valley
Position	Lower Slope (foot slope)	Lower Slope (foot slope)
Slope	Straight slope, 2%	Straight slope, 2%
Micro-topography	Gilgai	Gilgai
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Fluvial sediments derived from Trap volcanic rocks	Fluvial sediments derived from Trap volcanic rocks
Soil depth	120 cm+	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Few (2-5%)	Few (2-5%)
Erosion status	Slight sheet erosion	Slight sheet erosion
Surface sealing	thin crusts (<2mm)	thin crusts (<2mm)
Surface cracks	Wide cracks (4cm), very deep (>30cm)	Wide cracks (4cm), very deep (>30cm)
Internal drainage	Poor	Poor
External drainage	Slow	Slow
Flooding	Once a year for a duration of a week	Once a year for a duration of a week
Groundwater	None observed	None observed

1.4 Auger obsrvation for Alaje Tekha

Auger ID	**TALJ-TEK-A1**	**TALJ-TEK-A2**
Soil unit	TM(ha RG (eu))	SP(ha CM (eu))
Location (admin.)	Tigray, Alaje woreda, Teka Kebele	Tigray, Alaje woreda, Teka Kebele
Elevation (m.)	2809	2587
Coordinates (Deg, Min, Sec)	39°28'33",12°53'45"	39°28'11",12°54'28"
Soil taxonomic classification (WRB 2006)	Haplic Regosol (Eutric)	Haplic Cambisol (Eutric)
Local soil name	Hamed Qoriya	Hamed Qoriya
Topography	> 30	10-30
Landform	Steep land,High-gradient mountain	Sloping land,Dissected plain
Position	Middle slope (back slope)	Lower slope (foot slope)
Slope	Straight slope, 36%	Straight slope, 8%
Micro-topography	None	None
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Trap volcanic rocks (Basic igneos rock basalt)	Trap volcanic rocks (Basic igneos rock basalt)
Soil depth	85 cm	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Few (2-5%)	Common (5-15%)
Erosion status	Slight sheet erosion	Moderate sheet erosion
Surface sealing	thin crusts (<2mm)	None
Surface cracks	Wide cracks (4cm), very deep (>30cm)	None
Internal drainage	Poor	Well
External drainage	Slow	Rapid
Flooding	Once a year for a duration of a week	None
Groundwater	None observed	None observed

Auger ID	TALJ-TEK-A3	TALJ-TEK-A4
Soil unit	SV(ha LP (eu,sk))	SV(ha CM (eu))
Location (admin.)	Tigray, Alaje woreda, Teka Kebele	Tigray, Alaje woreda, Teka Kebele
Elevation (m.)	2597	2581
Coordinates (Deg, Min, Sec)	39°28'17",12°54'50"	39°28'27",12°54'30"
Soil taxonomic classification (WRB 2006)	Haplic Leptosol (Eutric, Skeletic)	Haplic Cambisol (Eutric)
Local soil name	Hamed Qoriya	Hamed Qoriya
Topography	10-30	10-30
Landform	Sloping land,Medium-gradient valley	Sloping land,Medium-gradient valley
Position	Middle slope (back slope)	Lower slope (foot slope)
Slope	Straight slope, 35%	Straight slope, 8%
Micro-topography	None	None
Land Use	Degraded Shrub land	Rainfed arable cultivation
Human influence	Overgrazing	DAP and Urea fertilizer
Vegetation	Grasses and shrubs	None
Parent material	Trap volcanic rocks (Basic igneos rock basalt)	Trap volcanic rocks (Basic igneos rock basalt)
Soil depth	30 cm	120 cm+
Land Use	Degraded Shrub land	Cultivated land
Rock outcrops	few	None
Surface coarse fragments	Few (2-5%)	Common (5-15%)
Erosion status	Slight sheet erosion	Moderate sheet erosion
Surface sealing	thin crusts (<2mm)	None
Surface cracks	Wide cracks (4cm), very deep (>30cm)	None
Internal drainage	Poor	Well
External drainage	Slow	Rapid
Flooding	Once a year for a duration of a week	None
Groundwater	None observed	None observed

Auger ID	TALJ-TEK-A5	TALJ-TEK-A6
Soil unit	SV(ha CM (eu))	SV(vr el CM (eu))
Location (admin.)	Tigray, Alaje woreda, Teka Kebele	Tigray, Alaje woreda, Teka Kebele
Elevation (m.)	2596	2653
Coordinates (Deg, Min, Sec)	39°28'47",12°54'35"	39°29'15",12°54'12"
Soil taxonomic classification (WRB 2006)	Haplic Cambisol (Eutric)	Vertic Epileptic Cambisol (Eutric)
Local soil name	Hamed Qoriya	Kelil Walka
Topography	10-30	10-30
Landform	Sloping land,Medium-gradient valley	Sloping land,Medium-gradient valley
Position	Lower slope (foot slope)	Middle slope (back slope)
Slope	Straight slope, 8%	Straight slope, 4%
Micro-topography	None	None
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Trap volcanic rocks (Basic igneos rock basalt)	Trap volcanic rocks (Basic igneos rock basalt)
Soil depth	120 cm+	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Common (5-15%)	Abundant (40-80%)
Erosion status	Moderate sheet erosion	Severe water erosion
Surface sealing	None	None
Surface cracks	None	None
Internal drainage	Well	Well
External drainage	Rapid	Rapid
Flooding	None	None
Groundwater	None observed	None observed

Auger ID	**TALJ-TEK-A7**	**TALJ-TEK-A8**
Soil unit	TV(vr el CM (eu))	SV(ha VR (eu, pe))
Location (admin.)	Tigray, Alaje woreda, Teka Kebele	Tigray, Alaje woreda, Teka Kebele
Elevation (m.)	2671	2628
Coordinates (Deg, Min, Sec)	39°30'7",12°54'10"	39°29'14",12°54'60"
Soil taxonomic classification (WRB 2006)	Vertic Epileptic Cambisol (Eutric)	Haplic Vertisol (Eutric, Pellic)
Local soil name	Kelil Walka	Walka
Topography	> 30	10-30
Landform	Steep land,High-gradient valley	Sloping land,Medium-gradient valley
Position	Middle slope (back slope)	Middle slope (back slope)
Slope	Straight slope, 4%	Concave slope, 2%
Micro-topography	None	terracing
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Trap volcanic rocks (Basic igneos rock basalt)	Trap volcanic rocks (Basic igneos rock basalt)
Soil depth	120 cm+	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Abundant (40-80%)	Few (2-5%)
Erosion status	Severe water erosion	Slight sheet erosion
Surface sealing	None	None
Surface cracks	None	Wide cracks (2-5cm), medium depth (2-10cm)
Internal drainage	Well	Well
External drainage	Rapid	Well
Flooding	None	Once per year for a day
Groundwater	None observed	None observed

1.5 Auger obsrvation for Enda Mehoni Mekan

Auger ID	**TENM-MEK-A1**	**TENM-MEK-A2**
Soil unit	SE(ha VR (eu, pe))	SH(ha VR (eu, pe))
Location (admin.)	Tigray, Enda Mokoni woreda, Mekan Kebele	Tigray, Enda Mokoni woreda, Mekan Kebele
Elevation (m.)	2470	2425
Coordinates (Deg, Min, Sec)	39°31'17",12°44'31"	39°31'29",12°44'37"
Soil taxonomic classification (WRB 2006)	Haplic Vertisol (Eutric, Pellic)	Haplic Vertisol (Eutric, Pellic)
Local soil name	Walka	Walka
Topography	10-30	10-30
Landform	Sloping land,Medium-gradient escarpment zone	Sloping land,Medium-gradient hill
Position	Upper slope (shoulder)	Middle slope (back slope)
Slope	Straight slope, 2%	Straight slope, 2%
Micro-topography	terracing	terracing
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Fluvial sediments derived from Trap volcanic rocks	Fluvial sediments derived from Trap volcanic rocks
Soil depth	120 cm+	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Few (2-5%)	Few (2-5%)
Erosion status	Slight sheet erosion	Slight sheet erosion
Surface sealing	thin crusts (<2mm)	thin crusts (<2mm)
Surface cracks	Wide cracks (2-5cm), medium depth (2-10cm)	Wide cracks (2-5cm), medium depth (2-10cm)
Internal drainage	Well	Well
External drainage	Well	Well
Flooding	None	None
Groundwater	None observed	None observed

Auger ID	**TENM-MEK-A3**	**TENM-MEK-A4**
Soil unit	SH(ha FL (eu))	SH(ha VR (eu, pe))
Location (admin.)	Tigray, Enda Mokoni woreda, Mekan Kebele	Tigray, Enda Mokoni woreda, Mekan Kebele
Elevation (m.)	2407	2412
Coordinates (Deg, Min, Sec)	39°31'42",12°44'47"	39°31'48",12°44'60"
Soil taxonomic classification (WRB 2006)	Haplic Fluvisol (Eutric)	Haplic Vertisol (Eutric, Pellic)
Local soil name	Boda	Walka
Topography	10-30	10-30
Landform	Sloping land,Medium-gradient hill	Sloping land,Medium-gradient hill
Position	Toe slope	Middle slope (Back slope)
Slope	Straight slope, 2%	Straight slope, 2%
Micro-topography	None	terracing
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Fluvial sediments derived from Trap volcanic rocks	Fluvial sediments derived from Trap volcanic rocks
Soil depth	120 cm+	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	None	Few (2-5%)
Erosion status	Slight sheet erosion	Slight sheet erosion
Surface sealing	thin crusts (<2mm)	thin crusts (<2mm)
Surface cracks	None	Wide cracks (2-5cm), medium depth (2-10cm)
Internal drainage	Imperfectly	Well
External drainage	Slow	Well
Flooding	Once per a year for a duration 2months	None
Groundwater	None observed	None observed

Auger ID	**TENM-MEK-A5**	**TENM-MEK-A6**
Soil unit	LL(ha VR (eu, pe))	SH(ha VR (eu, pe))
Location (admin.)	Tigray, Enda Mokoni woreda, Mekan Kebele	Tigray, Enda Mokoni woreda, Mekan Kebele
Elevation (m.)	2409	2430
Coordinates (Deg, Min, Sec)	39°32'1",12°45'10"	39°31'57",12°45'33"
Soil taxonomic classification (WRB 2006)	Haplic Vertisol (Eutric, Pellic)	Haplic Vertisol (Eutric, Pellic)
Local soil name	Walka	Walka
Topography	< 10	10-30
Landform	Level land,Plateau	Sloping land,Medium-gradient hill
Position	Lower slope (foot slope)	Middle slope (Back slope)
Slope	Straight slope, 2%	Straight slope, 2%
Micro-topography	terracing	terracing
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Fluvial sediments derived from Trap volcanic rocks	Fluvial sediments derived from Trap volcanic rocks
Soil depth	120 cm+	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Few (2-5%)	Few (2-5%)
Erosion status	Slight sheet erosion	Slight sheet erosion
Surface sealing	thin crusts (<2mm)	thin crusts (<2mm)
Surface cracks	Wide cracks (2-5cm), medium depth (2-10cm)	Wide cracks (2-5cm), medium depth (2-10cm)
Internal drainage	Well	Well
External drainage	Well	Well
Flooding	None	None
Groundwater	None observed	None observed

Auger ID	**TENM-MEK-A7**	**TENM-MEK-A8**
Soil unit	SV(ha VR (eu, pe))	SE(vr CM (eu))
Location (admin.)	Tigray, Enda Mokoni woreda, Mekan Kebele	Tigray, Enda Mokoni woreda, Mekan Kebele
Elevation (m.)	2537	2529
Coordinates (Deg, Min, Sec)	39°30'15",12°44'32"	39°30'18",12°45'6"
Soil taxonomic classification (WRB 2006)	Haplic Vertisol (Eutric, Pellic)	Vertic Cambisol (Eutric)
Local soil name	Walka	Walka
Topography	10-30	10-30
Landform	Sloping land,Medium-gradient valley	Sloping land,Medium-gradient escarpment zone
Position	Middle Slope (Back slope)	Lower slope (foot slope)
Slope	Straight slope, 2%	Straight slope, 2%
Micro-topography	None	None
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Trap volcanic rocks (Basic igneos rock basalt)	Trap volcanic rocks (Basic igneos rock basalt)
Soil depth	120 cm+	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Few (2-5%)	Few (2-5%)
Erosion status	Slight sheet erosion	Slight sheet erosion
Surface sealing	thin crusts (<2mm)	thin crusts (<2mm)
Surface cracks	None	None
Internal drainage	Well	Well
External drainage	Rapid	Rapid
Flooding	None	None
Groundwater	None observed	None observed

1.6 Auger obsrvation for Enda Mehoni Shibta

Auger ID	**TENM-SHI-A1**	**TENM-SHI-A2**
Soil unit	SE(ha LP (eu,sk))	SE(vr CM (eu))
Location (admin.)	Tigray, Enda Mokoni woreda, Shibta Kebele	Tigray, Enda Mokoni woreda, Shibta Kebele
Elevation (m.)	2771	2541
Coordinates (Deg, Min, Sec)	39°28'44",12°47'56"	39°29'18",12°47'50"
Soil taxonomic classification (WRB 2006)	Haplic Leptosol (Eutric, Skeletic)	Vertic Cambisol (Eutric)
Local soil name	Hamed Qoriya	Walka
Topography	10-30	10-30
Landform	Sloping land,Medium-gradient escarpment zone	Sloping land,Medium-gradient escarpment zone
Position	summit	Lower slope (foot slope)
Slope	Straight slope, 20%	Straight slope, 2%
Micro-topography	None	None
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Trap volcanic rocks (Basic igneos rock basalt)	Trap volcanic rocks (Basic igneos rock basalt)
Soil depth	38cm	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Few (2-5%)	Few (2-5%)
Erosion status	Slight sheet erosion	Slight sheet erosion
Surface sealing	thin crusts (<2mm)	thin crusts (<2mm)
Surface cracks	None	None
Internal drainage	Well	Well
External drainage	Rapid	Rapid
Flooding	None	None
Groundwater	None observed	None observed

Auger ID	TENM-SHI-A3	TENM-SHI-A4
Soil unit	SV(vr CM (eu))	SV(ha VR (eu, pe))
Location (admin.)	Tigray, Enda Mokoni woreda, Shibta Kebele	Tigray, Enda Mokoni woreda, Shibta Kebele
Elevation (m.)	2544	2539
Coordinates (Deg, Min, Sec)	39°29'31",12°47'23"	39°29'43",12°47'27"
Soil taxonomic classification (WRB 2006)	Vertic Cambisol (Eutric)	Haplic Vertisol (Eutric, Pellic)
Local soil name	Walka	Walka
Topography	10-30	10-30
Landform	Sloping land,Medium-gradient valley	Sloping land,Medium-gradient valley
Position	Middle slope (Back slope)	Middle slope (Back slope)
Slope	Straight slope, 2%	Straight slope, 35%
Micro-topography	None	soil bund & Gilgai
Land Use	Rainfed arable cultivation	Grass land
Human influence	DAP and Urea fertilizer	Overgrazing
Vegetation	None	Grass
Parent material	Trap volcanic rocks (Basic igneos rock basalt)	Trap volcanic rocks (Basic igneos rock basalt)
Soil depth	120 cm+	120 cm+
Land Use	Cultivated land	Grass land
Rock outcrops	None	None
Surface coarse fragments	Few (2-5%)	Few (2-5%)
Erosion status	Slight sheet erosion	Slight sheet erosion
Surface sealing	thin crusts (<2mm)	thin crusts (<2mm)
Surface cracks	None	Very wide cracks (5-10cm), deep (10-20cm)
Internal drainage	Well	Well
External drainage	Rapid	Well
Flooding	None	Once per year for a day
Groundwater	None observed	None observed

Auger ID	TENM-SHI-A5	TENM-SHI-A6
Soil unit	SE(vr CM (eu))	TM(ha CM (ca,bVR))
Location (admin.)	Tigray, Enda Mokoni woreda, Shibta Kebele	Tigray, Enda Mokoni woreda, Shibta Kebele
Elevation (m.)	2590	2477
Coordinates (Deg, Min, Sec)	39°31'14",12°47'36"	39°31'25",12°47'53"
Soil taxonomic classification (WRB 2006)	Vertic Cambisol (Eutric)	Haplic Cambisol (Calcaric) (Thapto-Vertisolic)
Local soil name	Walka	Hamed Qoriya
Topography	10-30	> 30
Landform	Sloping land,Medium-gradient escarpment zone	Steep land,High-gradient mountain
Position	Middle slope (Back slope)	Summit
Slope	Straight slope, 2%	Straight slope, 8%
Micro-topography	None	None
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Trap volcanic rocks (Basic igneos rock basalt)	Trap volcanic rocks (Basic igneos rock basalt)
Soil depth	120 cm+	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Few (2-5%)	Common (5-15%)
Erosion status	Slight sheet erosion	Moderate sheet erosion
Surface sealing	thin crusts (<2mm)	thin crusts (<2mm)
Surface cracks	None	None
Internal drainage	Well	Well
External drainage	Rapid	Rapid
Flooding	None	None
Groundwater	None observed	None observed

Auger ID	**TENM-SHI-A7**	**TENM-SHI-A8**
Soil unit	SE(ha LP (eu,sk))	TM(vr CM (eu))
Location (admin.)	Tigray, Enda Mokoni woreda, Shibta Kebele	Tigray, Enda Mokoni woreda, Shibta Kebele
Elevation (m.)	2751	2485
Coordinates (Deg, Min, Sec)	39°28'51",12°47'53"	39°31'30",12°47'40"
Soil taxonomic classification (WRB 2006)	Haplic Leptosol (Eutric, Skeletic)	Vertic Cambisol (Eutric)
Local soil name	Hamed Qoriya	Walka
Topography	10-30	> 30
Landform	Sloping land,Medium-gradient escarpment zone	Steep land,High-gradient mountain
Position	Middle slop (Back slope)	Middle slop (Back slope)
Slope	Straight slope, 20%	Straight slope, 2%
Micro-topography	None	None
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Trap volcanic rocks (Basic igneos rock basalt)	Trap volcanic rocks (Basic igneos rock basalt)
Soil depth	37cm	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Few (2-5%)	Few (2-5%)
Erosion status	Slight sheet erosion	Slight sheet erosion
Surface sealing	thin crusts (<2mm)	thin crusts (<2mm)
Surface cracks	None	None
Internal drainage	Well	Well
External drainage	Rapid	Rapid
Flooding	None	None
Groundwater	None observed	None observed

1.7 Auger obsrvation for Enda Mehoni Simret

Auger ID	**TENM-SIM-A1**	**TENM-SIM-A2**
Soil unit	SV(ha VR (eu, pe))	SV(ha VR (eu, pe))
Location (admin.)	Tigray, Enda Mokoni woreda, Simret Kebele	Tigray, Enda Mokoni woreda, Simret Kebele
Elevation (m.)	2507	2582
Coordinates (Deg, Min, Sec)	39°30'38",12°43'29"	39°30'44",12°43'36"
Soil taxonomic classification (WRB 2006)	Haplic Vertisol (Eutric, Pellic)	Haplic Vertisol (Eutric, Pellic)
Local soil name	Walka	Walka
Topography	10-30	10-30
Landform	Sloping land,Medium-gradient valley	Sloping land,Medium-gradient valley
Position	Middle slope (Back slope)	Lower slope (foot slope)
Slope	Straight slope, 2%	Straight slope, 2%
Micro-topography	None	None
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Trap volcanic rocks (Basic igneos rock basalt)	Trap volcanic rocks (Basic igneos rock basalt)
Soil depth	120 cm+	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Common (5-15%)	Common (5-15%)
Erosion status	Slight sheet erosion	Slight sheet erosion
Surface sealing	thin crusts (<2mm)	thin crusts (<2mm)
Surface cracks	Fine cracks (<1cm), surface (<2cm)	Fine cracks (<1cm), surface (<2cm)
Internal drainage	Well	Well
External drainage	Well	Well
Flooding	None	None
Groundwater	None observed	None observed

Auger ID	TENM-SIM-A3	TENM-SIM-A4
Soil unit	SV(ha VR (eu, pe))	SE(ha VR (eu, pe))
Location (admin.)	Tigray, Enda Mokoni woreda, Simret Kebele	Tigray, Enda Mokoni woreda, Simret Kebele
Elevation (m.)	2577	2622
Coordinates (Deg, Min, Sec)	39°30'55",12°43'46"	39°30'53",12°43'9"
Soil taxonomic classification (WRB 2006)	Haplic Vertisol (Eutric, Pellic)	Haplic Vertisol (Eutric, Pellic)
Local soil name	Walka	Walka
Topography	10-30	10-30
Landform	Sloping land,Medium-gradient valley	Sloping land,Medium-gradient escarpment zone
Position	Lower slope (foot slope)	Middle slope (Back slope)
Slope	Straight slope, 2%	Straight slope, 2%
Micro-topography	None	None
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Trap volcanic rocks (Basic igneos rock basalt)	Trap volcanic rocks (Basic igneos rock basalt)
Soil depth	120 cm+	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Common (5-15%)	Common (5-15%)
Erosion status	Slight sheet erosion	Slight sheet erosion
Surface sealing	thin crusts (<2mm)	thin crusts (<2mm)
Surface cracks	Fine cracks (<1cm), surface (<2cm)	Fine cracks (<1cm), surface (<2cm)
Internal drainage	Well	Well
External drainage	Well	Well
Flooding	None	None
Groundwater	None observed	None observed

Auger ID	TENM-SIM-A5	TENM-SIM-A6
Soil unit	SE(vr CM (eu))	SV(ha VR (eu, pe))
Location (admin.)	Tigray, Enda Mokoni woreda, Simret Kebele	Tigray, Enda Mokoni woreda, Simret Kebele
Elevation (m.)	2648	2596
Coordinates (Deg, Min, Sec)	39°30'34",12°43'16"	39°30'21",12°43'37"
Soil taxonomic classification (WRB 2006)	Vertic Cambisol (Eutric)	Haplic Vertisol (Eutric, Pellic)
Local soil name	Walka	Walka
Topography	10-30	10-30
Landform	Sloping land,Medium-gradient escarpment zone	Sloping land,Medium-gradient valley
Position	Upper slope (shoulder)	Middle slope (Back slope)
Slope	Straight slope, 2%	Straight slope, 2%
Micro-topography	None	None
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Trap volcanic rocks (Basic igneos rock basalt)	Trap volcanic rocks (Basic igneos rock basalt)
Soil depth	120 cm+	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Few (2-5%)	Common (5-15%)
Erosion status	Slight sheet erosion	Slight sheet erosion
Surface sealing	thin crusts (<2mm)	thin crusts (<2mm)
Surface cracks	None	Fine cracks (<1cm), surface (<2cm)
Internal drainage	Well	Well
External drainage	Rapid	Well
Flooding	None	None
Groundwater	None observed	None observed

Auger ID	TENM-SIM-A7	TENM-SIM-A8
Soil unit	SE(vr CM (eu))	SV(vr CM (eu))
Location (admin.)	Tigray, Enda Mokoni woreda, Simret Kebele	Tigray, Enda Mokoni woreda, Simret Kebele
Elevation (m.)	2560	2529
Coordinates (Deg, Min, Sec)	39°29'50",12°44'2"	39°29'58",12°44'17"
Soil taxonomic classification (WRB 2006)	Vertic Cambisol (Eutric)	Vertic Cambisol (Eutric)
Local soil name	Walka	Walka
Topography	10-30	10-30
Landform	Sloping land,Medium-gradient escarpment zone	Sloping land,Medium-gradient valley
Position	Middle slope (Back slope)	Lower slope (foot slope)
Slope	Straight slope, 2%	Straight slope, 2%
Micro-topography	None	None
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Trap volcanic rocks (Basic igneos rock basalt)	Trap volcanic rocks (Basic igneos rock basalt)
Soil depth	120 cm+	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Few (2-5%)	Few (2-5%)
Erosion status	Slight sheet erosion	Slight sheet erosion
Surface sealing	thin crusts (<2mm)	thin crusts (<2mm)
Surface cracks	None	None
Internal drainage	Well	Well
External drainage	Rapid	Rapid
Flooding	None	None
Groundwater	None observed	None observed

1.8 Auger obsrvation for Enda Mehoni Meswati

Auger ID	**TENM-MES-A1**	**TENM-MES-A2**
Soil unit	SV(cc VR (eu, pe))	SV(vr CM (eu))
Location (admin.)	Tigray, Enda Mokoni woreda, Meswati Kebele	Tigray, Enda Mokoni woreda, Meswati Kebele
Elevation (m.)	2353	2333
Coordinates (Deg, Min, Sec)	39°33'32",12°42'16"	39°33'41",12°41'45"
Soil taxonomic classification (WRB 2006)	Calcic Vertisol (Eutric, Pellic)	Vertic Cambisol (Eutric)
Local soil name	Walka	Walka
Topography	10-30	10-30
Landform	Sloping land,Medium-gradient valley	Sloping land,Medium-gradient valley
Position	Valley bottom	Middle Slope (Backslope)
Slope	Straight slope, 2%	Straight slope, 2%
Micro-topography	Gilgai	None
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Trap volcanic rocks (Basic igneos rock basalt)	Trap volcanic rocks (Basic igneos rock basalt)
Soil depth	120 cm+	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Few (2-5%)	Few (2-5%)
Erosion status	Moderate sheet and rill erosion	Slight sheet erosion
Surface sealing	thin crusts (<2mm)	thin crusts (<2mm)
Surface cracks	No visible surface cracks (can be filled due to soil tillage)	None
Internal drainage	Well	Well
External drainage	Well	Rapid
Flooding	None	None
Groundwater	None observed	None observed

Auger ID	TENM-MES-A3	TENM-MES-A4
Soil unit	SV(cc VR (eu, pe))	SP(vr CM (eu))
Location (admin.)	Tigray, Enda Mokoni woreda, Meswati Kebele	Tigray, Enda Mokoni woreda, Meswati Kebele
Elevation (m.)	2336	2418
Coordinates (Deg, Min, Sec)	39°34'24",12°41'45"	39°33'43",12°42'43"
Soil taxonomic classification (WRB 2006)	Calcic Vertisol (Eutric, Pellic)	Vertic Cambisol (Eutric)
Local soil name	Walka	Walka
Topography	10-30	10-30
Landform	Sloping land,Medium-gradient valley	Sloping land,Dissected plain
Position	Middle slope (Backslope)	Middle Slope (Backslope)
Slope	Straight slope, 2%	Straight slope, 2%
Micro-topography	Gilgai	None
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Trap volcanic rocks (Basic igneos rock basalt)	Trap volcanic rocks (Basic igneos rock basalt)
Soil depth	120 cm+	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Few (2-5%)	Few (2-5%)
Erosion status	Moderate sheet and rill erosion	Slight sheet erosion
Surface sealing	thin crusts (<2mm)	thin crusts (<2mm)
Surface cracks	No visible surface cracks (can be filled due to soil tillage)	None
Internal drainage	Well	Well
External drainage	Well	Rapid
Flooding	None	None
Groundwater	None observed	None observed

Auger ID	TENM-MES-A5	TENM-MES-A6
Soil unit	SV(cc VR (eu, pe))	SV(vr CM (eu))
Location (admin.)	Tigray, Enda Mokoni woreda, Meswati Kebele	Tigray, Enda Mokoni woreda, Meswati Kebele
Elevation (m.)	2388	2421
Coordinates (Deg, Min, Sec)	39°33'18",12°42'15"	39°32'48",12°41'54"
Soil taxonomic classification (WRB 2006)	Calcic Vertisol (Eutric, Pellic)	Vertic Cambisol (Eutric)
Local soil name	Walka	Walka
Topography	10-30	10-30
Landform	Sloping land,Medium-gradient valley	Sloping land,Medium-gradient valley
Position	Middle slope (Backslope)	Middle Slope (Backslope)
Slope	Straight slope, 2%	Straight slope, 2%
Micro-topography	Gilgai	None
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Trap volcanic rocks (Basic igneos rock basalt)	Trap volcanic rocks (Basic igneos rock basalt)
Soil depth	120 cm+	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Few (2-5%)	Few (2-5%)
Erosion status	Moderate sheet and rill erosion	Slight sheet erosion
Surface sealing	thin crusts (<2mm)	thin crusts (<2mm)
Surface cracks	No visible surface cracks (can be filled due to soil tillage)	None
Internal drainage	Well	Well
External drainage	Well	Rapid
Flooding	None	None
Groundwater	None observed	None observed

Auger ID	TENM-MES-A7	TENM-MES-A8
Soil unit	SP(vr CM (eu))	TE(ha LP (eu,sk))
Location (admin.)	Tigray, Enda Mokoni woreda, Meswati Kebele	Tigray, Enda Mokoni woreda, Meswati Kebele
Elevation (m.)	2406	2494
Coordinates (Deg, Min, Sec)	39°32'47",12°41'26"	39°32'28",12°41'42"
Soil taxonomic classification (WRB 2006)	Vertic Cambisol (Eutric)	Haplic Leptosol (Eutric, Skeletic)
Local soil name	Walka	Hamed Qoriya
Topography	10-30	> 30
Landform	Sloping land,Dissected plain	Steep land,High-gradient escarpment zone
Position	Middle Slope (Backslope)	Middle slop (Back slope)
Slope	Straight slope, 2%	Straight slope, 2%
Micro-topography	None	None
Land Use	Rainfed arable cultivation	Degraded Shrub land
Human influence	DAP and Urea fertilizer	Overgrazing
Vegetation	None	Grasses and shrubs
Parent material	Trap volcanic rocks (Basic igneos rock basalt)	Trap volcanic rocks (Basic igneos rock basalt)
Soil depth	120 cm+	30cm
Land Use	Cultivated land	Degraded Shrub land
Rock outcrops	None	few
Surface coarse fragments	Few (2-5%)	Few (2-5%)
Erosion status	Slight sheet erosion	Slight sheet erosion
Surface sealing	thin crusts (<2mm)	thin crusts (<2mm)
Surface cracks	None	None
Internal drainage	Well	Well
External drainage	Rapid	Rapid
Flooding	None	None
Groundwater	None observed	None observed

1.9 Auger obsrvation for Ofla Adigolo

Auger ID	**TOFL-AGO-A1**	**TOFL-AGO-A2**
Soil unit	LD(ha VR (eu, pe))	LD(ha VR (eu, pe))
Location (admin.)	Tigray, Ofla woreda, Adi Golo Kebele	Tigray, Ofla woreda, Adi Golo Kebele
Elevation (m.)	2443	2461
Coordinates (Deg, Min, Sec)	39°30'32",12°31'23"	39°30'4",12°31'15"
Soil taxonomic classification (WRB 2006)	Haplic Vertisol (Eutric, Pellic)	Haplic Vertisol (Eutric, Pellic)
Local soil name	Walka	Walka
Topography	< 10	< 10
Landform	Level land,Depression	Level land,Depression
Position	Lower Slope (foot slope)	Lower Slope (foot slope)
Slope	Straight slope, 2%	Straight slope, 2%
Micro-topography	Gilgai	Gilgai
Land Use	Grass land	Rainfed arable cultivation
Human influence	Overgrazing	DAP and Urea fertilizer
Vegetation	Grass	None
Parent material	Fluvial sediments derived from Trap volcanic rocks	Fluvial sediments derived from Trap volcanic rocks
Soil depth	120 cm+	120 cm+
Land Use	Grass land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Common (5-15%)	Common (5-15%)
Erosion status	Slight sheet erosion	Slight sheet erosion
Surface sealing	thin crusts (<2mm)	thin crusts (<2mm)
Surface cracks	Wide cracks (2-5cm), deep (10-20cm)	Wide cracks (2-5cm), deep (10-20cm)
Internal drainage	Imperfectly	Imperfectly
External drainage	Slow	Slow
Flooding	None	None
Groundwater	None observed	None observed

Auger ID	TOFL-AGO-A3	TOFL-AGO-A4
Soil unit	LD(ha VR (eu, pe))	SV(ha VR (eu, pe))
Location (admin.)	Tigray, Ofla woreda, Adi Golo Kebele	Tigray, Ofla woreda, Adi Golo Kebele
Elevation (m.)	2454	2472
Coordinates (Deg, Min, Sec)	39°29'52",12°31'32"	39°29'51",12°32'16"
Soil taxonomic classification (WRB 2006)	Haplic Vertisol (Eutric, Pellic)	Haplic Vertisol (Eutric, Pellic)
Local soil name	Walka	Walka
Topography	< 10	10-30
Landform	Level land,Depression	Sloping land,Medium-gradient valley
Position	Lower Slope (foot slope)	Lower Slope (foot slope)
Slope	Straight slope, 2%	Straight slope, 2%
Micro-topography	Gilgai	Gilgai
Land Use	Grass land	Rainfed arable cultivation
Human influence	Overgrazing	DAP and Urea fertilizer
Vegetation	Grass	None
Parent material	Fluvial sediments derived from Trap volcanic rocks	Fluvial sediments derived from Trap volcanic rocks
Soil depth	120 cm+	120 cm+
Land Use	Grass land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Common (5-15%)	Common (5-15%)
Erosion status	Slight sheet erosion	Slight sheet erosion
Surface sealing	thin crusts (<2mm)	thin crusts (<2mm)
Surface cracks	Wide cracks (2-5cm), deep (10-20cm)	Wide cracks (2-5cm), deep (10-20cm)
Internal drainage	Imperfectly	Imperfectly
External drainage	Slow	Slow
Flooding	None	None
Groundwater	None observed	None observed

Auger ID	**TOFL-AGO-A5**	**TOFL-AGO-A6**
Soil unit	SV(gl cc FL (eu))	SV(gl cc FL (eu))
Location (admin.)	Tigray, Ofla woreda, Adi Golo Kebele	Tigray, Ofla woreda, Adi Golo Kebele
Elevation (m.)	2452	2453
Coordinates (Deg, Min, Sec)	39°29'39",12°33'18"	39°29'19",12°33'38"
Soil taxonomic classification (WRB 2006)	Gleyic Calcic Fluvisol (Eutric)	Gleyic Calcic Fluvisol (Eutric)
Local soil name	Danshel	Danshel
Topography	10-30	10-30
Landform	Sloping land,Medium-gradient valley	Sloping land,Medium-gradient valley
Position	Bottom (flat)	Bottom (flat)
Slope	Straight slope, 2%	Straight slope, 2%
Micro-topography	None	None
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Fluvial sediments derived from Trap volcanic rocks	Fluvial sediments derived from Trap volcanic rocks
Soil depth	120 cm+	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Very few (0-2%)	Very few (0-2%)
Erosion status	Moderate deposition of lacustriine & fluvial materials	Moderate deposition of lacustriine & fluvial materials
Surface sealing	thin crusts (<2mm)	thin crusts (<2mm)
Surface cracks	Fine cracks (<1cm), surface (<2cm)	Fine cracks (<1cm), surface (<2cm)
Internal drainage	Imperfectly	Imperfectly
External drainage	Slow	Slow
Flooding	about 3 times a year for a duration of a week	about 3 times a year for a duration of a week
Groundwater	Very deep (185cm)	Very deep (185cm)

Auger ID	**TOFL-AGO-A7**
Soil unit	SV(ha VR (eu, pe))
Location (admin.)	Tigray, Ofla woreda, Adi Golo Kebele
Elevation (m.)	2457
Coordinates (Deg, Min, Sec)	39°30'45",12°32'3"
Soil taxonomic classification (WRB 2006)	Haplic Vertisol (Eutric, Pellic)
Local soil name	Walka
Topography	10-30
Landform	Sloping land,Medium-gradient valley
Position	Lower Slope (foot slope)
Slope	Straight slope, 2%
Micro-topography	Gilgai
Land Use	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer
Vegetation	None
Parent material	Fluvial sediments derived from Trap volcanic rocks
Soil depth	120 cm+
Land Use	Cultivated land
Rock outcrops	None
Surface coarse fragments	Common (5-15%)
Erosion status	Slight sheet erosion
Surface sealing	thin crusts (<2mm)
Surface cracks	Wide cracks (2-5cm), deep (10-20cm)
Internal drainage	Imperfectly
External drainage	Slow
Flooding	None
Groundwater	None observed

1.10 Auger obsrvation for Ofla Hashenge

Auger ID	**TOFL-HAS-A1**	**TOFL-HAS-A2**
Soil unit	TH(ha VR (eu, pe))	TH(ha VR (eu, pe))
Location (admin.)	Tigray, Ofla woreda, Hashenge Kebele	Tigray, Ofla woreda, Hashenge Kebele
Elevation (m.)	2499	2490
Coordinates (Deg, Min, Sec)	39°30'4",12°37'31"	39°29'48",12°37'22"
Soil taxonomic classification (WRB 2006)	Haplic Vertisol (Eutric, Pellic)	Haplic Vertisol (Eutric, Pellic)
Local soil name	Walka	Walka
Topography	> 30	> 30
Landform	Steep land,High-gradient hill	Steep land,High-gradient hill
Position	Middle Slope (Back slope)	Middle Slope (Back slope)
Slope	Concave slope, 3%	Concave slope, 3%
Micro-topography	Gilgai	Gilgai
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Fluvial sediments derived from Trap volcanic rocks	Fluvial sediments derived from Trap volcanic rocks
Soil depth	120 cm+	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Very few (0-2%)	Very few (0-2%)
Erosion status	Slight sheet erosion	Slight sheet erosion
Surface sealing	thin crusts (<2mm)	thin crusts (<2mm)
Surface cracks	No visible surface cracks (can be filled due to soil tillage)	No visible surface cracks (can be filled due to soil tillage)
Internal drainage	Well	Well
External drainage	Well	Well
Flooding	None	None
Groundwater	None observed	None observed

Auger ID	TOFL-HAS-A3	TOFL-HAS-A4
Soil unit	TH(ha VR (eu, pe))	TH(ha VR (eu, pe))
Location (admin.)	Tigray, Ofla woreda, Hashenge Kebele	Tigray, Ofla woreda, Hashenge Kebele
Elevation (m.)	2469	2468
Coordinates (Deg, Min, Sec)	39°29'28",12°36'30"	39°30'44",12°36'12"
Soil taxonomic classification (WRB 2006)	Haplic Vertisol (Eutric, Pellic)	Haplic Vertisol (Eutric, Pellic)
Local soil name	Walka	Walka
Topography	> 30	> 30
Landform	Steep land,High-gradient hill	Steep land,High-gradient hill
Position	Middle Slope (Back slope)	Middle Slope (Back slope)
Slope	Concave slope, 3%	Concave slope, 3%
Micro-topography	Gilgai	Gilgai
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Fluvial sediments derived from Trap volcanic rocks	Fluvial sediments derived from Trap volcanic rocks
Soil depth	120 cm+	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Very few (0-2%)	Very few (0-2%)
Erosion status	Slight sheet erosion	Slight sheet erosion
Surface sealing	thin crusts (<2mm)	thin crusts (<2mm)
Surface cracks	No visible surface cracks (can be filled due to soil tillage)	No visible surface cracks (can be filled due to soil tillage)
Internal drainage	Well	Well
External drainage	Well	Well
Flooding	None	None
Groundwater	None observed	None observed

Auger ID	**TOFL-HAS-A5**
Soil unit	TH(ha VR (eu, pe))
Location (admin.)	Tigray, Ofla woreda, Hashenge Kebele
Elevation (m.)	2483
Coordinates (Deg, Min, Sec)	39°30'51",12°35'57"
Soil taxonomic classification (WRB 2006)	Haplic Vertisol (Eutric, Pellic)
Local soil name	Walka
Topography	> 30
Landform	Steep land,High-gradient hill
Position	Middle Slope (Back slope)
Slope	Concave slope, 3%
Micro-topography	Gilgai
Land Use	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer
Vegetation	None
Parent material	Fluvial sediments derived from Trap volcanic rocks
Soil depth	120 cm+
Land Use	Cultivated land
Rock outcrops	None
Surface coarse fragments	Very few (0-2%)
Erosion status	Slight sheet erosion
Surface sealing	thin crusts (<2mm)
Surface cracks	No visible surface cracks (can be filled due to soil tillage)
Internal drainage	Well
External drainage	Well
Flooding	None
Groundwater	None observed

1.11 Auger obsrvation for Ofla Hugumberda

Auger ID	**TOFL-HUG-A1**	**TOFL-HUG-A2**
Soil unit	TH(ha VR (eu, pe))	TH(ha VR (eu, pe))
Location (admin.)	Tigray, Ofla woreda, Hugumberda Kebele	Tigray, Ofla woreda, Hugumberda Kebele
Elevation (m.)	2518	2503
Coordinates (Deg, Min, Sec)	39°31'50",12°38'9"	39°31'27",12°38'6"
Soil taxonomic classification (WRB 2006)	Haplic Vertisol (Eutric, Pellic)	Haplic Vertisol (Eutric, Pellic)
Local soil name	Walka	Walka
Topography	> 30	> 30
Landform	Steep land,High-gradient hill	Steep land,High-gradient hill
Position	Middle Slope (Back slope)	Middle Slope (Back slope)
Slope	Concave slope, 3%	Concave slope, 3%
Micro-topography	Gilgai	Gilgai
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Fluvial sediments derived from Trap volcanic rocks	Fluvial sediments derived from Trap volcanic rocks
Soil depth	120 cm+	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Very few (0-2%)	Very few (0-2%)
Erosion status	Slight sheet erosion	Slight sheet erosion
Surface sealing	thin crusts (<2mm)	thin crusts (<2mm)
Surface cracks	No visible surface cracks (can be filled due to soil tillage)	No visible surface cracks (can be filled due to soil tillage)
Internal drainage	Well	Well
External drainage	Well	Well
Flooding	None	None
Groundwater	None observed	None observed

Auger ID	TOFL-HUG-A3	TOFL-HUG-A4
Soil unit	TH(ha VR (eu, pe))	TH(ha VR (eu, pe))
Location (admin.)	Tigray, Ofla woreda, Hugumberda Kebele	Tigray, Ofla woreda, Hugumberda Kebele
Elevation (m.)	2530	2511
Coordinates (Deg, Min, Sec)	39°30'59",12°38'23"	39°30'36",12°38'7"
Soil taxonomic classification (WRB 2006)	Haplic Vertisol (Eutric, Pellic)	Haplic Vertisol (Eutric, Pellic)
Local soil name	Walka	Walka
Topography	> 30	> 30
Landform	Steep land,High-gradient hill	Steep land,High-gradient hill
Position	Middle Slope (Back slope)	Middle Slope (Back slope)
Slope	Concave slope, 3%	Concave slope, 3%
Micro-topography	Gilgai	Gilgai
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Fluvial sediments derived from Trap volcanic rocks	Fluvial sediments derived from Trap volcanic rocks
Soil depth	120 cm+	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Very few (0-2%)	Very few (0-2%)
Erosion status	Slight sheet erosion	Slight sheet erosion
Surface sealing	thin crusts (<2mm)	thin crusts (<2mm)
Surface cracks	No visible surface cracks (can be filled due to soil tillage)	No visible surface cracks (can be filled due to soil tillage)
Internal drainage	Well	Well
External drainage	Well	Well
Flooding	None	None
Groundwater	None observed	None observed

Auger ID	TOFL-HUG-A5	TOFL-HUG-A6
Soil unit	TH(ha VR (eu, pe))	SE(le CM (eu))
Location (admin.)	Tigray, Ofla woreda, Hugumberda Kebele	Tigray, Ofla woreda, Hugumberda Kebele
Elevation (m.)	2557	2651
Coordinates (Deg, Min, Sec)	39°31'55",12°38'39"	39°31'48",12°39'17"
Soil taxonomic classification (WRB 2006)	Haplic Vertisol (Eutric, Pellic)	Leptic Cambisol (Eutric)
Local soil name	Walka	Hawsi Hutsa
Topography	> 30	10-30
Landform	Steep land,High-gradient hill	Sloping land,Medium-gradient escarpment zone
Position	Upper Slope (shoulder)	Upper Slope (shoulder)
Slope	Concave slope, 3%	Concave slope, 2%
Micro-topography	Gilgai	None
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Fluvial sediments derived from Trap volcanic rocks	Fluvial sediments derived from Trap volcanic rocks
Soil depth	120 cm+	60 cm
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Very few (0-2%)	Common (5-15%)
Erosion status	Slight sheet erosion	Severe sheet and rill erosion
Surface sealing	thin crusts (<2mm)	thin crusts (<2mm)
Surface cracks	No visible surface cracks (can be filled due to soil tillage)	None
Internal drainage	Well	Well
External drainage	Well	Rapid
Flooding	None	None
Groundwater	None observed	None observed

Auger ID	TOFL-HUG-A7	TOFL-MEN-A1
Soil unit	TM(le CM (eu))	TH(ha VR (eu, pe))
Location (admin.)	Tigray, Ofla woreda, Hugumberda Kebele	Tigray, Ofla woreda, Menkere Kebele
Elevation (m.)	2568	2465
Coordinates (Deg, Min, Sec)	39°32'11",12°39'15"	39°32'0",12°35'8"
Soil taxonomic classification (WRB 2006)	Leptic Cambisol (Eutric)	Haplic Vertisol (Eutric, Pellic)
Local soil name	Hawsi Hutsa	Walka
Topography	> 30	> 30
Landform	Steep land,High-gradient mountain	Steep land,High-gradient hill
Position	Upper Slope (shoulder)	Middle Slope (Back slope)
Slope	Concave slope, 2%	Concave slope, 3%
Micro-topography	None	Gilgai
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Fluvial sediments derived from Trap volcanic rocks	Fluvial sediments derived from Trap volcanic rocks
Soil depth	58 cm	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Common (5-15%)	Very few (0-2%)
Erosion status	Severe sheet and rill erosion	Slight sheet erosion
Surface sealing	thin crusts (<2mm)	thin crusts (<2mm)
Surface cracks	None	No visible surface cracks (can be filled due to soil tillage)
Internal drainage	Well	Well
External drainage	Rapid	Well
Flooding	None	None
Groundwater	None observed	None observed

1.12 Auger obsrvation for Ofla Menkere

Auger ID	**TOFL-MEN-A1**	**TOFL-MEN-A3**
Soil unit	TH(ha VR (eu, pe))	TE(ha CM (eu))
Location (admin.)	Tigray, Ofla woreda, Menkere Kebele	Tigray, Ofla woreda, Menkere Kebele
Elevation (m.)	2465	2505
Coordinates (Deg, Min, Sec)	39°32'0",12°35'8"	39°31'58",12°34'17"
Soil taxonomic classification (WRB 2006)	Haplic Vertisol (Eutric, Pellic)	Haplic Cambisol (Eutric)
Local soil name	Walka	Boda
Topography	> 30	> 30
Landform	Steep land,High-gradient hill	Steep land,High-gradient escarpment zone
Position	Middle Slope (Back slope)	Upper slope (shoulder)
Slope	Concave slope, 3%	Straight slope, 2%
Micro-topography	Gilgai	None
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Fluvial sediments derived from Trap volcanic rocks	Fluvial sediments derived from Trap volcanic rocks
Soil depth	120 cm+	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Very few (0-2%)	Few (2-5%)
Erosion status	Slight sheet erosion	Moderate sheet and rill erosion in many areas
Surface sealing	thin crusts (<2mm)	thin crusts (<2mm)
Surface cracks	No visible surface cracks (can be filled due to soil tillage)	None
Internal drainage	Well	Well
External drainage	Well	Well
Flooding	None	None
Groundwater	None observed	None observed

Auger ID	TOFL-MEN-A4	TOFL-MEN-A5
Soil unit	TH(ha CM (eu))	LD(gl cc FL (eu))
Location (admin.)	Tigray, Ofla woreda, Menkere Kebele	Tigray, Ofla woreda, Menkere Kebele
Elevation (m.)	2485	2451
Coordinates (Deg, Min, Sec)	39°31'46",12°34'24"	39°31'29",12°35'0"
Soil taxonomic classification (WRB 2006)	Haplic Cambisol (Eutric)	Gleyic Calcic Fluvisol (Eutric)
Local soil name	Boda	Danshel
Topography	> 30	< 10
Landform	Steep land,High-gradient hill	Level land,Depression
Position	Middle slope (Back slope)	Bottom
Slope	Straight slope, 2%	Straight slope, 2%
Micro-topography	None	None
Land Use	Rainfed arable cultivation	Grass land
Human influence	DAP and Urea fertilizer	Overgrazing
Vegetation	None	Grass
Parent material	Fluvial sediments derived from Trap volcanic rocks	Fluvial sediments derived from Trap volcanic rocks
Soil depth	120 cm+	120 cm+
Land Use	Cultivated land	Grass land
Rock outcrops	None	None
Surface coarse fragments	Few (2-5%)	Very few (0-2%)
Erosion status	Moderate sheet and rill erosion in many areas	Moderate sheet and rill erosion in many areas
Surface sealing	thin crusts (<2mm)	thin crusts (<2mm)
Surface cracks	None	Fine cracks (<1cm), surface (<2cm)
Internal drainage	Well	Imperfectly
External drainage	Well	Slow
Flooding	None	about 3 times a year for a duration of a week
Groundwater	None observed	Very deep (185cm)

Auger ID	**TOFL-MEN-A6**
Soil unit	LD(gl cc FL (eu))
Location (admin.)	Tigray, Ofla woreda, Menkere Kebele
Elevation (m.)	2451
Coordinates (Deg, Min, Sec)	39°31'31",12°35'3"
Soil taxonomic classification (WRB 2006)	Gleyic Calcic Fluvisol (Eutric)
Local soil name	Danshel
Topography	< 10
Landform	Level land,Depression
Position	Middle slope (Back slope)
Slope	Straight slope, 2%
Micro-topography	None
Land Use	Grass land
Human influence	Overgrazing
Vegetation	Grass
Parent material	Fluvial sediments derived from Trap volcanic rocks
Soil depth	120 cm+
Land Use	Grass land
Rock outcrops	None
Surface coarse fragments	Very few (0-2%)
Erosion status	Moderate sheet and rill erosion in many areas
Surface sealing	thin crusts (<2mm)
Surface cracks	Fine cracks (<1cm), surface (<2cm)
Internal drainage	Imperfectly
External drainage	Slow
Flooding	about 3 times a year for a duration of a week
Groundwater	Very deep (185cm)

1.13 Auger obsrvation for Raya Alamata Gerjele

Auger ID	**TRAL-GER-A1**	**TRAL-GER-A2**
Soil unit	LP(ha VR (eu, pe))	LP(ha VR (eu, pe))
Location (admin.)	Tigray, Raya Alamata woreda, Gerajale Kebele	Tigray, Raya Alamata woreda, Gerajale Kebele
Elevation (m.)	1429	1437
Coordinates (Deg, Min, Sec)	39°38'5",12°28'7"	39°37'32",12°28'24"
Soil taxonomic classification (WRB 2006)	Haplic Vertisol (Eutric, Pellic)	Haplic Vertisol (Eutric, Pellic)
Local soil name	Walka	Walka
Topography	< 10	< 10
Landform	Level land,Plain	Level land,Plain
Position	Lower Slope (foot slope)	Lower Slope (foot slope)
Slope	Straight slope, 2%	Straight slope, 2%
Micro-topography	None	None
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Alluvium	Alluvium
Soil depth	120 cm+	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Common (5-15%)	Common (5-15%)
Erosion status	Slight sheet erosion	Slight sheet erosion
Surface sealing	thin crusts (<2mm)	thin crusts (<2mm)
Surface cracks	No visible surface cracks (can be filled due to soil tillage)	No visible surface cracks (can be filled due to soil tillage)
Internal drainage	Well	Well
External drainage	Well	Well
Flooding	Once per year for a duration of 4 days	Once per year for a duration of 4 days
Groundwater	None observed	None observed

Auger ID	TRAL-GER-A3	TRAL-GER-A4
Soil unit	LP(ha VR (eu, pe))	LP(ha VR (eu, pe))
Location (admin.)	Tigray, Raya Alamata woreda, Gerajale Kebele	Tigray, Raya Alamata woreda, Gerajale Kebele
Elevation (m.)	1431	1428
Coordinates (Deg, Min, Sec)	39°36'39",12°26'48"	39°37'0",12°26'45"
Soil taxonomic classification (WRB 2006)	Haplic Vertisol (Eutric, Pellic)	Haplic Vertisol (Eutric, Pellic)
Local soil name	Walka	Walka
Topography	< 10	< 10
Landform	Level land,Plain	Level land,Plain
Position	Lower Slope (foot slope)	Lower Slope (foot slope)
Slope	Straight slope, 2%	Straight slope, 2%
Micro-topography	None	None
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Alluvium	Alluvium
Soil depth	120 cm+	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Common (5-15%)	Common (5-15%)
Erosion status	Slight sheet erosion	Slight sheet erosion
Surface sealing	thin crusts (<2mm)	thin crusts (<2mm)
Surface cracks	No visible surface cracks (can be filled due to soil tillage)	No visible surface cracks (can be filled due to soil tillage)
Internal drainage	Well	Well
External drainage	Well	Well
Flooding	Once per year for a duration of 4 days	Once per year for a duration of 4 days
Groundwater	None observed	None observed

Auger ID	TRAL-GER-A5	TRAL-GER-A6
Soil unit	LP(ha VR (eu, pe))	SH(ha CM (ca,bVR))
Location (admin.)	Tigray, Raya Alamata woreda, Gerajale Kebele	Tigray, Raya Alamata woreda, Gerajale Kebele
Elevation (m.)	1423	1462
Coordinates (Deg, Min, Sec)	39°37'37",12°26'55"	39°36'8",12°26'52"
Soil taxonomic classification (WRB 2006)	Haplic Vertisol (Eutric, Pellic)	Haplic Cambisol (Calcaric) (Thapto-Vertisolic)
Local soil name	Walka	Boda
Topography	< 10	10-30
Landform	Level land,Plain	Sloping land,Medium-gradient hill
Position	Lower Slope (foot slope)	Lower Slope (foot slope)
Slope	Straight slope, 2%	Straight slope, 3%
Micro-topography	None	None
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Alluvium	Alluvium
Soil depth	120 cm+	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Common (5-15%)	Very few (0-2%)
Erosion status	Slight sheet erosion	Slight sheet erosion
Surface sealing	thin crusts (<2mm)	thin crusts (<2mm)
Surface cracks	No visible surface cracks (can be filled due to soil tillage)	None
Internal drainage	Well	Moderately well
External drainage	Well	Well
Flooding	Once per year for a duration of 4 days	None
Groundwater	None observed	None observed

Auger ID	**TRAL-GER-A7**	**TRAL-GER-A8**
Soil unit	SH(ha CM (ca,bVR))	SH(ha CM (ca,bVR))
Location (admin.)	Tigray, Raya Alamata woreda, Gerajale Kebele	Tigray, Raya Alamata woreda, Gerajale Kebele
Elevation (m.)	1522	1549
Coordinates (Deg, Min, Sec)	39°35'35",12°28'6"	39°35'13",12°28'18"
Soil taxonomic classification (WRB 2006)	Haplic Cambisol (Calcaric) (Thapto-Vertisolic)	Haplic Cambisol (Calcaric) (Thapto-Vertisolic)
Local soil name	Boda	Boda
Topography	10-30	10-30
Landform	Sloping land,Medium-gradient hill	Sloping land,Medium-gradient hill
Position	Lower Slope (foot slope)	Lower Slope (foot slope)
Slope	Straight slope, 3%	Straight slope, 3%
Micro-topography	None	None
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Alluvium	Alluvium
Soil depth	120 cm+	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Very few (0-2%)	Very few (0-2%)
Erosion status	Slight sheet erosion	Slight sheet erosion
Surface sealing	thin crusts (<2mm)	thin crusts (<2mm)
Surface cracks	None	None
Internal drainage	Moderately well	Moderately well
External drainage	Well	Well
Flooding	None	None
Groundwater	None observed	None observed

1.14 Auger obsrvation for Raya Alamata Selambi Kalsi

Auger ID	**TRAL-SBK-A1**	**TRAL-SBK-A2**
Soil unit	LP(cc VR (eu, pe))	LP(cc VR (eu, pe))
Location (admin.)	Tigray, Raya Alamata woreda, Selam BiKalsi Kebele	Tigray, Raya Alamata woreda, Selam BiKalsi Kebele
Elevation (m.)	1547	1526
Coordinates (Deg, Min, Sec)	39°33'33",12°23'48"	39°33'55",12°23'22"
Soil taxonomic classification (WRB 2006)	Calcic Vertisol (Eutric, Pellic)	Calcic Vertisol (Eutric, Pellic)
Local soil name	Walka	Walka
Topography	< 10	< 10
Landform	Level land,Plain	Level land,Plain
Position	Lower slope (foot slope)	Lower slope (foot slope)
Slope	Straight slope, 2%	Straight slope, 2%
Micro-topography	None	None
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Alluvium	Alluvium
Soil depth	120 cm+	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Common (5-15%)	Common (5-15%)
Erosion status	Slight sheet erosion	Slight sheet erosion
Surface sealing	thin crusts (<2mm)	thin crusts (<2mm)
Surface cracks	No visible surface cracks (can be filled due to soil tillage)	No visible surface cracks (can be filled due to soil tillage)
Internal drainage	Well	Well
External drainage	Well	Well
Flooding	Once per year for a duration of 4 days	Once per year for a duration of 4 days
Groundwater	None observed	None observed

Auger ID	TRAL-SBK-A3	TRAL-SBK-A4
Soil unit	LP(cc VR (eu, pe))	LP(gl cc FL (eu))
Location (admin.)	Tigray, Raya Alamata woreda, Selam BiKalsi Kebele	Tigray, Raya Alamata woreda, Selam BiKalsi Kebele
Elevation (m.)	1503	1414
Coordinates (Deg, Min, Sec)	39°34'24",12°23'50"	39°38'43",12°24'7"
Soil taxonomic classification (WRB 2006)	Calcic Vertisol (Eutric, Pellic)	Gleyic Calcic Fluvisol (Eutric)
Local soil name	Walka	Boda
Topography	< 10	< 10
Landform	Level land,Plain	Level land,Plain
Position	Lower slope (foot slope)	Middle Slope (Back slope)
Slope	Straight slope, 2%	Straight slope, 2%
Micro-topography	None	None
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Alluvium	Alluvium
Soil depth	120 cm+	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Common (5-15%)	None
Erosion status	Slight sheet erosion	Slight sheet erosion
Surface sealing	thin crusts (<2mm)	thin crusts (<2mm)
Surface cracks	No visible surface cracks (can be filled due to soil tillage)	None
Internal drainage	Well	Well
External drainage	Well	Well
Flooding	Once per year for a duration of 4 days	Once per year for a duration a week
Groundwater	None observed	None observed

Auger ID	TRAL-SBK-A5	TRAL-SBK-A6
Soil unit	LP(gl cc FL (eu))	LP(gl cc FL (eu))
Location (admin.)	Tigray, Raya Alamata woreda, Selam BiKalsi Kebele	Tigray, Raya Alamata woreda, Selam BiKalsi Kebele
Elevation (m.)	1483	1488
Coordinates (Deg, Min, Sec)	39°35'24",12°23'12"	39°35'17",12°22'53"
Soil taxonomic classification (WRB 2006)	Gleyic Calcic Fluvisol (Eutric)	Gleyic Calcic Fluvisol (Eutric)
Local soil name	Boda	Boda
Topography	< 10	< 10
Landform	Level land,Plain	Level land,Plain
Position	Middle Slope (Back slope)	Middle Slope (Back slope)
Slope	Straight slope, 2%	Straight slope, 2%
Micro-topography	None	None
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Alluvium	Alluvium
Soil depth	120 cm+	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	None	None
Erosion status	Slight sheet erosion	Slight sheet erosion
Surface sealing	thin crusts (<2mm)	thin crusts (<2mm)
Surface cracks	None	None
Internal drainage	Well	Well
External drainage	Well	Well
Flooding	Once per year for a duration a week	Once per year for a duration a week
Groundwater	None observed	None observed

Auger ID	TRAL-SBK-A7	TRAL-SBK-A8
Soil unit	SH(ha CM (eu))	SH(ha LP (eu,sk))
Location (admin.)	Tigray, Raya Alamata woreda, Selam BiKalsi Kebele	Tigray, Raya Alamata woreda, Selam BiKalsi Kebele
Elevation (m.)	1597	1595
Coordinates (Deg, Min, Sec)	39°32'46",12°23'3"	39°33'0",12°23'53"
Soil taxonomic classification (WRB 2006)	Haplic Cambisol (Eutric)	Haplic Leptosol (Eutric, Skeletic)
Local soil name	Hamed Qoriya	Hamed Qoriya
Topography	10-30	10-30
Landform	Sloping land,Medium-gradient hill	Sloping land,Medium-gradient hill
Position	Lower slope (foot slope)	Lower slope (foot slope)
Slope	Straight slope, 8%	Straight slope, 8%
Micro-topography	None	None
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Trap volcanic rocks (Basic igneos rock basalt)	Trap volcanic rocks (Basic igneos rock basalt)
Soil depth	120 cm+	35 cm
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Common (5-15%)	Common (5-15%)
Erosion status	Moderate sheet erosion	Moderate sheet erosion
Surface sealing	thin crusts (<2mm)	thin crusts (<2mm)
Surface cracks	None	None
Internal drainage	Well	Well
External drainage	Rapid	Rapid
Flooding	None	None
Groundwater	None observed	None observed

1.15 Auger obsrvation for Raya Alamata Tao

Auger ID	TRAL-TAO-A1	TRAL-TAO-A2
Soil unit	LP(ha VR (eu, pe))	LP(ha VR (eu, pe))
Location (admin.)	Tigray, Raya Alamata woreda, Tao Kebele	Tigray, Raya Alamata woreda, Tao Kebele
Elevation (m.)	1440	1443
Coordinates (Deg, Min, Sec)	39°38'52",12°30'1"	39°39'53",12°30'51"
Soil taxonomic classification (WRB 2006)	Haplic Vertisol (Eutric, Pellic)	Haplic Vertisol (Eutric, Pellic)
Local soil name	Walka	Walka
Topography	< 10	< 10
Landform	Level land,Plain	Level land,Plain
Position	Lower Slope (foot slope)	Lower Slope (foot slope)
Slope	Straight slope, 2%	Straight slope, 2%
Micro-topography	None	None
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Alluvium	Alluvium
Soil depth	120 cm+	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Common (5-15%)	Common (5-15%)
Erosion status	Slight sheet and wind erosion	Slight sheet and wind erosion
Surface sealing	thin crusts (<2mm)	thin crusts (<2mm)
Surface cracks	No visible surface cracks (can be filled due to soil tillage)	No visible surface cracks (can be filled due to soil tillage)
Internal drainage	Well	Well
External drainage	Well	Well
Flooding	Once per year for a duration of 4 days	Once per year for a duration of 4 days
Groundwater	None observed	None observed

Auger ID	TRAL-TAO-A3	TRAL-TAO-A4
Soil unit	LP(ha VR (eu, pe))	LP(ha VR (eu, pe))
Location (admin.)	Tigray, Raya Alamata woreda, Tao Kebele	Tigray, Raya Alamata woreda, Tao Kebele
Elevation (m.)	1449	1425
Coordinates (Deg, Min, Sec)	39°40'4",12°31'20"	39°38'15",12°28'25"
Soil taxonomic classification (WRB 2006)	Haplic Vertisol (Eutric, Pellic)	Haplic Vertisol (Eutric, Pellic)
Local soil name	Walka	Walka
Topography	< 10	< 10
Landform	Level land,Plain	Level land,Plain
Position	Lower Slope (foot slope)	Lower slope (foot slope)
Slope	Straight slope, 2%	Straight slope, 2%
Micro-topography	None	None
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Alluvium	Alluvium
Soil depth	120 cm+	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Common (5-15%)	Common (5-15%)
Erosion status	Slight sheet and wind erosion	Slight sheet and wind erosion
Surface sealing	thin crusts (<2mm)	thin crusts (<2mm)
Surface cracks	No visible surface cracks (can be filled due to soil tillage)	No visible surface cracks (can be filled due to soil tillage)
Internal drainage	Well	Well
External drainage	Well	Well
Flooding	Once per year for a duration of 4 days	Once per year for a duration of 4 days
Groundwater	None observed	None observed

1.16 Auger obsrvation for Raya Alamata Timuga

Auger ID	**TRAL-TIM-A1**	**TRAL-TIM-A2**
Soil unit	LP(cc VR (eu))	LP(cc VR (eu))
Location (admin.)	Tigray, Raya Alamata woreda, Timuga Kebele	Tigray, Raya Alamata woreda, Timuga Kebele
Elevation (m.)	1488	1475
Coordinates (Deg, Min, Sec)	39°34'54",12°16'54"	39°35'18",12°17'1"
Soil taxonomic classification (WRB 2006)	Calcic Vertisol (Eutric)	Calcic Vertisol (Eutric)
Local soil name	Walka	Walka
Topography	< 10	< 10
Landform	Level land,Plain	Level land,Plain
Position	Bottom	Bottom
Slope	Straight slope, 3%	Straight slope, 3%
Micro-topography	Gilgai	Gilgai
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Alluvium	Alluvium
Soil depth	120 cm+	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	None	None
Erosion status	Slight sheet and wind erosion	Slight sheet and wind erosion
Surface sealing	thin crusts (<2mm)	thin crusts (<2mm)
Surface cracks	Wide cracks (2-5cm), deep (10-20cm)	Wide cracks (2-5cm), deep (10-20cm)
Internal drainage	Imperfectly	Imperfectly
External drainage	Slow	Slow
Flooding	None	None
Groundwater	None observed	None observed

Auger ID	TRAL-TIM-A3	TRAL-TIM-A4
Soil unit	LP(cc VR (eu))	LP(cc VR (eu))
Location (admin.)	Tigray, Raya Alamata woreda, Timuga Kebele	Tigray, Raya Alamata woreda, Timuga Kebele
Elevation (m.)	1510	1523
Coordinates (Deg, Min, Sec)	39°34'29",12°16'34"	39°34'22",12°16'6"
Soil taxonomic classification (WRB 2006)	Calcic Vertisol (Eutric)	Calcic Vertisol (Eutric)
Local soil name	Walka	Walka
Topography	< 10	< 10
Landform	Level land,Plain	Level land,Plain
Position	Bottom	Bottom
Slope	Straight slope, 3%	Straight slope, 3%
Micro-topography	Gilgai	Gilgai
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Alluvium	Alluvium
Soil depth	120 cm+	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	None	None
Erosion status	Slight sheet and wind erosion	Slight sheet and wind erosion
Surface sealing	thin crusts (<2mm)	thin crusts (<2mm)
Surface cracks	Wide cracks (2-5cm), deep (10-20cm)	Wide cracks (2-5cm), deep (10-20cm)
Internal drainage	Imperfectly	Imperfectly
External drainage	Slow	Slow
Flooding	None	None
Groundwater	None observed	None observed

Auger ID	TRAL-TIM-A5	TRAL-TIM-A6
Soil unit	LP(cc VR (eu))	SH(ha CM (ca,bVR))
Location (admin.)	Tigray, Raya Alamata woreda, Timuga Kebele	Tigray, Raya Alamata woreda, Timuga Kebele
Elevation (m.)	1453	1460
Coordinates (Deg, Min, Sec)	39°35'34",12°18'21"	39°35'32",12°18'47"
Soil taxonomic classification (WRB 2006)	Calcic Vertisol (Eutric)	Haplic Cambisol (Calcaric) (Thapto-Vertisolic)
Local soil name	Walka	Boda
Topography	< 10	10-30
Landform	Level land,Plain	Sloping land,Medium-gradient hill
Position	Bottom	Lower slope (foot slope)
Slope	Straight slope, 3%	Straight slope, 3%
Micro-topography	Gilgai	None
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Alluvium	Alluvium
Soil depth	120 cm+	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	None	Very few (0-2%)
Erosion status	Slight sheet and wind erosion	Slight sheet and wind erosion
Surface sealing	thin crusts (<2mm)	thin crusts (<2mm)
Surface cracks	Wide cracks (2-5cm), deep (10-20cm)	None
Internal drainage	Imperfectly	Moderately well
External drainage	Slow	Well
Flooding	None	None
Groundwater	None observed	None observed

Auger ID	TRAL-TIM-A7	TRAL-TIM-A8
Soil unit	SH(ha CM (ca,bVR))	SH(ha CM (ca,bVR))
Location (admin.)	Tigray, Raya Alamata woreda, Timuga Kebele	Tigray, Raya Alamata woreda, Timuga Kebele
Elevation (m.)	1473	1475
Coordinates (Deg, Min, Sec)	39°35'13",12°18'45"	39°34'47",12°18'4"
Soil taxonomic classification (WRB 2006)	Haplic Cambisol (Calcaric) (Thapto-Vertisolic)	Haplic Cambisol (Calcaric) (Thapto-Vertisolic)
Local soil name	Boda	Boda
Topography	10-30	10-30
Landform	Sloping land,Medium-gradient hill	Sloping land,Medium-gradient hill
Position	Lower slope (foot slope)	Lower slope (foot slope)
Slope	Straight slope, 3%	Straight slope, 3%
Micro-topography	None	None
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Alluvium	Alluvium
Soil depth	120 cm+	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Very few (0-2%)	Very few (0-2%)
Erosion status	Slight sheet and wind erosion	Slight sheet and wind erosion
Surface sealing	thin crusts (<2mm)	thin crusts (<2mm)
Surface cracks	None	None
Internal drainage	Moderately well	Moderately well
External drainage	Well	Well
Flooding	None	None
Groundwater	None observed	None observed

1.17 Auger obsrvation for Raya Azebo Ebo

Auger ID	**TRAZ-EBO-A1**	**TRAZ-EBO-A2**
Soil unit	SH(cc VR (eu, pe))	SH(cc VR (eu, pe))
Location (admin.)	Tigray, Raya Alamata woreda, Ebo Kebele	Tigray, Raya Alamata woreda, Ebo Kebele
Elevation (m.)	1850	1856
Coordinates (Deg, Min, Sec)	39°39'55",12°51'59"	39°40'9",12°52'16"
Soil taxonomic classification (WRB 2006)	Calcic Vertisol (Eutric, Pellic)	Calcic Vertisol (Eutric, Pellic)
Local soil name	Walka	Walka
Topography	10-30	10-30
Landform	Sloping land,Medium-gradient hill	Sloping land,Medium-gradient hill
Position	Middle Slope (Back slope)	Middle Slope (Back slope)
Slope	Straight slope, 3%	Straight slope, 2%
Micro-topography	None	None
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Alluvium	Alluvium
Soil depth	120 cm+	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Very few (0-2%)	Very few (0-2%)
Erosion status	Slight sheet and wind erosion	Slight sheet and wind erosion
Surface sealing	thin crusts (<2mm)	thin crusts (<2mm)
Surface cracks	No visible surface cracks (can be filled due to soil tillage)	No visible surface cracks (can be filled due to soil tillage)
Internal drainage	Well	Well
External drainage	Well	Well
Flooding	Once per year for a duration 3 days	Once per year for a duration 3 days
Groundwater	None observed	None observed

Auger ID	TRAZ-EBO-A3	TRAZ-EBO-A4
Soil unit	SP(cc VR (eu, pe))	LP(cc VR (eu, pe))
Location (admin.)	Tigray, Raya Alamata woreda, Ebo Kebele	Tigray, Raya Alamata woreda, Ebo Kebele
Elevation (m.)	1856	1785
Coordinates (Deg, Min, Sec)	39°40'44",12°52'43"	39°41'8",12°51'34"
Soil taxonomic classification (WRB 2006)	Calcic Vertisol (Eutric, Pellic)	Calcic Vertisol (Eutric, Pellic)
Local soil name	Walka	Walka
Topography	10-30	< 10
Landform	Sloping land,Dissected plain	Level land,Plain
Position	Middle Slope (Back slope)	Lower Slope (foot slope)
Slope	Straight slope, 2%	Straight slope, 2%
Micro-topography	None	None
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Alluvium	Alluvium
Soil depth	120 cm+	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Very few (0-2%)	Very few (0-2%)
Erosion status	Slight sheet and wind erosion	Slight sheet and wind erosion
Surface sealing	thin crusts (<2mm)	thin crusts (<2mm)
Surface cracks	No visible surface cracks (can be filled due to soil tillage)	No visible surface cracks (can be filled due to soil tillage)
Internal drainage	Well	Well
External drainage	Well	Well
Flooding	Once per year for a duration 3 days	Once per year for a duration 3 days
Groundwater	None observed	None observed

Auger ID	TRAZ-EBO-A5	TRAZ-EBO-A6
Soil unit	LP(cc VR (eu, pe))	LP(cc VR (eu, pe))
Location (admin.)	Tigray, Raya Alamata woreda, Ebo Kebele	Tigray, Raya Alamata woreda, Ebo Kebele
Elevation (m.)	1801	1766
Coordinates (Deg, Min, Sec)	39°40'43",12°51'26"	39°41'33",12°51'21"
Soil taxonomic classification (WRB 2006)	Calcic Vertisol (Eutric, Pellic)	Calcic Vertisol (Eutric, Pellic)
Local soil name	Walka	Walka
Topography	< 10	< 10
Landform	Level land,Plain	Level land,Plain
Position	Lower Slope (foot slope)	Lower Slope (foot slope)
Slope	Straight slope, 2%	Straight slope, 2%
Micro-topography	None	None
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Alluvium	Alluvium
Soil depth	120 cm+	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Very few (0-2%)	Very few (0-2%)
Erosion status	Slight sheet and wind erosion	Slight sheet and wind erosion
Surface sealing	thin crusts (<2mm)	thin crusts (<2mm)
Surface cracks	No visible surface cracks (can be filled due to soil tillage)	No visible surface cracks (can be filled due to soil tillage)
Internal drainage	Well	Well
External drainage	Well	Well
Flooding	Once per year for a duration 3 days	Once per year for a duration 3 days
Groundwater	None observed	None observed

Auger ID	TRAZ-EBO-A7	TRAZ-EBO-A8
Soil unit	SH(cc VR (eu, pe))	LP(cc VR (eu, pe))
Location (admin.)	Tigray, Raya Alamata woreda, Ebo Kebele	Tigray, Raya Alamata woreda, Ebo Kebele
Elevation (m.)	1810	1771
Coordinates (Deg, Min, Sec)	39°40'56",12°52'7"	39°41'17",12°51'3"
Soil taxonomic classification (WRB 2006)	Calcic Vertisol (Eutric, Pellic)	Calcic Vertisol (Eutric, Pellic)
Local soil name	Walka	Walka
Topography	10-30	< 10
Landform	Sloping land,Medium-gradient hill	Level land,Plain
Position	Middle Slope (Back slope)	Lower Slope (foot slope)
Slope	Straight slope, 2%	Straight slope, 2%
Micro-topography	None	None
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Alluvium	Alluvium
Soil depth	120 cm+	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Very few (0-2%)	Very few (0-2%)
Erosion status	Slight sheet and wind erosion	Slight sheet and wind erosion
Surface sealing	thin crusts (<2mm)	thin crusts (<2mm)
Surface cracks	No visible surface cracks (can be filled due to soil tillage)	No visible surface cracks (can be filled due to soil tillage)
Internal drainage	Well	Well
External drainage	Well	Well
Flooding	Once per year for a duration 3 days	Once per year for a duration 3 days
Groundwater	None observed	None observed

1.18 Auger obsrvation for Raya Azebo Genete

Auger ID	**TRAZ-GEN-A1**	**TRAZ-GEN-A2**
Soil unit	SH(cc VR (eu, pe))	LP(cc VR (eu, pe))
Location (admin.)	Tigray, Raya Azebo woreda, Genete Kebele	Tigray, Raya Azebo woreda, Genete Kebele
Elevation (m.)	1727	1735
Coordinates (Deg, Min, Sec)	39°38'56",12°45'28"	39°38'39",12°45'23"
Soil taxonomic classification (WRB 2006)	Calcic Vertisol (Eutric, Pellic)	Calcic Vertisol (Eutric, Pellic)
Local soil name	Hawsi Walka	Hawsi Walka
Topography	10-30	< 10
Landform	Sloping land,Medium-gradient hill	Level land,Plain
Position	Middle Slope	Lower Slope
Slope	Straight slope, 2%	Straight slope, 2%
Micro-topography	None	None
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Alluvium	Alluvium
Soil depth	120 cm+	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Very few (0-2%)	Very few (0-2%)
Erosion status	Slight sheet and wind erosion	Slight sheet and wind erosion
Surface sealing	thin crusts (<2mm)	thin crusts (<2mm)
Surface cracks	Fine cracks (<1cm), surface (<2cm)	Fine cracks (<1cm), surface (<2cm)
Internal drainage	Well	Well
External drainage	Well	Well
Flooding	None	None
Groundwater	None observed	None observed

Auger ID	TRAZ-GEN-A3	TRAZ-GEN-A4
Soil unit	LP(cc VR (eu, pe))	LP(cc VR (eu, pe))
Location (admin.)	Tigray, Raya Azebo woreda, Genete Kebele	Tigray, Raya Azebo woreda, Genete Kebele
Elevation (m.)	1755	1741
Coordinates (Deg, Min, Sec)	39°38'12",12°45'27"	39°38'41",12°46'2"
Soil taxonomic classification (WRB 2006)	Calcic Vertisol (Eutric, Pellic)	Calcic Vertisol (Eutric, Pellic)
Local soil name	Hawsi Walka	Hawsi Walka
Topography	< 10	< 10
Landform	Level land,Plain	Level land,Plain
Position	Lower Slope	Lower Slope
Slope	Straight slope, 2%	Straight slope, 2%
Micro-topography	None	None
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Alluvium	Alluvium
Soil depth	120 cm+	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Very few (0-2%)	Very few (0-2%)
Erosion status	Slight sheet and wind erosion	Slight sheet and wind erosion
Surface sealing	thin crusts (<2mm)	thin crusts (<2mm)
Surface cracks	Fine cracks (<1cm), surface (<2cm)	Fine cracks (<1cm), surface (<2cm)
Internal drainage	Well	Well
External drainage	Well	Well
Flooding	None	None
Groundwater	None observed	None observed

Auger ID	TRAZ-GEN-A5	TRAZ-GEN-A6
Soil unit	LP(cc VR (eu, pe))	LP(cc VR (eu, pe))
Location (admin.)	Tigray, Raya Azebo woreda, Genete Kebele	Tigray, Raya Azebo woreda, Genete Kebele
Elevation (m.)	1772	1800
Coordinates (Deg, Min, Sec)	39°37'47",12°45'41"	39°37'33",12°46'25"
Soil taxonomic classification (WRB 2006)	Calcic Vertisol (Eutric, Pellic)	Calcic Vertisol (Eutric, Pellic)
Local soil name	Hawsi Walka	Hawsi Walka
Topography	< 10	< 10
Landform	Level land,Plain	Level land,Plain
Position	Middle Slope (Back slope)	Middle Slope (Back slope)
Slope	Straight slope, 2%	Straight slope, 2%
Micro-topography	None	None
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Alluvium	Alluvium
Soil depth	120 cm+	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Very few (0-2%)	Very few (0-2%)
Erosion status	Slight sheet and wind erosion	Slight sheet and wind erosion
Surface sealing	thin crusts (<2mm)	thin crusts (<2mm)
Surface cracks	Fine cracks (<1cm), surface (<2cm)	Fine cracks (<1cm), surface (<2cm)
Internal drainage	Well	Well
External drainage	Well	Well
Flooding	None	None
Groundwater	None observed	None observed

Auger ID	TRAZ-GEN-A7	TRAZ-GEN-A8
Soil unit	SH(cc VR (eu, pe))	LP(ha VR (ca))
Location (admin.)	Tigray, Raya Azebo woreda, Genete Kebele	Tigray, Raya Azebo woreda, Genete Kebele
Elevation (m.)	1816	1645
Coordinates (Deg, Min, Sec)	39°36'49",12°45'23"	39°40'52",12°44'15"
Soil taxonomic classification (WRB 2006)	Calcic Vertisol (Eutric, Pellic)	Haplic Vertisol (Calcaric)
Local soil name	Hawsi Walka	Walka
Topography	10-30	< 10
Landform	Sloping land,Medium-gradient hill	Level land,Plain
Position	Middle Slope (Back slope)	Middle Slope (Back slope)
Slope	Straight slope, 2%	Straight slope, 2%
Micro-topography	None	None
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Alluvium	Alluvium
Soil depth	120 cm+	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Very few (0-2%)	Very few (0-2%)
Erosion status	Slight sheet and wind erosion	Slight sheet and wind erosion
Surface sealing	thin crusts (<2mm)	thin crusts (<2mm)
Surface cracks	Fine cracks (<1cm), surface (<2cm)	Wide cracks (2-5cm), very deep (>20cm)
Internal drainage	Well	Well
External drainage	Well	Well
Flooding	None	Once per year for a duration of 1 day
Groundwater	None observed	None observed

1.19 Auger obsrvation for Raya Azebo Kara Adishabo

Auger ID	**TRAZ-KAS-A1**	**TRAZ-KAS-A2**
Soil unit	LP(ha VR (ca))	LP(ha VR (ca))
Location (admin.)	Tigray, Raya Azebo woreda, Kara Adi Shabo Kebele	Tigray, Raya Azebo woreda, Kara Adi Shabo Kebele
Elevation (m.)	1594	1623
Coordinates (Deg, Min, Sec)	39°40'5",12°40'40"	39°40'17",12°42'7"
Soil taxonomic classification (WRB 2006)	Haplic Vertisol (Calcaric)	Haplic Vertisol (Calcaric)
Local soil name	Walka	Walka
Topography	< 10	< 10
Landform	Level land,Plain	Level land,Plain
Position	Middle Slope (Back slope)	Middle Slope (Back slope)
Slope	Straight slope, 2%	Straight slope, 2%
Micro-topography	None	None
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Alluvium	Alluvium
Soil depth	120 cm+	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Very few (0-2%)	Very few (0-2%)
Erosion status	Slight sheet and wind erosion	Slight sheet and wind erosion
Surface sealing	thin crusts (<2mm)	thin crusts (<2mm)
Surface cracks	Wide cracks (2-5cm), very deep (>20cm)	Wide cracks (2-5cm), very deep (>20cm)
Internal drainage	Moderately Well	Moderately Well
External drainage	Slow	Slow
Flooding	None	None
Groundwater	None observed	None observed

Auger ID	TRAZ-KAS-A3	TRAZ-KAS-A4
Soil unit	LP(ha VR (ca))	LP(ha VR (ca))
Location (admin.)	Tigray, Raya Azebo woreda, Kara Adi Shabo Kebele	Tigray, Raya Azebo woreda, Kara Adi Shabo Kebele
Elevation (m.)	1616	1651
Coordinates (Deg, Min, Sec)	39°39'58",12°41'54"	39°38'59",12°41'11"
Soil taxonomic classification (WRB 2006)	Haplic Vertisol (Calcaric)	Haplic Vertisol (Calcaric)
Local soil name	Walka	Walka
Topography	< 10	< 10
Landform	Level land,Plain	Level land,Plain
Position	Middle Slope (Back slope)	Middle Slope (Back slope)
Slope	Straight slope, 2%	Straight slope, 2%
Micro-topography	None	None
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Alluvium	Alluvium
Soil depth	120 cm+	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Very few (0-2%)	Very few (0-2%)
Erosion status	Slight sheet and wind erosion	Slight sheet and wind erosion
Surface sealing	thin crusts (<2mm)	thin crusts (<2mm)
Surface cracks	Wide cracks (2-5cm), very deep (>20cm)	Wide cracks (2-5cm), very deep (>20cm)
Internal drainage	Moderately Well	Moderately Well
External drainage	Slow	Slow
Flooding	None	None
Groundwater	None observed	None observed

Auger ID	TRAZ-KAS-A5	TRAZ-KAS-A6
Soil unit	LP(vr CM (ca))	LP(ha VR (ca))
Location (admin.)	Tigray, Raya Azebo woreda, Kara Adi Shabo Kebele	Tigray, Raya Azebo woreda, Kara Adi Shabo Kebele
Elevation (m.)	1698	1621
Coordinates (Deg, Min, Sec)	39°38'8",12°41'46"	39°39'32",12°41'12"
Soil taxonomic classification (WRB 2006)	Vertic Cambisol (Calcaric)	Haplic Vertisol (Calcaric)
Local soil name	Boda	Walka
Topography	< 10	< 10
Landform	Level land,Plain	Level land,Plain
Position	Upper Slope (shoulder)	Middle Slope (Back slope)
Slope	Straight slope, 2%	Straight slope, 2%
Micro-topography	None	None
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Alluvium	Alluvium
Soil depth	120 cm+	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Very few (0-2%)	Very few (0-2%)
Erosion status	Slight sheet and wind erosion	Slight sheet and wind erosion
Surface sealing	thin crusts (<2mm)	thin crusts (<2mm)
Surface cracks	Fine cracks (<1cm), surface (<2cm)	Wide cracks (2-5cm), very deep (>20cm)
Internal drainage	Well	Moderately Well
External drainage	Slow	Slow
Flooding	Once per year for a duration 2 days	None
Groundwater	None observed	None observed

Auger ID	TRAZ-KAS-A7	TRAZ-KAS-A8
Soil unit	SH(vr CM (ca))	SH(vr CM (ca))
Location (admin.)	Tigray, Raya Azebo woreda, Kara Adi Shabo Kebele	Tigray, Raya Azebo woreda, Kara Adi Shabo Kebele
Elevation (m.)	1728	1724
Coordinates (Deg, Min, Sec)	39°37'48",12°41'57"	39°37'36",12°41'39"
Soil taxonomic classification (WRB 2006)	Vertic Cambisol (Calcaric)	Vertic Cambisol (Calcaric)
Local soil name	Boda	Boda
Topography	10-30	10-30
Landform	Sloping land,Medium-gradient hill	Sloping land,Medium-gradient hill
Position	Upper Slope (shoulder)	Upper Slope (shoulder)
Slope	Straight slope, 2%	Straight slope, 2%
Micro-topography	None	None
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Alluvium	Alluvium
Soil depth	120 cm+	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Very few (0-2%)	Very few (0-2%)
Erosion status	Slight sheet and wind erosion	Slight sheet and wind erosion
Surface sealing	thin crusts (<2mm)	thin crusts (<2mm)
Surface cracks	Fine cracks (<1cm), surface (<2cm)	Fine cracks (<1cm), surface (<2cm)
Internal drainage	Well	Well
External drainage	Slow	Slow
Flooding	Once per year for a duration 2 days	Once per year for a duration 2 days
Groundwater	None observed	None observed

1.20 Auger obsrvation for Raya Azebo Tsegaa

Auger ID	**TRAZ-TSE-A1**	**TRAZ-TSE-A2**
Soil unit	SH(le RG (eu))	SH(le RG (eu))
Location (admin.)	Tigray, Raya Azebo woreda, Tsegaa Kebele	Tigray, Raya Azebo woreda, Tsegaa Kebele
Elevation (m.)	1868	1835
Coordinates (Deg, Min, Sec)	39°36'17",12°48'8"	39°36'59",12°48'11"
Soil taxonomic classification (WRB 2006)	Leptic Regosol (Eutric)	Leptic Regosol (Eutric)
Local soil name	Walka	Walka
Topography	10-30	10-30
Landform	Sloping land,Medium-gradient hill	Sloping land,Medium-gradient hill
Position	Lower slope (foot slope)	Middle slope (Back slope)
Slope	Straight slope, 2%	Straight slope, 2%
Micro-topography	None	None
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Alluvium	Alluvium
Soil depth	87 cm	90 cm
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Common (5-15%)	Common (5-15%)
Erosion status	Severe sheet and wind erosion	Severe sheet and wind erosion
Surface sealing	thin crusts (<2mm)	thin crusts (<2mm)
Surface cracks	None	None
Internal drainage	Well	Well
External drainage	Rapid	Rapid
Flooding	None	None
Groundwater	None observed	None observed

Auger ID	TRAZ-TSE-A3	TRAZ-TSE-A4
Soil unit	LP(cc VR (eu, pe))	LP(cc VR (eu, pe))
Location (admin.)	Tigray, Raya Azebo woreda, Tsegaa Kebele	Tigray, Raya Azebo woreda, Tsegaa Kebele
Elevation (m.)	1752	1799
Coordinates (Deg, Min, Sec)	39°39'17",12°47'50"	39°38'12",12°48'22"
Soil taxonomic classification (WRB 2006)	Calcic Vertisol (Eutric, Pellic)	Calcic Vertisol (Eutric, Pellic)
Local soil name	Walka	Walka
Topography	< 10	< 10
Landform	Level land,Plain	Level land,Plain
Position	Lower Slope (foot slope)	Lower Slope (foot slope)
Slope	Straight slope, 2%	Straight slope, 2%
Micro-topography	None	None
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Alluvium	Alluvium
Soil depth	120 cm+	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Common (5-15%)	Common (5-15%)
Erosion status	Slight sheet and wind erosion	Slight sheet and wind erosion
Surface sealing	thin crusts (<2mm)	thin crusts (<2mm)
Surface cracks	No visible surface cracks (can be filled due to soil tillage)	No visible surface cracks (can be filled due to soil tillage)
Internal drainage	Well	Well
External drainage	Well	Well
Flooding	Once per year for a duration of 4 days	Once per year for a duration of 4 days
Groundwater	None observed	None observed

Auger ID	TRAZ-TSE-A5	TRAZ-TSE-A6
Soil unit	LP(cc VR (eu, pe))	LP(cc VR (eu, pe))
Location (admin.)	Tigray, Raya Azebo woreda, Tsegaa Kebele	Tigray, Raya Azebo woreda, Tsegaa Kebele
Elevation (m.)	1728	1708
Coordinates (Deg, Min, Sec)	39°39'60",12°47'43"	39°40'22",12°47'8"
Soil taxonomic classification (WRB 2006)	Calcic Vertisol (Eutric, Pellic)	Calcic Vertisol (Eutric, Pellic)
Local soil name	Walka	Walka
Topography	< 10	< 10
Landform	Level land,Plain	Level land,Plain
Position	Lower Slope (foot slope)	Lower Slope (foot slope)
Slope	Straight slope, 2%	Straight slope, 2%
Micro-topography	None	None
Land Use	Rainfed arable cultivation	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer	DAP and Urea fertilizer
Vegetation	None	None
Parent material	Alluvium	Alluvium
Soil depth	120 cm+	120 cm+
Land Use	Cultivated land	Cultivated land
Rock outcrops	None	None
Surface coarse fragments	Common (5-15%)	Common (5-15%)
Erosion status	Slight sheet and wind erosion	Slight sheet and wind erosion
Surface sealing	thin crusts (<2mm)	thin crusts (<2mm)
Surface cracks	No visible surface cracks (can be filled due to soil tillage)	No visible surface cracks (can be filled due to soil tillage)
Internal drainage	Well	Well
External drainage	Well	Well
Flooding	Once per year for a duration of 4 days	Once per year for a duration of 4 days
Groundwater	None observed	None observed

Auger ID	**TRAZ-TSE-A7**
Soil unit	LP(cc VR (eu, pe))
Location (admin.)	Tigray, Raya Azebo woreda, Tsegaa Kebele
Elevation (m.)	1829
Coordinates (Deg, Min, Sec)	39°38'22",12°49'20"
Soil taxonomic classification (WRB 2006)	Calcic Vertisol (Eutric, Pellic)
Local soil name	Walka
Topography	< 10
Landform	Level land,Plain
Position	Lower Slope (foot slope)
Slope	Straight slope, 2%
Micro-topography	None
Land Use	Rainfed arable cultivation
Human influence	DAP and Urea fertilizer
Vegetation	None
Parent material	Alluvium
Soil depth	120 cm+
Land Use	Cultivated land
Rock outcrops	None
Surface coarse fragments	Common (5-15%)
Erosion status	Slight sheet and wind erosion
Surface sealing	thin crusts (<2mm)
Surface cracks	No visible surface cracks (can be filled due to soil tillage)
Internal drainage	Well
External drainage	Well
Flooding	Once per year for a duration of 4 days
Groundwater	None observed

Annex 2:Soil profile descriptions with Analytical data

2.1 Soil profile descriptions with analytical data for Alaje Atsela P1

Profile site description

Profile ID	TALJ-ATS-P1
Soil profile description status	Reference profile description
Date of description	13/01/2014
Author(s)	Amanuel Z. & Girmay G
Soil unit	SV(ha VR (eu, pe))
Location (admin.)	Tigray, Alaje woreda, Atsela Kebele
Elevation (m.)	2502
Map sheet number and grid reference	
Longitude (Deg, Min, Sec)	39°32'48",
Latitude	12 ° 55'43"
Soil taxonomic classification (WRB 2006) (WRB 2006)	Haplic Vertisol (Eutric, Pellic)
Local soil name	Walka
Topography	10-30%
Landform	Sloping land, medium-gradient valley (SV)
Position	Toe slope
Slope	Straight slope of ±2% over more than 200 m long.
Micro-topography	Gilgai
Land Use	The area is intensively farmed for cereals, such as wheat, field pea and chick pea. Irrigation is practiced by the farmers in the dry seasons to cultivate vegetables in addition to the field crops.
Human influence	Combination of DAP and Urea fertilizer is used for wheat and barley.
Vegetation	None
Parent material	Unconsolidated sediment alluvial from basalt
Soil depth	Very deep (>150cm)
Rock outcrops	None
Surface coarse fragments	Few (2-5%) of the soil surface is covered by fine (0.2cm) to coarse (6cm) surface fragments
Erosion	Slight sheet erosion, locally degradation caused by cattle tracks
Surface sealing	None
Surface cracks	Wide cracks (2-5cm), very deep (>30cm) and the cracks are closely spaced (0.2 – 0.5m)
Internal drainage	Imperfectlydrained
External drainage	Slow
Flooding	None
Groundwater	Very deep

Soil description

Hor.	*Depth cm*	*Description*
Ap	0-26	Very dark grey(10 YR 3/1) when dry, very dark brown (10 YR 2/2) when moist; dry clay; moderate to strong, coarse, sub-angular to angular blocky structure; very hard when dry,friable when moist, very sticky & vey plastic when wet; few medium pores; few very fine roots; very few to few fresh or slightly weathered fine to coarse gravelfragments;diffuse boundary; with no mottling and biological activity; no reaction with HCL.
Bi1_1	26-60	Very dark grey (10 YR 3/1) when dry, very dark brown (10 YR 2/2) when moist; slightly moist clay; moderate to strong coarse sub-angular to angular blocky structure; slickensides; very hard when dry, friable when moist, very sticky & vey plastic when wet; few medium pores; very few very fine roots; very few to few fresh or slightly weathered fine to coarse gravel fragments; clear and wavy boundary; with no mottling and biological activity; no reaction with HCL
Bi1_2	60-105	<Same>
C	105-200	Weathered rock material with boulders of various origin basalt and volcanic ash (common rock fragments) And no roots

Analytical data

Profile Code: TALJ-ATS-P1 Location: Alaje; Atsela kebele

Horizon	Ap	Bi1_1	Bi1_2	C
Upper depth	0	26	60	105
Lower depth	26	60	105	200
Coarse fragments %	1-5	1-5	1-5	
Sand %	12.01	5.91	11.47	
Silt %	29.33	34.72	33.2	
Clay %	58.66	59.37	55.33	
Texture class	clay	clay	clay	
pH-H2O (1:2.5)	7.8	7.32	6.74	
pH-KCL (1:2.5)	6.91	6.49	5.94	
EC (ms/cm)(1:2.5)	0.19	0.14	0.1	
Exch Na (meq/100gm of soil)	1.24	1.22	1.21	
Exch K (meq/100gm of soil)	0.48	0.52	0.54	
Exch Ca (meq/100gm of soil)	35.52	26.64	29.92	
Exch Mg (meq/100gm of soil)	9.77	8.88	9.68	
Sum of cations (meq/100gm soil)	47.01	37.25	41.35	
CEC (meq/100gm of soil)	53.09	39.57	44.48	
BS %	88.55	94.14	92.96	
Total N %	0.09	0.09	0.08	
OC %	0.85	0.71	0.70	
C/N	9.15	8.25	9.08	
Bulk density (gram/Cm^3)	1.17	1.30	1.27	
Avail. P (mg P2O5/kg soil)	22.30			
Available S (%)	0.65			
Exchangeable Sodium% (ESP)	2.33	3.07	2.71	
Zn (mg/kg soil)	0.23			
Mn (mg/kg soil)	3.83			
Cu (mg/kg soil)	2.40			
Fe (mg/kg soil)	7.38			

2.2 Soil profile descriptions with analytical data for Alaje Ayba P1

Profile site description

Profile ID	TALJ-AYB-P1
Soil profile description status	Reference profile description
Date of description	10/01/2014
Author(s)	Amanuel Z. & Girmay G
Soil unit	SE(cc VR (eu, pe))
Location (admin.)	Tigray, Alaje woreda, Ayba Kebele, Ayni May area
Elevation (m.)	2987
Map sheet number and grid reference	
Coordinates (Deg, Min, Sec)	39 ^{o} 32'22" 12 ^{o} 53'58"
Soil taxonomic classification (WRB 2006)	Calcic Vertisol (Eutric, Pellic)
Local soil name	Walka
Topography	10-30%
Landform	Sloping land, Medium-gradient escarpment zone (SE)
Position	Lower slope (foot slope)
Slope	Straight slope of ±2% over more than 200 m long.
Micro-topography	Gilgai
Land Use	The area is intensively farmed for cereals, such as wheat, field pea and chick pea.
Human influence	Rainfed arable cultivation. Combination of DAP and Urea fertilizer is used for wheat and barley.
Vegetation	None
Parent material	Unconsolidated sediment alluvial from basalt
Soil depth	Moderately deep
Rock outcrops	None
Surface coarse fragments	Few (2-5%) of the soil surface is covered by fine (0.2cm) to coarse (6cm) surface fragments
Erosion	Slight sheet erosion, locally degradation caused by cattle tracks
Surface sealing	None
Surface cracks	Wide cracks (2-5cm), very deep (>30cm) and the cracks are closely spaced (0.2 – 0.5m)
Internal drainage	Imperfectly drained
External drainage	Well
Flooding	None
Groundwater	Very deep

Soil description

Hor.	*Depth cm*	*Description*
Ap	0-17	Very dark greyish brown (10 YR 3/2) when moist, dark brown (10 YR 3/3) when dry; dry clay; moderate, medium to coarse angular and sub-angular blocky structure; hard when dry, very friable when moist, very sticky & very plastic when wet; medium fine pores; very few, faint pressure face coatings; with no compaction; very few fine roots; no biological activity; few fresh or slightly weathered fine and medium gravel; diffuse boundary; no mineral concretions; no reaction with HCL
Bic1_1	17-56	Very dark brown (10 YR 2/2) when moist, very dark greyish (10 YR 3/2) brown) when dry; slightly moist clay; strong, medium to coarse angular and sub-angular blocky structure; slickensides; very hard when dry, friable when moist, very sticky & very plastic when wet; medium fine pores; common,distinct pressure face coatings; with compacted but not cemented; few fine roots; no biological activity; common fresh or slightly weathered fine and coarse fragments; diffuse boundary; few medium hard carbonates mineral concretions; moderate reaction with HCL
Bic1_2	56-95	<same>
Bic2_1	95-143	Black (10 YR 2/1) when moist, very dark greyish (10 YR 3/2) when dry; moist clay; strong, medium to coarse angular and sub-angular blocky structure; slickensides; very hard when dry, friable when moist, very sticky & very plastic when wet; medium fine pores; abundant,prominent pressure face coatings; with compacted but not cemented; no roots; no biological activity; abundant weathered fine coarse fragments; diffuse boundary; many medium hard carbonates mineral concretions; moderate reaction with HCL
Bic2_2	143-200+	<same>

Analytical data

Profile Code: TALJ-AYB-P1 Location: Alaje woreda; Ayba kebele

Horizon	Ap	Bic1_1	Bic1_2	Bic2_1	Bic2_2
Upper depth	0-17	17-56	56-95	95-143	143-200
Lower depth					200
Coarse fragments %	3-5	5-15	5-15	40-80	40-80
Sand %	36.5	29.55	29.43	19.02	9.79
Silt %	13.99	20.59	27.14	24.4	25.94
Clay %	49.51	49.86	43.43	56.57	64.28
Texture class	clay	clay	clay	clay	clay
pH-H2O (1:2.5)	7.06	7.58	7.75	7.88	8.06
pH-KCL (1:2.5)	5.27	6.62	6.82	7	7.18
EC (ms/cm)(1:2.5)	0.07	0.09	0.11	0.25	0.25
Exch Na (meq/100gm of soil)	1.16	1.00	1.20	1.15	1.09
Exch K (meq/100gm of soil)	0.31	0.27	0.30	0.40	0.51
Exch Ca (meq/100gm of soil)	23.97	29.38	30.24	31.68	32.41
Exch Mg (meq/100gm of soil)	11.13	10.37	9.94	10.12	10.21
Sum of cations (meq/100gm soil)	36.57	41.01	41.68	43.35	44.22
CEC (meq/100gm of soil)	43.73	47.43	45.08	47.83	53.09
BS %	83.63	86.48	92.47	90.64	83.30
Total N %	0.13	0.08	0.07	0.06	0.05
OC %	1.06	0.61	0.57	0.54	0.51
C/N	7.88	8.02	8.39	8.71	9.38
Bulk density (gram/Cm3)	1.24	1.26	1.38	1.33	1.28
Avail. P (mg P2O5/kg soil)	17.60				
Available S (%)	0.83				
Exchangeable Sodium% (ESP)	2.66	2.12	2.67	2.40	2.05
Zn (mg/kg soil)	0.15				
Mn (mg/kg soil)	8.37				
Cu (mg/kg soil)	2.23				
Fe (mg/kg soil)	17.95				

2.3 Soil profile descriptions with analytical data for Alaje Ayba P2

Profile site description

Profile ID	TALJ-AYB-P2
Soil profile description status	Reference profile description
Date of description	11/01/2014
Author(s)	Amanuel Z. & Girmay G
Soil unit	
Location (admin.)	Tigray, Alaje woreda, Ayba Kebele
Elevation (m.)	2700
Map sheet number and grid reference	SV(ng CM (eu, bVR))
Coordinates (Deg, Min, Sec)	39 ^{o} 32'5", 12 ^{o} 53'22"

Soil taxonomic classification (WRB 2006)	Endogleyic Cambisol (Eutric) (Thapto-Vertisolic)
Local soil name	Walka
Topography	10-30%
Landform	Sloping land, Medium-gradient valley (SV)
Position	Toe slope
Slope	Concave slope of ± 1 % over more than 200 m long.
Micro-topography	Gilgai
Land Use	The area is intensively farmed for cereals, such as wheat, field pea and chick pea.
Human influence	Rainfed arable cultivation. Combination of DAP and Urea fertilizer is used for wheat and barley.
Vegetation	None
Parent material	Alluvial
Soil depth	Shallow
Rock outcrops	None
Surface coarse fragments	Many (15-40%) of the soil surface is covered by fine (0.2cm) to coarse (6cm) surface fragments
Erosion	Slight deposition of materials by water
Surface sealing	None
Surface cracks	Cracks can not be seen due to plough obliteration
Internal drainage	Imperfectly drained
External drainage	Slow
Flooding	about 3 times a year for a duration of a week
Groundwater	Moderately deep

Soil description

Hor.	*Depth cm*	*Description*
Ap	0-18	Very dark grey (10 YR 3/1) when moist, dark greyish brown (10 YR 4/2) when dry; very dry clay loam; moderate, medium to coarse angular to sub-angular blocky structure; hard when dry, friable when moist, sticky & plastic when wet; medium very few pores; no coatings; with no compaction; few very fine roots; nobiological activity; medium to coarse common fresh or slightly weathered coarse fragments; gradual wavy boundary; no mineral concretions; no reaction with HCL
B	18-33	Black (10 YR 2/1) when moist, very dark grey (10 YR 3/1) when dry; dry sandy clay loam; weak, fine to medium angular to sub-angular blocky structure; slightly hard when dry, friable when moist, slightly sticky & slightly plastic when wet; medium few pores; no coatings; with no compaction; very few very fine roots; no biological activity; stones fine few many weathered fresh or slightly coarse fragments; clear smooth boundary; very few fine hard mineral concretions; no reaction with HCL
BC	33-58	Very dark greyish brown (10YR 3/2) when moist, dark greyish brown (10 YR 4/2) when dry; slightly moist sand; weak, fine to mediumangular to sub-angular blocky structure; loose when dry, very friable when moist, non-sticky & non plastic when wet; low very few pores; nocoatings; with no compaction; very few very fine roots; no biological activity; coarse, fine to medium very few, dominant weathered fresh or slightly coarse fragments; clear smooth boundary; very few fine both hard & soft mineral concretions; no reaction with HCL
2ABb	58-105	Very dark greyish brown (10 YR 3/2) when moist, very dark grey (10 YR 3/1) when dry; moist clay; moderate, medium to coarse angular to sub-angular blocky structure; very hard when dry, friable when moist, very sticky & very plastic when wet; low very few pores; no coatings; with no compaction; very few very fine roots; no biological activity; medium to coarse common weathered fresh or slightly coarse fragments; clear smooth boundary; very few fine both hard & soft mineral concretions; no reaction with HCL
2Bb	105-180	Very dark greyish brown (10YR 3/2) when moist, 10 YR 3/1 (very dark grey) when dry; very wet clay; moderate, medium to coarse angular to sub-angular blocky structure; very hard when dry, very friable when moist, very sticky & very plastic when wet; low very few pores; no coatings; with no compaction; very few very fine roots; no biological activity; medium to coarse common fresh or slightly weathered coarse fragments; no mineral concretions; no reaction with HCL

Analytical data

Profile Code: TALJ-AYB-P2 Location: Alaje woreda; Ayba kebele

Horizon	Ap	B	BC	2ABb	2Bb
Depth	0-18	18-33	33-58	58-105	105-180
Sand %	25.31	55.34	60.9	40.2	43.53
Silt %	24.16	6.38	7.4	16.31	13.03
Clay %	50.53	38.28	31.7	43.49	43.44
Texture class	clay	Sandy clay	Sandy clay loam	clay	clay
pH-H2O (1:2.5)	7.55	7.83	7.93	7.23	7.36
pH-KCL (1:2.5)	6.58	6.97	7.08	6.3	6.38
EC (ms/cm)(1:2.5)	0.16	0.12	0.1	0.16	0.15
Exch Na (meq/100gm of soil)	1.28	1.15	1.30	1.23	1.29
Exch K (meq/100gm of soil)	1.34	0.93	1.03	0.68	0.34
Exch Ca (meq/100gm of soil)	27.03	23.74	21.00	29.38	32.83
Exch Mg (meq/100gm of soil)	9.59	8.90	8.40	9.50	9.50
Sum of cations (meq/100gm soil)	39.25	34.73	31.73	40.79	43.97
CEC (meq/100gm of soil)	40.28	36.87	34.24	42.26	44.61
BS %	97.42	94.20	92.67	96.51	98.56
Total N %	0.17	0.09	0.09	0.08	0.06
OC %	1.36	0.81	0.81	0.71	0.62
C/N	8.11	9.15	9.24	9.38	10.29
Bulk density (gram/Cm3)	1.27	1.21	1.27	1.30	1.25
Avail. P (mg P2O5/kg soil)	47.40				
Available S (%)	1.02				
Exchangeable Sodium% (ESP)	3.18	3.13	3.79	2.91	2.88
Zn (mg/kg soil)	0.65				
Mn (mg/kg soil)	9.04				
Cu (mg/kg soil)	2.24				
Fe (mg/kg soil)	18.34				

2.4 Soil profile descriptions with analytical data for Alaje Sesat P1

Profile site description

Profile ID	TALJ-SES-P1
Soil profile description status	Reference profile description
Date of description	13/01/2014
Author(s)	Amanuel Z. & Girmay G
Soil unit	SV(ha VR (eu, pe))
Location (admin.)	Tigray, Alaje woreda, Sesat Kebele
Elevation (m.)	2502
Map sheet number and grid reference	
Coordinates (Deg, Min, Sec)	39 ^{o} 34'29", 12 ^{o} 55'21"
Soil taxonomic classification (WRB 2006)	Haplic Vertisol (Eutric, Pellic)
Local soil name	Walka
Topography	10-30%
Landform	Sloping land, Medium-gradient valley (SV)
Position	Lower slope (foot slope)
Slope	Straight slope of ±2% over more than 200 m long.
Micro-topography	Gilgai
Land Use	The area is intensively farmed for cereals, such as wheat, field pea and chick pea.
Human influence	Rainfed arable cultivation. Combination of DAP and Urea fertilizer is used for wheat and barley.
Vegetation	None
Parent material	Unconsolidated sedimentary rock fluvial and or colluvial from basalt
Soil depth	Moderate (110 cm)
Rock outcrops	None
Surface coarse fragments	Few (2-5%) of the soil surface is covered by fine (0.2 - 0.6cm), medium (0.6-2cm) and coarse (6cm) surface fragments
Erosion	Slight sheet erosion, locally degradation caused by cattle tracks
Surface sealing	thin crusts (<2mm) with slightly hard consistence after the top soil dried
Surface cracks	Wide cracks (4cm), very deep (>30cm) and the cracks are closely spaced (0.2 – 0.5m)
Internal drainage	poor
External drainage	Slow
Flooding	Once a year for a duration of a week
Groundwater	Very deep

Soil description

Hor.	*Depth cm*	*Description*
Ap	0-20	Black (10 YR 2/1) when moist, very dark grey (10 YR 3/1) when dry; dry clay; moderate coarse, angular and sub-angular blocky structure; very hard when dry, friable when moist, very stick & very plastic when wet; medium very few pores; few, faint pressure face coatings; with no compaction; coarse very fine roots; no biological activity; coarse, fine to medium very few, common fresh or slightly fresh coarse fragments; diffused boundary; few fine to medium hard mineral concretions; no reaction with HCL
Bi1	20-57	Black (10 YR 2/1) when moist, very dark grey (10 YR 3/1) when dry; slightly moist clay; strong, coarse angular to sub-angular blocky structure; very hard when dry, friable when moist, very sticky & very plastic when wet; medium very few pores; medium ,prominent pressure face coatings; with compacted but not cemented; few roots; no biological activity; coarse, fine to medium very few, common fresh or slightly coarse fragments; diffused boundary; fine, medium to coarse both hard & soft, hard very fine mineral concretions; no reaction with HCL
Bi2	57-110	Very dark greyish brown (10 YR 3/2) when moist, very dark brown (10 YR 2/2) when dry; moist clay/silt; strong, coarse angular to sub-angular blocky structure; very hard when dry, friable when moist, very sticky & very plastic when wet; low very few pores; medium ,prominent pressure face coatings; with compacted but not cemented; very few very fine roots; no biological activity; coarse, fine to medium very few, common fresh or slightly coarse fragments; diffused wavy boundary; common, very few fine, medium to coarse hard mineral concretions; no reaction with HCL
C	110-180+	dark brown (10 YR 3/3) when moist, dark yellowish brown (10 YR 4/4) when dry; slightly moist silt clay loam; rock structure; hard when dry, friable when moist, slightly sticky when wet; high many pores; no coatings; with no compaction; no roots; no biological activity; weathered rock coarse fragments; no mineral concretions; no reaction with HCL

Analytical data

Profile Code: TALJ-SES-P1 Location: Alaje woreda; Sesat kebele

Horizon	Ap	Bi1	Bi2	C
Depth	0-20	20-57	57-110	110-180
Sand %	25.04	9.13	25.31	37.99
Silt %	19.02	29.92	7.8	14.14
Clay %	55.94	60.95	66.89	47.87
Texture class	clay	clay	clay	clay
pH-H2O (1:2.5)	7.27	7.61	7.8	7.71
pH-KCL (1:2.5)	6.61	6.81	7.02	6.71
EC (ms/cm)(1:2.5)	0.17	0.38	0.25	0.16
Exch Na (meq/100gm of soil)	0.97	1.10	1.56	1.61
Exch K (meq/100gm of soil)	0.53	0.58	0.43	0.23
Exch Ca (meq/100gm of soil)	29.75	31.24	36.52	25.06
Exch Mg (meq/100gm of soil)	9.77	10.56	11.88	8.64
Sum of cations (meq/100gm soil)	41.02	43.48	50.39	35.53
CEC (meq/100gm of soil)	50.67	54.04	52.61	36.63
BS %	80.95	80.46	95.79	97.02
Total N %	0.14	0.11	0.08	0.04
OC %	0.98	0.85	0.66	0.30
C/N	7.01	7.84	7.77	8.00
Bulk density (gram/Cm3)	1.16	1.21	1.14	1.34
Avail. P (mg P2O5/kg soil)	32.30			
Available S (%)	0.76			
Exchangeable Sodium% (ESP)	1.92	2.04	2.96	4.38
Zn (mg/kg soil)	0.21			
Mn (mg/kg soil)	5.33			
Cu (mg/kg soil)	1.25			
Fe (mg/kg soil)	6.86			

2.5Soil profile descriptions with analytical data for Alaje Tekha P1

Profile site description

`	TALJ-TEK-P1
Soil profile description status	Reference profile description
Date of description	05/01/2014
Author(s)	Amanuel Z. & Girmay G
Soil unit	SE(ha CM (eu))
Location (admin.)	Tigray, Alaje woreda, Teka Kebele
Elevation (m.)	2712
Map sheet number and grid reference	
Coordinates (Deg, Min, Sec)	39 ^{o} 28'41", 12 ^{o} 53'60"
Soil taxonomic classification (WRB 2006)	Haplic Cambisol (Eutric)
Local soil name	Hamed Qoriya
Topography	10-30%
Landform	Sloping land, Medium-gradient escarpment zone (SE)
Position	Lower slope (foot slope)
Slope	Straight slope of ±8% over more than 200 m long.
Micro-topography	None
Land Use	The area is intensively farmed for cereals, such as wheat, field pea and chick pea.
Human influence	Rainfed arable cultivation. Combination of DAP and Urea fertilizer is used for wheat and barley.
Vegetation	None
Parent material	Basic igneous rock basalt
Soil depth	Very deep (>150cm)
Rock outcrops	None
Surface coarse fragments	Common (5-15%) of the soil surface is covered by fine (0.2 -0.6cm), medium (0.6-2cm) and coarse (6cm) surface fragments
Erosion	Moderate sheet erosion affecting abbove 50% of the mapping unit, locally degradation caused by cattle tracks
Surface sealing	None
Surface cracks	None
Internal drainage	Well
External drainage	Rapid
Flooding	None
Groundwater	Very deep

Soil description

Hor.	*Depth cm*	*Description*
Ap	0-25	Very dark brown (10 YR 2/2) when moist, dark greyish brown (10 YR 4/2) when dry; dry sandy clay loam; weak, fine to medium sub-angular blocky structure; slightly hard when dry, very friable when moist, slightly sticky & slightly plastic when wet; medium pores; no coatings; with no compaction; few very fine roots; few biological activity (ant channels and other insect activity); fine to medium common fresh or slightly weathered coarse fragments; diffuse boundary; no mineral concretions; no reaction with HCL
Bw	25-90	Black (10 YR 2/1) when moist, very dark brown (10 YR 2/2) when dry; slightly moist sandy clay loam; moderate fine to medium angular to sub-angular blocky structure; hard when dry, very friable when moist, very sticky & very plastic when wet; low pores; no coatings; with no compaction; very few very fine roots; no biological activity; fine to coarse common fresh or slightly coarse fragments; diffuse boundary; no mineral concretions; no reaction with HCL
BC	90-150	Black (10 YR 2/1) when moist, very dark brown (10 YR 2/2) when dry; slightly moist sandy clay;very friable clay; weak, fine to medium angular to sub-angular blocky structure; hard when dry, very friable when moist, very sticky & very plastic when wet; high pores; no coatings; with no compaction; no roots; biological activity; fine common weathered coarse fragments; clear & wavy boundary; no mineral concretions; no reaction with HCL.
C(R)	150-207+	Brown (10 YR 5/3) when moist, yellowish brown brown (10 YR 5/4) when dry; no reaction with HCL with rock structure

Analytical data

Profile Code: TALJ-TEK-P1 Location: Alaje woreda; Tekha kebele

Horizon	Ap	Bw	BC	
Depth	0-25	25-90	90-150	207
Sand %	49.57	53.62	47.22	
Silt %	15.76	14.76	15.08	
Clay %	34.67	31.62	37.7	
Texture class	Sandy clay loam	Sandy clay loam	Sandy clay	
pH-H2O (1:2.5)	7	7.01	7.2	
pH-KCL (1:2.5)	6.03	6.01	6.24	
EC (ms/cm)(1:2.5)	0.29	0.15	0.14	
Exch Na (meq/100gm of soil)	1.20	1.07	1.18	
Exch K (meq/100gm of soil)	2.53	2.10	4.66	
Exch Ca (meq/100gm of soil)	25.20	21.84	24.40	
Exch Mg (meq/100gm of soil)	8.40	7.56	7.70	
Sum of cations (meq/100gm soil)	37.33	32.57	37.95	
CEC (meq/100gm of soil)	38.80	34.70	38.61	
BS %	96.19	93.87	98.27	
Total N %	0.16	0.13	0.06	
OC %	1.52	1.45	0.49	
C/N	9.40	10.93	8.23	
Bulk density (gram/Cm3)	1.38	1.26	1.20	
Avail. P (mg P2O5/kg soil)	55.00			
Available S (%)	1.15			
Exchangeable Sodium% (ESP)	3.08	3.08	3.06	
Zn (mg/kg soil)	0.33			
Mn (mg/kg soil)	5.59			
Cu (mg/kg soil)	0.93			
Fe (mg/kg soil)	9.87			

2.6Soil profile descriptions with analytical data for Alaje Tekha P2

Profile site description

Profile ID	TALJ-TEK-P2
Soil profile description status	Reference profile description
Date of description	05/01/2014
Author(s)	Amanuel Z. & Girmay G
Soil unit	SV(vr el CM (eu))
Location (admin.)	Tigray, Alaje woreda, Teka Kebele
Elevation (m.)	2663
Map sheet number and grid reference	
Coordinates (Deg, Min, Sec)	39 ^{o} 28'58", 12 ^{o} 54'11"
Soil taxonomic classification (WRB 2006)	Vertic Epileptic Cambisol (Eutric)
Local soil name	Kelil Walka
Topography	10-30%
Landform	Sloping land, Medium-gradient valley (SV)
Position	Middle slope (back slope)
Slope	Straight slope of ±4% over more than 200 m long.
Micro-topography	None
Land Use	The area is intensively farmed for cereals, such as wheat, field pea and chick pea.
Human influence	Rainfed arable cultivation. Combination of DAP and Urea fertilizer is used for wheat and barley.
Vegetation	None
Parent material	Basic igneous rock basalt
Soil depth	Shallow (44cm)
Rock outcrops	None
Surface coarse fragments	Abundant (40-80%) of the soil surface is covered by gravel , stone and boulders
Erosion	Severe water erosion
Surface sealing	None
Surface cracks	Cracks cannot be seen due to plough obliteration
Internal drainage	Well
External drainage	Rapid
Flooding	None
Groundwater	Very deep

Soil description

Hor.	*Depth cm*	*Description*
Ap	0-15	Very dark greyish brown (10 YR 3/2) when moist, dark brown (10 YR 3/3) when dry; dry clay; moderate medium sub-angular blocky structure; hard when dry, friable when moist, very sticky & very plastic when wet; medium very few pores; no coatings; with no compaction; common very fine roots; biological activity; few stones, fine to coarse gravel many weathered fresh or slightly coarse fragments; diffuse boundary; no mineral concretions; no reaction with HCL
Bw	15-44	very dark greyish brown (10 YR 3/2) when moist, very dark brown (10 YR 2/2) when dry; dry clay; weak, medium sub-angular blocky structure; hard when dry, friable when moist, very sticky & very plastic when wet; medium very few pores; no coatings; with no compaction; few very fine roots; few biological activity; many fine gravel & common stones common coarse fragments; clear & wavy airy boundary; no mineral concretions; no reaction with HCL
R	44+	Hard Rock

Table with analytical data

Profile Code: TALJ-TEK-P2 Location: Alaje woreda; Tekha kebele

Horizon	Ap	Bw	R
Depth	0-15	15-44	44+
Sand %	29.51	30.67	
Silt %	21.36	21.67	
Clay %	49.13	47.67	
Texture class	clay	clay	
pH-H2O (1:2.5)	6.33	6.55	
pH-KCL (1:2.5)	5.35	5.68	
EC (ms/cm)(1:2.5)	0.1	0.12	
Exch Na (meq/100gm of soil)	1.12	1.05	
Exch K (meq/100gm of soil)	0.52	0.59	
Exch Ca (meq/100gm of soil)	25.44	25.06	
Exch Mg (meq/100gm of soil)	9.33	9.50	
Sum of cations (meq/100gm soil)	36.41	36.20	
CEC (meq/100gm of soil)	46.09	45.08	
BS %	79.01	80.31	
Total N %	0.22	0.15	
OC %	1.83	1.26	
C/N	8.23	8.32	
Bulk density (gram/Cm3)	1.21	1.22	
Avail. P (mg P2O5/kg soil)	32.60		
Available S (%)	0.70		
Exchangeable Sodium% (ESP)	2.44	2.33	
Zn (mg/kg soil)	0.62		
Mn (mg/kg soil)	25.36		
Cu (mg/kg soil)	3.17		
Fe (mg/kg soil)	39.20		

2.7Soil profile descriptions with analytical data for Alaje Tekha P3

Profile site description

Profile ID	TALJ-TEK-P3
Soil profile description status	Reference profile description
Date of description	11/01/2014
Author(s)	Amanuel Z. & Girmay G
Soil unit	SV(ha VR (eu, pe))
Location (admin.)	Tigray, Alaje woreda, Teka Kebele
Elevation (m.)	2609
Map sheet number and grid reference	
Coordinates (Deg, Min, Sec)	39 ^{o} 29'11", 12 ^{o} 54'40"
Soil taxonomic classification (WRB 2006)	Haplic Vertisol (Eutric, Pellic)
Local soil name	Walka
Topography	10-30%
Landform	Sloping land, Medium-gradient valley (SV)
Position	Middle slope (back slope)
Slope	Concave slope of ± 1 % over more than 200 m long.
Micro-topography	Terracing
Land Use	The area is intensively farmed for cereals, such as wheat, field pea and chick pea.
Human influence	Irrigation is practiced by the farmers in the dry seasons to cultivate vegetables in addition to the field crops. Combination of DAP and Urea fertilizer is used for wheat and barley.
Vegetation	None
Parent material	Basic igneous rock basalt
Soil depth	Very deep (>150cm)
Rock outcrops	None
Surface coarse fragments	Few (2-5%) of the soil surface is covered by medium gravel (0.6-2cm), coarse gravel (2-6cm) and stone (6-20cm) surface fragments
Erosion	Slight sheet erosion, locally degradation caused by cattle tracks
Surface sealing	None
Surface cracks	Wide cracks (2-5cm), medium depth (2-10cm) and the cracks are closely spaced (0.2 – 0.5m)
Internal drainage	Poor
External drainage	Well
Flooding	Once per year for a day
Groundwater	Very deep (>150cm)

Soil description

Hor.	*Depth cm*	*Description*
Ap	0-19	Very dark grey (10YR 3/1) when moist, dark grey (10YR 4/1) when dry; clay; moderate, coarse angular to sub-angular blocky structure;very hard when dry, friable when moist, very sticky & very plastic when wet; medium few pores; no coatings; with no compaction; common very fine roots; no biological activity; medium, coarsecommon, very few fresh or slightly weathered coarse fragments; diffuse boundary; very fewvery finehard mineral concretions; no reaction with HCL
Bi1_1	19-80	very dark grey (10YR 3/1) when moist, dark grey (10YR 4/1) when dry; slightly moist clay; moderate, medium to coarse angular to sub-angular blocky structure; slickensides; very hard when dry, friable when moist, very sticky & very plastic when wet; medium few pores; few,faint pressure face coatings; with compacted but not cemented; few very fine roots; few biological activity; medium, coarsefew, very few fresh or slightly weathered coarse fragments; gradual & wavy boundary; fewvery fineboth soft & hard mineral concretions; no reaction with HCL
Bi1_2	80-130	<same>
Bi2_1	130-165	black (10YR 2/1) when moist, very dark grey (10YR 3/1) when dry; wet clay (heavy); strong, medium angular to sub-angular blocky structure; slickensides; very hard when dry, friable when moist, very sticky & very plastic when wet; low very few pores; dominant ,prominent pressure face coatings; with compacted but not cemented; no roots; no biological activity; medium very few fresh or slightly weathered coarse fragments; clear & wavy boundary; very few fine to medium both soft & hard mineral concretions; no reaction with HCL
BC	165-200+	<same>

Analytical data

Profile Code: TALJ-TEK-P3 Location: Alaje woreda; Tekha kebele

Horizon	Ap	Bi1_1	Bi1_2	Bi2	BC
Depth	0-19	19-80	80-130	130-165	165-200
Sand %	19.23	20.37	11.98	10.89	35.03
Silt %	28.38	30.97	31.6	26.28	20.16
Clay %	52.39	48.66	56.42	62.83	44.8
Texture class	clay	clay	clay	clay	clay
pH-H2O (1:2.5)	7.56	7.53	7.75	7.71	7.84
pH-KCL (1:2.5)	6.72	6.61	6.84	6.76	6.89
EC (ms/cm)(1:2.5)	0.16	0.2	0.25	0.23	0.22
Exch Na (meq/100gm of soil)	1.20	1.08	1.30	1.36	1.25
Exch K (meq/100gm of soil)	0.24	0.21	0.28	0.41	0.25
Exch Ca (meq/100gm of soil)	34.56	34.32	31.08	30.46	34.19
Exch Mg (meq/100gm of soil)	9.94	10.12	11.10	9.86	10.21
Sum of cations (meq/100gm soil)	45.94	45.73	43.76	42.10	45.91
CEC (meq/100gm of soil)	48.37	48.30	45.85	43.83	48.26
BS %	94.99	94.67	95.45	96.05	95.12
Total N %	0.12	0.11	0.09	0.07	0.05
OC %	0.88	0.85	0.62	0.60	0.38
C/N	7.29	7.84	7.28	8.44	8.10
Bulk density (gram/Cm3)	1.29	1.40	1.25	1.23	1.34
Avail. P (mg P2O5/kg soil)	26.60				
Available S (%)	0.71				
Exchangeable Sodium% (ESP)	2.49	2.24	2.84	3.11	2.60
Zn (mg/kg soil)	0.13				
Mn (mg/kg soil)	4.18				
Cu (mg/kg soil)	3.10				
Fe (mg/kg soil)	10.86				

2.8Soil profile descriptions with analytical data for Enda Mehoni Mekan P1

Profile site description

Profile ID	TENM-MEK-P1
Soil profile description status	Reference profile description
Date of description	9/12/2013
Author(s)	Amanuel Z., Atkilt G & Koos
Soil unit	SH(ha VR (eu, pe))
Location (admin.)	Tigray, Enda Mokoni woreda, Mekan Kebele
Elevation (m.)	2415
Map sheet number and grid reference	
Coordinates (Deg, Min, Sec)	39 ^{o} 31'41", 12 ^{o} 44'51"
Soil taxonomic classification (WRB 2006)	Haplic Vertisol (Eutric, Pellic)
Local soil name	Walka
Topography	10-30%
Landform	Sloping land, Medium-gradient hill (SH)
Position	Toe slope
Slope	Straight slope of ±2% over more than 200 m long.
Micro-topography	terracing
Land Use	The area is intensively farmed for cereals, such as wheat, field pea and chick pea.
Human influence	Rainfed arable cultivation. Combination of DAP and Urea fertilizer is used for wheat and barley.
Vegetation	None
Parent material	Unconsolidated sedimentary rock fluvial and or colluvial from basalt
Soil depth	Very deep (>150cm)
Rock outcrops	None
Surface coarse fragments	Few (2-5%) of the soil surface is covered by medium gravel (0.6-2cm), coarse gravel (2-6cm) and stone (6-20cm) surface fragments
Erosion	Slight sheet erosion, locally degradation caused by cattle tracks
Surface sealing	thin crusts (<2mm) with hard consistence after the top soil dried
Surface cracks	Wide cracks (2-5cm), moderately deep (2-10cm) and the cracks are widely spaced (0.5 – 2m)
Internal drainage	Well
External drainage	Well
Flooding	None
Groundwater	Very deep (>150cm)

Soil description

Hor.	*Depth cm*	*Description*
Ap	0-24	Black (10 YR 2/1) when moist, very dark grey (10 YR 3/1) when dry; very dry clay (heavy); moderate, coarse sub-angular blocky structure; hard when dry, friable when moist, sticky & plastic when wet; medium few pores; no coatings; with no compaction; common fine roots; no biological activity; fine few fresh or slightly weathered coarse fragments; diffused boundary; no mineral concretions; no reaction with HCL
Bi1_1	24-60	Black (10 YR 2/1) when moist, very dark grey (10 YR 3/1) when dry; dry clay; moderate, coarse sub-angular blocky structure; hard when dry, friable when moist, sticky & plastic when wet; low few pores; common, faint pressure face coatings; with no compaction; common fine roots; no biological activity; fine to coarse few fresh or slightly coarse fragments; diffused boundary; no mineral concretions; no reaction with HCL
Bi1_2	60-90	<same>
Bi2	90-185+	Black (10YR 2/1) when moist, very dark grey (10YR 3/1) when dry; slightly moist clay; moderate, medium angular blocky structure; hard when dry, friable when moist, sticky & plastic when wet; low few pores; common, faint pressure face coatings; with no compaction; few fine roots; no biological activity; fine to medium many fresh or slightly coarse fragments; diffused boundary; no mineral concretions; no reaction with HCL

Analytical data

Profile Code: TENM-MEK-P1 Location: Enda Mekhoni woreda; Mekan kebele

Horizon	Ap	Bi1_1	Bi1_2	Bi2
Depth	0-24	24-60	60-90	90-185
Sand %	30.05	28.68	41.04	41.98
Silt %	14.84	28.1	18.22	15.04
Clay %	55.11	43.23	40.73	42.98
Texture class	clay	clay	clay	clay
pH-H2O (1:2.5)	6.87	7.37	7.74	7.73
pH-KCL (1:2.5)	5.89	6.41	6.79	6.81
EC (ms/cm)(1:2.5)	0.09	0.09	0.12	0.11
Exch Na (meq/100gm of soil)	0.96	1.04	1.04	1.02
Exch K (meq/100gm of soil)	0.55	0.37	0.39	0.46
Exch Ca (meq/100gm of soil)	24.17	29.53	25.68	26.96
Exch Mg (meq/100gm of soil)	8.90	9.42	9.42	9.42
Sum of cations (meq/100gm soil)	34.58	40.36	36.53	37.86
CEC (meq/100gm of soil)	48.85	46.06	44.66	47.92
BS %	70.78	87.63	81.79	79.01
Total N %	0.15	0.10	0.10	0.09
OC %	1.24	0.82	0.79	0.77
C/N	8.33	7.84	8.16	8.54
Bulk density (gram/Cm3)	1.30	1.29	1.31	1.28
Avail. P (mg P2O5/kg soil)	35.10			
Available S (%)	0.65			
Exchangeable Sodium% (ESP)	1.96	2.26	2.33	2.14
Zn (mg/kg soil)	0.45			
Mn (mg/kg soil)	14.16			
Cu (mg/kg soil)	2.76			
Fe (mg/kg soil)	13.86			

2.9Soil profile descriptions with analytical data for Enda Mehoni Shibta P1

Profile site description

Profile ID	TENM-SHI-P1
Soil profile description status	Reference profile description
Date of description	02/01/2014
Author(s)	Amanuel Z. & Girmay G
Soil unit	TM(ha VR (eu, pe))
Location (admin.)	Tigray, Enda Mokoni woreda, Shibta Kebele
Elevation (m.)	2538
Map sheet number and grid reference	
Coordinates (Deg, Min, Sec)	39°30'10", 12°47'57"
Soil taxonomic classification (WRB 2006)	Haplic Vertisol (Eutric, Pellic)
Local soil name	Walka
Topography	> 30%
Landform	Steep land, High-gradient mountain (TM)
Position	Lower slope (foot slope)
Slope	Straight slope of ±2% over more than 200 m long.
Micro-topography	soil bund & Gilgai
Land Use	The area is intensively farmed for cereals, such as wheat, field pea and chick pea.
Human influence	Rainfed arable cultivation. Combination of DAP and Urea fertilizer is used for wheat and barley.
Vegetation	None
Parent material	Basic igneos rock basalt
Soil depth	Very deep (>150cm)
Rock outcrops	None
Surface coarse fragments	Few (2-5%) of the soil surface is covered by medium-sized (0.6-2cm)surface fragments
Erosion	Slight sheet erosion, locally degradation caused by cattle tracks
Surface sealing	None
Surface cracks	Very wide cracks (5-10cm), deep (10-20cm) and the cracks are moderately widely spaced (0.5 – 2m)
Internal drainage	Well
External drainage	Well
Flooding	Once per year for a day
Groundwater	Very deep (>150cm)

Soil description

Hor.	*Depth cm*	*Description*
Ap	0-23	Black (10YR 2/1) when moist, black (10YR 2/1) when dry; very dry clay; moderate, medium to coarse angular to sub-angular blocky structure; very hard when dry, firm when moist, very sticky & very plastic when wet; low very few pores; very few, faint pressure face coatings; with compacted but not cemented; many fine roots; no biological activity; fine very few fresh or slightly weathered coarse fragments; diffused boundary; no mineral concretions; no reaction with HCL
Bi1	23-80	Black (10YR 2/1) when moist, black (10YR 2/1) when dry; slightly moist clay; moderate, medium to coarse angular to sub-angular blocky structure; slickensides; very hard when dry, firm when moist, very sticky & very plastic when wet; low very few pores; common, prominent pressure face coatings; with compacted but not cemented; common very fine to fine roots; no biological activity; fine very few fresh or slightly weathered coarse fragments; diffused boundary; no mineral concretions; no reaction with HCL
Bi2	80-140	Black (10 YR 2/1) when moist, black (10 YR 2/1) when dry; moist clay; moderate, fine to medium angular to sub-angular blocky structure; slickensides; very hard when dry, firm when moist, very sticky &very plastic when wet; low very few pores; common, prominent pressure face coatings; with compacted but not cemented; very few very fine roots; no biological activity; fine very few fresh or slightly weathered coarse fragments; diffused boundary; no mineral concretions; no reaction with HCL
C	140-195	Black (10 YR 2/1) when moist, light yellowish brown (10 YR 6/4) when dry; moist clay; weak, fine sub-angular blocky structure; very hard when dry, friable when moist, very sticky & very plastic when wet; low very few pores; common,prominent pressure face coatings; with no compaction; very few very fine roots; no biological activity; fine Very few fresh or slightly weathered coarse fragments; Clear & wavy boundary; no mineral concretions; no reaction with HCL

Analytical data

Profile Code: TENM-SHI-P1 Location: Enda Mekhoni woreda; Shibta kebele

Horizon	Ap	Bi1	Bi2	C
Depth	0-23	23-80	80-140	140-195
Sand %	6.8	4.76	5.04	12.35
Silt %	22.19	26.58	25.7	33.96
Clay %	71.01	68.66	69.27	53.68
Texture class	clay	clay	clay	clay
pH-H2O (1:2.5)	7.38	7.86	8.17	8.03
pH-KCL (1:2.5)	6.42	6.84	7.26	7.15
EC (ms/cm)(1:2.5)	0.13	0.15	0.25	0.26
Exch Na (meq/100gm of soil)	1.13	1.42	1.62	1.82
Exch K (meq/100gm of soil)	0.73	0.46	0.42	0.56
Exch Ca (meq/100gm of soil)	36.96	39.60	42.24	26.16
Exch Mg (meq/100gm of soil)	12.32	13.20	14.96	8.72
Sum of cations (meq/100gm soil)	51.14	54.68	59.24	37.26
CEC (meq/100gm of soil)	55.00	57.87	63.13	43.13
BS %	92.99	94.49	93.84	86.41
Total N %	0.17	0.14	0.11	0.03
OC %	1.54	1.23	0.90	0.24
C/N	9.11	8.84	8.33	8.00
Bulk density (gram/Cm3)	1.21	1.27	1.21	1.26
Avail. P (mg P2O5/kg soil)	26.78			
Available S (%)	0.71			
Exchangeable Sodium% (ESP)	2.05	2.45	2.56	4.22
Zn (mg/kg soil)	0.39			
Mn (mg/kg soil)	8.03			
Cu (mg/kg soil)	4.47			
Fe (mg/kg soil)	15.66			

2.10 Soil profile descriptions with analytical data for Enda Mehoni Shibta P2

Profile site description

Profile ID	TENM-SHI-P2
Soil profile description status	Reference profile description
Date of description	13/01/2014
Author(s)	Amanuel Z. & Girmay G
Soil unit	SV(vr CM (eu))
Location (admin.)	Tigray, Enda Mokoni woreda, Shibta Kebele
Elevation (m.)	2592
Map sheet number and grid reference	
Coordinates (Deg, Min, Sec)	39 ^{o} 30'21", 12 ^{o} 47'54"
Soil taxonomic classification (WRB 2006)	Vertic Cambisol (Eutric)
Local soil name	Walka
Topography	10-30%
Landform	Sloping land, Medium-gradient valley (SV)
Position	Middle slope (back slope)
Slope	Straight slope of ±2% over more than 200 m long.
Micro-topography	None
Land Use	The area is intensively farmed for cereals, such as wheat, field pea and chick pea.
Human influence	Rainfed arable cultivation. Combination of DAP and Urea fertilizer is used for wheat and barley.
Vegetation	None
Parent material	Basic igneous rock basalt
Soil depth	Very deep (>150cm)
Rock outcrops	None
Surface coarse fragments	Few (2-5%) of the soil surface is covered by medium-sized (0.6-2cm)surface fragments
Erosion	Slight sheet erosion, locally degradation caused by cattle tracks
Surface sealing	None
Surface cracks	Cracks cannot be seen due to plough obliteration
Internal drainage	Well
External drainage	Rapid
Flooding	None
Groundwater	Very deep (>150cm)

Soil description

Hor.	*Depth cm*	*Description*
Ap	0-18	Very dark grey (10 YR 3/1) when moist, dark grey (10 YR 4/1) when dry; very dry clay; moderate, coarse angular blocky & sub-angular blocky structure; hard when dry, friable when moist, sticky & plastic when wet; low channel pores; no coatings; with no compaction; common fine to medium roots; no biological activity; medium common fresh or slightly coarse fragments; diffused boundary; no mineral concretions; no reaction with HCL
Bw	18-40	Very dark grey (10 YR 3/1) when moist, dark grey (10 YR 4/1) when dry; slightly moist clay; moderate, coarse angular blocky & sub-angular blocky structure; hard when dry, friable when moist, sticky & plastic when wet; low channel pores; no coatings; with no compaction; few fine roots; no biological activity; fine few fresh or slightly coarse fragments; clear & wavy boundary; no mineral concretions; no reaction with HCL
BC	40-200	Brown (10 YR 4/3) when moist, pale brown (10 YR 6/3) when dry; slightly moist sandy clay loam; weak, coarse angular blocky & sub-angular blocky structure; slightly hard when dry, friable when moist, non-sticky & non-plastic when wet; medium channel pores; no coatings; with no compaction; few fine roots; no biological activity; coarse, fine very few, many fresh or slightly coarse fragments; no mineral concretions; no reaction with HCL

Analytical data

Profile Code: TENM-SHI-P2 Location: Enda Mekhoni woreda; Shibta kebele

Horizon	Ap	Bw	C
Depth	0-18	18-40	40-200
Sand %	42.47	38.1	53.47
Silt %	17.05	21.34	13.29
Clay %	40.49	40.55	33.23
Texture class	clay	clay	Sandy clay loam
pH-H2O (1:2.5)	7.04	8.06	8.09
pH-KCL (1:2.5)	6.16	7.18	7.21
EC (ms/cm)(1:2.5)	0.08	0.07	0.08
Exch Na (meq/100gm of soil)	1.15	1.12	1.23
Exch K (meq/100gm of soil)	0.24	0.25	0.19
Exch Ca (meq/100gm of soil)	27.14	27.98	26.40
Exch Mg (meq/100gm of soil)	8.90	9.33	8.80
Sum of cations (meq/100gm soil)	37.44	38.68	36.63
CEC (meq/100gm of soil)	38.25	41.94	37.30
BS %	97.87	92.22	98.18
Total N %	0.13	0.13	0.03
OC %	1.29	1.26	0.26
C/N	9.66	9.40	8.44
Bulk density (gram/Cm3)	1.28	1.26	1.26
Avail. P (mg P2O5/kg soil)	33.20		
Available S (%)	0.70		
Exchangeable Sodium% (ESP)	3.01	2.66	3.31
Zn (mg/kg soil)	0.49		
Mn (mg/kg soil)	8.40		
Cu (mg/kg soil)	3.45		
Fe (mg/kg soil)	18.32		

2.11 Soil profile descriptions with analytical data for Enda Mehoni Shibta P3

Profile site description

Profile ID	TENM-SHI-P3(RC)
Soil profile description status	Reference profile description fresh road cut
Date of description	04/01/2014
Author(s)	Amanuel Z. & Girmay G.
Soil unit	TM(vr CM (eu))
Location (admin.)	Tigray, Enda Mokoni woreda, Shibta Kebele
Elevation (m.)	2469
Map sheet number and grid reference	
Coordinates (Deg, Min, Sec)	39 ^{o} 31'30", 12 ^{o} 47'40"
Soil taxonomic classification (WRB 2006)	Vertic Cambisol (Eutric)
Local soil name	Walka
Topography	> 30%
Landform	Steep land, High-gradient mountain (TM)
Position	Middle slope (back slope)
Slope	Straight slope of ±15% over more than 200 m long.
Micro-topography	None
Land Use	The area is intensively farmed for cereals, such as wheat, field pea and chick pea.
Human influence	Rainfed arable cultivation. Combination of DAP and Urea fertilizer is used for wheat and barley.
Vegetation	Agro-pastural
Parent material	Basic igneous rock basalt
Soil depth	Very deep (>115cm)
Rock outcrops	None
Surface coarse fragments	Many (15-40%) of the soil surface is covered by fine(0.2-0.6cm) to coarse (2-6cm)-sized surface fragments
Erosion	Moderate sheet and rill erosion in many areas
Surface sealing	None
Surface cracks	Fine cracks (<1cm), surface (<2cm) and the cracks are moderately widely spaced (0.5 – 2m)
Internal drainage	Well
External drainage	Rapid
Flooding	None
Groundwater	Very deep (>150cm)

Soil description

Hor.	*Depth cm*	*Description*
Ap	0-30	very dark gray (10YR3/1)when moist, very dark grayish brown (10YR3/2)when dry; dry clay; moderate, coarse angular blocky & sub-angular blocky structure; very sticky & very plastic when wet; low channel pores; no coatings; with no compaction; common fine to medium roots; no biological activity; medium common fresh or slightly coarse fragments; diffused boundary; no mineral concretions; no reaction with HCL
Bw	30-55	black (10YR2/1)when moist, dark grey very dark grayish brown (10YR3/2) when dry; slightly moist clay; moderate, coarse angular blocky & sub-angular blocky structure; very sticky & very plastic when wet; low channel pores; no coatings; with no compaction; common fine to medium roots; no biological activity; medium common fresh or slightly coarse fragments; diffused boundary; no mineral concretions; moderate reaction with HCL
CB	55-115	Highly weathered material with common fine to medium roots

Analytical data

Profile Code: TENM-SHI-P2 Location: Enda Mekhoni woreda; Shibta kebele

Horizon	Ap	Bw	CB
Depth	0-30	30-55	55-115+
Sand %	53.72	51.48	
Silt %	16.83	16.88	
Clay %	29.45	31.64	
Texture class	Sandy clay loam	Sandy clay loam	
pH-H2O (1:2.5)	7	7	
pH-KCL (1:2.5)	6.11	6.14	
EC (ms/cm)(1:2.5)	0.07	0.06	
Exch Na (meq/100gm of soil)	1.13	1.10	
Exch K (meq/100gm of soil)	0.28	0.24	
Exch Ca (meq/100gm of soil)	26.46	25.20	
Exch Mg (meq/100gm of soil)	8.40	8.40	
Sum of cations (meq/100gm soil)	36.27	34.93	
CEC (meq/100gm of soil)	37.43	36.52	
BS %	96.89	95.65	
Total N %	0.13	0.10	
OC %	0.96	0.82	
C/N	7.28	7.97	
Bulk density (gram/Cm3)	1.34	1.33	
Avail. P (mg P2O5/kg soil)	25.30		
Available S (%)	0.60		
Exchangeable Sodium% (ESP)	3.02	3.00	
Zn (mg/kg soil)	0.12		
Mn (mg/kg soil)	5.43		
Cu (mg/kg soil)	0.80		
Fe (mg/kg soil)	7.70		

2.12 Soil profile descriptions with analytical data for Enda Mehoni Simret P1

Profile site description

Profile ID	TENM-SIM-P1
Soil profile description status	Reference profile description
Date of description	09/12/2013
Author(s)	Amanuel Z., Atkilt G & Koos
Soil unit	SV(ha VR (eu, pe))
Location (admin.)	Tigray, Enda Mokoni woreda, Simret Kebele
Elevation (m.)	2590
Map sheet number and grid reference	
Coordinates (Deg, Min, Sec)	39 ^{o} 30'40", 12 ^{o} 43'33"
Soil taxonomic classification (WRB 2006)	Haplic Vertisol (Calcaric, Pellic)
Local soil name	Walka
Topography	10-30%
Landform	Sloping land, Medium-gradient valley (SV)
Position	Lower slope (foot slope)
Slope	Straight slope of ± 2% over more than 200 m long.
Micro-topography	None
Land Use	The area is intensively farmed for cereals, such as wheat, field pea and chick pea.
Human influence	Rainfed arable cultivation. Combination of DAP and Urea fertilizer is used for wheat and barley.
Vegetation	None
Parent material	Basic igneous rock basalt
Soil depth	Very deep (164cm)
Rock outcrops	None
Surface coarse fragments	Common (5-15%) of the soil surface is covered by fine(0.2-0.6cm) to medium (0.6-2cm)-sized surface fragments
Erosion	Slight sheet and erosion, locally degradation caused by cattle tracks
Surface sealing	None
Surface cracks	Fine cracks (<1cm), surface (<2cm) and the cracks are moderately widely spaced (0.5 – 2m)
Internal drainage	Well
External drainage	Well
Flooding	None
Groundwater	Very deep (>150cm)

Soil description

Hor.	*Depth cm*	*Description*
Ap	0-20	Very dark grey (10 YR 3/1) when moist, very dark grey (10 YR 3/1) when dry; slightly moist clay; strong, coarse sub-angular blocky structure; hard when dry, friable when moist, very sticky & very sticky when wet; low channel pores; no coatings; with no compaction; common fine roots; no biological activity; mediumfew fresh or slightly weathered coarse fragments; diffused wavy boundary; no mineral concretions; slightly reaction with HCL
Bi	20-50	Very dark grey (10 YR 3/1) when moist, dark grey (10 YR 4/1) when dry; slightly moist clay; structure; hard when dry, friable when moist, very sticky & very sticky when wet; low channel pores; no ,faint clay & pressure face coatings; with compacted but not cemented; few fine roots; no biological activity; medium few fresh or slightly weathered coarse fragments; clear wavy boundary; no mineral concretions; slightly reaction with HCL
Bic	50-66	Very dark grey (10 YR 3/1) when moist, dark grey (10 YR 4/1) when dry; slightly moist clay;strong, coarse to very coarse angular blocky structure; hard when dry, friable when moist, very sticky & very sticky when wet; low channel pores; many ,faint pressure face coatings; with compacted but not cemented; no roots; no biological activity; medium few fresh or slightly weathered coarse fragments; diffused wavy boundary; few finehard, secondary carbonates 2-5% mineral concretions; slightly reaction with HCL
Bc	66-87	Dark greyish brown (10 YR 4/2) when moist, dark brown (10 YR 3/3) when dry; slightly moist clay; strong, fine to medium angular blocky structure; hard when dry, friable when moist, very sticky & very sticky when wet; low channel pores; common ,faint pressure face coatings; with compacted but not cemented; no roots; no biological activity; stones many fresh or slightly weathered coarse fragments; gradual wavy boundary; commonvery fine to finehard, secondary carbonates 2-5% mineral concretions; moderate reaction with HCL
Cc	87-164+	Brown (10 YR 5/3) when moist, dark (10 YR 4/4) when dry; slightly moist silty clay; dominantly rock structure; hard when dry, friable when moist, slightly sticky & slightly plastic when wet; low channel pores; no coatings; with no compaction; no roots; no biological activity; stones dominant fresh or slightly coarse fragments; clear wavy boundary; no mineral concretions; slightly reaction with HCL

Analytical data

Profile Code: TENM-SIM-P1 Location: Enda Mekhoni woreda; Simret kebele

Horizon	Ap	Bi	Bic	Bc
Depth	0-20	20-50	50-66	66-87
Sand %	22.63	19.88	16.22	24.09
Silt %	13.97	23.82	26.46	14.3
Clay %	63.4	56.3	57.32	61.61
Texture class	clay	clay	clay	clay
pH-H2O (1:2.5)	6.92	7.33	7.9	8.13
pH-KCL (1:2.5)	6.01	6.48	6.93	7.21
EC (ms/cm)(1:2.5)	0.13	0.09	0.2	0.27
Exch Na (meq/100gm of soil)	1.17	1.16	1.29	1.16
Exch K (meq/100gm of soil)	0.38	0.37	0.53	0.42
Exch Ca (meq/100gm of soil)	28.25	28.94	36.19	35.32
Exch Mg (meq/100gm of soil)	9.42	9.94	11.77	11.77
Sum of cations (meq/100gm soil)	39.22	40.40	49.77	48.66
CEC (meq/100gm of soil)	53.03	45.08	51.18	50.23
BS %	73.95	89.62	97.25	96.87
Total N %	0.25	0.21	0.23	0.14
OC %	2.09	1.80	1.61	1.33
C/N	8.21	8.49	7.01	9.72
Bulk density (gram/Cm3)	1.26	1.32	1.30	1.28
Avail. P (mg P2O5/kg soil)	31.80			
Available S (%)	0.76			
Exchangeable Sodium% (ESP)	2.21	2.56	2.52	2.30
Zn (mg/kg soil)	0.24			
Mn (mg/kg soil)	9.50			
Cu (mg/kg soil)	3.30			
Fe (mg/kg soil)	16.70			

2.13 Soil profile descriptions with analytical data for Enda Mehoni Meswati P1

Profile site description

Profile ID	TENM-MES-P1
Soil profile description status	Reference profile description
Date of description	06/01/2014
Author(s)	Amanuel Z.
Soil unit	SV(cc VR (eu, pe))
Location (admin.)	Tigray, Enda Mokoni woreda, Meswati Kebele
Elevation (m.)	2358
Map sheet number and grid reference	
Coordinates (Deg, Min, Sec)	39 ^{o} 33'37", 12 ^{o} 42'20"
Soil taxonomic classification (WRB 2006)	Calcic Vertisol (Eutric, Pellic)
Local soil name	Walka
Topography	10-30%
Landform	Sloping land, Medium-gradient valley (SV)
Position	Middle slope (back slope)
Slope	Straight slope of ± 2% over more than 200 m long.
Micro-topography	Gilgai
Land Use	The area is intensively farmed for cereals, such as wheat, field pea and chick pea.
Human influence	Rainfed arable cultivation. Combination of DAP and Urea fertilizer is used for wheat and barley.
Vegetation	None
Parent material	Basic igneous rock basalt
Soil depth	Very Deep (195cm)
Rock outcrops	None
Surface coarse fragments	Few (2-5%) of the soil surface is covered by medium(0.6-2cm) to coarse (2-6cm) surface fragments
Erosion	Moderate sheet and rill erosion in many areas
Surface sealing	None
Surface cracks	No visible surface cracks (can be filled due to soil tillage)
Internal drainage	Well
External drainage	Well
Flooding	None
Groundwater	Very deep (>150cm)

Soil description

Hor.	*Depth cm*	*Description*
Ap	0-23	Very dark greyish brown (10 YR 3/2) when moist, dark grey (10 YR 4/1) when dry; very dry clay (lightly); moderate, coarse angular blocky &sub-angular blocky structure; very hard when dry, very friable when moist; medium few pores; no coatings; with no compaction; few fine roots; no biological activity; fine very few fresh or slightly coarse fragments; diffuse boundary; no mineral concretions; no reaction with HCL
Bi1	23-72	Black (10 YR 2/1) when moist, very dark grey (10 YR 3/1) when dry; dry clay (heavy); moderate, coarse angular blocky &sub-angular blocky structure; slickensides; very hard when dry, very friable when moist; low few pores; few,distinct pressure face coatings; compacted but not cemented; few very fine roots; no biological activity; fine to medium very few coarse fragments; gradual & wavy boundary; very fewvery fineboth mineral concretions; no reaction with HCL
Bic2_1	72-120	Dark brown (10 YR 3/3) when moist, very dark greyish brown (10 YR 3/2) when dry; slightly moist clay; moderate, medium angular blocky & sub-angular blocky structure; slickensides;very hard when dry, firm when moist, when wet; low few pores; common,distinct pressure face coatings; compacted but not cemented; very few very fine roots; no biological activity; medium very few fresh or slightly coarse fragments; gradual & wavy boundary; very fewvery fineboth mineral concretions; slightly reaction with HCL
Bic2_2	120-160	<same>
Bc	160-195	Very dark brown (10 YR 2/2) when moist, dark brown (10 YR 3/3) when dry; moist sandy clay; moderate, medium angular blocky & sub-angular blocky structure; very hard when dry, firm when moist, very sticky and plastic when wet; low few pores; common, distinct pressure face coatings; compacted but not cemented; no roots; no biological activity; fine very few fresh or slightly weathered coarse fragments; many coarse both mineral concretions; extremely effervescence with HCL

Analytical data

Profile Code: TENM-MES-P1 Location: Enda Mekhoni woreda; Meswati kebele

Horizon	Ap	Bi1	Bic2_1	Bic2_2	Bc
Depth	0-23	23-72	72-120	120-160	160-195
Sand %	26.05	22.89	8.59	9.23	49.52
Silt %	18.49	18.73	29.74	29.53	13.17
Clay %	55.46	58.38	61.67	61.24	37.31
Texture class	clay	clay	clay	clay	Sandy clay
pH-H2O (1:2.5)	6.84	7.16	7.42	7.78	7.89
pH-KCL (1:2.5)	5.95	6.2	6.39	6.82	6.78
EC (ms/cm)(1:2.5)	0.11	0.18	0.19	0.39	0.12
Exch Na (meq/100gm of soil)	1.16	1.04	1.18	1.23	1.60
Exch K (meq/100gm of soil)	0.75	0.57	0.73	0.75	0.22
Exch Ca (meq/100gm of soil)	27.65	30.52	30.96	30.52	26.16
Exch Mg (meq/100gm of soil)	10.37	10.46	10.90	10.90	8.72
Sum of cations (meq/100gm soil)	39.92	42.60	43.77	43.40	36.71
CEC (meq/100gm of soil)	49.30	49.76	45.02	52.13	37.91
BS %	80.98	85.60	97.21	83.26	96.81
Total N %	0.17	0.12	0.09	0.08	0.05
OC %	1.36	0.94	0.69	0.64	0.37
C/N	8.15	7.67	7.53	8.42	8.15
Bulk density (gram/Cm3)	1.24	1.25	1.22	1.22	1.11
Avail. P (mg P2O5/kg soil)	29.50				
Available S (%)	0.68				
Exchangeable Sodium% (ESP)	2.34	2.10	2.63	2.36	4.23
Zn (mg/kg soil)	0.64				
Mn (mg/kg soil)	8.78				
Cu (mg/kg soil)	4.37				
Fe (mg/kg soil)	16.47				

2.14 Soil profile descriptions with analytical data for Ofla Adigolo P1

Profile site description

Profile ID	TOFL-AGO-P1
Soil profile description status	Reference profile description
Date of description	10/03/2014
Author(s)	Amanuel Z.
Soil unit	SV(ha VR (eu, pe))
Location (admin.)	Tigray, Ofla woreda, Adi Golo Kebele
Elevation (m.)	2366
Map sheet number and grid reference	
Coordinates (Deg, Min, Sec)	39 ^{o} 30'10", 12 ^{o} 32'1"
Soil taxonomic classification (WRB 2006)	Haplic Vertisol (Eutric)
Local soil name	Walka
Topography	10-30%
Landform	Sloping land, Medium-gradient valley (SV)
Position	Lower slope (foot slope)
Slope	Straight slope of ± 2% over more than 200 m long.
Micro-topography	Gilgai
Land Use	The area is intensively farmed for cereals, such as wheat, field pea and chick pea.
Human influence	Rainfed arable cultivation. Combination of DAP and Urea fertilizer is used for wheat and barley.
Vegetation	None
Parent material	Unconsolidated sedimentary rock fluvial and or colluvial from basalt
Soil depth	Very deep (180+cm)
Rock outcrops	None
Surface coarse fragments	Common (5-15%) of the soil surface is covered by fine(0.2-0.6cm) to coarse (2-6cm)-sized surface fragments
Erosion	Slight sheet erosion, locally degradation caused by cattle tracks
Surface sealing	None
Surface cracks	Wide cracks (2-5cm), deep (10-20cm) and the cracks are modderately widely spaced (0.5-2m)
Internal drainage	Imperfectly
External drainage	Slow
Flooding	None
Groundwater	Very deep (>200cm)

Soil description

Hor.	*Depth cm*	*Description*
Ap	0-25	Very dark brown (10 YR 2/2) when moist, very dark greyish brown (10 YR 3/2) when dry; very dry clay; moderate, coarse angular and sub-angular blocky structure; very hard when dry, friable when moist, very sticky & very plastic when wet; medium few pores; very few, faint pressure face coatings; no compaction; very few very fine roots; no biological activity; medium gravel to stones very few fresh or slightly weathered coarse fragments; diffused boundary; no mineral concretions; no reaction with HCL
Bi1_1	25-60	Very dark brown (10 YR 2/2) when moist, very dark greyish brown (10 YR 3/2) when dry; dry clay; strong, very coarse angular and sub-angular blocky structure; very hard when dry, friable when moist, very sticky & very plastic when wet; low few pores; common, faint pressure face coatings; compacted but not cemented; very fine roots; no biological activity; fine gravel to stones very few fresh or slightly weathered coarse fragments; diffused boundary; no mineral concretions; no reaction with HCL
Bi1_2	60-120	<Same>
Bi2	120-180	Black (10 YR 2/1) when moist, black (10 YR 2/1) when dry; slightly moist clay; strong, very coarse angular and sub-angular blocky structure; very hard when dry, friable when moist, very sticky & very plastic when wet; low few pores; abundant, prominent pressure face coatings; compacted but not cemented;no roots; no biological activity; no coarse fragments; no mineral concretions; no reaction with HCL

Analytical data

Profile Code: TOFL-AGO-P1 Location: Ofla woreda; AdiGolo kebele

Horizon	Ap	Bi1_1	Bi1_2	Bi2
Depth	0-25	25-60	60-120	120-180
Sand %	23.01	22.04	11.75	11.83
Silt %	36.36	23.82	41.92	27.13
Clay %	40.64	54.14	46.33	61.04
Texture class	clay	clay	Silty clay	clay
pH-H2O (1:2.5)	6.44	6.51	7	7.63
pH-KCL (1:2.5)	5.52	5.64	6.11	6.59
EC (ms/cm)(1:2.5)	0.09	0.06	0.08	0.18
Exch Na (meq/100gm of soil)	0.66	0.83	0.91	0.70
Exch K (meq/100gm of soil)	0.20	0.14	0.12	0.07
Exch Ca (meq/100gm of soil)	25.56	29.70	30.17	33.45
Exch Mg (meq/100gm of soil)	8.52	12.05	8.74	14.72
Sum of cations (meq/100gm soil)	34.94	42.72	39.94	48.93
CEC (meq/100gm of soil)	41.67	44.44	45.62	53.81
BS %	83.84	96.13	87.55	90.94
Total N %	0.18	0.17	0.17	0.16

OC %	1.49	1.40	1.39	1.21
C/N	8.33	8.10	8.29	7.78
Bulk density (gram/Cm3)	1.27	1.27	1.30	1.24
Avail. P (mg P2O5/kg soil)	72.60			
Available S (%)	0.76			
Exchangeable Sodium% (ESP)	1.58	1.87	2.00	1.30
Zn (mg/kg soil)	1.27			
Mn (mg/kg soil)	25.25			
Cu (mg/kg soil)	3.66			
Fe (mg/kg soil)	43.23			

2.15 Soil profile descriptions with analytical data for Ofla Hashenge P1

Profile site description

Profile ID	TOFL-HAS-P1
Soil profile description status	Reference profile description
Date of description	09/01/2014
Author(s)	Amanuel Z. & Girmay G.
Soil unit	LP(ha VR (ca))
Location (admin.)	Tigray, Ofla woreda, Hashenge Kebele
Elevation (m.)	2457
Map sheet number and grid reference	
Coordinates (Deg, Min, Sec)	39 ^{o} 30'51", 12 ^{o} 36'25"
Soil taxonomic classification (WRB 2006)	Haplic Vertisol (Eutric, Pellic)
Local soil name	Walka
Topography	> 30%
Landform	Steep land, High-gradient hill (TH)
Position	Toe slope
Slope	Concave slope of ± 3% over more than 200 m long.
Micro-topography	Gilgai
Land Use	The area is intensively farmed for cereals, such as wheat, field pea and chick pea.
Human influence	Rainfed arable cultivation. Combination of DAP and Urea fertilizer is used for wheat and barley.
Vegetation	None
Parent material	Unconsolidated sedimentary rock fluvial and or colluvial from basalt
Soil depth	Very deep (>200cm)
Rock outcrops	None
Surface coarse fragments	Very few (0-2%) of the soil surface is covered by coarse (2-6cm)-sized surface fragments
Erosion	Slight sheet erosion, locally degradation caused by cattle tracks
Surface sealing	None
Surface cracks	No visible surface cracks (can be filled due to soil tillage)
Internal drainage	Well
External drainage	Well
Flooding	None
Groundwater	Very deep (>150cm)

Soil description

Hor.	*Depth cm*	*Description*
Ap	0-25	Black (10 YR 2/1) when moist, very dark grey (10 YR 3/1) when dry; dry clay; moderate , coarse angular & sub-angular blocky structure; very hard when dry, friable when moist, very sticky & very plastic when wet; medium few pores; no coatings; no compaction; few very fine to medium roots; no biological activity; fine to medium gravel few fresh or slightly coarse fragments; diffused boundary; no mineral concretions; no reaction with HCL
Bi1_1	25-65	Black (10 YR 2/1) when moist, very dark grey (10 YR 3/1) when dry; slightly moist clay; moderate, coarse angular & sub-angular blocky structure; very hard when dry, friable when moist, very sticky & very plastic when wet; low few pores; abundant,dominant pressure face coatings; compacted but not cemented; very few very fine roots; no biological activity; very fine to fine gravel few fresh or slightly coarse fragments; clear smooth boundary; very fewvery fine hard mineral concretions; no reaction with HCL
Bi1_2	65-95	<same>
Bi2_1	95-109	Very dark grey (10 YR 3/1) when moist, greyish brown (10 YR 5/2) when dry; moist; weak , fine angular & sub-angular blocky structure; soft when dry, friable when moist, very sticky & very plastic when wet; low few pores; no coatings; compacted but not cemented;no roots; no biological activity; very fine to coarse gravel few fresh or slightly coarse fragments; clear wavy boundary; no mineral concretions; no reaction with HCL
Bi2_2	109-200	Black (10 YR 2/1) when moist, very dark grey (10 YR 3/1) when dry; moist silty clay; moderate, coarse angular & sub-angular blocky structure; very hard when dry, friable when moist, very sticky & very plastic when wet; low few pores; abundant,dominant pressure face coatings; compacted but not cemented; no roots; no biological activity; no coarse fragments; very fewvery fineboth mineral concretions; no reaction with HCL

Analytical data

Profile Code: TOFL-HAS-P1 Location: Ofla woreda; Hashenge kebele

Horizon	Ap	Bi1_1	Bi1_2	Bi2_1	Bi2_2
Depth	0-25	25-65	65-95	95-109	109-200
Sand %	21.38	4.98	37.94	4.51	7.64
Silt %	29.9	38.46	13.91	27.28	40.55
Clay %	48.72	56.56	48.15	68.21	51.81
Texture class	clay	clay	clay	clay	Silty clay
pH-H2O (1:2.5)	6.63	7.82	7.91	7.12	8.06
pH-KCL (1:2.5)	5.74	7	7.11	6.1	7.15
EC (ms/cm)(1:2.5)	0.13	0.16	0.11	0.09	0.17
Exch Na (meq/100gm of soil)	0.89	1.40	1.10	0.93	0.42
Exch K (meq/100gm of soil)	0.38	0.30	0.10	0.25	0.06
Exch Ca (meq/100gm of soil)	26.77	34.82	28.97	29.57	27.58
Exch Mg (meq/100gm of soil)	8.34	9.82	9.37	9.86	10.23

Sum of cations (meq/100gm soil)	36.37	46.34	39.55	40.61	38.29
CEC (meq/100gm of soil)	45.79	51.92	40.28	42.85	44.96
BS %	79.44	89.25	98.17	94.76	85.15
Total N %	0.23	0.16	0.12	0.11	0.10
OC %	1.77	1.29	1.08	1.00	0.94
C/N	7.70	8.23	9.03	9.15	9.29
Bulk density (gram/Cm3)	1.16	1.23	1.38	1.14	1.25
Avail. P (mg P2O5/kg soil)	67.60				
Available S (%)	0.74				
Exchangeable Sodium% (ESP)	1.94	2.69	2.74	2.18	0.92
Zn (mg/kg soil)	0.51				
Mn (mg/kg soil)	10.44				
Cu (mg/kg soil)	3.92				
Fe (mg/kg soil)	18.45				

2.16 Soil profile descriptions with analytical data for Ofla Hugumberda P1

Profile site description

Profile ID	TOFL-HUG-P1
Soil profile description status	Reference profile description
Date of description	10/03/2014
Author(s)	Amanuel Z.
Soil unit	SE(le CM (eu))
Location (admin.)	Tigray, Ofla woreda, Hugumberda Kebele
Elevation (m.)	2597
Map sheet number and grid reference	
Coordinates (Deg, Min, Sec)	39 ^{o} 32'6", 12 ^{o} 39'23"
Soil taxonomic classification (WRB 2006)	Leptic Cambisol (Eutric)
Local soil name	Hawsi Hutsa
Topography	10-30%
Landform	Sloping land, Medium-gradient escarpment zone (SE)
Position	Upper slope (shoulder)
Slope	Concave slope of ± 2% over 100 m long.
Micro-topography	None
Land Use	The area is intensively farmed for cereals, such as wheat, field pea and chick pea.
Human influence	Rainfed arable cultivation. Combination of DAP and Urea fertilizer is used for wheat and barley.
Vegetation	None
Parent material	Basic igneous rock basalt
Soil depth	Moderately deep (55 cm)
Rock outcrops	None
Surface coarse fragments	Common (5-15%) of the soil surface is covered by medium (0.6-2cm), coarse gravel (0.6-2cm) and stones (6-20cm) surface fragments
Erosion	Severe sheet and rill erosion
Surface sealing	None
Surface cracks	None
Internal drainage	Well
External drainage	Rapid
Flooding	None
Groundwater	Very deep (>150cm)

Soil description

Hor.	*Depth cm*	*Description*
Ap	0-25	very dark grey (10 YR 3/1) when moist, dark greyish brown (10 YR 4/2) when dry; dry sandy clay; moderate, coarse angular and sub-angular blocky structure; soft when dry, very friable when moist, when wet; few medium pores; no coatings; no compaction; very few very fine roots; no biological activity; fine gravel very few fresh or slightly weathered coarse fragments; diffused boundary; no mineral concretions; no reaction with HCL
Bw	25-55	Very dark grey (10 YR 3/1) when moist, dark greyish brown (10 YR 4/2) when dry; slightly moist clay; moderate, coarse angular and sub-angular blocky structure; soft when dry, very friable when moist, when wet; few medium pores; no coatings; no compaction; very few very fine roots; no biological activity; medium gravel very few fresh or slightly coarse fragments; clear wavy boundary; no mineral concretions; no reaction with HCL
BC	55-90	Very dark grey (10 YR 3/1) when moist, dark greyish brown (10 YR 4/2) when dry; slightly moist; moderate, angular and sub-angular blocky structure; hard when dry; no coatings; medium gravel very few fresh or slightly coarse fragments; clear wavy boundary; no reaction with HCL
R/C	90-150	rock structure dominant; no reaction with HCL

Analytical data

Profile Code: TOFL-HUG-P1 Location: Ofla woreda; Hugmburda kebele

Horizon	Ap	Bw	BC	R/C
Depth	0-25	25-55		
Sand %	48.67	41.87		
Silt %	14.97	15.07		
Clay %	36.36	43.06		
Texture class	Sandy clay	clay		
pH-H2O (1:2.5)	6.76	6.87		
pH-KCL (1:2.5)	5.83	6		
EC (ms/cm)(1:2.5)	0.09	0.09		
Exch Na (meq/100gm of soil)	1.10	0.87		
Exch K (meq/100gm of soil)	0.18	0.10		
Exch Ca (meq/100gm of soil)	25.44	23.97		
Exch Mg (meq/100gm of soil)	8.90	8.13		
Sum of cations (meq/100gm soil)	35.63	33.06		
CEC (meq/100gm of soil)	39.17	34.89		
BS %	90.94	94.76		
Total N %	0.10	0.09		
OC %	0.96	0.74		
C/N	9.20	8.21		
Bulk density (gram/Cm3)	1.50	1.41		
Avail. P (mg P2O5/kg soil)	21.70			

Available S (%)	0.60			
Exchangeable Sodium% (ESP)	2.80	2.48		
Zn (mg/kg soil)	0.00			
Mn (mg/kg soil)	1.86			
Cu (mg/kg soil)	0.53			
Fe (mg/kg soil)	5.60			

2.17 Soil profile descriptions with analytical data for Ofla Menkere P1

Profile site description

Profile ID	TOFL-MEN-P1
Soil profile description status	Reference profile description
Date of description	15/01/2014
Author(s)	Amanuel Z.& Girmay G.
Soil unit	LD(gl cc FL (eu))
Location (admin.)	Tigray, Ofla woreda, Menkere Kebele
Elevation (m.)	2451
Map sheet number and grid reference	
Coordinates (Deg, Min, Sec)	39 ^{o} 31'30", 12 ^{o} 35'15"
Soil taxonomic classification (WRB 2006)	Gleyic Calcic Fluvisol (Eutric)
Local soil name	Danshel
Topography	< 10%
Landform	Level land, Depression (LD)
Position	Lower slope (foot slope)
Slope	Straight slope of ± 1% over more than 200 m long.
Micro-topography	None
Land Use	The area is intensively farmed for cereals, such as highland sorghum, teff, wheat, field pea and chick pea. Irrigation is practiced by the farmers in the dry seasons to cultivate vegetables in addition to the field crops.
Human influence	Combination of DAP and Urea fertilizer is used for wheat and barley.
Vegetation	None
Parent material	Unconsolidated sedimentary rock lacustrine and fluvial from basalt
Soil depth	Very deep (185 cm)
Rock outcrops	None
Surface coarse fragments	Very few (0-2%) of the soil surface is covered by fine (0.2-0.6cm)-sized surface fragments
Erosion	Moderate deposition of lacustriine & fluvial materials
Surface sealing	None
Surface cracks	Fine cracks (<1cm), surface (<2cm) and the cracks are moderately widely spaced (0.5 – 2m)
Internal drainage	Imperfectly drained
External drainage	Slow
Flooding	about 3 times a year for a duration of a week
Groundwater	Very deep (185cm)

Soil description

Hor.	*Depth cm*	*Description*
Ap	0-10	Very dark greyish brown (10 YR 3/2) when moist; sandy clay; moderate coarseangular & sub-angular blockystructure; soft when dry, very friable when moist, slightly sticky &slightly plastic when wet; few medium pores; no coatings; no compaction; few fine roots; no biological activity; very fine very few weathered coarse fragments; clear wavy boundary; very fewvery finesoftfossil mineral concretions; strongly calcareous reaction with HCL
B1	10-30	Very pale brown (10 YR 7/4) when moist; sandy clay loam; weak, fine angular & sub-angular blocky structure; soft when dry, very friable when moist, slightly sticky &slightly plastic when wet; few medium pores; no coatings; no compaction; few fine roots; very few fossil biological activity; very fine very few weathered coarse fragments; clear wavy boundary; very few very finesoftfossil mineral concretions; strongly calcareous reaction with HCL
B2	30-60	Light grey (10 YR 7/2) when moist; sandy clay; moderate, coarse angular & sub-angular blocky structure; soft when dry, slightly sticky &slightly plastic when wet; few medium pores; no coatings; no compaction; very few fine roots; very few fossil biological activity; very fine very few weathered coarse fragments; clear wavy boundary; few to very fewvery finesoftfossil mineral concretions; strongly calcareous reaction with HCL
B3	60-77	Dark greyish brown (10 YR 4/2) when moist; sandy clay loam; weak, fine angular & sub-angular blocky structure; soft when dry, slightly sticky &slightly plastic when wet; few medium pores; no coatings; no compaction; very few fine roots; very few fossil biological activity; very fine very few weathered coarse fragments; clear wavy boundary; common very finesoftfossil mineral concretions; strongly calcareous reaction with HCL
2B1	77-105	Very pale brown (10 YR 7/4) when moist; sandy clay; moderate, medium angular & sub-angular blocky structure; loose when dry, very friable when moist, slightly sticky &slightly plastic when wet; few medium pores; no coatings; no compaction; no roots; very few fossil biological activity; very fine very few weathered coarse fragments; clear wavy boundary; few to very few very finesoftfossil mineral concretions; strongly calcareous reaction with HCL
2B2	105-110	Very pale brown (10 YR 7/4) when moist; sandy clay; weak, fine angular & sub-angular blocky structure; loose when dry, when moist, slightly sticky &slightly plastic when wet; few medium pores; no coatings; no compaction; no roots; common fossil biological activity; very fine very few weathered coarse fragments; clear smooth boundary; few to very few very finesoftfossil mineral concretions; strongly calcareous reaction with HCL
2B3	110-120	Light grey (10 YR 7/2) when moist; sandy clay loam; moderate, coarse angular & sub-angular blocky structure; loose when dry, when moist, slightly sticky &slightly plastic when wet; few medium pores; no coatings; no compaction; no roots; very few fossil biological activity; very fine very few weathered coarse fragments; abrupt smooth boundary; few to very few very finesoftfossil mineral concretions; strongly calcareous reaction with HCL
3B1	120-140	Light grey (10 YR 7/2) when moist; clay; moderate, coarse angular & sub-angular blocky structure; loose when dry, loose when moist, slightly sticky &slightly plastic when wet; very few low pores; no coatings; no compaction; no roots; very few fossil biological activity; very fine very few weathered coarse fragments; abrupt smooth boundary; few to very few very finesoftfossil mineral concretions; strongly calcareous reaction with HCL

4B1	140-185	Very dark grey (10 YR 3/1) when moist; clay loam; moderate, coarse angular & sub-angular blocky structure; very hard when dry, very friable when moist, slightly sticky & slightly plastic when wet; few medium pores; no coatings; no compaction; no roots; very few fossil biological activity; very fine very few weathered coarse fragments; abrupt smooth boundary; few to very few very finesoft fossil mineral concretions; strongly calcareous reaction with HCL
	185-200+	Water

Table with analytical data

Profile Code: TOFL-MEN-P1 Location: Ofla woreda; Menkere kebele

Horizon	Ap	B1	B2	B3	2B1	2B2	2B3	3B1	4B1
Depth	0-10	10-30	30-60	60-77	77-105	105-110	110-120	120-140	140-185
Sand %	46.17	48.55	47.34	55.18	51	51.84	53.53	23.36	43.92
Silt %	13.72	25.73	13.42	16.3	10.21	10.25	18.18	35.77	16.18
Clay %	40.11	25.73	39.23	28.52	38.79	37.91	28.29	40.88	39.9
Texture class	Sandy clay	Sandy clay loam	Sandy clay	Sandy clay loam	Sandy clay	Sandy clay	Sandy clay loam	clay	Clay loam
pH-H2O (1:2.5)	7.82	7.64	7.73	7.61	7.76	7.66	7.81	7.8	8.09
pH-KCL (1:2.5)	7.18	6.7	6.87	6.88	6.85	6.59	6.9	7.08	7.16
EC (ms/cm)(1:2.5)	0.32	0.24	0.22	0.22	0.23	0.23	0.19	0.29	0.4
Exch Na (meq/100gm of soil)	1.08	1.02	1.08	0.90	1.24	0.88	0.92	1.03	1.24
Exch K (meq/100gm of soil)	0.13	0.05	0.06	0.04	0.06	0.05	0.04	0.05	0.09
Exch Ca (meq/100gm of soil)	27.30	19.36	21.84	16.32	19.58	22.94	14.95	18.38	23.61
Exch Mg (meq/100gm of soil)	9.66	5.36	7.83	6.12	6.12	7.78	6.46	6.13	8.58
Sum of cations (meq/100gm soil)	38.17	25.79	30.81	23.37	27.00	31.65	22.37	25.58	33.52
CEC (meq/100gm of soil)	41.09	34.03	34.48	29.27	33.26	36.51	27.67	35.51	37.32
BS %	92.89	75.79	89.34	79.85	81.19	86.70	80.86	72.03	89.83
Total N %	0.28	0.13	0.10	0.09	0.07	0.09	0.07	0.13	0.17
OC %	2.07	0.90	0.82	0.75	0.66	0.71	0.64	1.15	1.32
C/N	7.40	6.91	8.16	8.74	9.23	8.25	8.99	8.91	7.98
Bulk density (gram/Cm3)	1.06	0.87	1.07	0.95	0.94	0.88	0.88	0.76	0.35
Avail. P (mg P2O5/kg soil)	59.40								
Available S (%)	0.87								
Exchangeable Sodium% (ESP)	2.62	3.00	3.14	3.06	3.73	2.41	3.33	2.90	3.33
Zn (mg/kg soil)	0.24								
Mn (mg/kg soil)	5.81								
Cu (mg/kg soil)	1.14								
Fe (mg/kg soil)	17.12								

2.18 Soil profile descriptions with analytical data for Ofla Menkere P2

Profile site description

Profile ID	TOFL-MEN-P2
Soil profile description status	Reference profile description
Date of description	15/01/2014
Author(s)	Amanuel Z.& Girmay G.
Soil unit	
Location (admin.)	Tigray, Ofla woreda, Menkere Kebele
Elevation (m.)	2479
Map sheet number and grid reference	TE(ha CM (eu))
Coordinates (Deg, Min, Sec)	39 ^{o} 31'20", 12 ^{o} 33'60"
Soil taxonomic classification (WRB 2006)	Haplic Cambisol (Eutric)
Local soil name	Boda (Asase)
Topography	> 30%
Landform	Steep land, High-gradient escarpment zone (TE)
Position	Middle slope (back slope)
Slope	Straight slope of ± 2% over more than 200 m long.
Micro-topography	None
Land Use	The area is intensively farmed for cereals, such as highland sorghum, teff, wheat, field pea and chick pea.
Human influence	Rainfed arable cultivation. Combination of DAP and Urea fertilizer is used for wheat and barley.
Vegetation	None
Parent material	Unconsolidated sedimentary rock fluvial and / or colluvial from basalt
Soil depth	Very deep (>200cm)
Rock outcrops	None
Surface coarse fragments	surface fragments of the area are few (2-5%) medium-sized (0.6-2cm) and common (5-15%) coarse (2-6cm) gravel
Erosion	Moderate sheet and rill erosion in many areas
Surface sealing	None
Surface cracks	None
Internal drainage	Well
External drainage	Well
Flooding	None
Groundwater	Very deep (>150cm)

Soil description

Hor.	*Depth cm*	*Description*
Ap	0-24	Very dark greyish brown (10 YR 3/2) when moist, dark greyish brown (10 YR 4/2) when dry; dry sandy clay loam; moderate medium angular block &sub-angular blocky structure; friable when moist, slightly sticky &slightly plastic when wet; low very few pores; no coatings; no compaction; common very fine roots; no biological activity; fine many fresh & slightly weathered coarse fragments; distinct boundary; no mineral concretions; no reaction with HCL
Bw1	24-78	Very dark greyish brown (10 YR 3/2) when moist, brown (10 YR 4/3) when dry; slightly moist clay loam; moderate medium angular block &sub-angular blocky structure; very friable when moist, sticky & plastic when wet; low very few pores; very few ,faint shiny face& pressure face coatings; no compaction; few very fine to fine roots; no biological activity; fine to medium many fresh & slightly weathered coarse fragments; abrupt wavy boundary; no mineral concretions; no reaction with HCL
Bw2	78-90	Very dark greyish brown (10 YR 3/2) when moist, brown (10 YR 5/3) when dry; slightly moist clay; weak very fine angular block & sub-angular blocky structure; very friable when moist, slightly sticky & slightly plastic when wet; low few pores; no coatings; no compaction; few very fine to fine roots; no biological activity; fine to medium many fresh & slightly weathered coarse fragments; clear boundary; no mineral concretions; no reaction with HCL
2ABb	90-145	Very dark brown (10 YR 2/2) when moist, very dark greyish brown (10 YR 3/2) when dry; slightly moist sandy clay; moderate, fine to medium angular block & sub-angular blocky structure; when dry, very friable when moist, very sticky & very plastic when wet; low very few pores; common, distinct shiny face& pressure face coatings; compacted but not cemented; no roots; no biological activity; coarse very few fresh & slightly weathered coarse fragments; distinct boundary; no mineral concretions; no reaction with HCL
2Bb	145-200	Very dark brown (10 YR 2/2) when moist, very dark greyish (10 YR 3/2 when dry; moist clay; moderate medium angular block & sub-angular blocky structure; when dry, friable when moist, very sticky & very plastic when wet; low very few pores; common, distinct shiny face& pressure face coatings; no compaction; no roots; no biological activity; fine very few fresh & slightly weathered coarse fragments; no mineral concretions; no reaction with HCL

Analytical data

Profile Code: TOFL-MEN-P2 Location: Ofla woreda; Menkere kebele

Horizon	Ap	Bw1	Bw2	2ABb	2Bb
Depth	0-24	24-78	78-90	90-145	145-200
Sand %	55.69	44.69	40.46	45.11	33.94
Silt %	14.77	19.14	17.76	10.56	10.66
Clay %	29.54	36.16	41.79	44.33	55.41
Texture class	Sandy clay loam	Clay loam	clay	Sandy clay	clay
pH-H2O (1:2.5)	6.6	6.63	6.7	6.94	7.21
pH-KCL (1:2.5)	5.88	5.79	5.77	6.03	6.19
EC (ms/cm)(1:2.5)	0.06	0.05	0.04	0.05	0.1
Exch Na (meq/100gm of soil)	0.78	0.96	0.83	1.03	0.81
Exch K (meq/100gm of soil)	0.18	0.11	0.10	0.08	0.11
Exch Ca (meq/100gm of soil)	25.25	25.02	22.11	25.69	33.13
Exch Mg (meq/100gm of soil)	8.42	8.90	7.93	9.69	8.92
Sum of cations (meq/100gm soil)	34.62	34.99	30.97	36.48	42.98
CEC (meq/100gm of soil)	36.13	36.87	38.09	38.00	43.40
BS %	95.82	94.89	81.31	96.01	99.02
Total N %	0.16	0.13	0.12	0.10	0.07
OC %	1.15	1.16	0.85	0.77	0.64
C/N	7.07	8.67	7.26	8.05	8.58
Bulk density (gram/Cm3)	1.58	1.43	1.45	1.40	1.36
Avail. P (mg P2O5/kg soil)	28.00				
Available S (%)	0.56				
Exchangeable Sodium% (ESP)	2.15	2.60	2.19	2.70	1.87
Zn (mg/kg soil)	0.39				
Mn (mg/kg soil)	5.07				
Cu (mg/kg soil)	1.13				
Fe (mg/kg soil)	14.35				

2.19 Soil profile descriptions with analytical data for Raya Alamata Gerjele P1

Profile site description

Profile ID	TRAL-GER-P1
Soil profile description status	Reference profile description
Date of description	13/03/2014
Author(s)	Amanuel Z.
Soil unit	LP(ha FL (eu))
Location (admin.)	Tigray, Raya Alamata woreda, Gerjele Kebele
Elevation (m.)	1436
Map sheet number and grid reference	
Coordinates (Deg, Min, Sec)	39 ^{o} 38'15", 12 ^{o} 28'25"
Soil taxonomic classification (WRB 2006)	Haplic Fluvisol (Eutric)
Local soil name	Boda
Topography	< 10%
Landform	Level land, Plain (LP)
Position	Footslope
Slope	Straight slope of ± 1% over more than 200 m long.
Micro-topography	None
Land Use	The area is intensively farmed for cereals, such as sorghum, teff, maize, and chick pea. Irrigation is practiced by the farmers in the dry seasons to cultivate vegetables in addition to the field crops.
Human influence	Combination of DAP and Urea fertilizer is used for wheat and barley.
Vegetation	None
Parent material	Unconsolidated sedimentary rock fluvial and / or colluvial from basalt
Soil depth	Very deep (>200cm)
Rock outcrops	None
Surface coarse fragments	None
Erosion	Slight deposition of fluvial materials
Surface sealing	None
Surface cracks	None
Internal drainage	Imperfectly drained
External drainage	Slow
Flooding	Once per a year for a duration 2months
Groundwater	Very deep (200cm)

Soil description

Hor.	*Depth cm*	*Description*
Ap	0-25	Black (10 YR 2/1) when moist, dark greyish brown (10 YR 4/2) when dry; very dry clay loam; moderate, coarse angular & sub-angular blocky structure; very hard when dry, firm when moist, very sticky & very plastic when wet; low very few pores; no coatings; no compaction; common very fine roots; no biological activity; fine very few fresh or slightly weathered coarse fragments; abrupt & smooth boundary; no mineral concretions; slightly reaction with HCL
A1	25-40	Black (10 YR 2/1) when moist, very dark brown (10 YR 2/2) when dry; dry sandy clay loam; weak, fine angular & sub-angular blocky structure; soft when dry, very friable when moist, non-sticky & non-plastic when wet; medium few pores; no coatings; no compaction; few very fine roots; nobiological activity; very fine common fresh or coarse fragments; clear broken boundary; no mineral concretions; slightly reaction with HCL
A2	40-50	Very dark greyish brown (10 YR 3/2) when moist, brown (10 YR 4/3) when dry; dry clay loam; weak, fine angular & sub-angular blocky structure; hard when dry, friable when moist, sticky & plastic when wet; low very few pores; no coatings; no compaction; few very fine roots; nobiological activity; very fine very few fresh or coarse fragments; clear wavy boundary; no mineral concretions; slight reaction with HCL
AB	50-60	Very dark brown (10 YR 2/2) when moist, very dark brown (10 YR 2/2) when dry; dry sandy clay; weak, medium angular & subangular blocky structure; hard when dry, firm when moist, very sticky & very plastic when wet; low very few pores; no coatings; no compaction; few very fine roots; nobiological activity; very fine very few fresh or coarse fragments; diffused boundary; no mineral concretions; slightly reaction with HCL
B1	60-140	Black (10 YR 2/1) when moist, very dark grey (10 YR 3/1) when dry; slightly moist silty clay; strong, fine angular & sub-angular blocky structure; very hard when dry, firm when moist, very sticky & very plastic when wet; medium few pores; few,distinct pressure face coatings; no compaction; few very fine roots; nobiological activity; very fine very few fresh or coarse fragments; diffused boundary; no mineral concretions; slight reaction with HCL
B2	140-200	Black (10 YR 2/1) when moist, very dark grey (10 YR 3/1) when dry; dry silty clay; strong, coarse angular & sub-angular blocky structure; very hard when dry, firm when moist, very sticky & very plastic when wet; low very few pores; few,distinct pressure face coatings; no compaction; few very fine roots; no biological activity; no coarse fragments; diffused boundary; no mineral concretions; slight reaction with HCL

Analytical data

Profile Code: TRAL-GER-P1 Location: Raya Alamata woreda; Gerjele kebele

Horizon	Ap	A1	A2	AB	B1	B2
Depth	0-25	25-40	40-50	50-60	60-140	140-200
Sand %	33.25	64.68	33.78	48.73	7.59	3.52
Silt %	29.07	8.31	36.31	12.82	46.2	41.51
Clay %	37.68	27.01	29.91	38.45	46.2	54.97
Texture class	Clay loam	Sandy clay loam	Clay loam	Sandy clay	Silty clay	Silty clay
pH-H2O (1:2.5)	7.98	7.63	7.87	8.1	8.03	8.25
pH-KCL (1:2.5)	7.11	6.68	6.83	7.24	7.16	7.28
EC (ms/cm)(1:2.5)	0.23	0.11	0.22	0.25	0.31	0.34
Exch Na (meq/100gm of soil)	0.47	0.28	0.45	0.77	0.54	1.15
Exch K (meq/100gm of soil)	0.18	0.06	0.14	0.30	0.36	0.26
Exch Ca (meq/100gm of soil)	26.13	14.52	22.13	20.78	26.16	31.08
Exch Mg (meq/100gm of soil)	8.57	4.56	7.66	6.36	9.16	8.88
Sum of cations (meq/100gm soil)	35.36	19.42	30.38	28.20	36.21	41.36
CEC (meq/100gm of soil)	38.18	28.86	31.92	32.72	38.86	44.88
BS %	92.60	67.30	95.18	86.18	93.19	92.16
Total N %	0.15	0.12	0.12	0.10	0.10	0.09
OC %	1.35	1.12	1.03	0.97	0.88	0.75
C/N	9.01	9.62	8.68	9.31	8.87	8.08
Bulk density (gram/Cm3)	1.37	1.54	1.35	1.41	1.32	1.18
Avail. P (mg P2O5/kg soil)	50.80					
Available S (%)	0.72					
Exchangeable Sodium% (ESP)	1.24	0.97	1.42	2.34	1.39	2.56
Zn (mg/kg soil)	0.22					
Mn (mg/kg soil)	3.73					
Cu (mg/kg soil)	2.11					
Fe (mg/kg soil)	9.56					

2.20 Soil profile descriptions with analytical data for Raya Alamata Selambi Kalsi P1

Profile site description

Profile ID	TRAL-SBK-P1
Soil profile description status	Reference profile description
Date of description	13/03/2014
Author(s)	Amanuel Z.
Soil unit	LP(gl cc FL (eu))
Location (admin.)	Tigray, Raya Alamata woreda, Selam BiKalsi Kebele
Elevation (m.)	1472
Map sheet number and grid reference	
Coordinates (Deg, Min, Sec)	39 ^{o} 35'43", 12 ^{o} 23'13"
Soil taxonomic classification (WRB 2006)	Gleyic Calcic Fluvisol (Eutric)
Local soil name	Boda
Topography	< 10%
Landform	Level land, Plain (LP)
Position	Middle slope (back slope)
Slope	Straight slope of ± 1% over more than 200 m long.
Micro-topography	None
Land Use	The area is intensively farmed for cereals, such as sorghum, teff, maize, and chick pea.
Human influence	Rainfed arable cultivation. Combination of DAP and Urea fertilizer is used for wheat and barley.
Vegetation	None
Parent material	Unconsolidated sedimentary rock fluvial and / or colluvial from basalt
Soil depth	Very deep (>200cm)
Rock outcrops	None
Surface coarse fragments	None
Erosion	Slight deposition of fluvial materials
Surface sealing	None
Surface cracks	None
Internal drainage	Well
External drainage	Well
Flooding	Once per year for a duration a week
Groundwater	Very deep (20m)

Soil description

Hor.	*Depth cm*	*Description*
Ap	0-20	Very dark greyish brown (10 YR 3/2) when moist, 10 YR 4/2 (dark greyish brown) when dry; dry silt clay; moderate, medium angular& sub-angular blocky structure; very hard when dry, very friable when moist, sticky & plastic when wet; low few pores; no coatings; no compaction; few fine roots; no biological activity; finevery few fresh &coarse fragments; clear & smooth boundary; no mineral concretions; no reaction with HCL
B1	20-59	Very dark brown (10 YR 2/2) when moist, very dark greyish brown (10 YR 3/2) when dry; dry clay; moderate, medium angular& sub-angular blocky structure; very hard when dry, friable when moist, sticky & plastic when wet; low few pores; coatings; no compaction; few fine roots; no biological activity; fine very few fresh & coarse fragments; clear & broken boundary; no mineral concretions; no reaction with HCL
2B1	59-67	Very dark greyish brown (10 YR 3/2) when moist, dark greyish brown (10 YR 4/2) when dry; slightly moist sandy clay loam; single grain structure; soft when dry, very friable when moist, sticky & plastic when wet; low few pores; no coatings; no compaction; few very fine roots; no biological activity; medium common fresh &coarse fragments; clear & wavy boundary; no mineral concretions; moderate reaction with HCL
2B2	67-85	Very dark greyish brown (10 YR 3/2) when moist, dark greyish brown (10 YR 4/2) when dry; slightly moist clay loam; moderate , medium angular & sub-angular blocky structure; hard when dry, very friable when moist, sticky &plastic when wet; low few pores; no coatings; no compaction; few very fine roots; no biological activity; no coarse fragments; clear & wavy boundary; no mineral concretions; moderate reaction with HCL
3B	85-94	Very dark greyish brown (10 YR 3/2) when moist, dark greyish brown (10 YR 4/2) when dry; slightly moist sand; single grainstructure; soft when dry, very friable when moist, sticky &plastic when wet; low few pores; no coatings; no compaction; few very fine to fine roots; no biological activity; no coarse fragments; clear & wavy boundary; no mineral concretions; moderate reaction with HCL
4B	94-111	Very dark greyish brown (10 YR 3/2) when moist, dark greyish brown (10 YR 4/2) when dry; slightly moist clay; moderate, medium angular& sub-angular blocky structure; very hard when dry, very friable when moist, sticky & plastic when wet; low few pores; no coatings; no compaction; few very fine roots; no biological activity; no coarse fragments; clear & wavy boundary; no mineral concretions; moderate reaction with HCL
5B	111-115	Very dark greyish brown (10 YR 3/2) when moist, dark greyish brown (10 YR 4/2) when dry; slightly moist sand; structure; soft when dry, very friable when moist, sticky & plastic when wet; low few pores; no, coatings; no compaction; few very fine roots; no biological activity; no coarse fragments; clear & wavy boundary; no mineral concretions; moderate reaction with HCL
6B	115-137	Very dark greyish brown (10 YR 3/2) when moist, dark greyish brown (10 YR 4/2 2) when dry; slightly moist clay; moderate, medium angular& sub-angular blocky structure; very hard when dry, very friable when moist, sticky & plastic when wet; low few pores; no, coatings; no compaction; few very fine roots; no biological activity; no coarse fragments; clear & wavy boundary; no mineral concretions; moderate reaction with HCL

7B	137-146	Very dark greyish brown (10 YR 3/2) when moist, dark greyish brown (10 YR 4/2) when dry; slightly moist sand; single grain structure; soft when dry, very friable when moist, sticky & plastic when wet; low few pores; no, coatings; no compaction; few very fine roots; no biological activity; no coarse fragments; clear & wavy boundary; no mineral concretions; moderate reaction with HCL
8B1	146-169	Very dark greyish brown (10 YR 3/2) when moist, dark greyish brown (10 YR 4/2) when dry; slightly moist clay; moderate medium angular& sub-angular blocky structure; very hard when dry, very friable when moist, sticky & plastic when wet; low few pores; no coatings; no compaction; few very fine roots; no biological activity; nocoarse fragments; clear &wavy boundary; no mineral concretions; moderate reaction with HCL
8B2	169-185	Very dark greyish brown (10 YR 3/2) when moist, dark greyish brown (10 YR 4/2) when dry; slightly moist clay; structure; soft when dry, very friable when moist, sticky &plastic when wet; low few pores; no coatings; no compaction; few very fine roots; no biological activity; fine very few fresh & slightly weathered coarse fragments; clear &wavy boundary; no mineral concretions; moderate reaction with HCL
8B3	185-200+	Very dark greyish brown (10 YR 3/2) when moist, dark greyish brown (10 YR 4/2) when dry; slightly moist clay loam; moderate, medium angular& sub-angular blocky structure; hard when dry, very friable when moist, sticky & plastic when wet; low few pores; no coatings; no compaction; roots; no biological activity; coarse fragments;no mineral concretions; moderate reaction with HCL

Analytical data

Profile Code: TRAL-SBK-P1 Location: Raya Alamata woreda; Selam Bi Kalsi kebele

Horizon	Ap	3B3	3B4	4B	B1	2B1	2B2	3B1	3B2
Depth	0-20	146-169	169-185	185-200	20-59	59-67	67-85	94-111	115-137
Sand %	12.89	42.32	44.45	27.41	32.25	58.17	42.72	35.17	32.88
Silt %	44.65	12.82	12.82	42.7	23.66	14.64	17.29	21.61	21.65
Clay %	42.47	44.86	42.73	29.89	44.09	27.19	39.98	43.22	45.47
Texture class	Silty clay	clay	clay	Clay loam	clay	Sandy clay loam	Clay loam	clay	clay
pH-H2O (1:2.5)	7.67	8.13	7.95	8.12	8.11	8.03	8.18	8.09	8.21
pH-KCL (1:2.5)	6.85	7.16	7.01	7.17	7.23	7	7.2	7.14	7.18
EC (ms/cm)(1:2.5)	0.15	0.47	0.38	0.48	0.16	0.19	0.22	0.27	0.29
Exch Na (meq/100gm of soil)	0.29	1.09	0.26	1.04	0.37	0.52	0.46	0.51	0.56
Exch K (meq/100gm of soil)	0.46	0.15	0.04	0.10	0.12	0.09	0.15	0.19	0.14
Exch Ca (meq/100gm of soil)	23.80	21.28	20.43	22.11	23.54	19.21	22.79	25.80	21.09
Exch Mg (meq/100gm of soil)	8.22	8.09	7.66	7.65	8.56	7.10	8.17	8.60	8.61
Sum of cations (meq/100gm soil)	32.78	30.61	28.39	30.91	32.59	26.92	31.57	35.10	30.40
CEC (meq/100gm of soil)	44.22	31.46	29.61	31.89	38.61	29.50	35.52	35.99	34.15
BS %	74.13	97.31	95.90	96.93	84.41	91.23	88.87	97.53	89.02
Total N %	0.15	0.07	0.06	0.06	0.10	0.10	0.09	0.08	0.08
OC %	1.36	0.65	0.55	0.54	0.87	0.83	0.72	0.70	0.66
C/N	9.01	8.75	9.15	9.01	8.28	8.09	8.00	8.42	8.75
Bulk density (gram/Cm3)	1.27	1.37	1.46	1.29	1.42	1.58	1.42	1.39	1.33
Avail. P (mg P2O5/kg soil)	32.30								
Available S (%)	0.63								
Exchangeable Sodium% (ESP)	0.66	3.47	0.88	3.28	0.96	1.75	1.29	1.43	1.64
Zn (mg/kg soil)	0.16								
Mn (mg/kg soil)	6.01								
Cu (mg/kg soil)	1.66								
Fe (mg/kg soil)	4.17								

2.21 Soil profile descriptions with analytical data for Raya Alamata Tao P1

Profile site description

Profile ID	TRAL-TAO-P1
Soil profile description status	Reference profile description
Date of description	14/03/2014
Author(s)	Amanuel Z.
Soil unit	LP(vr CM (ca))
Location (admin.)	Tigray, Raya Alamata woreda, Tao Kebele
Elevation (m.)	1472
Map sheet number and grid reference	
Coordinates (Deg, Min, Sec)	39 ^{o} 38'55", 12 ^{o} 31'32"
Soil taxonomic classification (WRB 2006)	Vertic Cambisol (Calcaric)
Local soil name	Boda
Topography	< 10%
Landform	Level land, Plain (LP)
Position	Middle slope (back slope)
Slope	Straight slope of ± 1% over more than 200 m long.
Micro-topography	None
Land Use	The area is intensively farmed for cereals, such as sorghum, teff, maize, and chick pea.
Human influence	Rainfed arable cultivation. Combination of DAP and Urea fertilizer is used for wheat and barley.
Vegetation	None
Parent material	Unconsolidated sedimentary rock fluvial and / or colluvial from basalt
Soil depth	Very deep (>200cm)
Rock outcrops	None
Surface coarse fragments	Very few (0-2%) of the soil surface is covered by fine (0.2-0.6cm)-sized surface fragments
Erosion	Slight sheet and wind erosion, locally degradation caused by cattle tracks
Surface sealing	None
Surface cracks	Fine cracks (<1cm), surface (<2cm) and the cracks are moderately widely spaced (0.5 – 2m)
Internal drainage	Well
External drainage	Slow
Flooding	Once per year for a duration 2 days
Groundwater	Very deep (200cm)

Soil description

Hor.	*Depth cm*	*Description*
Ap	0-20	Very dark brown (10 YR 2/2) when moist, dark brown (10 YR 3/3) when dry; wet clay; weak, medium angular &sub-angular blocky structure; slightly hard when dry, very friable when moist, sticky & plastic when wet; low few pores; very few,faint pressure face coatings; no compaction; very few fine roots; biological activity; fine very few fresh and slightly weathered coarse fragments; diffused boundary; no mineral concretions; slightly reaction with HCL
Bw1-1	20-70	Very dark brown (10 YR 2/2) when moist, 10 YR 3/3 (dark brown) when dry; slightly moist silty clay; weak, fine angular &sub-angular blocky structure; slightly hard when dry, very friable when moist, sticky & plastic when wet; low few pores; very few,faint pressure face coatings; compacted but not cemented; very few very fine roots; biological activity; fine very few fresh and slightly coarse fragments; gradual and wavy boundary; no mineral concretions; moderate reaction with HCL
Bw1-2	70-120	<same>
Bw2	120-180	Black (10 YR 2/1) when moist, very dark brown (10 YR 2/2) when dry; slightly moist clay; moderate, fine angular & sub-angular blocky structure; slightly hard when dry, friable when moist, sticky & plastic when wet; low few pores; very few, faint pressure face coatings; compacted but not cemented; very few very fine roots; biological activity; fine to medium very few fresh and slightly coarse fragments; no mineral concretions; slightly reaction with HCL

Analytical data

Profile Code: TRAL-TAO-P1 Location: Raya Alamata woreda; Tao kebele

Horizon	Ap	Bw1-1	Bw1-2	Bw2
Depth	0-20	20-70	70-120	120-180
Sand %	33.93	7.95	25.38	25.25
Silt %	24.51	40.55	28.53	28.58
Clay %	41.56	51.5	46.09	46.17
Texture class	clay	Silty clay	clay	clay
pH-H2O (1:2.5)	7.93	8.09	8.34	8.06
pH-KCL (1:2.5)	7.1	7.13	7.37	7.18
EC (ms/cm)(1:2.5)	0.17	0.15	0.16	0.17
Exch Na (meq/100gm of soil)	0.68	0.34	0.62	0.57
Exch K (meq/100gm of soil)	0.48	0.20	0.30	0.46
Exch Ca (meq/100gm of soil)	20.39	18.26	23.52	29.65
Exch Mg (meq/100gm of soil)	7.65	6.96	7.41	9.16
Sum of cations (meq/100gm soil)	29.20	25.75	31.84	39.84
CEC (meq/100gm of soil)	33.71	46.79	42.14	41.70
BS %	86.64	55.04	75.56	95.52
Total N %	0.13	0.12	0.11	0.10
OC %	1.10	1.04	0.93	0.85
C/N	8.20	8.58	8.15	8.58
Bulk density (gram/Cm3)	1.30	1.18	1.15	1.29
Avail. P (mg P2O5/kg soil)	27.20			
Available S (%)	0.45			
Exchangeable Sodium% (ESP)	2.03	0.73	1.46	1.36
Zn (mg/kg soil)	0.10			
Mn (mg/kg soil)	4.04			
Cu (mg/kg soil)	1.10			
Fe (mg/kg soil)	1.08			

2.22 Soil profile descriptions with analytical data for Raya Alamata Timuga P1

Profile ID	TRAL-TIM-P1
Soil profile description status	Reference profile description
Date of description	10/12/2013
Author(s)	Amanuel Z., Atkilt G & Koos
Soil unit	
Location (admin.)	Tigray, Raya Alamata woreda, Timuga Kebele
Elevation (m.)	1458
Map sheet number and grid reference	SH(ha CM (ca,bVR))
Coordinates (Deg, Min, Sec)	39 ^{o} 35'19", 12 ^{o} 18'28"
Soil taxonomic classification (WRB 2006)	Haplic Cambisol (Calcaric) (Thapto-Vertisolic)
Local soil name	Boda
Topography	10-30%
Landform	Sloping land, Medium-gradient hill (SH)
Position	Lower slope (footslope)
Slope	Straight slope of ± 3% over more than 200 m long.
Micro-topography	None
Land Use	The area is intensively farmed for cereals, such as sorghum, teff, maize, and chick pea.
Human influence	Rainfed arable cultivation. Combination of DAP and Urea fertilizer is used for wheat and barley.
Vegetation	None
Parent material	Alluvium
Soil depth	Deep (125cm)
Rock outcrops	None
Surface coarse fragments	Very few (0-2%) of the soil surface is covered by stone (6-20cm)-sized surface fragments
Erosion	Slight sheet and wind erosion, locally degradation caused by cattle tracks
Surface sealing	None
Surface cracks	None
Internal drainage	Moderately well drained
External drainage	Well
Flooding	None
Groundwater	Very deep (200cm)

Soil description

Hor.	*Depth cm*	*Description*
Ap	0-20	Very dark greyish brown (10 YR 3/2) when moist, dark greyish brown (10 YR 4/2) when dry; very dry clay; moderate, medium to coarse sub-angular blocky structure; slightly hard when dry, friable when moist, slightly sticky & slightly plastic when wet; medium few pores; no coatings; no compaction; few fine to coarse roots; few biological activity; no coarse fragments; abrupt & smooth boundary; no mineral concretions;moderate reaction with HCL
Bw	20-60	Very dark greyish brown (10 YR 3/2) when moist, dark greyish brown (10 YR 4/2) when dry; very dry clay; moderate medium to coarse sub-angular blocky structure; slightly hard when dry, friable when moist, slightly sticky & slightly plastic when wet; low very few pores; no coatings; no compaction; few fine roots; few biological activity; no coarse fragments; abrupt & smooth boundary; no mineral concretions; moderate reaction with HCL
Bcb1-1	60-90	Black (10 YR 2/1) when moist, very dark grey (10 YR 3/1) when dry; dry clay; moderate, medium to coarse angular to sub-angular blocky structure; hard when dry, friable when moist, sticky & plastic when wet; low very few pores; common,faint carbonate concretions coatings; no compaction; few fine roots; few biological activity; no coarse fragments; diffused boundary; no mineral concretions; moderate reaction with HCL
Bcb1-2	90-125	<Same>
Bcb2-1	125-155	Black (10 YR 2/1) when moist; slightly moist clay; moderate, fine to medium angular blocky structure; hard when dry, friable when moist, sticky & plastic when wet; very low very few pores; common, distinct carbonate concretions coatings; compacted but not cemented; very few very fine roots; few biological activity; no coarse fragments;no mineral concretions; moderate reaction with HCL
Bcb2-2	155-200	<Same>

Analytical data

Profile Code: TRAL-TIM-P1 Location: Raya Alamata woreda; Timuga kebele

Horizon	Ap	A	Bc1-1	Bc1-2	Bc2-1	Bc2-2
Depth	0-20	20-60	60-90	90-125	125-155	155-200
Sand %	30.86	32.76	20	22.68	9.52	22.67
Silt %	25.14	23.11	32.22	32.03	35.97	30.93
Clay %	44	44.13	47.78	45.29	54.51	46.4
Texture class	clay	clay	clay	clay	clay	clay
pH-H2O (1:2.5)	8.09	8.33	7.9	7.87	7.68	7.73
pH-KCL (1:2.5)	7.16	7.48	6.97	7	6.83	6.88
EC (ms/cm)(1:2.5)	0.27	0.16	0.2	1.52	0.21	3.35
Exch Na (meq/100gm of soil)	0.70	0.31	0.45	0.70	0.43	0.52
Exch K (meq/100gm of soil)	0.70	0.13	0.08	0.11	0.20	0.10
Exch Ca (meq/100gm of soil)	25.62	23.10	25.52	26.60	27.65	26.16
Exch Mg (meq/100gm of soil)	9.24	7.98	9.24	9.59	9.07	9.59
Sum of cations (meq/100gm soil)	36.26	31.53	35.29	37.00	37.35	36.37
CEC (meq/100gm of soil)	40.63	41.09	43.52	38.86	47.90	41.23
BS %	89.25	76.73	81.08	95.21	77.98	88.21
Total N %	0.16	0.16	0.15	0.17	0.17	0.14
OC %	1.48	1.47	1.36	1.40	1.41	1.26
C/N	9.15	9.08	8.83	8.32	8.48	9.15
Bulk density (gram/Cm3)	1.29	1.20	1.24	1.27	1.14	1.18
Avail. P (mg P2O5/kg soil)	33.20					
Available S (%)	0.75					
Exchangeable Sodium% (ESP)	1.73	0.76	1.03	1.80	0.90	1.26
Zn (mg/kg soil)	0.17					
Mn (mg/kg soil)	9.62					
Cu (mg/kg soil)	2.27					
Fe (mg/kg soil)	5.99					

2.23 Soil profile descriptions with analytical data for Raya Alamata TimugaP2

Profile site description

Profile ID	TRAL-TIM-P2
Soil profile description status	Reference profile description
Date of description	10/12/2013
Author(s)	Amanuel Z., Atkilt G & Koos
Soil unit	LP(cc VR (eu))
Location (admin.)	Tigray, Raya Alamata woreda, Timuga Kebele
Elevation (m.)	1514
Map sheet number and grid reference	
Coordinates (Deg, Min, Sec)	39 ^{o} 34'25", 12 ^{o} 16'39"
Soil taxonomic classification (WRB 2006)	Calcic Vertisol (Eutric)
Local soil name	Walka
Topography	< 10%
Landform	Level land, Plain (LP)
Position	Bottom (flat)
Slope	Straight slope of ± 3% over more than 200 m long.
Micro-topography	Gilgai
Land Use	The area is intensively farmed for cereals, such as sorghum, teff, maize, and chick pea.
Human influence	Rainfed arable cultivation. Combination of DAP and Urea fertilizer is used for wheat and barley.
Vegetation	None
Parent material	Alluvium
Soil depth	Very deep (>200cm)
Rock outcrops	None
Surface coarse fragments	None
Erosion	Slight sheet and wind erosion, locally degradation caused by cattle tracks
Surface sealing	None
Surface cracks	Wide cracks (2-5cm), deep (10-20cm) and the cracks are modderately widely spaced (0.5-2m)
Internal drainage	Imperfectly drained
External drainage	Slow
Flooding	None
Groundwater	Very deep (200cm)

Soil description

Hor.	*Depth cm*	*Description*
Ap	0-20	Very dark brown (10 YR 2/2) when moist, dark greyish brown (10 YR 4/2) when dry; very dry clay; moderate, fine to medium sub-angular blocky structure; very hard when dry, sticky & plastic when wet; low few pores; no coatings; no compaction; no roots; very few biological activity; no coarse fragments; gradual smooth boundary; no mineral concretions; no reaction with HCL
AB	20-40	Very dark brown (10 YR 2/2) when moist, dark greyish brown (10 YR 4/2) when dry; very dry clay; moderate, medium to coarse sub-angular blocky structure; very hard when dry, when moist, very sticky & very plastic when wet; low few pores; no, coatings; nocompaction; no roots; very few biological activity; fine very few fresh & slightly weathered coarse fragments; gradual smooth boundary; no mineral concretions; noreaction with HCL
Bi1	40-88	Black (10 YR 2/1) when moist, very dark brown (10 YR 2/2) when dry; dry clay; moderate, medium to coarse angular blocky to sub-angular blockystructure; slickensides; very hard when dry, firm when moist, very sticky & very plastic when wet; very low very few pores; very few, faint coatings; no compaction; no roots; very few biological activity; no coarse fragments; gradual smooth boundary; no mineral concretions; no reaction with HCL
Bi2	88-123	Black (10 YR 2/1) when moist, very dark brown (10 YR 2/2) when dry; slightly moist clay; moderate, medium to coarse angular blocky structure; slickensides; very hard when dry, firm when moist, very sticky & very plastic when wet; very low very few pores; very few,faint pressure face coatings; compacted but not cemented; very fine very few roots; no biological activity; no coarse fragments; clear smooth boundary; no mineral concretions; moderate reaction with HCL
Bck	123-170	Very dark greyish brown (10 YR 3/2) when moist, dark greyish brown (10 YR 4/2) when dry; slightly moist clay loam; weak, fine to medium angular blocky to sub-angular blocky structure; slightly hard when dry, friable when moist, slightly sticky & plastic when wet; very low very few pores; abundant,distinct calcium carbonate concretions coatings; compacted but not cemented; very fine very few roots; no biological activity; fine very few fresh slightly weathered coarse fragments; clear smooth boundary; no mineral concretions; strong reaction with HCL

Analytical data

Profile Code: TRAL-TIM-P2 Location: Raya Alamata woreda; Timuga kebele

Horizon	Ap	AB	Bi1	Bi2	Bc
Depth	0-20	20-40	40-88	88-123	123-170
Sand %	24.96	26.52	23.94	29.21	44.26
Silt %	32.76	29.17	28.66	29.86	18.22
Clay %	42.28	44.3	47.4	40.92	37.52
Texture class	clay	clay	clay	clay	Clay loam
pH-H2O (1:2.5)	8.06	7.82	8	8.19	7.04
pH-KCL (1:2.5)	7.14	7	7.1	7.28	6.15
EC (ms/cm)(1:2.5)	0.21	0.19	0.24	0.24	0.23
Exch Na (meq/100gm of soil)	0.38	0.77	0.34	0.39	0.70
Exch K (meq/100gm of soil)	0.30	0.49	0.38	0.83	0.39
Exch Ca (meq/100gm of soil)	20.58	26.54	22.24	23.76	25.68
Exch Mg (meq/100gm of soil)	8.40	9.84	8.28	8.80	8.56
Sum of cations (meq/100gm soil)	29.67	37.64	31.24	33.79	35.33
CEC (meq/100gm of soil)	36.52	42.33	40.28	39.22	37.68
BS %	81.23	88.91	77.56	86.15	93.75
Total N %	0.25	0.16	0.17	0.14	0.04
OC %	1.80	1.48	1.47	1.35	0.54
C/N	7.21	8.97	8.73	9.76	12.06
Bulk density (gram/Cm3)	1.34	1.28	1.25	1.20	1.38
Avail. P (mg P2O5/kg soil)	51.40				
Available S (%)	0.79				
Exchangeable Sodium% (ESP)	1.05	1.82	0.85	1.00	1.85
Zn (mg/kg soil)	0.28				
Mn (mg/kg soil)	11.41				
Cu (mg/kg soil)	2.52				
Fe (mg/kg soil)	6.73				

2.24 Soil profile descriptions with analytical data for Raya Azebo Ebo P1

Profile site description

Profile ID	TRAZ-EBO-P1
Soil profile description status	Reference profile description
Date of description	12/03/2014
Author(s)	Amanuel Z.
Soil unit	LP(cc VR (eu, pe))
Location (admin.)	Tigray, Raya Alamata woreda, Ebo Kebele, Adi Shambel area
Elevation (m.)	1757
Map sheet number and grid reference	
Coordinates (Deg, Min, Sec)	39 ^{o} 40'57", 12 ^{o} 51'46"
Soil taxonomic classification (WRB 2006)	Calcic Vertisol (Eutric, Pellic)
Local soil name	Walka
Topography	< 10%
Landform	Level land, Plain (LP)
Position	Upper slope (shoulder)
Slope	Straight slope of ± 2% over more than 200 m long.
Micro-topography	None
Land Use	The area is intensively farmed for cereals, such as sorghum, teff, maize, and chick pea.
Human influence	Rainfed arable cultivation. Combination of DAP and Urea fertilizer is used for wheat and barley.
Vegetation	None
Parent material	Unconsolidated sedimentary rock fluvial and / or colluvial from basalt
Soil depth	Very deep (>200cm)
Rock outcrops	None
Surface coarse fragments	Very few (0-2%) of the soil surface is covered by coarse (2-6cm)-sized fragments
Erosion	Slight sheet and wind erosion, locally degradation caused by cattle tracks
Surface sealing	None
Surface cracks	No visible surface cracks (can be filled due to soil tillage)
Internal drainage	Well
External drainage	Well
Flooding	Once per year for a duration 3 days
Groundwater	Very deep (200cm)

Soil description

Hor.	*Depth cm*	*Description*
Ap	0-23	Very dark grey (10 YR 3/1) when moist, very dark greyish brown (10 YR 3/2) when dry; dry clay; weak, very fine granular structure; soft when dry, very friable when moist, very sticky & very plastic when wet; low few pores; no, coatings; no compaction; very few very fine roots; no biological activity; fine to medium very few fresh & slightly weathered coarse fragments; clear & wavy boundary; very fewfine hard mineral concretions; slightly reaction with HCL
Bic1-1	23-62	Black (10 YR 2/1) when moist, very dark grey (10 YR 3/1) when dry; dry clay; strong, coarse angular blocky &sub-angular blocky structure; when dry, friable when moist, very sticky & very plastic when wet; low very few pores; coarse,distinct pressure face coatings; compacted but not cemented; very few very fine roots; very few biological activity (and one mole rat was observed); fine to medium very few fresh & slightly weathered coarse fragments; clear & wavy boundary; manyfinehard mineral concretions;moderate reaction with HCL
Bic1-2	62-114	Dark brown (10 YR 3/3) when moist, brown (10 YR 4/3) when dry; slightly moist clay; strong, coarse angular blocky &sub-angular blocky structure; slightly hard when dry, friable when moist, very sticky & very plastic when wet; low few pores; coarse,distinct pressure face coatings; no compaction; very few very fine roots; biological activity; no coarse fragments; abundant medium to coarsehard mineral concretions; strong reaction with HCL
Bic2	114-180	<Same>

Analytical data

Profile Code: TRAZ-EBO-P1 Location: Raya Azebo woreda; Ebo kebele

Horizon	Ap	Bic1-1	Bic1-2	Bic2
Depth	0-23	23-62	62-114	114-180
Sand %	34.88	10.27	24.69	8.89
Silt %	13.02	28.04	18.83	24.44
Clay %	52.1	61.69	56.48	66.67
Texture class	clay	clay	clay	clay
pH-H2O (1:2.5)	7.88	8.13	8.01	8.05
pH-KCL (1:2.5)	7.06	7.2	7.13	7.11
EC (ms/cm)(1:2.5)	0.19	0.42	0.43	0.8
Exch Na (meq/100gm of soil)	0.45	1.92	2.86	3.01
Exch K (meq/100gm of soil)	0.19	0.38	0.34	0.41
Exch Ca (meq/100gm of soil)	28.92	35.46	32.47	28.60
Exch Mg (meq/100gm of soil)	9.93	13.30	10.09	10.56
Sum of cations (meq/100gm soil)	39.48	51.04	45.77	42.58
CEC (meq/100gm of soil)	51.14	61.66	42.93	47.35
BS %	77.21	82.78	106.62	89.93
Total N %	0.17	0.14	0.11	0.06
OC %	1.41	1.34	1.07	0.51
C/N	8.51	9.58	9.92	8.33
Bulk density (gram/Cm3)	1.34	1.13	1.24	1.19
Avail. P (mg P2O5/kg soil)	29.90			
Available S (%)	0.83			
Exchangeable Sodium% (ESP)	0.88	3.11	6.67	6.36
Zn (mg/kg soil)	0.23			
Mn (mg/kg soil)	6.24			
Cu (mg/kg soil)	0.98			
Fe (mg/kg soil)	4.58			

2.25 Soil profile descriptions with analytical data for Raya Azebo Genete P1

Profile site description

Profile ID	TRAZ-GEN-P1
Soil profile description status	Reference profile description
Date of description	16/03/2014
Author(s)	Amanuel Z.
Soil unit	SH(ha VR (ca))
Location (admin.)	Tigray, Raya Azebo woreda, Genete Kebele, Gandaso area
Elevation (m.)	1701
Map sheet number and grid reference	
Coordinates (Deg, Min, Sec)	39 ^{o} 39'33", 12 ^{o} 45'22"
Soil taxonomic classification (WRB 2006)	Haplic Vertisol (Calcaric)
Local soil name	Walka
Topography	10-30%
Landform	Sloping land, Medium-gradient hill (SH)
Position	Middle slope (back slope)
Slope	Straight slope of ± 1% over more than 200 m long.
Micro-topography	None
Land Use	The area is intensively farmed for cereals, such as sorghum, teff, maize, and chick pea.
Human influence	Rainfed arable cultivation. Combination of DAP and Urea fertilizer is used for wheat and barley.
Vegetation	None
Parent material	Unconsolidated sedimentary rock fluvial and / or colluvial from basalt
Soil depth	Very deep (>200cm)
Rock outcrops	None
Surface coarse fragments	Very few (0-2%) of the soil surface is covered by fine (0.2-0.6cm)-sized fragments
Erosion	Slight sheet and wind erosion, locally degradation caused by cattle tracks
Surface sealing	None
Surface cracks	Wide cracks (2-5cm), very deep (>20cm) and the cracks are moderately widely spaced (0.5 – 2m)
Internal drainage	Well
External drainage	Well
Flooding	Once per year for a duration of 1 day
Groundwater	Very deep (200cm)

Soil description

Hor.	*Depth cm*	*Description*
Ap	0-28	Very dark brown (10 YR 2/2) when moist, very dark greyish brown (10 YR 3/2) when dry; wet clay; weak, fine angular and sub-angular blocky structure; hard when dry, very friable when moist, very sticky & very plastic when wet; low few pores; no, coatings; no compaction;common very fine roots; few biological activity; no coarse fragments; diffused boundary; no mineral concretions; slightly reaction with HCL
Bic1-1	28-85	Black (10 YR 2/1) when moist, very dark grey (10 YR 3/1) when dry; moist clay; strong, coarse angular and sub-angular blocky structure; very hard when dry, very friable when moist, very sticky & very plastic when wet; low few pores; no, coatings; compacted but not cemented; few very fine roots; no biological activity; no coarse fragments; gradual & wavy boundary; fewvery fineboth soft & hard mineral concretions; moderate reaction with HCL
Bic1-2	85-150	Very dark greyish brown (10 YR 3/2) when moist, dark brown (10 YR 3/3) when dry; slightly moist clay; moderate, coarse angular and sub-angular blocky structure; very hard when dry, very friable when moist, very sticky & very plastic when wet; low few pores; no, coatings; compacted but not cemented; very few very fine roots; no biological activity; no coarse fragments; commonvery fineboth soft & hard mineral concretions; strong reaction with HCL
Bic2	150-185	<Same>

Analytical data

Profile Code: TRAZ-GEN-P1 Location: Raya Azebo woreda; Genete kebele

Horizon	Ap	Bic1-1	Bic1-2	Bic2
Depth	0-28	28-85	85-150	150-185
Sand %	6.14	3.4	7.26	22.21
Silt %	32.05	27.6	19.46	21.42
Clay %	61.81	69	73.27	56.37
Texture class	clay	clay	clay	clay
pH-H2O (1:2.5)	7.54	7.62	7.9	8
pH-KCL (1:2.5)	6.6	6.71	7.15	7.25
EC (ms/cm)(1:2.5)	0.23	0.25	0.42	0.36
Exch Na (meq/100gm of soil)	0.36	0.53	2.20	1.00
Exch K (meq/100gm of soil)	0.19	0.14	0.30	0.15
Exch Ca (meq/100gm of soil)	31.53	26.67	27.05	21.81
Exch Mg (meq/100gm of soil)	10.36	8.14	9.02	8.90
Sum of cations (meq/100gm soil)	42.44	35.48	38.56	31.86
CEC (meq/100gm of soil)	59.24	55.52	41.16	39.20
BS %	71.64	63.91	93.68	81.29
Total N %	0.24	0.19	0.17	0.05
OC %	2.00	1.80	1.55	0.50
C/N	8.46	9.49	8.94	10.78
Bulk density (gram/Cm3)	1.12	1.09	1.11	1.10
Avail. P (mg P2O5/kg soil)	54.50			
Available S (%)	0.56			
Exchangeable Sodium% (ESP)	0.61	0.96	5.33	2.54
Zn (mg/kg soil)	0.43			
Mn (mg/kg soil)	7.19			
Cu (mg/kg soil)	1.68			
Fe (mg/kg soil)	2.74			

2.26 Soil profile descriptions with analytical data for Raya Azebo Genete P2

Profile site description

Profile ID	TRAZ-GEN-P2
Soil profile description status	Reference profile description
Date of description	16/03/2014
Author(s)	Amanuel Z.
Soil unit	LP(cc VR (eu, pe))
Location (admin.)	Tigray, Raya Azebo woreda, Genete Kebele, Wakhel-Adi Sara area
Elevation (m.)	1796
Map sheet number and grid reference	
Coordinates (Deg, Min, Sec)	39 ^{o} 37'36", 12 ^{o} 45'49"
Soil taxonomic classification (WRB 2006)	Calcic Vertisol (Eutric, Pellic)
Local soil name	Hawsi Walka
Topography	< 10%
Landform	Level land, Plain (LP)
Position	Middle slope (back slope)
Slope	Straight slope of ± 1% over more than 200 m long.
Micro-topography	None
Land Use	The area is intensively farmed for cereals, such as sorghum, teff, maize, and chick pea.
Human influence	Rainfed arable cultivation. Combination of DAP and Urea fertilizer is used for wheat and barley.
Vegetation	None
Parent material	Unconsolidated sedimentary rock fluvial and / or colluvial from basalt
Soil depth	Very deep (>200cm)
Rock outcrops	None
Surface coarse fragments	Very few (0-2%) of the soil surface is covered by medium (0.6-2cm)-sized fragments
Erosion	Slight sheet and wind erosion, locally degradation caused by cattle tracks
Surface sealing	None
Surface cracks	Fine cracks (<1cm), surface (<2cm) and the cracks are moderately widely spaced (0.5 – 2m)
Internal drainage	Well
External drainage	Well
Flooding	None
Groundwater	Very deep (200cm)

Soil description

Hor.	*Depth cm*	*Description*
Ap	0-35	Black (10 YR 2/1) when moist, very dark greyish brown (10 YR 3/2) when dry; slightly moist; moderate, fine angular & sub-angular blocky structure;when dry, when moist, when wet; pores; no, coatings; no compaction; few very fine roots; very fine biological activity; finevery fewfresh & slightly weathered coarse fragments; gradual & wavy boundary; no mineral concretions; no reaction with HCL
Bic1	35-80	Black (10 YR 2/1) when moist, black (10 YR 2/1) when dry; dry; moderate, medium angular & sub-angular blocky structure; when dry, when moist, when wet; pores; no, coatings; no compaction; very few very fine roots; very few biological activity (one mole rat was observed); fine very few fresh & slightly weathered coarse fragments; diffused boundary; no mineral concretions; slight reaction with HCL
Bic2	80-150	Black (10 YR 2/1) when moist, black (10 YR 2/1) when dry; dry; moderate, medium angular & sub-angular blocky structure; Slickensides; when dry, when moist, when wet; pores; dominant,distinct calcium carbonate coatings; no compaction; very few very fine roots; very fine biological activity; medium very few fresh & slightly weathered coarse fragments; gradual & wavy boundary; no mineral concretions; moderate reaction with HCL
Bic3	150-180	Very dark greyish brown (10 YR 3/2) when moist, dark brown (10 YR 3/3) when dry; dry; moderate, medium angular & sub-angular blocky structure; slickensides; when dry, when moist, when wet; pores; dominant,distinct calcium carbonate coatings; no compaction; very few very fine roots; very fine biological activity; medium very few fresh & slightly weathered coarse fragments;no mineral concretions; moderate reaction with HCL

Analytical data

Profile Code: TRAZ-GEN-P2 Location: Raya Azebo woreda; Genete kebele

Horizon	Ap	Bic1	Bic2	Bic3
Depth	0-35	35-80	80-150	150-180
Sand %	26.81	24.49	28.45	40.75
Silt %	32.16	32.2	25.71	9.7
Clay %	41.03	43.31	45.84	49.56
Texture class	clay	clay	clay	clay
pH-H2O (1:2.5)	7.18	6.9	7.8	7.87
pH-KCL (1:2.5)	6.22	6.1	7.03	7.12
EC (ms/cm)(1:2.5)	0.17	0.16	0.32	0.45
Exch Na (meq/100gm of soil)	0.77	0.85	0.40	1.09
Exch K (meq/100gm of soil)	0.73	0.32	0.22	0.19
Exch Ca (meq/100gm of soil)	26.79	28.60	24.33	36.45
Exch Mg (meq/100gm of soil)	9.22	9.24	8.85	13.72
Sum of cations (meq/100gm soil)	37.51	39.01	33.81	51.45
CEC (meq/100gm of soil)	39.62	40.17	39.43	53.60
BS %	94.68	97.11	85.73	95.99
Total N %	0.26	0.22	0.20	0.08
OC %	2.66	2.29	2.04	0.57
C/N	10.17	10.64	10.13	7.55
Bulk density (gram/Cm3)	1.22	1.17	1.12	1.38
Avail. P (mg P2O5/kg soil)	58.90			
Available S (%)	0.54			
Exchangeable Sodium% (ESP)	1.95	2.12	1.02	2.03
Zn (mg/kg soil)	0.26			
Mn (mg/kg soil)	7.31			
Cu (mg/kg soil)	1.17			
Fe (mg/kg soil)	2.59			

2.27 Soil profile descriptions with analytical data for Raya Azebo Kara AdiShabo P1

Profile ID	TRAZ-KAS-P1
Soil profile description status	Reference profile description
Date of description	15/03/2014
Author(s)	Amanuel Z.
Soil unit	LP(ha VR (ca))
Location (admin.)	Tigray, Raya Azebo woreda, Kara Adi Shabo Kebele
Elevation (m.)	1614
Map sheet number and grid reference	
Coordinates (Deg, Min, Sec)	39 ^{o} 39'57", 12 ^{o} 41'53"
Soil taxonomic classification (WRB 2006)	Haplic Vertisol (Calcaric)
Local soil name	Walka
Topography	< 10%
Landform	Level land, Plain (LP)
Position	Middle slope (back slope)
Slope	Straight slope of ± 1% over more than 200 m long.
Micro-topography	None
Land Use	The area is intensively farmed for cereals, such as sorghum, teff, maize, and chick pea.
Human influence	Rainfed arable cultivation. Combination of DAP and Urea fertilizer is used for wheat and barley.
Vegetation	None
Parent material	Unconsolidated sedimentary rock fluvial and / or colluvial from basalt
Soil depth	Very deep (>200cm)
Rock outcrops	None
Surface coarse fragments	Very few (0-2%) of the soil surface is covered by fine (0.2-0.6cm)-sized surface fragments and few (2-5%) is covered by medium gravel
Erosion	Slight sheet and wind erosion, locally degradation caused by cattle tracks
Surface sealing	None
Surface cracks	Wide cracks (2-5cm), deep (10-20cm) and the cracks are moderately widely spaced (0.5-2m)
Internal drainage	Moderately Well drained
External drainage	Slow
Flooding	None
Groundwater	Very deep (200cm)

Soil description

Hor.	*Depth cm*	*Description*
Ap	0-30	Very dark brown (10 YR 2/2) when moist, very dark greyish brown (10 YR 3/2) when dry; wet clay; weak medium angular and sub-angular blocky structure; very hard when dry, very friable when moist, sticky & plastic when wet; low few pores; no, no coatings; no compaction; few very fine roots; no biological activity; fine very few fresh & slightly weathered coarse fragments; diffused boundary; no mineral concretions; slightly reaction with HCL
Bi1-1	30-100	Very dark brown (10 YR 2/2) when moist, 10 YR 2/1 (black) when dry; moist clay; strong, coarse angular and sub-angular blocky structure; Slikensides; extremely hard when dry, friable when moist, very sticky & very plastic when wet; very low few pores; many,many distinct coatings; compacted but not cemented; very few very fine roots; no biological activity; no coarse fragments; diffused boundary; fewvery fineboth soft & hard mineral concretions; slightly reaction with HCL
Bi1-2	100-170	<Same>
Bi2	170-200	Very dark greyish brown (10 YR 3/2) when moist, dark brown (10 YR 3/3) when dry; slightly moist clay; moderate, coarse angular and sub-angular blocky structure; slickensides; extremely hard when dry, friable when moist, very sticky & very plastic when wet; very low few pores; very few,very few fine coatings; no compaction; very few very fine roots; no biological activity; no coarse fragments; commonvery fineboth soft & hard mineral concretions; slightly reaction with HCL

Analytical data

Profile Code: TRAZ-KAS-P1 Location: Raya Azebo woreda; Kara Adi Shabo kebele

Horizon	Ap	Bi1-1	Bi1-2	Bi2
Depth	0-30	30-100	100-170	170-200
Sand %	20	18.91	7.99	18.21
Silt %	21.11	23.17	22.13	36.35
Clay %	58.89	57.92	69.88	45.44
Texture class	clay	clay	clay	clay
pH-H2O (1:2.5)	7.83	8.33	8.37	7.94
pH-KCL (1:2.5)	7.05	7.46	7.51	7.06
EC (ms/cm)(1:2.5)	3.15	0.51	0.38	0.61
Exch Na (meq/100gm of soil)	2.00	3.02	0.60	3.02
Exch K (meq/100gm of soil)	0.32	0.22	0.09	0.35
Exch Ca (meq/100gm of soil)	35.20	27.74	25.10	25.54
Exch Mg (meq/100gm of soil)	10.56	8.64	9.58	8.06
Sum of cations (meq/100gm soil)	48.08	39.62	35.37	36.97
CEC (meq/100gm of soil)	51.17	41.53	41.67	38.96
BS %	93.96	95.40	84.88	94.90
Total N %	0.32	0.30	0.27	0.08
OC %	2.79	2.66	2.41	0.77
C/N	8.63	8.81	8.88	9.78
Bulk density (gram/Cm3)	1.15	1.18	1.22	1.26
Avail. P (mg P2O5/kg soil)	21.90			
Available S (%)	0.91			
Exchangeable Sodium% (ESP)	3.91	7.26	1.43	7.75
Zn (mg/kg soil)	0.26			
Mn (mg/kg soil)	4.54			
Cu (mg/kg soil)	2.11			
Fe (mg/kg soil)	1.44			

2.28 Soil profile descriptions with analytical data for Raya Azebo Tsegaa P1

Profile site description

Profile ID	TRAZ-TSE-P1
Soil profile description status	Reference profile description
Date of description	12/03/2014
Author(s)	Amanuel Z.
Soil unit	LP(cc VR (eu, pe))
Location (admin.)	Tigray, Raya Azebo woreda, Tsegaa Kebele
Elevation (m.)	1841
Map sheet number and grid reference	
Coordinates (Deg, Min, Sec)	39 ^{o} 37'42", 12 ^{o} 48'55"
Soil taxonomic classification (WRB 2006)	Calcic Vertisol (Eutric, Pellic)
Local soil name	Walka
Topography	< 10%
Landform	Level land, Plain (LP)
Position	Lower slope (foot slope)
Slope	Straight slope of ± 2% over more than 200 m long.
Micro-topography	None
Land Use	The area is intensively farmed for cereals, such as sorghum, teff, maize, and chick pea.
Human influence	Rainfed arable cultivation. Combination of DAP and Urea fertilizer is used for wheat and barley.
Vegetation	None
Parent material	Unconsolidated sedimentary rock fluvial and / or colluvial from basalt
Soil depth	Very deep (>200cm)
Rock outcrops	None
Surface coarse fragments	Common (5-15%) of the soil surface is covered by medium (0.6-2cm), coarse gravel (0.6-2cm) and stones (6-20cm) surface fragments
Erosion	Slight sheet and wind erosion, locally degradation caused by cattle tracks
Surface sealing	None
Surface cracks	No visible surface cracks (can be filled due to soil tillage)
Internal drainage	Well
External drainage	Well
Flooding	Once per year for a duration of 4 days
Groundwater	Very deep (200cm)

Soil description

Hor.	*Depth cm*	*Description*
Ap	0-20	Very dark greyish brown (10 YR 3/2) when moist, dark brown (10 YR 3/3) when dry; dry clay; strong, medium angular blocky &sub-angular blocky structure; soft when dry, very friable when moist, sticky & plastic when wet; low few pores; no, coatings; no compaction; no roots; very fine biological activity; fine gravel common fresh & slightly weathered coarse fragments; clear & wavy boundary; no mineral concretions; no reaction with HCL
B1	20-50	Very dark grey (10 YR 3/1) when moist, dark brown (10 YR 3/3) when dry; dry clay; strong, coarse angular blocky &sub-angular blocky structure; hard when dry, friable when moist, very sticky & very plastic when wet; low very few pores; no, coatings; no compaction;no roots; very fine biological activity; fine gravel common fresh & slightly weathered coarse fragments; diffused boundary; no mineral concretions; no reaction with HCL
B2	50-83	Black (10 YR 2/1) when moist, very dark brown (10 YR 3/1) when dry; dry clay; strong, coarse angular blocky &sub-angular blocky structure; very hard when dry, friable when moist, very sticky & very plastic when wet; low very few pores; no, coatings; compacted but not cemented;no roots; very fine biological activity; fine gravel common fresh & slightly weathered coarse fragments; clear & wavy boundary; mineral concretions; no reaction with HCL
Bc1	83-150	Black (10 YR 2/1) when moist, very dark brown (10 YR 3/1) when dry; dry clay; strong, coarse angular blocky &sub-angular blocky structure; very hard when dry, friable when moist, very sticky & very plastic when wet; low very few pores; very few,faint pressure face and calcium carbonates coatings; compacted but not cemented; no roots; very fine biological activity; fine gravel common fresh & slightly weathered coarse fragments; clear & wavy boundary; mineral concretions; moderate reaction with HCL
Bc2	150-180	Black (10 YR 2/1) when moist, very dark brown (10 YR 3/1) when dry; dry clay; moderate, coarse angular blocky &sub-angular blocky structure; very hard when dry, friable when moist, very sticky & very plastic when wet; low very few pores; very few,faint pressure face and calcium carbonates coatings; no compaction; no roots; very fine biological activity; fine gravel common fresh & slightly weathered coarse fragments;no mineral concretions; slightly reaction with HCL

Analytical data

Profile Code: TRAZ-TSE-P1 Location: Raya Azebo woreda; Tsegeaa kebele

Horizon	Ap	B1	B2	Bc1	Bc2
Depth	0-20	20-50	50-83	83-150	150-180
Sand %	34.65	34.37	21.63	12.52	23.04
Silt %	18.21	18.29	34.22	34.33	23.09
Clay %	47.14	47.34	44.15	53.15	53.87
Texture class	clay	clay	clay	clay	clay
pH-H2O (1:2.5)	7.41	7.4	7.63	7.82	7.78
pH-KCL (1:2.5)	6.58	6.49	6.8	7	6.9
EC (ms/cm)(1:2.5)	0.11	0.08	0.1	0.12	0.14
Exch Na (meq/100gm of soil)	0.52	0.66	0.48	0.37	0.49
Exch K (meq/100gm of soil)	0.34	0.16	0.06	0.08	0.08
Exch Ca (meq/100gm of soil)	27.74	25.70	25.82	29.84	32.70
Exch Mg (meq/100gm of soil)	9.82	9.42	10.06	9.65	10.90
Sum of cations (meq/100gm soil)	38.42	35.95	36.41	39.95	44.18
CEC (meq/100gm of soil)	45.46	44.24	41.86	46.26	46.44
BS %	84.50	81.27	87.00	86.35	95.12
Total N %	0.19	0.18	0.18	0.17	0.17
OC %	1.67	1.41	1.36	1.33	1.28
C/N	8.60	7.84	7.71	7.90	7.61
Bulk density (gram/Cm3)	1.29	1.29	1.20	1.11	1.05
Avail. P (mg P2O5/kg soil)	54.80				
Available S (%)	0.47				
Exchangeable Sodium% (ESP)	1.14	1.49	1.14	0.80	1.06
Zn (mg/kg soil)	0.18				
Mn (mg/kg soil)	7.64				
Cu (mg/kg soil)	1.37				
Fe (mg/kg soil)	6.24				

2.29 Soil profile descriptions with analytical data for Raya Azebo Tsegaa P2

Profile ID	TRAZ-TSE-P2
Soil profile description status	Reference profile description
Date of description	12/01/2014
Author(s)	Amanuel Z.& Girmay G.
Soil unit	SH(le RG (eu))
Location (admin.)	Tigray, Raya Azebo woreda, Tsegaa Kebele
Elevation (m.)	1853
Map sheet number and grid reference	
Coordinates (Deg, Min, Sec)	39 ^{o} 36'27", 12 ^{o} 48'11"
Soil taxonomic classification (WRB 2006)	Leptic Regosol (Eutric)
Local soil name	Walka
Topography	10-30%
Landform	Sloping land, Medium-gradient hill (SH)
Position	Lower slope (foot slope)
Slope	Straight slope of ± 1% over more than 200 m long.
Micro-topography	None
Land Use	Intensive grazing
Human influence	Traditional grazing resulted in overgrazing
Vegetation	None
Parent material	Unconsolidated sedimentary rock alluvial from basalt
Soil depth	Moderately deep (92cm)
Rock outcrops	None
Surface coarse fragments	Common (5-15%) of the soil surface is covered by medium (0.6-2cm) and coarse gravel (0.6-2cm) surface fragments
Erosion	Severe sheet and wind erosion, locally degradation caused by cattle tracks
Surface sealing	None
Surface cracks	None
Internal drainage	Well
External drainage	Rapid
Flooding	None
Groundwater	Very deep

Soil description

Hor.	*Depth cm*	*Description*
Ah	0-34	Dark reddish brown (5YR 2.5/2) clay loam; strong, fine, granular structure; very friable when moist, slightly sticky when wet; many pores; many fine and medium roots; very few small quartz fragments; gradual, smooth boundary; no reaction with HCl.
CA	34-92	Very dusky red (2.5YR 2.5/2) moist clay loam; strong, fine to medium sub-angular blocky structure; very friable when moist, slightly sticky when wet; many, very fine to coarse pores; common, very fine and fine roots; very few small quartz fragments; gradual, smooth boundary; no reaction with HCl.
R	92+	Rock

Analytical data

Profile Code: TRAZ-TSE-P2 Location: Raya Azebo woreda; Tsegeaa kebele

Horizon	Ah	CA	R
Depth	0-34	34-92	92+
Sand %	48.09	49.03	
Silt %	9.94	14.73	
Clay %	41.97	36.25	
Texture class	Sandy clay	Sandy clay	
pH-H2O (1:2.5)	7.81	8.17	
pH-KCL (1:2.5)	7	7.3	
EC (ms/cm)(1:2.5)	0.21	0.19	
Exch Na (meq/100gm of soil)	0.32	0.83	
Exch K (meq/100gm of soil)	0.15	0.10	
Exch Ca (meq/100gm of soil)	19.71	28.60	
Exch Mg (meq/100gm of soil)	7.01	8.49	
Sum of cations (meq/100gm soil)	27.19	38.01	
CEC (meq/100gm of soil)	38.56	42.25	
BS %	70.52	89.95	
Total N %	0.15	0.06	
OC %	1.33	0.54	
C/N	8.66	8.58	
Bulk density (gram/Cm3)	1.31	1.24	
Avail. P (mg P2O5/kg soil)	33.20		
Available S (%)	0.63		
Exchangeable Sodium% (ESP)	0.84	1.95	
Zn (mg/kg soil)	0.12		
Mn (mg/kg soil)	4.51		
Cu (mg/kg soil)	0.66		
Fe (mg/kg soil)	2.70		

Annex 3A: Physico-chemical properties of Vertisol in the study area

Soil properties	Surface horizon			Subsurface horizon		
	Min	Max	Mean	Min	Max	Mean
n	16	16	16	16	16	16
pH-H2O (1:2.5)	6.44	8.06	7.29	6.76	8.21	7.67
pH-KCL (1:2.5)	5.27	7.14	6.36	5.88	7.34	6.79
EC (ms/cm)(1:2.5)	0.07	3.15	0.33	0.07	0.55	0.23
Sand %	6.14	36.50	23.13	7.38	37.23	20.23
Silt %	13.02	36.36	23.49	17.29	33.96	25.59
Clay %	40.64	71.01	53.38	42.31	66.21	54.18
Exch Na (meq/100gm of soil)	0.36	2.00	0.94	0.50	2.60	1.26
Exch K (meq/100gm of soil)	0.19	0.75	0.42	0.10	0.57	0.34
Exch Ca (meq/100gm of soil)	20.58	36.96	28.99	24.55	36.00	29.77
Exch Mg (meq/100gm of soil)	8.34	12.32	9.80	8.69	12.29	10.07
CEC (meq/100gm of soil)	36.52	59.24	48.29	39.88	54.71	46.05
Sum of cations (meq/100gm soil)	29.67	51.14	40.15	34.50	50.39	41.45
OC %	0.85	2.79	1.60	0.56	1.95	1.09
Total N %	0.09	0.32	0.19	0.06	0.22	0.13
Avail. P (mg P2O5/kg soil)	17.60	72.60	39.60			
Bulk density (gram/Cm3)	1.12	1.34	1.23	1.10	1.31	1.25
Available S (%)	0.47	0.91	0.71			
Exchangeable Sodium% (ESP)	0.61	3.91	1.94	1.12	5.48	2.78
Zn (mg/kg soil)	0.13	1.27	0.37			
Mn (mg/kg soil)	3.83	25.25	8.89			
Cu (mg/kg soil)	0.98	4.47	2.58			
Fe (mg/kg soil)	1.44	43.23	11.98			
BS %	70.78	94.99	83.33	79.63	95.32	90.23
Exchangeable Na & Mg%	23.41	33.61	26.91	25.35	29.99	27.38

Annex 3B: Physico-chemical properties of Cambisol in the study area

Soil properties	Surface horizon			Subsurface horizon		
	Min	Max	Mean	Min	Max	Mean
n	8	8	8	8	8	8
pH-H2O (1:2.5)	6.33	8.09	7.16	6.87	8.16	7.51
pH-KCL (1:2.5)	5.35	7.16	6.26	5.95	7.23	6.60
EC (ms/cm)(1:2.5)	0.06	0.29	0.15	0.06	1.09	0.24
Sand %	25.31	55.69	39.50	19.53	50.42	36.49
Silt %	14.77	25.14	19.72	10.78	32.55	20.27
Clay %	29.54	50.53	40.79	34.66	52.08	43.23
Exch Na (meq/100gm of soil)	0.68	1.28	1.00	0.48	1.24	0.94
Exch K (meq/100gm of soil)	0.18	2.53	0.77	0.10	3.38	0.67
Exch Ca (meq/100gm of soil)	20.39	27.14	25.19	23.12	31.02	26.02
Exch Mg (meq/100gm of soil)	7.65	9.59	8.80	7.63	10.16	8.73
CEC (meq/100gm of soil)	33.71	46.09	39.13	34.89	46.26	40.26
Sum of cations (meq/100gm soil)	29.20	39.25	35.77	32.48	42.74	36.36
OC %	0.96	1.83	1.34	0.74	1.38	0.89
Total N %	0.10	0.22	0.16	0.08	0.16	0.10
Avail. P (mg P2O5/kg soil)	21.70	55.00	34.79			
Bulk density (gram/Cm3)	1.21	1.58	1.35	1.20	1.41	1.28
Available S (%)	0.45	1.15	0.74			
Exchangeable Sodium% (ESP)	1.73	3.18	2.55	1.15	3.18	2.38
Zn (mg/kg soil)	0.00	0.65	0.34			
Mn (mg/kg soil)	1.86	25.36	8.62			
Cu (mg/kg soil)	0.53	3.45	1.85			
Fe (mg/kg soil)	1.08	39.20	14.09			
BS %	79.01	97.87	91.64	75.37	96.07	90.73
Exchangeable Na & Mg%	25.71	28.70	27.44	24.95	27.59	26.72

Annex 3C: Physico-chemical properties of Fluvisol in the study area

Soil properties	Surface horizon			Subsurface horizon		
	Min	Max	Mean	Min	Max	Mean
n	3	3	3	3	3	3
pH-H2O (1:2.5)	7.67	7.98	7.82	7.76	8.10	7.95
pH-KCL (1:2.5)	6.85	7.18	7.05	6.88	7.14	7.02
EC (ms/cm)(1:2.5)	0.15	0.32	0.23	0.25	0.31	0.27
Sand %	12.89	46.17	30.77	31.66	46.84	39.31
Silt %	13.72	44.65	29.15	18.26	29.03	22.73
Clay %	37.68	42.47	40.09	34.91	39.68	37.96
Exch Na (meq/100gm of soil)	0.29	1.08	0.61	0.60	1.04	0.76
Exch K (meq/100gm of soil)	0.13	0.46	0.26	0.05	0.22	0.13
Exch Ca (meq/100gm of soil)	23.80	27.30	25.75	19.62	22.93	21.53
Exch Mg (meq/100gm of soil)	8.22	9.66	8.82	6.80	8.05	7.39
CEC (meq/100gm of soil)	38.18	44.22	41.16	33.34	35.45	34.10
Sum of cations (meq/100gm soil)	32.78	38.17	35.43	27.51	31.12	`
OC %	1.35	2.07	1.59	0.69	0.95	0.84
Total N %	0.15	0.28	0.19	0.08	0.11	0.10
Avail. P (mg P2O5/kg soil)	32.30	59.40	47.50			
Bulk density (gram/Cm3)	1.06	1.37	1.23	0.84	1.41	1.20
Available S (%)	0.63	0.87	0.74			
Exchangeable Sodium% (ESP)	0.66	2.62	1.51	1.74	3.11	2.23
Zn (mg/kg soil)	0.16	0.24	0.21			
Mn (mg/kg soil)	3.73	6.01	5.18			
Cu (mg/kg soil)	1.14	2.11	1.64			
Fe (mg/kg soil)	4.17	17.12	10.28			
BS %	74.13	92.89	86.54	81.95	92.65	87.13
Exchangeable Na & Mg%	25.58	28.13	26.56	25.59	28.58	27.44

Annex 3D: Physico-chemical properties of Regosol in the study area

Soil properties	Surface horizon			Subsurface horizon		
	Min	Max	Mean	Min	Max	Mean
n	1	1	1	1	1	1
pH-H2O (1:2.5)	7.81	7.81	7.81	8.17	8.17	8.17
pH-KCL (1:2.5)	7.00	7.00	7.00	7.30	7.30	7.30
EC (ms/cm)(1:2.5)	0.21	0.21	0.21	0.19	0.19	0.19
Sand %	48.09	48.09	48.09	49.03	49.03	49.03
Silt %	9.94	9.94	9.94	14.73	14.73	14.73
Clay %	41.97	41.97	41.97	36.25	36.25	36.25
Exch Na (meq/100gm of soil)	0.32	0.32	0.32	0.83	0.83	0.83
Exch K (meq/100gm of soil)	0.15	0.15	0.15	0.10	0.10	0.10
Exch Ca (meq/100gm of soil)	19.71	19.71	19.71	28.60	28.60	28.60
Exch Mg (meq/100gm of soil)	7.01	7.01	7.01	8.49	8.49	8.49
CEC (meq/100gm of soil)	38.56	38.56	38.56	42.25	42.25	42.25
Sum of cations (meq/100gm soil)	27.19	27.19	27.19	38.01	38.01	38.01
OC %	1.33	1.33	1.33	0.54	0.54	0.54
Total N %	0.15	0.15	0.15	0.06	0.06	0.06
Avail. P (mg P2O5/kg soil)	33.20	33.20	33.20			
Bulk density (gram/Cm3)	1.31	1.31	1.31	1.24	1.24	1.24
Available S (%)	0.63	0.63	0.63			
Exchangeable Sodium% (ESP)	0.84	0.84	0.84	1.95	1.95	1.95
Zn (mg/kg soil)	0.12	0.12	0.12			
Mn (mg/kg soil)	4.51	4.51	4.51			
Cu (mg/kg soil)	0.66	0.66	0.66			
Fe (mg/kg soil)	2.70	2.70	2.70			
BS %	70.52	70.52	70.52	89.95	89.95	89.95
Exchangeable Na & Mg%	26.96	26.96	26.96	24.51	24.51	24.51

Annex 4: Soil types area proportion according to woreda and kebelle

3.1 The different major soil types, and their respective proportions for Alaje Woreda-Atsela Kebele

Land Mapping Unt	Soil Mapping Unit	Area (ha)	Per cent
Sloping land,Medium-gradient escarpment zone(SSE)		999	26
	Built-up Areas-[Built-up Areas]	21	1
	Gleyic Calcic Fluvisol (Eutric)-[gl cc FL (eu)]	3	0
	Haplic Cambisol (Eutric)-[ha CM (eu)]	23	1
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	111	3
	Haplic Regosol (Eutric)-[ha RG (eu)]	11	0
`	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	392	10
	Homestead-[Homestead]	119	3
	Leptic Regosol (Eutric)-[le RG (eu)]	319	8
Sloping land,Medium-gradient valley(SSV)		879	23
	Built-up Areas-[Built-up Areas]	121	3
	Gleyic Calcic Fluvisol (Eutric)-[gl cc FL (eu)]	74	2
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	75	2
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	577	15
	Homestead-[Homestead]	20	1
	Leptic Regosol (Eutric)-[le RG (eu)]	13	0
Steep land,High-gradient hill(TTH)		88	2
	Built-up Areas-[Built-up Areas]	29	1
	Gleyic Calcic Fluvisol (Eutric)-[gl cc FL (eu)]	0	0
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	32	1
	Homestead-[Homestead]	1	0
	Leptic Regosol (Eutric)-[le RG (eu)]	26	1

Land Mapping Unt	Soil Mapping Unit	Area (ha)	Per cent
Steep land,High-gradient mountain(TTM)		1908	49
	Haplic Cambisol (Eutric)-[ha CM (eu)]	1	0
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	440	11
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	115	3
	Homestead-[Homestead]	54	1
	Leptic Regosol (Eutric)-[le RG (eu)]	1298	33
Total		**3875**	**100**

3.2 The different major soil types, and their respective proportions for Alaje Woreda-Ayba Kebele

Land Mapping Unt	Soil Mapping Unit	Area (ha)	Per cent
Sloping land,Medium-gradient escarpment zone(SSE)		1605	34
	Calcic Vertisol (Eutric, Pellic)-[cc VR (eu, pe)]	430	9
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	494	11
	Haplic Regosol (Eutric)-[ha RG (eu)]	291	6
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	17	0
	Homestead-[Homestead]	268	6
	Vertic Epileptic Cambisol (Eutric)-[vr el CM (eu)]	104	2
Sloping land,Medium-gradient valley(SSV)		424	9
	Calcic Vertisol (Eutric, Pellic)-[cc VR (eu, pe)]	122	3
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	30	1
	Homestead-[Homestead]	24	1
	Vertic Epileptic Cambisol (Eutric)-[vr el CM (eu)]	247	5
Steep land,High-gradient hill(TTH)		63	1
	Calcic Vertisol (Eutric, Pellic)-[cc VR (eu, pe)]	2	0
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	45	1
	Haplic Regosol (Eutric)-[ha RG (eu)]	6	0
	Vertic Epileptic Cambisol (Eutric)-[vr el CM (eu)]	10	0
Steep land,High-gradient mountain(TTM)		2597	55
	Calcic Vertisol (Eutric, Pellic)-[cc VR (eu, pe)]	118	3
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	2086	44
	Haplic Regosol (Eutric)-[ha RG (eu)]	164	3
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	8	0
	Homestead-[Homestead]	130	3
	Vertic Epileptic Cambisol (Eutric)-[vr el CM (eu)]	91	2
Steep land,High-gradient valley(TTV)		9	0
	Homestead-[Homestead]	3	0
	Vertic Epileptic Cambisol (Eutric)-[vr el CM (eu)]	6	0
Total		**4698**	**100**

3.3 The different major soil types, and their respective proportions for Alaje Woreda-Sesat Kebele

Land Mapping Unt	Soil Mapping Unit	Area (ha)	Per cent
Sloping land,Medium-gradient escarpment zone(SSE)		959	22
	Gleyic Calcic Fluvisol (Eutric)-[gl cc FL (eu)]	3	0
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	374	9
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	267	6
	Homestead-[Homestead]	110	3
	Leptic Regosol (Eutric)-[le RG (eu)]	206	5
Sloping land,Medium-gradient valley(SSV)		740	17
	Gleyic Calcic Fluvisol (Eutric)-[gl cc FL (eu)]	105	2
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	30	1
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	568	13
	Homestead-[Homestead]	13	0
	Leptic Regosol (Eutric)-[le RG (eu)]	24	1
Steep land,High-gradient hill(TTH)		36	1
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	31	1
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	4	0
Steep land,High-gradient mountain(TTM)		2615	60
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	977	22
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	112	3
	Homestead-[Homestead]	66	2
	Leptic Regosol (Eutric)-[le RG (eu)]	1460	34
Total		**4351**	**100**

3.4 The different major soil types, and their respective proportions for Alaje Woreda-Tekea Kebele

Land Mapping Unt	Soil Mapping Unit	Area (ha)	Per cent
Sloping land,Dissected plain(SSP)		285	6
	Endogleyic Cambisol (Eutric) (Thapto-Vertisolic)-[ng CM (eu, bVR)]	30	1
	Haplic Cambisol (Eutric)-[ha CM (eu)]	79	2
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	61	1
	Haplic Regosol (Eutric)-[ha RG (eu)]	60	1
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	4	0
	Homestead-[Homestead]	27	1
	Leptic Regosol (Eutric)-[le RG (eu)]	24	0
Sloping land,Medium-gradient escarpment zone(SSE)		1847	37
	Endogleyic Cambisol (Eutric) (Thapto-Vertisolic)-[ng CM (eu, bVR)]	17	0
	Haplic Cambisol (Eutric)-[ha CM (eu)]	181	4
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	848	17
	Haplic Regosol (Eutric)-[ha RG (eu)]	505	10
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	4	0
	Homestead-[Homestead]	104	2
	Leptic Regosol (Eutric)-[le RG (eu)]	123	2
	Vertic Epileptic Cambisol (Eutric)-[vr el CM (eu)]	63	1

Land Mapping Unt	Soil Mapping Unit	Area (ha)	Per cent
Sloping land,Medium-gradient valley(SSV)		618	12
	Endogleyic Cambisol (Eutric) (Thapto-Vertisolic)-[ng CM (eu, bVR)]	233	5
	Haplic Cambisol (Eutric)-[ha CM (eu)]	160	3
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	53	1
	Haplic Regosol (Eutric)-[ha RG (eu)]	11	0
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	103	2
	Homestead-[Homestead]	32	1
	Leptic Regosol (Eutric)-[le RG (eu)]	2	0
	Vertic Epileptic Cambisol (Eutric)-[vr el CM (eu)]	22	0
Steep land,High-gradient hill(TTH)		26	1
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	13	0
	Haplic Regosol (Eutric)-[ha RG (eu)]	12	0
Steep land,High-gradient mountain(TTM)		1961	39
	Endogleyic Cambisol (Eutric) (Thapto-Vertisolic)-[ng CM (eu, bVR)]	0	0
	Haplic Cambisol (Eutric)-[ha CM (eu)]	13	0
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	1550	31
	Haplic Regosol (Eutric)-[ha RG (eu)]	259	5
	Homestead-[Homestead]	31	1
	Leptic Regosol (Eutric)-[le RG (eu)]	106	2
	Vertic Epileptic Cambisol (Eutric)-[vr el CM (eu)]	2	0
Steep land,High-gradient valley(TTV)		229	5
	Endogleyic Cambisol (Eutric) (Thapto-Vertisolic)-[ng CM (eu, bVR)]	52	1
	Haplic Cambisol (Eutric)-[ha CM (eu)]	47	1
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	20	0
	Haplic Regosol (Eutric)-[ha RG (eu)]	13	0
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	18	0
	Homestead-[Homestead]	23	0
	Vertic Epileptic Cambisol (Eutric)-[vr el CM (eu)]	57	1
Total		**4966**	**100**

3.5 The different major soil types, and their respective proportions for Endamehoni Woreda-Mekan

Land Mapping Unt	Soil Mapping Unit	Area (ha)	Per cent
Level land,Plateau(LLL)		48	2
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	48	2
Sloping land,Dissected plain(SSP)		231	10
	Haplic Regosol (Eutric)-[ha RG (eu)]	82	3
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	85	4
	Homestead-[Homestead]	64	3
Sloping land,Medium-gradient escarpment zone(SSE)		963	40
	Haplic Fluvisol (Eutric)-[ha FL (eu)]	91	4
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	140	6
	Haplic Regosol (Eutric)-[ha RG (eu)]	262	11
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	97	4
	Homestead-[Homestead]	83	3
	Vertic Cambisol (Eutric)-[vr CM (eu)]	288	12
Sloping land,Medium-gradient hill(SSH)		574	24
	Haplic Fluvisol (Eutric)-[ha FL (eu)]	32	1
	Haplic Regosol (Eutric)-[ha RG (eu)]	37	2
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	451	19
	Homestead-[Homestead]	54	2
Sloping land,Medium-gradient valley(SSV)		116	5
	Haplic Fluvisol (Eutric)-[ha FL (eu)]	12	0
	Haplic Regosol (Eutric)-[ha RG (eu)]	6	0
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	78	3
	Homestead-[Homestead]	12	0
	Vertic Cambisol (Eutric)-[vr CM (eu)]	8	0

Land Mapping Unt	Soil Mapping Unit	Area (ha)	Per cent
Steep land,High-gradient hill(TTH)		54	2
	Haplic Fluvisol (Eutric)-[ha FL (eu)]	3	0
	Haplic Regosol (Eutric)-[ha RG (eu)]	34	1
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	10	0
	Vertic Cambisol (Eutric)-[vr CM (eu)]	7	0
Steep land,High-gradient mountain(TTM)		449	18
	Haplic Fluvisol (Eutric)-[ha FL (eu)]	2	0
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	189	8
	Haplic Regosol (Eutric)-[ha RG (eu)]	233	10
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	8	0
	Homestead-[Homestead]	1	0
	Vertic Cambisol (Eutric)-[vr CM (eu)]	15	1
Total		**2435**	**100**

3.6 The different major soil types, and their respective proportions for Endamehoni Woreda-Meswati

Land Mapping Unt	Soil Mapping Unit	Area (ha)	Per cent
Sloping land,Dissected plain(SSP)		432	8
	Built-up Areas-[Built-up Areas]	0	0
	Calcic Vertisol (Eutric, Pellic)-[cc VR (eu, pe)]	68	1
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	135	2
	Haplic Regosol (Eutric)-[ha RG (eu)]	33	1
	Homestead-[Homestead]	86	2
	Vertic Cambisol (Eutric)-[vr CM (eu)]	109	2
Sloping land,Medium-gradient escarpment zone(SSE)		852	15
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	678	12
	Haplic Regosol (Eutric)-[ha RG (eu)]	77	1
	Homestead-[Homestead]	12	0
	Leptic Cambisol (Eutric)-[le CM (eu)]	84	2
	Vertic Cambisol (Eutric)-[vr CM (eu)]	1	0
Sloping land,Medium-gradient hill(SSH)		26	0
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	26	0
Sloping land,Medium-gradient valley(SSV)		603	11
	Built-up Areas-[Built-up Areas]	39	1
	Calcic Vertisol (Eutric, Pellic)-[cc VR (eu, pe)]	342	6
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	50	1
	Haplic Regosol (Eutric)-[ha RG (eu)]	90	2
	Homestead-[Homestead]	22	0
	Vertic Cambisol (Eutric)-[vr CM (eu)]	60	1

Land Mapping Unt	Soil Mapping Unit	Area (ha)	Per cent
Steep land,High-gradient escarpment zone(TTE)		558	10
	Built-up Areas-[Built-up Areas]	22	0
	Calcic Vertisol (Eutric, Pellic)-[cc VR (eu, pe)]	8	0
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	297	5
	Haplic Regosol (Eutric)-[ha RG (eu)]	154	3
	Homestead-[Homestead]	7	0
	Vertic Cambisol (Eutric)-[vr CM (eu)]	71	1
Steep land,High-gradient hill(TTH)		139	2
	Calcic Vertisol (Eutric, Pellic)-[cc VR (eu, pe)]	1	0
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	96	2
	Haplic Regosol (Eutric)-[ha RG (eu)]	9	0
	Homestead-[Homestead]	20	0
	Vertic Cambisol (Eutric)-[vr CM (eu)]	13	0
Steep land,High-gradient mountain(TTM)		2975	53
	Calcic Vertisol (Eutric, Pellic)-[cc VR (eu, pe)]	16	0
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	2788	50
	Haplic Regosol (Eutric)-[ha RG (eu)]	71	1
	Homestead-[Homestead]	33	1
	Leptic Cambisol (Eutric)-[le CM (eu)]	47	1
	Vertic Cambisol (Eutric)-[vr CM (eu)]	20	0
Total		**5585**	**100**

3.7 The different major soil types, and their respective proportions for Endamehoni Woreda-Shibta Kebele

Land Mapping Unt	Soil Mapping Unit	Area (ha)	Per cent
Sloping land,Medium-gradient escarpment zone(SSE)		2230	44
	Haplic Fluvisol (Eutric)-[ha FL (eu)]	191	4
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	1355	27
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	1	0
	Homestead-[Homestead]	148	3
	Lithic Leptosol (Eutric)-[li LP (eu)]	240	5
	Vertic Cambisol (Eutric)-[vr CM (eu)]	295	6
Sloping land,Medium-gradient valley(SSV)		440	9
	Haplic Cambisol (Calcaric) (Thapto-Vertisolic)-[ha CM (ca,bVR)]	22	0
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	0	0
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	140	3
	Homestead-[Homestead]	21	0
	Vertic Cambisol (Eutric)-[vr CM (eu)]	257	5
Steep land,High-gradient escarpment zone(TTE)		51	1
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	40	1
	Lithic Leptosol (Eutric)-[li LP (eu)]	11	0
Steep land,High-gradient hill(TTH)		26	1
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	5	0
	Lithic Leptosol (Eutric)-[li LP (eu)]	21	0
	Vertic Cambisol (Eutric)-[vr CM (eu)]	0	0
Steep land,High-gradient mountain(TTM)		2296	46
	Haplic Cambisol (Calcaric) (Thapto-Vertisolic)-[ha CM (ca,bVR)]	16	0
	Haplic Fluvisol (Eutric)-[ha FL (eu)]	80	2
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	1380	27
	Homestead-[Homestead]	56	1
	Lithic Leptosol (Eutric)-[li LP (eu)]	722	14
	Vertic Cambisol (Eutric)-[vr CM (eu)]	42	1
Total		**5044**	**100**

3.8 The different major soil types, and their respective proportions for Endamehoni Woreda-Simret Kebele

Land Mapping Unt	Soil Mapping Unit	Area (ha)	Per cent
Sloping land,Medium-gradient escarpment zone(SSE)		1125	26
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	238	5
	Haplic Regosol (Eutric)-[ha RG (eu)]	86	2
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	134	3
	Homestead-[Homestead]	91	2
	Leptic Cambisol (Eutric)-[le CM (eu)]	17	0
	Lithic Leptosol (Eutric)-[li LP (eu)]	203	5
	Vertic Cambisol (Eutric)-[vr CM (eu)]	357	8
Sloping land,Medium-gradient valley(SSV)		373	8
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	0	0
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	262	6
	Homestead-[Homestead]	33	1
	Vertic Cambisol (Eutric)-[vr CM (eu)]	78	2
Steep land,High-gradient escarpment zone(TTE)		31	1
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	6	0
	Haplic Regosol (Eutric)-[ha RG (eu)]	25	1
Steep land,High-gradient hill(TTH)		29	1
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	9	0
	Haplic Regosol (Eutric)-[ha RG (eu)]	1	0
	Lithic Leptosol (Eutric)-[li LP (eu)]	15	0
	Vertic Cambisol (Eutric)-[vr CM (eu)]	3	0

Land Mapping Unt	Soil Mapping Unit	Area (ha)	Per cent
Steep land,High-gradient mountain(TTM)		2853	65
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	1583	36
	Haplic Regosol (Eutric)-[ha RG (eu)]	86	2
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	31	1
	Homestead-[Homestead]	46	1
	Leptic Cambisol (Eutric)-[le CM (eu)]	135	3
	Lithic Leptosol (Eutric)-[li LP (eu)]	943	21
	Vertic Cambisol (Eutric)-[vr CM (eu)]	28	1
Total		**4411**	**100**

3.9 The different major soil types, and their respective proportions for Ofla Woreda-Adigolo Kebele

Land Mapping Unt	Soil Mapping Unit	Area (ha)	Per cent
Lake (L)		9	0
	Lake (L)	9	0
Level land,Depression(LLD)		400	9
	Haplic Cambisol (Eutric)-[ha CM (eu)]	46	1
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	322	7
	Homestead-[Homestead]	32	1
Sloping land,Dissected plain(SSP)		95	2
	Haplic Cambisol (Eutric)-[ha CM (eu)]	7	0
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	17	0
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	33	1
	Homestead-[Homestead]	38	1
Sloping land,Medium-gradient escarpment zone(SSE)		747	16
	Haplic Cambisol (Eutric)-[ha CM (eu)]	67	1
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	661	14
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	3	0
	Homestead-[Homestead]	17	0
Sloping land,Medium-gradient valley(SSV)		1287	28
	Gleyic Calcic Fluvisol (Eutric)-[gl cc FL (eu)]	70	2
	Haplic Cambisol (Eutric)-[ha CM (eu)]	305	7
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	158	3
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	672	15
	Homestead-[Homestead]	82	2

Land Mapping Unt	Soil Mapping Unit	Area (ha)	Per cent
Steep land,High-gradient escarpment zone(TTE)		468	10
	Gleyic Calcic Fluvisol (Eutric)-[gl cc FL (eu)]	13	0
	Haplic Cambisol (Eutric)-[ha CM (eu)]	91	2
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	69	2
	Haplic Regosol (Eutric)-[ha RG (eu)]	46	1
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	105	2
	Homestead-[Homestead]	143	3
Steep land,High-gradient hill(TTH)		96	2
	Gleyic Calcic Fluvisol (Eutric)-[gl cc FL (eu)]	8	0
	Haplic Cambisol (Eutric)-[ha CM (eu)]	3	0
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	40	1
	Haplic Regosol (Eutric)-[ha RG (eu)]	21	0
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	3	0
	Homestead-[Homestead]	21	0
Steep land,High-gradient mountain(TTM)		1498	33
	Gleyic Calcic Fluvisol (Eutric)-[gl cc FL (eu)]	0	0
	Haplic Cambisol (Eutric)-[ha CM (eu)]	12	0
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	1480	32
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	3	0
	Homestead-[Homestead]	2	0
Total		**4600**	**100**

3.10 The different major soil types, and their respective proportions for Ofla Woreda-Hashenge Kebele

Land Mapping Unt	Soil Mapping Unit	Area (ha)	Per cent
Lake (L)		1362	26
	Lake (L)	1362	26
Level land,Depression(LLD)		580	11
	Gleyic Calcic Fluvisol (Eutric)-[gl cc FL (eu)]	467	9
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	86	2
	Lake-[Lake]	28	1
Sloping land,Dissected plain(SSP)		265	5
	Gleyic Calcic Fluvisol (Eutric)-[gl cc FL (eu)]	1	0
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	86	2
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	40	1
	Homestead-[Homestead]	94	2
	Vertic Epileptic Cambisol (Eutric)-[vr el CM (eu)]	44	1
Sloping land,Medium-gradient escarpment zone(SSE)	Sloping land,Medium-gradient escarpment zone(SSE)	163	3
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	60	1
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	4	0
	Homestead-[Homestead]	71	1
	Vertic Epileptic Cambisol (Eutric)-[vr el CM (eu)]	28	1
Sloping land,Medium-gradient valley(SSV)		267	5
	Gleyic Calcic Fluvisol (Eutric)-[gl cc FL (eu)]	3	0
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	259	5
	Homestead-[Homestead]	4	0
	Lake-[Lake]	1	0

Land Mapping Unt	Soil Mapping Unit	Area (ha)	Per cent
Steep land,High-gradient escarpment zone(TTE)		172	3
	Gleyic Calcic Fluvisol (Eutric)-[gl cc FL (eu)]	54	1
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	49	1
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	4	0
	Homestead-[Homestead]	20	0
	Lake-[Lake]	4	0
	Vertic Epileptic Cambisol (Eutric)-[vr el CM (eu)]	40	1
Steep land,High-gradient hill(TTH)		1005	19
	Gleyic Calcic Fluvisol (Eutric)-[gl cc FL (eu)]	337	7
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	57	1
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	474	9
	Homestead-[Homestead]	46	1
	Lake-[Lake]	7	0
	Vertic Epileptic Cambisol (Eutric)-[vr el CM (eu)]	84	2
Steep land,High-gradient mountain(TTM)		1173	23
	Gleyic Calcic Fluvisol (Eutric)-[gl cc FL (eu)]	3	0
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	1018	20
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	1	0
	Homestead-[Homestead]	134	3
	Vertic Epileptic Cambisol (Eutric)-[vr el CM (eu)]	17	0
Steep land,High-gradient valley(TTV)		180	3
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	180	3
Total		**5167**	**100**

3.11 The different major soil types, and their respective proportions for Ofla Woreda- Hugmburda Kebele

Land Mapping Unt	Soil Mapping Unit	Area (ha)	Per cent
Level land,Depression(LLD)		160	5
	Gleyic Calcic Fluvisol (Eutric)-[gl cc FL (eu)]	108	3
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	53	2
Sloping land,Dissected plain(SSP)		83	2
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	4	0
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	21	1
	Homestead-[Homestead]	21	1
	Vertic Epileptic Cambisol (Eutric)-[vr el CM (eu)]	37	1
Sloping land,Medium-gradient escarpment zone(SSE)		497	14
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	210	6
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	14	0
	Homestead-[Homestead]	43	1
	Leptic Cambisol (Eutric)-[le CM (eu)]	128	4
	Vertic Epileptic Cambisol (Eutric)-[vr el CM (eu)]	102	3
Sloping land,Medium-gradient hill(SSH)		90	3
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	20	1
	Homestead-[Homestead]	16	0
	Vertic Epileptic Cambisol (Eutric)-[vr el CM (eu)]	54	2

3.12 The different major soil types, and their respective proportions for Ofla Woreda- Menkere Kebele

Land Mapping Unt	Soil Mapping Unit	Area (ha)	Per cent
Steep land,High-gradient hill(TTH)		402	17
	Haplic Cambisol (Eutric)-[ha CM (eu)]	41	2
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	15	1
	Haplic Regosol (Eutric)-[ha RG (eu)]	101	4
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	225	9
	Homestead-[Homestead]	17	1
	Vertic Epileptic Cambisol (Eutric)-[vr el CM (eu)]	3	0
Steep land,High-gradient mountain(TTM)		1002	41
	Haplic Cambisol (Eutric)-[ha CM (eu)]	12	1
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	943	39
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	2	0
	Homestead-[Homestead]	40	2
	Vertic Epileptic Cambisol (Eutric)-[vr el CM (eu)]	4	0
Steep land,High-gradient valley(TTV)		22	1
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	22	1
Total		**2428**	**100**

3.13 The different major soil types, and their respective proportions for Raya Alamata Woreda- Gerjele Kebele

Land Mapping Unt	Soil Mapping Unit	Area (ha)	Per cent
Level land,Plain(LLP)		2556	56
	Gleyic Calcic Fluvisol (Eutric)-[gl cc FL (eu)]	202	4
	Haplic Cambisol (Calcaric) (Thapto-Vertisolic)-[ha CM (ca,bVR)]	115	3
	Haplic Fluvisol (Eutric)-[ha FL (eu)]	77	2
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	1839	40
	Homestead-[Homestead]	325	7
Sloping land,Medium-gradient escarpment zone(SSE)		620	14
	Haplic Cambisol (Calcaric) (Thapto-Vertisolic)-[ha CM (ca,bVR)]	106	2
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	488	11
	Homestead-[Homestead]	25	1
Sloping land,Medium-gradient hill(SSH)		851	19
	Built-up Areas-[Built-up Areas]	10	0
	Haplic Cambisol (Calcaric) (Thapto-Vertisolic)-[ha CM (ca,bVR)]	603	13
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	102	2
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	80	2
	Homestead-[Homestead]	56	1
Steep land,High-gradient hill(TTH)		73	2
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	73	2
Steep land,High-gradient mountain(TTM)		449	10
	Haplic Cambisol (Calcaric) (Thapto-Vertisolic)-[ha CM (ca,bVR)]	3	0
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	446	10
Steep land,High-gradient valley(TTV)		32	1
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	32	1
Total		**4582**	**100**

3.14 The different major soil types, and their respective proportions for Raya Alamata Woreda- Selambi Kalsi Kebele

Land Mapping Unt	Soil Mapping Unit	Area (ha)	Per cent
Level land,Plain(LLP)		3457	67
	Calcic Vertisol (Eutric, Pellic)-[cc VR (eu, pe)]	267	5
	Gleyic Calcic Fluvisol (Eutric)-[gl cc FL (eu)]	2877	56
	Haplic Cambisol (Eutric)-[ha CM (eu)]	223	4
	Homestead-[Homestead]	90	2
Sloping land,Medium-gradient escarpment zone(SSE)		714	14
	Gleyic Calcic Fluvisol (Eutric)-[gl cc FL (eu)]	5	0
	Haplic Cambisol (Eutric)-[ha CM (eu)]	8	0
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	701	14
Sloping land,Medium-gradient hill(SSH)		469	9
	Calcic Vertisol (Eutric, Pellic)-[cc VR (eu, pe)]	103	2
	Gleyic Calcic Fluvisol (Eutric)-[gl cc FL (eu)]	79	2
	Haplic Cambisol (Eutric)-[ha CM (eu)]	193	4
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	94	2
Steep land,High-gradient hill(TTH)		11	0
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	11	0
Steep land,High-gradient mountain(TTM)		393	8
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	393	8
Steep land,High-gradient valley(TTV)		91	2
	Calcic Vertisol (Eutric, Pellic)-[cc VR (eu, pe)]	0	0
	Gleyic Calcic Fluvisol (Eutric)-[gl cc FL (eu)]	3	0
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	88	2
Total		**5136**	**100**

3.15 The different major soil types, and their respective proportions for Raya Alamata Woreda-Tao Kebele

Land Mapping Unt	Soil Mapping Unit	Area (ha)	Per cent
Level land,Plain(LLP)		3687	88
	Haplic Fluvisol (Eutric)-[ha FL (eu)]	109	3
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	11	0
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	2330	56
	Homestead-[Homestead]	597	14
	Vertic Cambisol (Calcaric)-[vr CM (ca)]	640	15
Sloping land,Dissected plain(SSP)		53	1
	Haplic Fluvisol (Eutric)-[ha FL (eu)]	8	0
	Homestead-[Homestead]	45	1
Sloping land,Medium-gradient escarpment zone(SSE)		62	1
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	37	1
	Homestead-[Homestead]	25	1
Sloping land,Medium-gradient hill(SSH)		347	8
	Haplic Fluvisol (Eutric)-[ha FL (eu)]	6	0
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	50	1
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	80	2
	Homestead-[Homestead]	158	4
	Vertic Cambisol (Calcaric)-[vr CM (ca)]	53	1
Steep land,High-gradient hill(TTH)		24	1
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	23	1
	Homestead-[Homestead]	0	0
Total		**4173**	**100**

3.16 The different major soil types, and their respective proportions for Raya Alamata Woreda- Tumuga Kebele

Land Mapping Unt	Soil Mapping Unit	Area (ha)	Per cent
Level land,Plain(LLP)		3070	51
	Built-up Areas-[Built-up Areas]	51	1
	Calcic Vertisol (Eutric)-[cc VR (eu)]	823	14
	Gleyic Calcic Fluvisol (Eutric)-[gl cc FL (eu)]	484	8
	Haplic Cambisol (Calcaric) (Thapto-Vertisolic)-[ha CM (ca,bVR)]	1549	26
	Homestead-[Homestead]	162	3
Sloping land,Dissected plain(SSP)		333	6
	Gleyic Calcic Fluvisol (Eutric)-[gl cc FL (eu)]	3	0
	Haplic Cambisol (Calcaric) (Thapto-Vertisolic)-[ha CM (ca,bVR)]	58	1
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	249	4
	Homestead-[Homestead]	24	0
Sloping land,Medium-gradient escarpment zone(SSE)		678	11
	Gleyic Calcic Fluvisol (Eutric)-[gl cc FL (eu)]	1	0
	Haplic Cambisol (Calcaric) (Thapto-Vertisolic)-[ha CM (ca,bVR)]	32	1
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	644	11
	Homestead-[Homestead]	0	0

Land Mapping Unt	Soil Mapping Unit	Area (ha)	Per cent
Sloping land,Medium-gradient hill(SSH)		1294	22
	Built-up Areas-[Built-up Areas]	11	0
	Calcic Vertisol (Eutric)-[cc VR (eu)]	40	1
	Gleyic Calcic Fluvisol (Eutric)-[gl cc FL (eu)]	90	1
	Haplic Cambisol (Calcaric) (Thapto-Vertisolic)-[ha CM (ca,bVR)]	860	14
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	173	3
	Homestead-[Homestead]	120	2
Steep land,High-gradient hill(TTH)		64	1
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	64	1
Steep land,High-gradient mountain(TTM)	Steep land,High-gradient mountain(TTM)	547	9
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	547	9
Total		**5986**	**100**

3.17 The different major soil types, and their respective proportions for Raya Azebo Woreda- Ebo Kebele

Land Mapping Unt	Soil Mapping Unit	Area (ha)	Per cent
Level land,Plain(LLP)		358	5
	Calcic Vertisol (Eutric, Pellic)-[cc VR (eu, pe)]	302	5
	Haplic Regosol (Eutric)-[ha RG (eu)]	22	0
	Homestead-[Homestead]	34	1
Sloping land,Dissected plain(SSP)		677	10
	Calcic Vertisol (Eutric, Pellic)-[cc VR (eu, pe)]	92	1
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	442	7
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	81	1
	Homestead-[Homestead]	62	1
Sloping land,Medium-gradient escarpment zone(SSE)		1741	27
	Calcic Vertisol (Eutric, Pellic)-[cc VR (eu, pe)]	15	0
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	1320	20
	Haplic Regosol (Eutric)-[ha RG (eu)]	207	3
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	90	1
	Homestead-[Homestead]	109	2
Sloping land,Medium-gradient hill(SSH)		867	13
	Calcic Vertisol (Eutric, Pellic)-[cc VR (eu, pe)]	387	6
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	90	1
	Haplic Regosol (Eutric)-[ha RG (eu)]	147	2
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	150	2
	Homestead-[Homestead]	94	1

Land Mapping Unt	Soil Mapping Unit	Area (ha)	Per cent
Steep land,High-gradient escarpment zone(TTE)		132	2
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	131	2
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	1	0
Steep land,High-gradient hill(TTH)		254	4
	Calcic Vertisol (Eutric, Pellic)-[cc VR (eu, pe)]	18	0
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	224	3
	Homestead-[Homestead]	12	0
Steep land,High-gradient mountain(TTM)		2455	37
	Calcic Vertisol (Eutric, Pellic)-[cc VR (eu, pe)]	2	0
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	2380	36
	Haplic Regosol (Eutric)-[ha RG (eu)]	56	1
	Homestead-[Homestead]	17	0
Steep land,High-gradient valley(TTV)		67	1
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	67	1
Total		**6552**	**100**

3.18 The different major soil types, and their respective proportions for Raya Azebo Woreda- Genete Kebele

Land Mapping Unt	Soil Mapping Unit	Area (ha)	Per cent
Level land,Plain(LLP)		1686	26
	Calcic Vertisol (Eutric, Pellic)-[cc VR (eu, pe)]	821	13
	Gleyic Calcic Fluvisol (Eutric)-[gl cc FL (eu)]	130	2
	Haplic Vertisol (Calcaric)-[ha VR (ca)]	558	9
	Homestead-[Homestead]	176	3
Sloping land,Dissected plain(SSP)		118	2
	Gleyic Calcic Fluvisol (Eutric)-[gl cc FL (eu)]	6	0
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	109	2
	Haplic Regosol (Eutric)-[ha RG (eu)]	2	0
Sloping land,Medium-gradient escarpment zone(SSE)		1304	20
	Calcic Vertisol (Eutric, Pellic)-[cc VR (eu, pe)]	125	2
	Gleyic Calcic Fluvisol (Eutric)-[gl cc FL (eu)]	60	1
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	968	15
	Homestead-[Homestead]	144	2
	Leptic Regosol (Eutric)-[le RG (eu)]	7	0
Sloping land,Medium-gradient hill(SSH)		2162	34
	Calcic Vertisol (Eutric, Pellic)-[cc VR (eu, pe)]	890	14
	Gleyic Calcic Fluvisol (Eutric)-[gl cc FL (eu)]	517	8
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	258	4
	Haplic Regosol (Eutric)-[ha RG (eu)]	32	1
	Haplic Vertisol (Calcaric)-[ha VR (ca)]	258	4
	Homestead-[Homestead]	194	3
	Leptic Regosol (Eutric)-[le RG (eu)]	13	0

Land Mapping Unt	Soil Mapping Unit	Area (ha)	Per cent
Steep land,High-gradient hill(TTH)		133	2
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	127	2
	Haplic Vertisol (Calcaric)-[ha VR (ca)]	0	0
	Homestead-[Homestead]	5	0
Steep land,High-gradient mountain(TTM)		968	15
	Calcic Vertisol (Eutric, Pellic)-[cc VR (eu, pe)]	1	0
	Gleyic Calcic Fluvisol (Eutric)-[gl cc FL (eu)]	10	0
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	956	15
	Homestead-[Homestead]	1	0
Total		**6371**	**100**

3.19 The different major soil types, and their respective proportions for Raya Azebo Woreda- Kara Adishabo Kebele

Land Mapping Unt	Soil Mapping Unit	Area (ha)	Per cent
Level land,Plain(LLP)		6108	72
	Gleyic Calcic Fluvisol (Eutric)-[gl cc FL (eu)]	85	1
	Haplic Vertisol (Calcaric)-[ha VR (ca)]	4438	52
	Homestead-[Homestead]	1473	17
	Vertic Cambisol (Calcaric)-[vr CM (ca)]	112	1
Sloping land,Dissected plain(SSP)		18	0
	Haplic Vertisol (Calcaric)-[ha VR (ca)]	18	0
Sloping land,Medium-gradient escarpment zone(SSE)		367	4
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	299	4
	Haplic Vertisol (Calcaric)-[ha VR (ca)]	35	0
	Vertic Cambisol (Calcaric)-[vr CM (ca)]	33	0
Sloping land,Medium-gradient hill(SSH)		1016	12
	Gleyic Calcic Fluvisol (Eutric)-[gl cc FL (eu)]	20	0
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	95	1
	Haplic Vertisol (Calcaric)-[ha VR (ca)]	322	4
	Homestead-[Homestead]	130	2
	Vertic Cambisol (Calcaric)-[vr CM (ca)]	449	5
Steep land,High-gradient mountain(TTM)		1007	12
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	984	12
	Haplic Vertisol (Calcaric)-[ha VR (ca)]	23	0
Total		**8516**	**100**

3.20 The different major soil types, and their respective proportions for Raya Azebo Woreda- Tsigaa Wargiba Kebele

Land Mapping Unt	Soil Mapping Unit	Area (ha)	Per cent
Level land,Plain(LLP)		5210	55
	Built-up Areas-[Built-up Areas]	178	2
	Calcic Vertisol (Eutric, Pellic)-[cc VR (eu, pe)]	4220	45
	Gleyic Calcic Fluvisol (Eutric)-[gl cc FL (eu)]	325	3
	Homestead-[Homestead]	488	5
Sloping land,Medium-gradient escarpment zone(SSE)		1089	12
	Calcic Vertisol (Eutric, Pellic)-[cc VR (eu, pe)]	297	3
	Gleyic Calcic Fluvisol (Eutric)-[gl cc FL (eu)]	11	0
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	654	7
	Homestead-[Homestead]	94	1
	Leptic Regosol (Eutric)-[le RG (eu)]	33	0
Sloping land,Medium-gradient hill(SSH)		1110	12
	Calcic Vertisol (Eutric, Pellic)-[cc VR (eu, pe)]	773	8
	Gleyic Calcic Fluvisol (Eutric)-[gl cc FL (eu)]	62	1
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	103	1
	Homestead-[Homestead]	114	1
	Leptic Regosol (Eutric)-[le RG (eu)]	58	1

Land Mapping Unt	Soil Mapping Unit	Area (ha)	Per cent
Steep land,High-gradient escarpment zone(TTE)		3	0
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	3	0
Steep land,High-gradient hill(TTH)	Steep land,High-gradient hill(TTH)	57	1
	Calcic Vertisol (Eutric, Pellic)-[cc VR (eu, pe)]	0	0
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	51	1
	Homestead-[Homestead]	6	0
Steep land,High-gradient mountain(TTM)		1945	21
	Calcic Vertisol (Eutric, Pellic)-[cc VR (eu, pe)]	19	0
	Gleyic Calcic Fluvisol (Eutric)-[gl cc FL (eu)]	1	0
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	1924	20
	Leptic Regosol (Eutric)-[le RG (eu)]	1	0
Total		**9414**	**100**

Annex 5: Proportion of Soil types per land mapping units according to woreda

4.1 Proportion soils per land mapping unit of Alaje Woreda

Land Mapping Unt	Soil Mapping Unit	Area (ha)	Per cent
Sloping land, Dissected plain (SSP)		285	2
	Endogleyic Cambisol (Eutric) (Thapto-Vertisolic)-[ng CM (eu, bVR)]	30	0
	Haplic Cambisol (Eutric)-[ha CM (eu)]	79	0
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	61	0
	Haplic Regosol (Eutric)-[ha RG (eu)]	60	0
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	4	0
	Homestead-[Homestead]	27	0
	Leptic Regosol (Eutric)-[le RG (eu)]	24	0
Sloping land, Medium-gradient escarpment zone (SSE)		5410	30
	Built-up Areas-[Built-up Areas]	21	0
	Calcic Vertisol (Eutric, Pellic)-[cc VR (eu, pe)]	430	2
	Endogleyic Cambisol (Eutric) (Thapto-Vertisolic)-[ng CM (eu, bVR)]	17	0
	Gleyic Calcic Fluvisol (Eutric)-[gl cc FL (eu)]	6	0
	Haplic Cambisol (Eutric)-[ha CM (eu)]	204	1
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	1827	10
	Haplic Regosol (Eutric)-[ha RG (eu)]	808	5
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	680	4
	Homestead-[Homestead]	602	3
	Leptic Regosol (Eutric)-[le RG (eu)]	648	4
	Vertic Epileptic Cambisol (Eutric)-[vr el CM (eu)]	167	1
Sloping land, Medium-gradient valley (SSV)		2662	15
	Built-up Areas-[Built-up Areas]	121	1
	Calcic Vertisol (Eutric, Pellic)-[cc VR (eu, pe)]	122	1

	Endogleyic Cambisol (Eutric) (Thapto-Vertisolic)-[ng CM (eu, bVR)]	233	1
	Gleyic Calcic Fluvisol (Eutric)-[gl cc FL (eu)]	179	1
	Haplic Cambisol (Eutric)-[ha CM (eu)]	160	1
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	188	1
	Haplic Regosol (Eutric)-[ha RG (eu)]	11	0
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	1249	7
	Homestead-[Homestead]	90	1
	Leptic Regosol (Eutric)-[le RG (eu)]	39	0
	Vertic Epileptic Cambisol (Eutric)-[vr el CM (eu)]	270	2
Steep land, High-gradient hill (TTH)		212	1
	Built-up Areas-[Built-up Areas]	29	0
	Calcic Vertisol (Eutric, Pellic)-[cc VR (eu, pe)]	2	0
	Gleyic Calcic Fluvisol (Eutric)-[gl cc FL (eu)]	0	0
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	121	1
	Haplic Regosol (Eutric)-[ha RG (eu)]	18	0
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	4	0
	Homestead-[Homestead]	1	0
	Leptic Regosol (Eutric)-[le RG (eu)]	26	0
	Vertic Epileptic Cambisol (Eutric)-[vr el CM (eu)]	10	0
Steep land, High-gradient mountain (TTM)		9081	51
	Calcic Vertisol (Eutric, Pellic)-[cc VR (eu, pe)]	118	1
	Endogleyic Cambisol (Eutric) (Thapto-Vertisolic)-[ng CM (eu, bVR)]	0	0
	Haplic Cambisol (Eutric)-[ha CM (eu)]	14	0
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	5054	28
	Haplic Regosol (Eutric)-[ha RG (eu)]	423	2
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	235	1
	Homestead-[Homestead]	281	2
	Leptic Regosol (Eutric)-[le RG (eu)]	2864	16
	Vertic Epileptic Cambisol (Eutric)-[vr el CM (eu)]	93	1
Steep land, High-gradient valley (TTV)		239	1

Endogleyic Cambisol (Eutric) (Thapto-Vertisolic)-[ng CM (eu, bVR)]	52	0
Haplic Cambisol (Eutric)-[ha CM (eu)]	47	0
Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	20	0
Haplic Regosol (Eutric)-[ha RG (eu)]	13	0
Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	18	0
Homestead-[Homestead]	26	0
Vertic Epileptic Cambisol (Eutric)-[vr el CM (eu)]	63	0
	17889	100

4.2 Proportion soils per land mapping unit of Endamoheni Woreda

Land Mapping Unt	Soil Mapping Unit	Area (ha)	Per cent
Level land, Plateau (LLL)		48	0
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	48	0
Sloping land, Dissected plain (SSP)		663	4
	Built-up Areas-[Built-up Areas]	0	0
	Calcic Vertisol (Eutric, Pellic)-[cc VR (eu, pe)]	68	0
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	135	1
	Haplic Regosol (Eutric)-[ha RG (eu)]	115	1
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	85	0
	Homestead-[Homestead]	151	1
	Vertic Cambisol (Eutric)-[vr CM (eu)]	109	1
Sloping land, Medium-gradient escarpment zone (SSE)		5169	30
	Haplic Fluvisol (Eutric)-[ha FL (eu)]	283	2
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	2411	14
	Haplic Regosol (Eutric)-[ha RG (eu)]	424	2
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	232	1
	Homestead-[Homestead]	333	2
	Leptic Cambisol (Eutric)-[le CM (eu)]	102	1
	Lithic Leptosol (Eutric)-[li LP (eu)]	443	3
	Vertic Cambisol (Eutric)-[vr CM (eu)]	942	5
Sloping land, Medium-gradient hill (SSH)		600	3
	Haplic Fluvisol (Eutric)-[ha FL (eu)]	32	0
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	26	0
	Haplic Regosol (Eutric)-[ha RG (eu)]	37	0
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	451	3
	Homestead-[Homestead]	54	0
Sloping land, Medium-gradient valley (SSV)		1533	9
	Built-up Areas-[Built-up Areas]	39	0

	Calcic Vertisol (Eutric, Pellic)-[cc VR (eu, pe)]	342	2
	Haplic Cambisol (Calcaric) (Thapto-Vertisolic)-[ha CM (ca,bVR)]	22	0
	Haplic Fluvisol (Eutric)-[ha FL (eu)]	12	0
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	51	0
	Haplic Regosol (Eutric)-[ha RG (eu)]	96	1
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	479	3
	Homestead-[Homestead]	88	1
	Vertic Cambisol (Eutric)-[vr CM (eu)]	403	2
Steep land, High-gradient escarpment zone (TTE)		640	4
	Built-up Areas-[Built-up Areas]	22	0
	Calcic Vertisol (Eutric, Pellic)-[cc VR (eu, pe)]	8	0
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	343	2
	Haplic Regosol (Eutric)-[ha RG (eu)]	179	1
	Homestead-[Homestead]	7	0
	Lithic Leptosol (Eutric)-[li LP (eu)]	11	0
	Vertic Cambisol (Eutric)-[vr CM (eu)]	71	0
Steep land, High-gradient hill (TTH)		248	1
	Calcic Vertisol (Eutric, Pellic)-[cc VR (eu, pe)]	1	0
	Haplic Fluvisol (Eutric)-[ha FL (eu)]	3	0
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	110	1
	Haplic Regosol (Eutric)-[ha RG (eu)]	45	0
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	10	0
	Homestead-[Homestead]	20	0
	Lithic Leptosol (Eutric)-[li LP (eu)]	36	0
	Vertic Cambisol (Eutric)-[vr CM (eu)]	24	0
Steep land, High-gradient mountain (TTM)		8572	49
	Calcic Vertisol (Eutric, Pellic)-[cc VR (eu, pe)]	16	0
	Haplic Cambisol (Calcaric) (Thapto-Vertisolic)-[ha CM (ca,bVR)]	16	0
	Haplic Fluvisol (Eutric)-[ha FL (eu)]	82	0

Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	5940	34
Haplic Regosol (Eutric)-[ha RG (eu)]	390	2
Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	40	0
Homestead-[Homestead]	136	1
Leptic Cambisol (Eutric)-[le CM (eu)]	182	1
Lithic Leptosol (Eutric)-[li LP (eu)]	1665	10
Vertic Cambisol (Eutric)-[vr CM (eu)]	106	1
	17475	100

4.3 Proportion soils per land mapping unit of Ofla Woreda

Land Mapping Unt	Soil Mapping Unit	Area (ha)	Per cent
	Lake (L)	1371	9
Level land, Depression (LLD)		1163	7
	Gleyic Calcic Fluvisol (Eutric)-[gl cc FL (eu)]	574	4
	Haplic Cambisol (Eutric)-[ha CM (eu)]	46	0
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	483	3
	Homestead-[Homestead]	32	0
	Lake-[Lake]	28	0
Sloping land, Dissected plain (SSP)		772	5
	Gleyic Calcic Fluvisol (Eutric)-[gl cc FL (eu)]	1	0
	Haplic Cambisol (Eutric)-[ha CM (eu)]	7	0
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	429	3
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	100	1
	Homestead-[Homestead]	154	1
	Vertic Epileptic Cambisol (Eutric)-[vr el CM (eu)]	81	1
Sloping land, Medium-gradient escarpment zone (SSE)		1408	9
	Haplic Cambisol (Eutric)-[ha CM (eu)]	67	0
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	931	6
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	21	0
	Homestead-[Homestead]	130	1
	Leptic Cambisol (Eutric)-[le CM (eu)]	128	1
	Vertic Epileptic Cambisol (Eutric)-[vr el CM (eu)]	130	1
Sloping land, Medium-gradient hill (SSH)		90	1
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	20	0
	Homestead-[Homestead]	16	0
	Vertic Epileptic Cambisol (Eutric)-[vr el CM (eu)]	54	0
Sloping land, Medium-gradient valley (SSV)		1615	10
	Gleyic Calcic Fluvisol (Eutric)-[gl cc FL (eu)]	74	0
	Haplic Cambisol (Eutric)-[ha CM (eu)]	305	2

	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	417	3
	Haplic Regosol (Eutric)-[ha RG (eu)]	1	0
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	729	5
	Homestead-[Homestead]	87	1
	Lake-[Lake]	1	0
Steep land, High-gradient escarpment zone (TTE)		1230	8
	Gleyic Calcic Fluvisol (Eutric)-[gl cc FL (eu)]	67	0
	Haplic Cambisol (Eutric)-[ha CM (eu)]	202	1
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	171	1
	Haplic Regosol (Eutric)-[ha RG (eu)]	122	1
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	277	2
	Homestead-[Homestead]	338	2
	Lake-[Lake]	4	0
	Vertic Epileptic Cambisol (Eutric)-[vr el CM (eu)]	49	0
Steep land, High-gradient hill (TTH)		1892	12
	Gleyic Calcic Fluvisol (Eutric)-[gl cc FL (eu)]	387	2
	Haplic Cambisol (Eutric)-[ha CM (eu)]	45	0
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	115	1
	Haplic Regosol (Eutric)-[ha RG (eu)]	122	1
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	1004	6
	Homestead-[Homestead]	86	1
	Lake-[Lake]	7	0
	Vertic Epileptic Cambisol (Eutric)-[vr el CM (eu)]	126	1
Steep land, High-gradient mountain (TTM)		5406	34
	Gleyic Calcic Fluvisol (Eutric)-[gl cc FL (eu)]	4	0
	Haplic Cambisol (Eutric)-[ha CM (eu)]	24	0
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	4875	31
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	6	0
	Homestead-[Homestead]	225	1
	Leptic Cambisol (Eutric)-[le CM (eu)]	240	2
	Vertic Epileptic Cambisol (Eutric)-[vr el CM (eu)]	32	0

Steep land, High-gradient valley (TTV)		765	5
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	677	4
	Homestead-[Homestead]	19	0
	Leptic Cambisol (Eutric)-[le CM (eu)]	70	0
		15712	100

4.4 Proportion soils per land mapping unit of Raya Alamata Woreda

Land Mapping Unt	Soil Mapping Unit	Area (ha)	Per cent
Level land,Plain(LLP)		12771	64
	Built-up Areas-[Built-up Areas]	51	0
	Calcic Vertisol (Eutric)-[cc VR (eu)]	823	4
	Calcic Vertisol (Eutric, Pellic)-[cc VR (eu, pe)]	267	1
	Gleyic Calcic Fluvisol (Eutric)-[gl cc FL (eu)]	3563	18
	Haplic Cambisol (Calcaric) (Thapto-Vertisolic)-[ha CM (ca,bVR)]	1664	8
	Haplic Cambisol (Eutric)-[ha CM (eu)]	223	1
	Haplic Fluvisol (Eutric)-[ha FL (eu)]	186	1
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	11	0
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	4169	21
	Homestead-[Homestead]	1173	6
	Vertic Cambisol (Calcaric)-[vr CM (ca)]	640	3
Sloping land, Dissected plain (SSP)		387	2
	Gleyic Calcic Fluvisol (Eutric)-[gl cc FL (eu)]	3	0
	Haplic Cambisol (Calcaric) (Thapto-Vertisolic)-[ha CM (ca,bVR)]	58	0
	Haplic Fluvisol (Eutric)-[ha FL (eu)]	8	0
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	249	1
	Homestead-[Homestead]	69	0
Sloping land, Medium-gradient escarpment zone (SSE)		2073	10
	Gleyic Calcic Fluvisol (Eutric)-[gl cc FL (eu)]	6	0
	Haplic Cambisol (Calcaric) (Thapto-Vertisolic)-[ha CM (ca,bVR)]	138	1
	Haplic Cambisol (Eutric)-[ha CM (eu)]	8	0
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	1870	9
	Homestead-[Homestead]	50	0
Sloping land, Medium-gradient hill (SSH)		2961	15
	Built-up Areas-[Built-up Areas]	21	0

	Calcic Vertisol (Eutric)-[cc VR (eu)]	40	0
	Calcic Vertisol (Eutric, Pellic)-[cc VR (eu, pe)]	103	1
	Gleyic Calcic Fluvisol (Eutric)-[gl cc FL (eu)]	169	1
	Haplic Cambisol (Calcaric) (Thapto-Vertisolic)-[ha CM (ca,bVR)]	1463	7
	Haplic Cambisol (Eutric)-[ha CM (eu)]	193	1
	Haplic Fluvisol (Eutric)-[ha FL (eu)]	6	0
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	419	2
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	160	1
	Homestead-[Homestead]	334	2
	Vertic Cambisol (Calcaric)-[vr CM (ca)]	53	0
Steep land, High-gradient hill (TTH)		173	1
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	173	1
	Homestead-[Homestead]	0	0
Steep land, High-gradient mountain (TTM)		1389	7
	Haplic Cambisol (Calcaric) (Thapto-Vertisolic)-[ha CM (ca,bVR)]	3	0
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	1386	7
Steep land, High-gradient valley (TTV)		123	1
	Calcic Vertisol (Eutric, Pellic)-[cc VR (eu, pe)]	0	0
	Gleyic Calcic Fluvisol (Eutric)-[gl cc FL (eu)]	3	0
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	120	1
		19876	100

4.5 Proportion major soils per land mapping unit of Raya Azebo Woreda

Land Mapping Unt	Soil Mapping Unit	Area (ha)	Per cent
Level land, Plain (LLP)		13362	43
	Built-up Areas-[Built-up Areas]	178	1
	Calcic Vertisol (Eutric, Pellic)-[cc VR (eu, pe)]	5342	17
	Gleyic Calcic Fluvisol (Eutric)-[gl cc FL (eu)]	541	2
	Haplic Regosol (Eutric)-[ha RG (eu)]	22	0
	Haplic Vertisol (Calcaric)-[ha VR (ca)]	4996	16
	Homestead-[Homestead]	2171	7
	Vertic Cambisol (Calcaric)-[vr CM (ca)]	112	0
Sloping land, Dissected plain (SSP)		813	3
	Calcic Vertisol (Eutric, Pellic)-[cc VR (eu, pe)]	92	0
	Gleyic Calcic Fluvisol (Eutric)-[gl cc FL (eu)]	6	0
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	551	2
	Haplic Regosol (Eutric)-[ha RG (eu)]	2	0
	Haplic Vertisol (Calcaric)-[ha VR (ca)]	18	0
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	81	0
	Homestead-[Homestead]	62	0
Sloping land, Medium-gradient escarpment zone (SSE)		4501	15
	Calcic Vertisol (Eutric, Pellic)-[cc VR (eu, pe)]	437	1
	Gleyic Calcic Fluvisol (Eutric)-[gl cc FL (eu)]	71	0
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	3241	11
	Haplic Regosol (Eutric)-[ha RG (eu)]	207	1
	Haplic Vertisol (Calcaric)-[ha VR (ca)]	35	0
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	90	0
	Homestead-[Homestead]	348	1
	Leptic Regosol (Eutric)-[le RG (eu)]	40	0
	Vertic Cambisol (Calcaric)-[vr CM (ca)]	33	0
Sloping land, Medium-gradient hill (SSH)		5155	17
	Calcic Vertisol (Eutric, Pellic)-[cc VR (eu, pe)]	2050	7

	Gleyic Calcic Fluvisol (Eutric)-[gl cc FL (eu)]	599	2
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	546	2
	Haplic Regosol (Eutric)-[ha RG (eu)]	179	1
	Haplic Vertisol (Calcaric)-[ha VR (ca)]	580	2
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	150	0
	Homestead-[Homestead]	531	2
	Leptic Regosol (Eutric)-[le RG (eu)]	71	0
	Vertic Cambisol (Calcaric)-[vr CM (ca)]	449	1
Steep land, High-gradient escarpment zone (TTE)		134	0
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	134	0
	Haplic Vertisol (Eutric, Pellic)-[ha VR (eu, pe)]	1	0
Steep land, High-gradient hill (TTH)		444	1
	Calcic Vertisol (Eutric, Pellic)-[cc VR (eu, pe)]	18	0
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	402	1
	Haplic Vertisol (Calcaric)-[ha VR (ca)]	0	0
	Homestead-[Homestead]	23	0
Steep land, High-gradient mountain (TTM)		6376	21
	Calcic Vertisol (Eutric, Pellic)-[cc VR (eu, pe)]	21	0
	Gleyic Calcic Fluvisol (Eutric)-[gl cc FL (eu)]	11	0
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	6244	20
	Haplic Regosol (Eutric)-[ha RG (eu)]	56	0
	Haplic Vertisol (Calcaric)-[ha VR (ca)]	23	0
	Homestead-[Homestead]	18	0
	Leptic Regosol (Eutric)-[le RG (eu)]	1	0
Steep land, High-gradient valley (TTV)		67	0
	Haplic Leptosol (Eutric, Skeletic)-[ha LP (eu,sk)]	67	0
Total		30852	100