Characterization of Agricultural Soils in CASCAPE Intervention Woredas in Western Oromia Region

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1. Introduction

Understanding of soil properties and their distribution over a landscape is crucial for developing soil management practices that will maintain the productive potential of a soil. Also, good and appropriate advice to regional land use planning and agricultural extension services needs comprehensive knowledge of soil resources and soil fertility.

Though Ethiopia is endowed with a diverse soil types due to the diverse range of topography, geology and climatic conditions prevailing in the country, available information on the characteristics and spatial distribution of the soils and other land resources is rather scanty. The few existing soil resource inventories are of small scale nature with high level of generalization, being based on a rather few observations scattered over large areas. Therefore, absence of detailed and area specific soil surveys has hampered the sustainable use and management of the soil resources based on their potentials and limitations.

Upon understanding the problem posed by the lack of detailed information on the spatial distribution and characteristics of soils resources of the country in general and the problem of soil fertility as one of the key challenges to meet the five year (2011-2015) Growth and Transformation Plan (GTP) in particular, the government of Ethiopia has recently established a project called Ethiopian Soils Information System (EthioSIS) to establish national and regional soils and other land resources. Thus, soil characterization provides information that relates to certain soil fertility variables and predictions of soil responses to various management options.

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 a soil characterization study conducting

detailed soil profile studies and classification of agricultural soils in all 30 CASCAPE intervention woredas. This report presents the results for woredas in West Oromia region namely Omo Nada, Limu Saka, Gera, Didessa and Bedele Zuria weredas.

1.1. Objective of the study

The goal of the conducted study is to characterise and understand the qualities and behaviour of the major agricultural soils occurring in the 5 CASCAPE intervention woredas in western oromia region 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.

1.2. Specific Objectives

- To survey soil variability and to identify major soil types in each woreda (4 kebeles per woreda) through auger observations
- 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

1.3. Scope of the study

The scope of this report is the soil characterization study of 5 CASCAPE intervention woredas: Omo Nada, Limu Saka, Gera (in Jimma zone) and

Didessa and Bedele Zuria woredas (Illu abbabora zone) located in west oromia region (Fig. 1). The study has been carried out by Dr. Alemayehu Regassa.

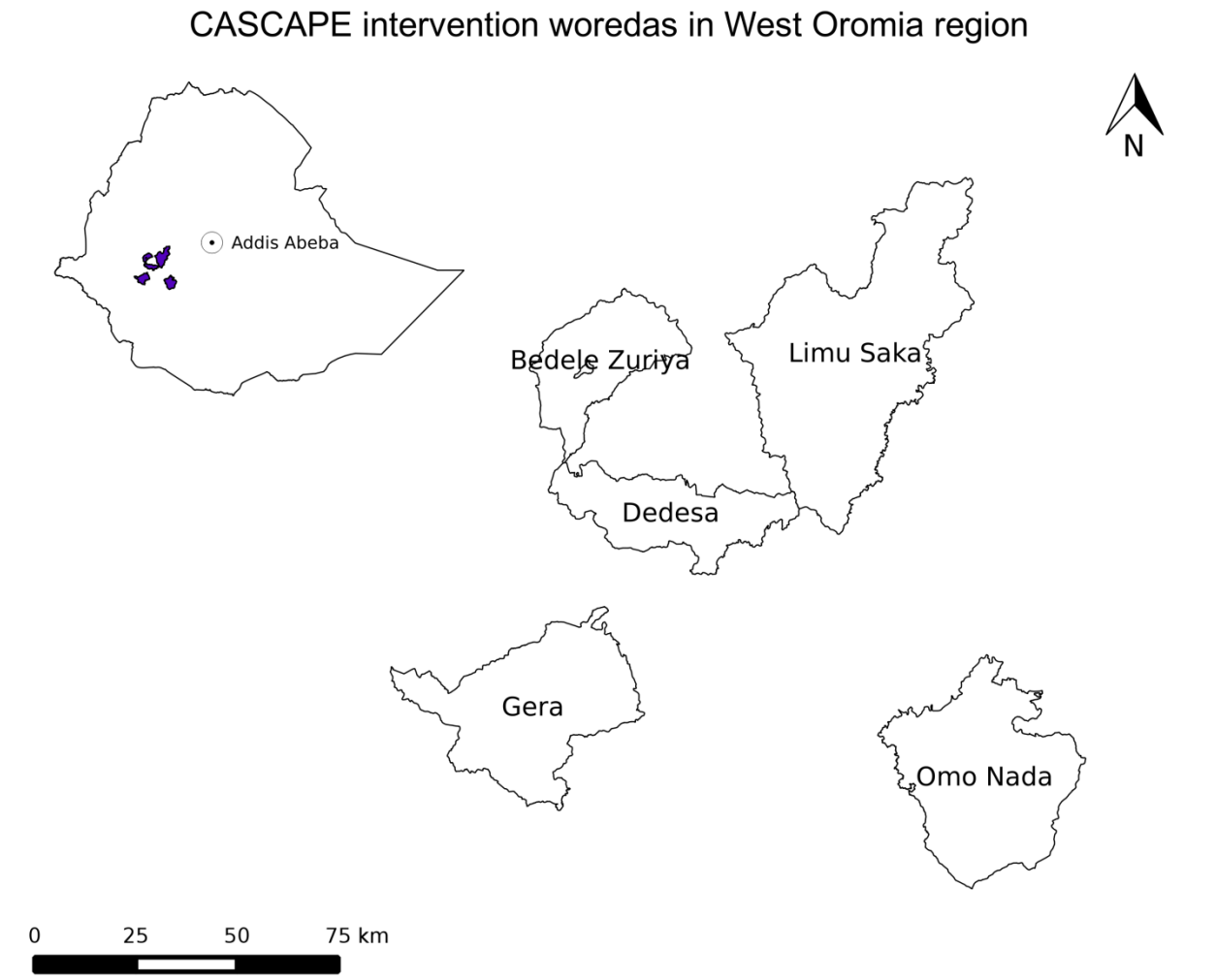

Figure 1. Location of the CASCAPE intervention woredas in Western Oromia regional cluster

2. Materials and Methods

The soil characterization activity was carried out in the following three consecutive phases: the pre-field work preparation phase, the field work

phase and the post field work data analysis, interpretation and report writing phases.

2.1. The pre-fieldwork preparation phase

Before starting the actual field work previous studies related to the survey area such as geomorphology and soils of Ethiopia, Omo-Gibe and Arjo-Didessa integrated master plan studies and other area specific studies Such as the Nada Asendabo watershed study by Sustainable Land Management (SLM) project in Omo nada and MSc thesis studies were collected and carefully studied. A CASCAPE PRA result of 2011 was obtained from west region, JU cluster office.

Topographic maps of the study areas at 1:50,000 scale were obtained from Ethiopian mapping agency and a preliminary interpretation map of land units was produced based on features such as density of contour lines, drainage alignment, land use and cover. In addition, slope maps were produced for each studied kebele from a 90 x 90m vertical resolution Digital Elevation Model (DEM). On the basis of the topographical maps and the slope maps it was possible to delineate physiographic units and identify linear features which was used as a base map for the subsequent actual field work.

The necessary soil survey facilities and formats such as the FAO guidelines for soil profile and auger description (FAO, 2006), Munsell soil color chart (Munsell color company, 1994), WRB soil classification manual (WRB Working Group, 2006), GPS, Clinometer, soil profile and auger description sheets etc were collected and prepared during this phase.

2.2. The fieldwork phase

The field work was done in three stages: reconnaissance, auger observation and description and soil profile description and sampling.

2.3. Reconnaissance

Aided by the base map and following a free survey method, reconnaissance trips were undertaken throughout the area along numerous traverses crossing the various physiographic units. Point locations for observation were identified and augere observations were made. Augers were described according to the standard description form and 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. Furthermore, visual observation of roadside cuts, gullies and river banks were made and correlatio,n between the physiographic units in the field and the interpreted units on the base maps was checked. The observation points were georeferenced by GPS.

2.4. Detailed profile description

Detailed characterization of soil profiles (soil pits) that are representative for the distinguished major soil types were made following the reconnaissance survey. 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). The designated soil horizons of the soil pits were sampled (about 1 kg per sample) for laboratory analysis. The samples were properly and traceably labeled and administrated.

2.5. Laboratory analysis

Soil samples were analysed in WWDSE laboratory following standard laboratory methods and procedures. pH was determined potentiometrically in water and in 1N KCl at the ratio of 1:2.5 soil-water and soil-KCl (McLean, 1982). Electrical conductivity (ECe) was determined by conductivity meter in a 1:2.5 soil-water suspension. Organic carbon was determined by the Walkley and Black wet oxidation method as outlined by Nelson and Sommers (1982). Total nitrogen was determined by Kjeldahl method (Bremner and Mulvaney, 1982). Available phosphorus was extracted by Bray and Kurtz-1 method (Bray and Kurtz, 1945) for soils with pHwater less than 7 and Olsen method for soils with pH water above 7 and determined spectrophotometrically (Murphy and Riley, 1962; Watanabe and Olsen, 1965). Cation Exchange Capacity (CEC) and exchangeable bases were determined by saturating soil with neutral 1M NH4OAc and the adsorbed NH4+ were displaced using 1M KCl and then determined by Kjeldahl distillation method for the estimation of CEC of the soil. The bases (Ca2+, Mg2+, Na+, K+) were determined by atomic absorption spectrophotometer. CEC of clay was calculated using the formula outlined by Baize (1993) which corrects for the CEC contributed by organic matter (OM) as follows: CEC clay = ({CEC soil - (%OM * 2)}/ % clay) * 100. The available micronutrients content of the soils (Fe, Mn, Zn, and Cu) was determined by diethylenetriaminepentaacetic acid (DTPA) method (Tan, 1996).

2.6. 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 profiles were classified according to Word Reference Base for soil resources (WRB Working Group, 2006). The report was written per woreda and includes a synthesis of the woreda. a description of the soil-

landscape, including distinguished major landforms & geology, major soil types, including proportions. 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. Agronomic management implications of the soil properties were discussed, with emphasis on the soil fertility management recommendations.

3. Results

3.1. Description of the environmental settings of the studied woredas

3.1.1. Omo Nada Woreda

Omo Nada woreda lies at 7°17'to 7°49'N 37°00' to 37°28'E. It is located at a distance of about 71 kms from the zonal capital town, Jimma. It is bordered by Dedo in the west, Sokoru in the North, kersa in the South and Tiro Afata in the east. According to the report of the Central Statistical Agency report of 2007 (CSA, 2007), the population of the woreda was estimated to be 254,417.

The rainfall of the area is bimodal, with unpredictable short rains from March to April and the main season ranging over June to September. The minimum and maximum annual rainfall ranges from 1066 to 1200mm with a mean annual temperature ranging from 18 to 25°C (SLMP, 2009).

The area is characterized by gentle, flat and undulating topography with the altitude ranging from 1650 – 2200 m.a.s.l.

The land cover categories of the woreda comprises 26.5% potential arable or cultivable land which include 23.4% annual crops and 7.0% pasture and

56.6% forest land and the remaining 9.9% was classified as degraded, built-up or otherwise unusable.

3.1.2. Limu saka

Limu Saka woreda is located at 100km from Jimma and 450 from Addis Ababa. It is bounded by Yaanfa woreda in the west, Limu Genet in the North, Nono Benja woreda in the South and Choora Botori woreda in the east.

Agroecologically, the woreda is characterized by 13% highland and 55% lowland and 32% lowland. The elevation of the woreda ranges from 1400 to 2200 m.a.s.l.

Regarding land use in the woreda, about 10241 ha is forest and bush land while 38,874 ha of land is used for crop production. Moderately dense vegetation coverage includes forests, bushes, scrublands and grasslands. The woreda potential for agriculture is estimated to be around 42704 ha of land. From the cereal crops sorghum cover 21,538 ha and maize cover 12.66 ha of land. Coffee is the major cash crop produced by the majority of the farmers as main source of income and covers more than 12,964 ha of land. The woreda has more than 3427 ha of land under irrigation from which 109 is irrigated by modern motor pump.

There are two distinct seasons: the rainy season starting in late March and ending in October and the dry season occurring during November to early March. The mean annual rainfall is 1800 mm. The topography of the woreda is complex and consists of hills, undulating landscape and plains.

3.1.3. Gera Woreda

Gera woreda is located in Jimma zone, 430 km southwest of the capital, Addis Ababa. The woreda is bounded by Goma woreda, Sigmo woreda and

Gumay woreda respectively in the south, west, and north directions respectively. The woredas has over 130,000 inhabitants (CSA 2012). It has 24 kebeles.

Topographically, the district is characterized by hills, valleys, and plains, within an altitudinal range of between 1390 and 2980 masl. Of the total area of the district, midhighland (1500–2000 masl) comprises about 50% of the area, followed by highland (> 2000 masl, 46%) and lowland (< 1500 masl, 4%).

The mean annual temperature of the area is about 19°C while average annual rainfall varies between 1880 and 2080 mm (Socioeconomic Profile of Gera District [SePGD], unpublished data). In 2012, Gera district had over 130,000 inhabitants (CSA 2012), with a crude population density of 90 persons per km^2.

More than half of the district is covered by forest and the extent of forest cover has been reduced over the past few decades (Hylander et al. 2013). Most of this forest belongs to a state-owned enterprise, the Oromia Forest and Wildlife Enterprise. Private companies and farmers, however, own a significant proportion of the forest, which shelters wild coffee (Coffea arabica). The remaining area is mainly covered by arable land, pasture, and built-up areas.

From the total area in the district 80,830 ha is currently covered by coffee while 21,733 ha of land is used for crop production. Maize and tef (Eragrostis tef) are two of the important crops cultivated. Honey and beef production as well as enset (Ensete ventricosum) and root crops such as taro (Colocasia esculenta) are also common.

3.1.4. Didessa Woreda

Dhidhessa woreda is located at 7°054'33'' to 8°013'00''north latitude and 36°017'15'' to 36°047'00'' east. Administratively, it is located in Illu abba bora zone at a distance of about 180km from zonal town, Metu and 420km away from Addis Ababa. It is bounded by Gatira woreda in the west, Gechi in the North and Gummay woreda in the South and Goma woreda in east.

The mean annual temperature and rainfall are 20.7ºC and 1800 mm respectively. There are two distinct seasons: the rainy season starting in late March and ending in October and the dry season occurring during November to early March.

Of the total area of the woreda, 10,352 ha are covered by forest and bush while 9,556 ha has a potential for crop production. The woreda has both highlands, mid and lowlands agro ecologies. The farming system is characterized by forest coffee-cereal-livestock mixed farming system. Different kinds of crops, vegetables, livestock, oil crops and coffee etc are under production in the woreda.

3.1.5. Bedele zuria woreda

Bedele woreda lies between 8°20'-80 35' N and 36°15'-36°30' E at about 480 km road distance south-west of Addis Ababa. Adminitratively the woreda is located in Illu Ababora Zone at about 120km from Metu, the zonal capital. It is bounded by Borecha woreda in the east, Chora woreda in the west, Gachi woreda in the South and Dabo woreda in the North. It has 43 Kebeles, 41 rural and 2 towns. The total population in the woreda is 118,157(male 58,510 and female 59, 647).

Agroecologically, the woreda is divided into three ecological zones namely mid-altitude (81.34%), low-land (18.6%) and highland (0.06%). Altitude in the woreda ranges from 1300 to 2000m a.s.l.

The woreda is characterized as mixed farming system of coffee-crop-livestock production with a total area of 88,049 ha of land used for different purposes; annual crops (35801 ha), perennial crops (16549 ha), forest land (10047 ha), grazing land (10120 ha), wetland (1112 ha) and area not used for any purpose (14420 ha).

3.2. Results of Preparation and Review of Existing Information

Exploratory surveys indicate that soils in the highlands of Ethiopia are in general variable in response to topography, climate and parent materials (FAO/UNDP, 1984). In the southwest highlands of Ethiopia, particularly in the studied woredas, the limited available surveys indicated that topography plays an important role in the differentiation of soil types in the region(Wodroof, 1996).

Description of landform in soil and land resource surveys is useful for finding relationships to support the extrapolation of point observations and to predict the impact of various land use options on the future incidence of land forming processes (Speight, 1984). The landform description is also seen as being a useful aid in that it allows the report users to locate themselves within the terrain or to identify that part which is under discussion.

For soil mapping purposes landform patterns are the key features as they can easily be recognized and they are also formed by the same geomorphic events that are responsible for providing the parent materials for the soils formed (Northcote 1983).

Based on these facts and field observations and interpretation of the base maps of the study woredas and kebeles, it was found that topography and landform are important elements dictating variability in the soil types in the study areas. Accordingly, maps and proportion of each land form facets and slope categories were calculated (table 1 and 2 and figures 2 -5). Landform classification has been calculated using Topographic Position Index (TPI) (Jenness, 2005). TPI is simply the difference between a cell elevation value and the average elevation of the neighbourhood around that cell. Positive values mean the cell is higher than its surroundings while negative values mean it is lower. The originator of the algorithm, Jennese (2005) stated that Using the TPI at different scales, plus slope, users can classify the landscape into both slope position (i.e. ridge top, valley bottom, mid-slope, etc.) and landform category (i.e. steep narrow canyons, gentle valleys, plains, open slopes, mesas, etc.). The degree to which it is higher or lower, plus the slope of the cell, can be used to classify the cell into slope position. If it is significantly higher than the surrounding neighborhood, then it is likely to be at or near the top of a hill or ridge.

The dominant land form in CASCAPE intervention Kebeles of Omo nada woreda, Didessa and Bedele Zuria are canyons, deeply incised streams making up respectively 22.9%, 24.9% and 25.1% of the total landform. The next largest proportion of the landform for these woredas is U-shaped valleys that make up respectively 21.7%, 19.1% and 20.8% of the landforms in the woreda. For Kebeles in the other remaining two woredas: Limu Seka and Gera woredas, U shaped valleys constitute the largest proportion of the landforms making up respectively 26.9% and 26.5%. The next largest proportion of the landforms in the kebeles of these woredas is the canyons, deeply incised streams constituting respectively 21.9% and 25.4% (Table 1). Except for kebels in Gera woreda where the third largest

proportion of the landform is mountain tops, high ridges (18.8%), in the kebeles of all the other woredas, upper slopes constitute the third largest landform category making up respectively 17.6%, 19%,17.5 and 17.2 % in Omo nada, Limu Saka, Didessa and Bedele Zuria woredas (table 1 and Figures 2-6).

Table 1. Total area and percentage coverage of different landforms for kebeles in CASCAPE intervention woredas

Landform	Area and percentage coverage per kebele per woreda									
	Omo nada		Limu saka		Gera		Didessa		Bedele zuria	
	Total (km2)	%	Total (km2)	%	Total (km2)	%	Total (km2)	%	Total (km2)	%
Canyons, deeply incised steams	35.10	22.9	27.42	21.9	17.77	25.4	32.27	24.9	18.49	25.1
Midslope drainages, shallow valleys	1.64	1.1	0.96	0.8	0.76	1.1	1.23	1.0	0.74	1.0
Upland drainages, headwaters	7.97	5.2	4.19	3.4	2.42	3.5	6.46	5.0	3.29	4.5
U-shaped valleys	33.20	21.7	33.70	26.9	18.52	26.5	24.76	19.1	15.33	20.8
Plains	1.62	1.1	1.85	1.5	1.29	1.8	0.30	0.2	0.48	0.7
Open slopes	2.56	1.7	2.43	1.9	1.19	1.7	2.05	1.6	1.05	1.4
Upper slopes, mesas	26.94	17.6	23.78	19.0	10.00	14.3	22.74	17.5	12.70	17.2
Local ridges, small hills in Valleys	10.20	6.7	5.60	4.5	3.69	5.3	7.36	5.7	3.32	1.2
Midslope ridges, small hills in Plains	1.98	1.3	1.31	1.0	1.12	1.6	1.41	1.1	0.88	1.2
Mountain tops, high ridges	31.97	20.9	23.84	19.1	13.11	18.8	31.02	23.9	17.42	23.6

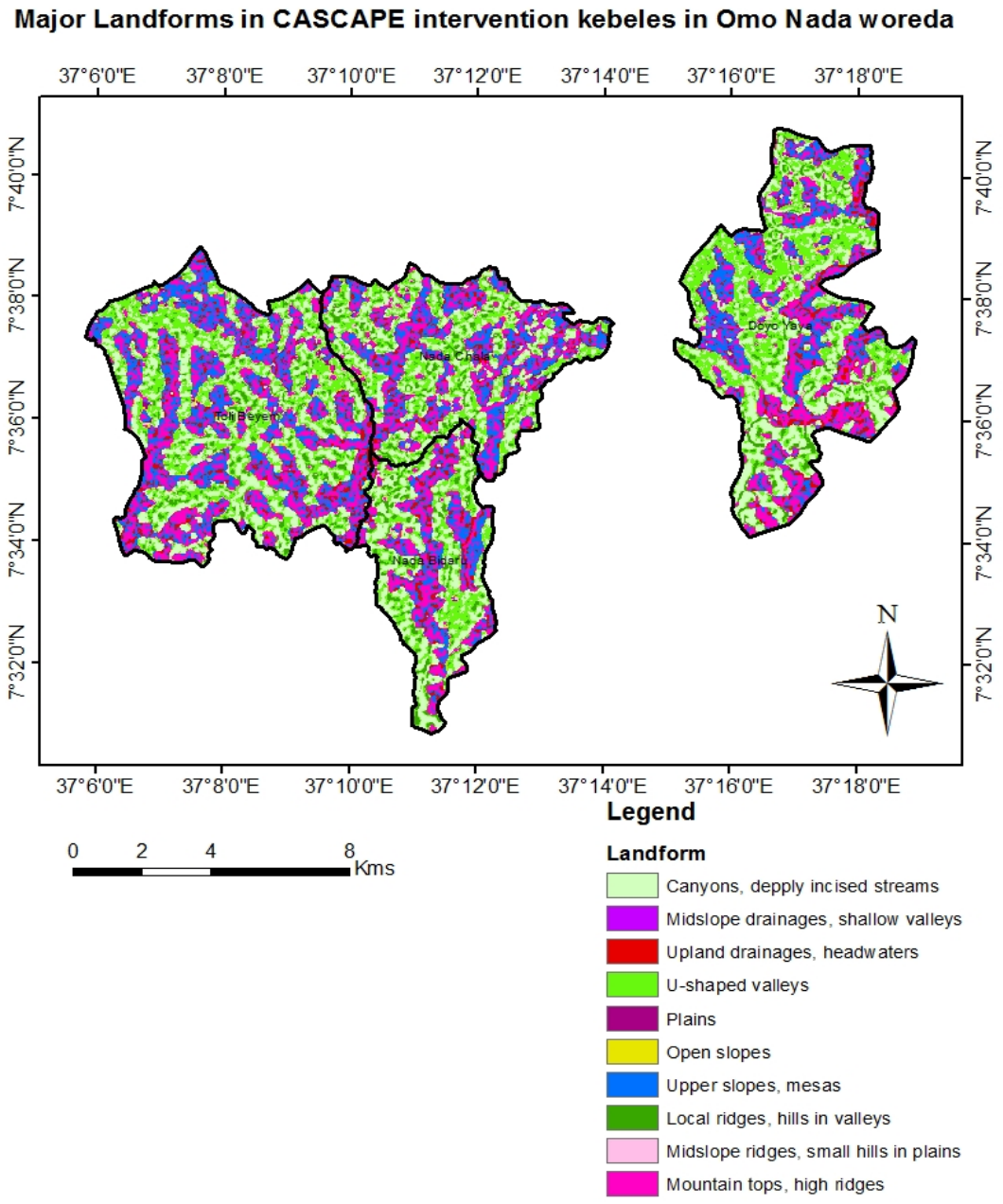

Figure 2. Landform map of CASCAPE intervention kebeles in Omo Nada woreda

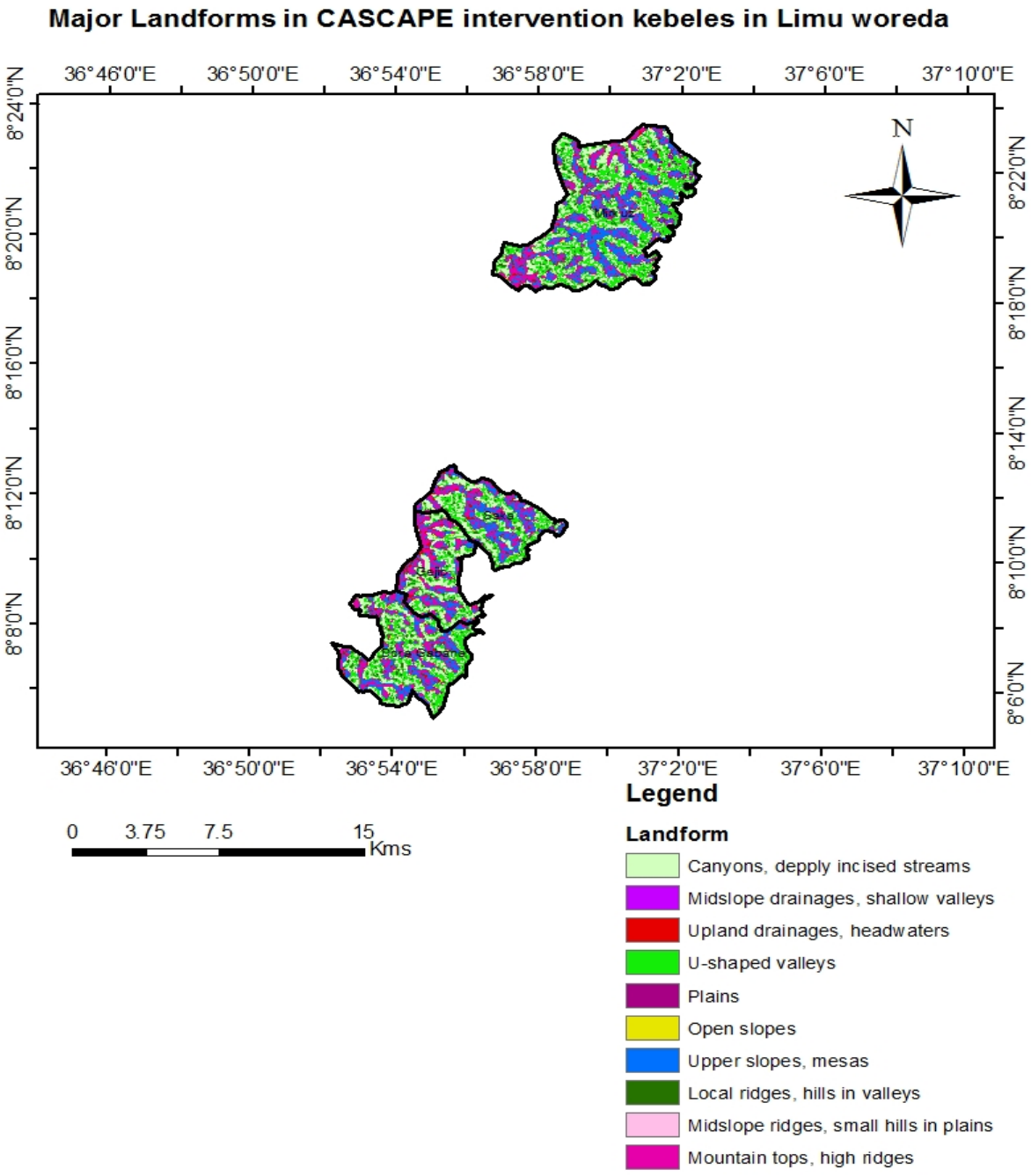

Figure 3. Landform map of CASCAPE intervention kebeles in Limu Saka woreda

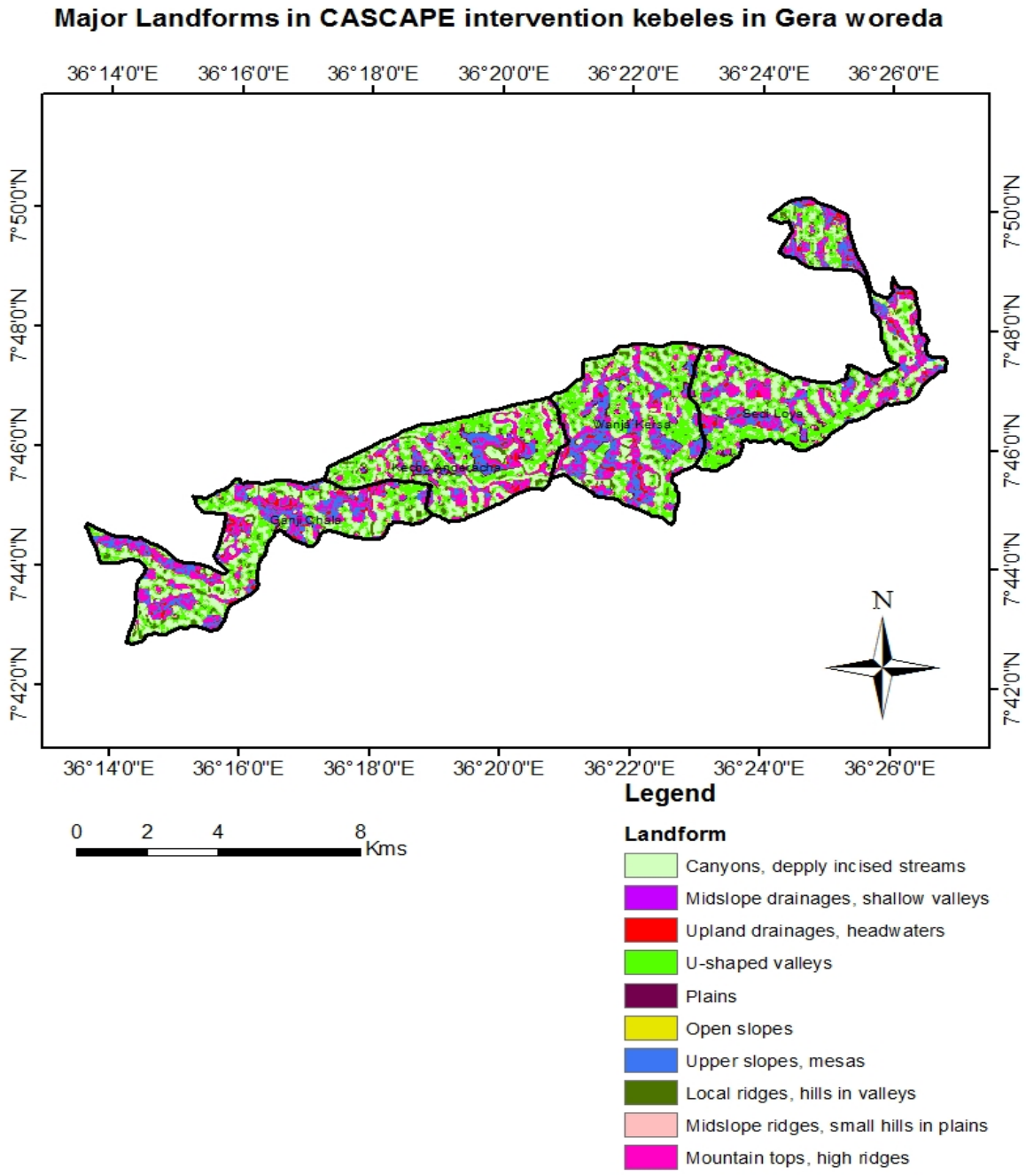

Figure 4. Landform map CASCAPE intervention kebeles in Gera woreda

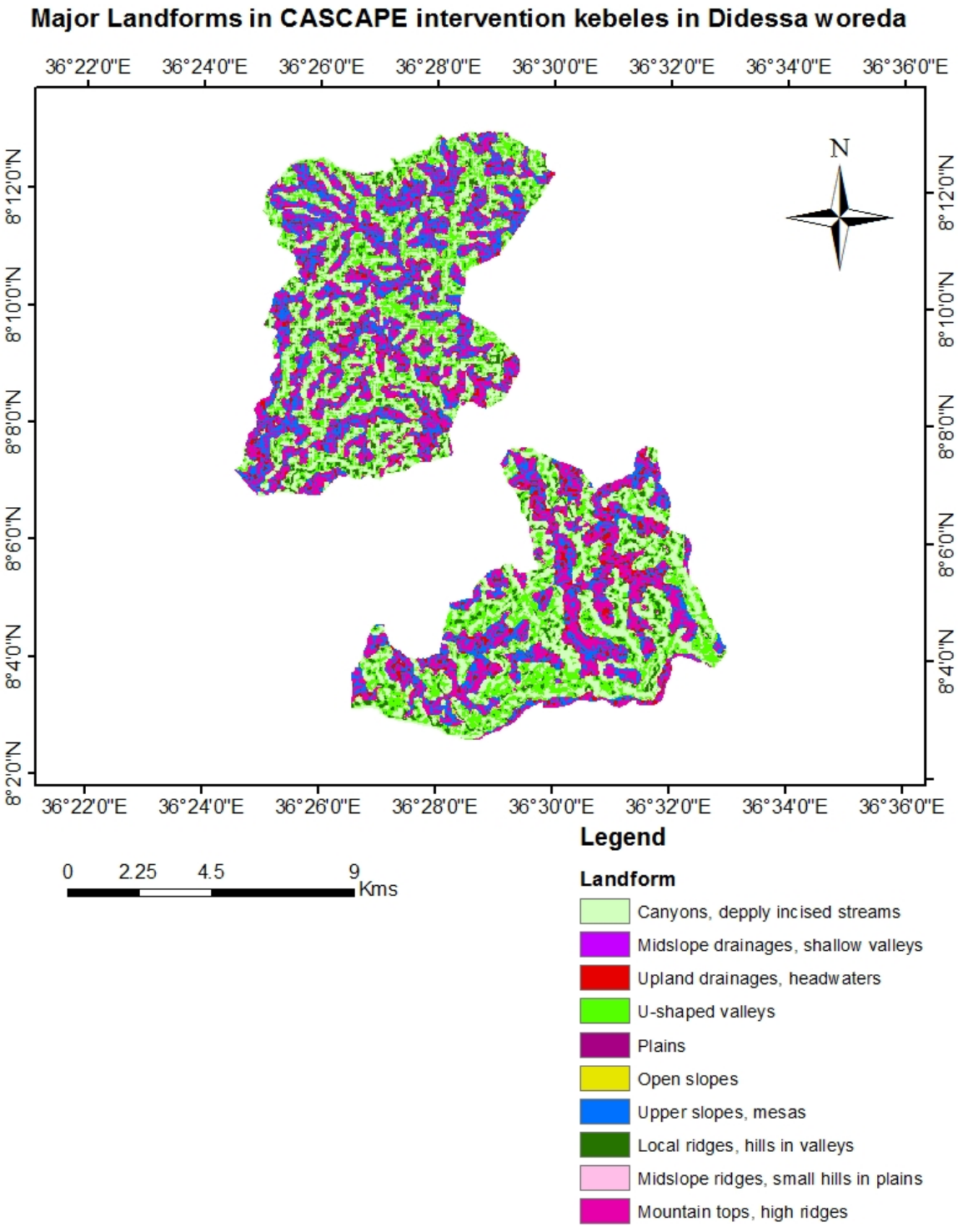

Figure 5. Landform map of CASCAPE intervention kebeles in Didessa woreda

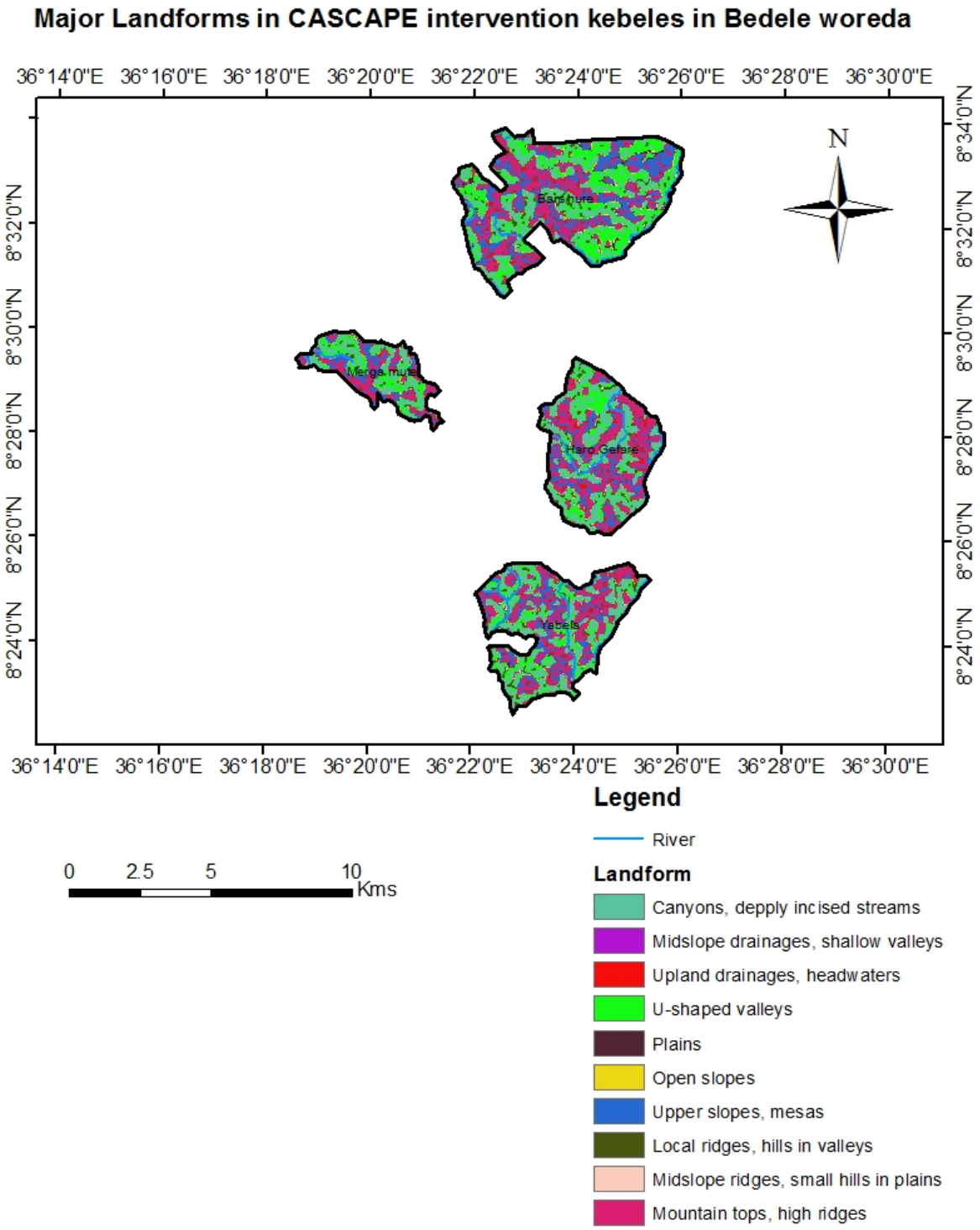

Figure 6. Landform map of CASCAPE intervention kebeles in Bedele woreda

Slopes maps were produced from 90 x 90m vertical resolution Digital Elevation Model (DEM). Proportion of the slope gradient in percent was calculated using GIS software for each woreda and kebele.

The slope class categories and the definitions of each slope class was made following the FAO guideline for soil profile description (FAO, 2006).

At the woreda level, for all woredas the dominant slope class is 5-10% ranging from 28% (for Omo nada woreda) to 39% (for Bedele zuria woreda). This slope category is defined as sloping according to the description of FAO guidelines for soil profile description (FAO, 2006).The percentage distribution of each slope category is indicated in table 2 (for each woreda) and in table 3 (for each kebele) and in Figures 7-11. While for the Gera and Didessa woredas the next dominant slope class is the 10-15% slope consitituting 24.9 % and 23.4 % respectively, for Limu Saka and Bedele Zuria woredas the 2-5% slope class is the second dominant slope making up 26.7 and 26.1% respectively. According to the FAO guideline these slopes are described as strongly slopping (5-10%) and gently sloping (2-5%). In Omo Nada woreda the second dominant slope class 15-30% (moderately steep) which accounts for about 25.7% of the total slope distribution. Only small area of all woredas are in a sleep slope class (> 30%) ranging from 0.4% (in didessa and Bedele woredas) to 5.4% (in Omo Nada woreda). It is therefore evident from slope distribution in table 2 that Omo Nada woreda and gera woreda have more area of land with steep topography, 5.4% and 2.1% respectively.

Table 2: Slope classes in CASCAPE intervention woredas of west oromia region

No	Woreda	Total area (km2)	Percent area per slope category					
			0-2%	2-5%	5-10%	10-15%	15-30%	>30%
1	Omo Nada	81.25	4.85	16.97	28.04	19.01	25.69	5.44
2	Limu Saka	188.60	7.58	26.71	37.86	15.65	11.59	0.60
3	Gera	48.73	3.65	14.39	32.02	24.88	22.92	2.14
4	Bedele Zuria	62.62	7.57	26.09	38.98	18.03	8.91	0.42
5	Didessa	31.62	6.25	19.17	38.16	23.35	12.64	0.44

Evaluation of the slope classes in kebeles as depicted in table 3 below also indicated that the dominance of the different slope classes follows the same trend to that of the woredas.

Table 3: Slope classes of Kebeles in CASCAPE intervention woredas

Woreda	Kebele	Total area (km^2)	Percent area per slope category					
			0-2%	2-5%	5-10%	10-15%	15-30%	>30%
Omo Nada	Doyo Yaya	43.94	5.64	24.44	34.73	14.76	16.53	3.89
	Nada Bidaru	31.85	1.27	7.58	23.86	19.63	15.99	1.14
	Nada Chala	22.14	11.21	42.17	61.89	22.80	5.72	0.02
	Toli Beyem	53.27	5.47	22.01	41.11	21.70	9.55	0.15
Limu Saka	Mirkuz	58.79	8.81	29.27	38.85	12.56	10.30	0.20
	Saka	20.13	4.90	20.40	45.18	21.09	8.08	0.33
	Gejib	17.95	2.51	12.38	38.05	38.05	17.16	0.17
	Dora	13.98	6.18	20.70	43.01	17.59	10.83	1.67
Gera	Ganji Chala	18.44	6.17	25.06	45.47	18.62	4.70	0.02
	Kacho Andaracha	14.19	16.91	36.57	27.11	10.81	7.46	1.10
	Wanja Kersa	17.07	13.50	37.86	35.41	8.84	4.33	0.11
	Sadi Loya	17.32	10.83	27.44	40.77	15.66	5.28	0.01
Didessa	Sobo	22.18	1.85	11.40	37.19	30.86	17.31	1.85
	Masara	23.59	4.08	4.08	4.08	26.19	9.92	0.15
	Goro	33.72	2.14	9.76	30.28	29.35	27.28	1.17
	Yembero	17.72	5.09	19.97	37.04	23.56	14.06	0.26
Bedele	Banshure	28.95	5.04	23.75	36.30	19.69	14.74	0.47
	Merga mute	8.03	2.18	11.80	43.71	2.18	10.70	2.18
	Haro Gefare	18.19	2.67	13.53	32.00	26.06	25.10	0.64
	Yabela	18.57	4.66	20.72	42.37	22.39	9.67	0.19

In Omo Nada woreda, of all kebeles, nada chala kebels has the largest proportion of flat to very gently sloping land (0-2%) which constitutes about 11.2%. On the other hand Doyo yaya has the largest proportion of land with steep slope (>30%).

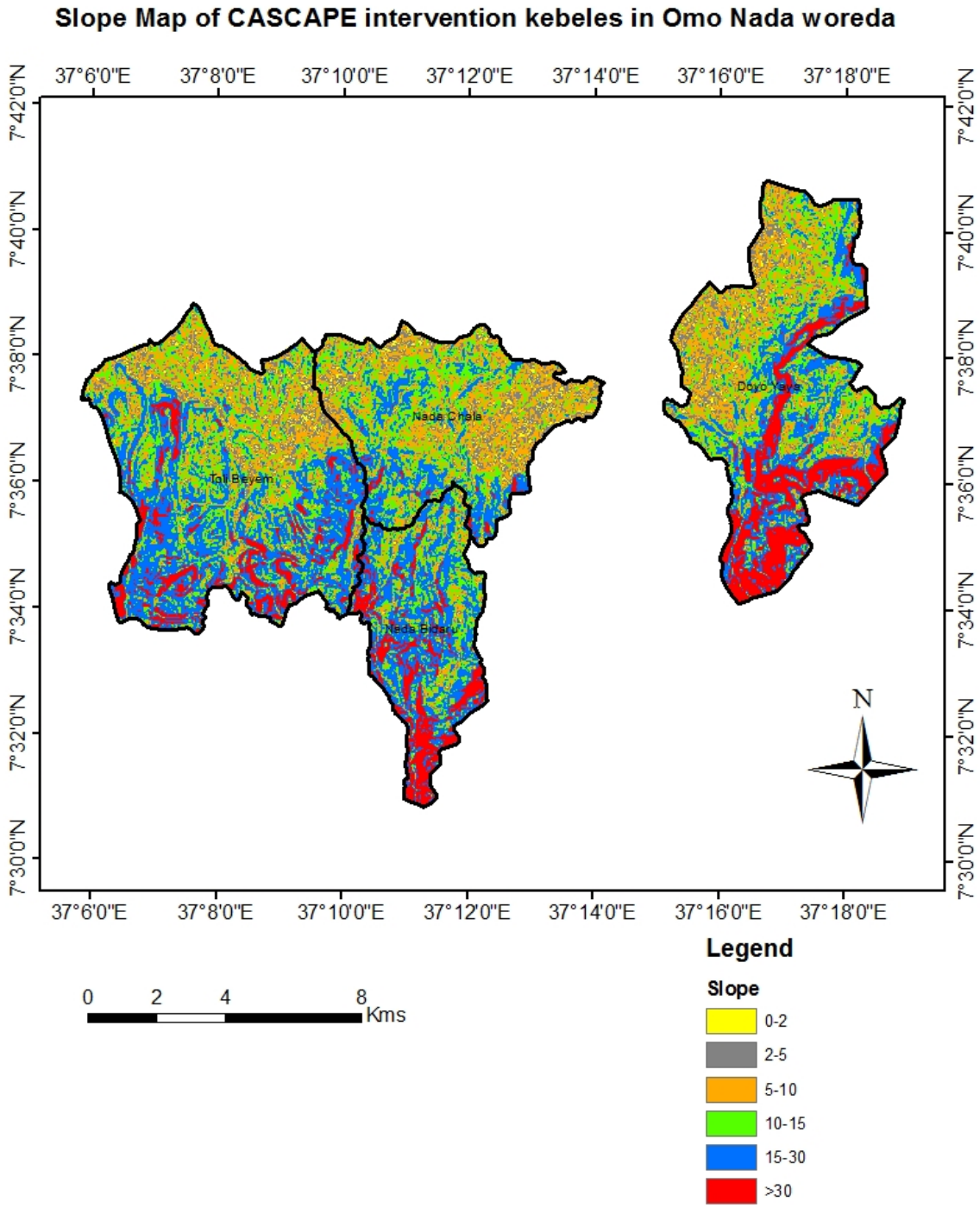

Figure 7. Slope map of CASCAPE intervention kebeles in Omo Nada woreda.

From the CASCAPE intervention kebeles in Limu saka woreda, Mirkuz (8.8%) and Dora (6.2%) are characterized by a more flat to very gently undulating slope compared to the other two kebeles. Gejib has the highest proportion (17.2%) of moderately steep (15-30%) slope. Extent of steep slope (>30%) is very low in all the kebeles and ranges from 0.2% to 1.7 %.

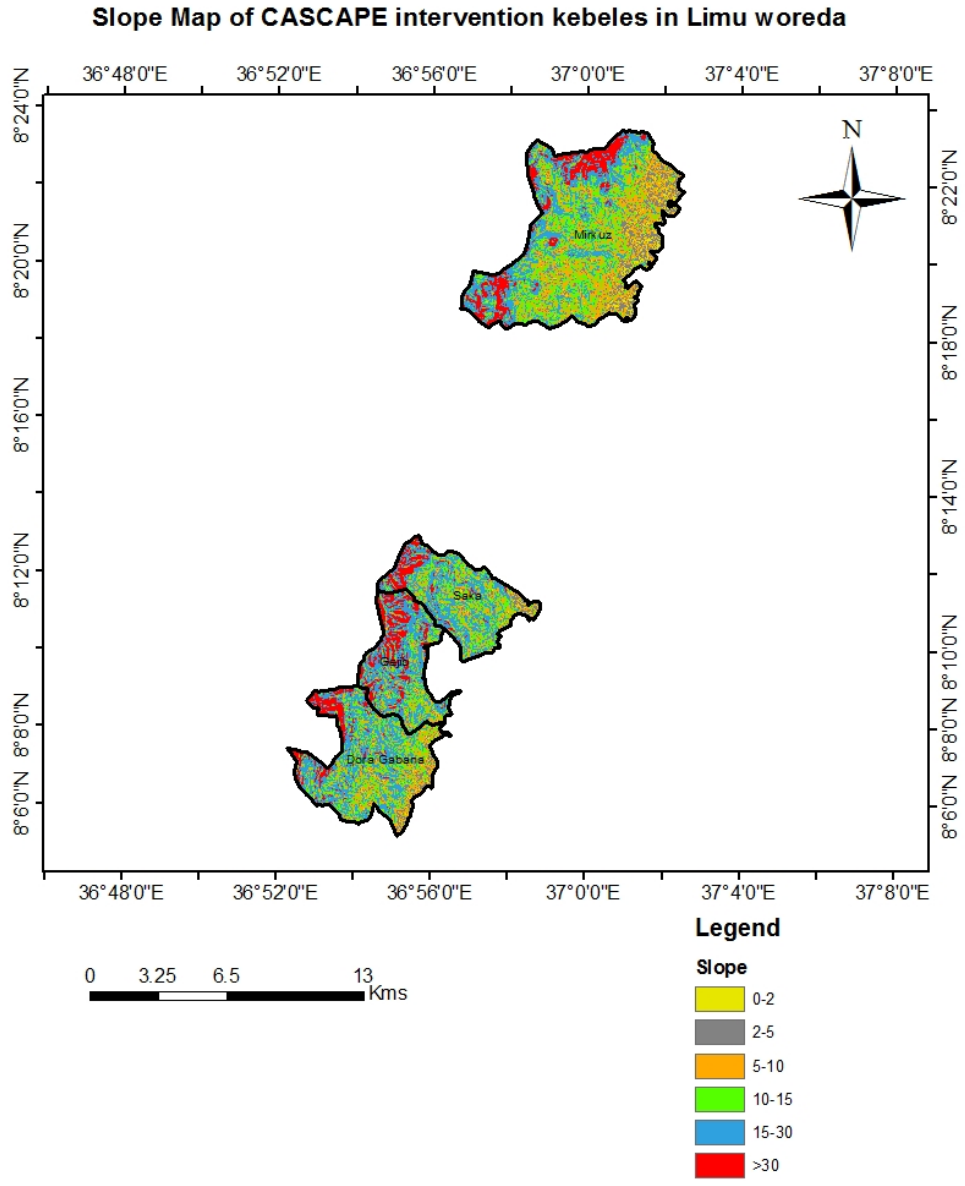

Figure 8. Slope map of CASCAPE intervention woredas in Limu Saka woreda

In Gera woreda, Kacho Andaracha and Wanja Kersa woredas have by far the greater proportion of land with flat to gently sloping topography (0-2%) constituting about 17% and 13.5% of the total slope class respectively. The largest proportion of the landscape in these kebeles is gently sloping constituting 36.5 % in Kacho Andaracha and 37.9% in Wanja Kersa kebele. Proportion of steep slopes (>30%) is invariably small in all the kebeles in this woreda.

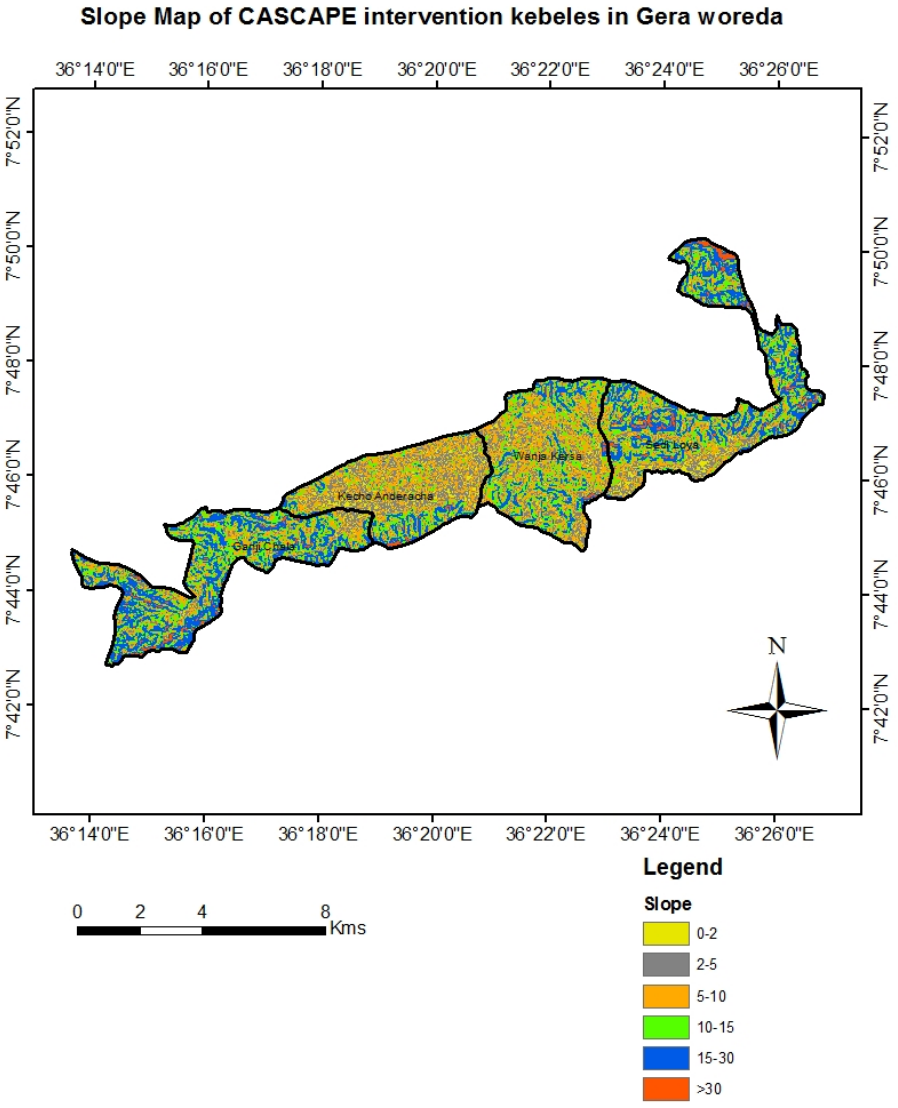

Figure 9. Slope map of CASCAPE intervention kebeles in Gera woreda

Goro Kebele in Didessa woreda has the largest proportion of land with moderately steep (15-30%) topography constituting about 27.3% of the total slope classes. Considerably large proportions of the landscape in all kebeles of this woreda have strongly sloping (10-15%) topography. The area of both flat (>2%) and steep (>30%) is small in all the kebeles in this woreda.

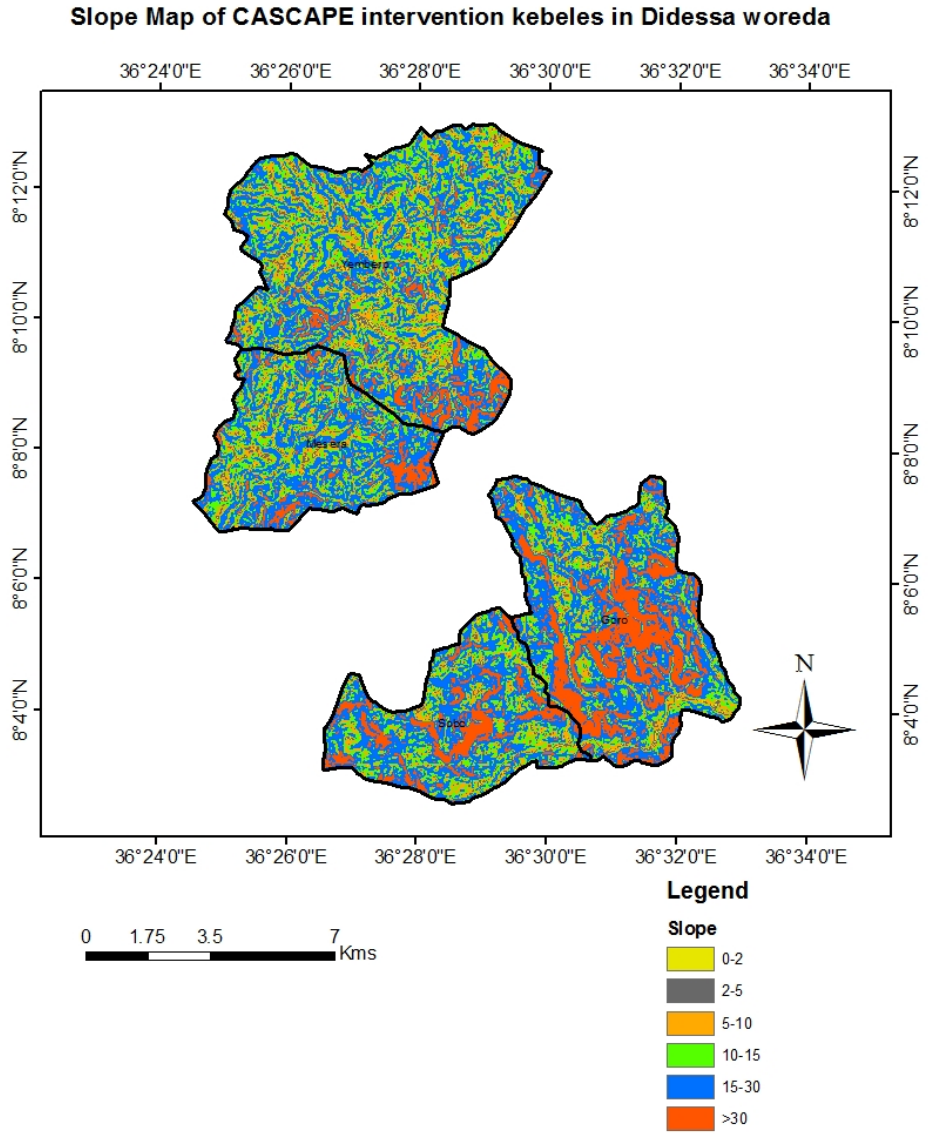

Figure 10. Slope map of CASCAPE intervention kebeles in Didessa woreda

Banshure Kebele in Bedele woreda has the largest proportion of land (23.8%) with gently sloping topography (2-5%). Considerably larger percentage of the land in haro gefere and Yaballa are in the strongly sloping (10-15%) slope class which constitutes 26.1% and 22.4% respectively. Mirga Mute has relatively higher proportion of land with steep slope (>30%) topography.

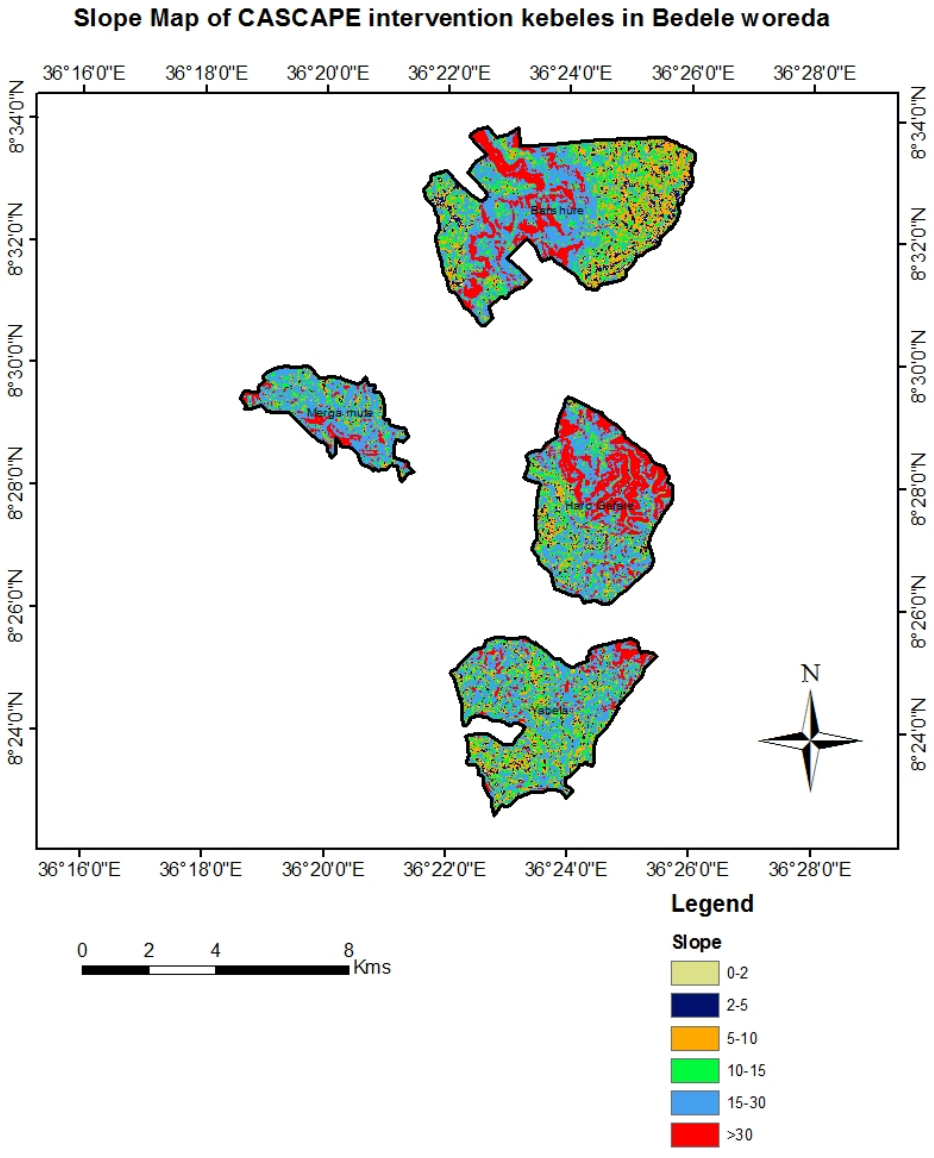

Figure 11 Slope map of CASCAPE intervention kebeles in Bedele woreda

3.3. Results of Field Work and Data processing

Following the base map, a minimum of 8 augers per kebele and 6 profile pere woreda were described. The auger and profile ID's, with reference to the corresponding major soil type and soil-landscape (mapping) unit, are provided in table format in annex 2.

Based on the interpretation of topographic maps, geomorphology, slope, geology and previous studies land units were identified. Soil profile descriptions and auger observations in the identified land units enabled to identify and delineate preliminary soil types and soil units. For the purpose of this survey it was found that information on landform was essential. For this reason and limitation imposed by time and financial constraints the soils map is the map of soils and landform. The soil maps produced are essentially a map of landform and soils. The mapping units are therefore based on more or less uniform landform characteristics.

The soils were classified and characterized based on the morphological and laboratory physical and chemical parameters following World Reference Base for soil resources (WRB Working Group, 2006).

3.4. Soils of CASCAPE intervention Kebeles in Omo Nada Woreda

3.4.1. Geomorphology and Geology

Geomorphological study which takes into account all the past and present processes to explain the landform and its present day evolution provides the best account of the land pattern in an area. In general, the geomorphology of the studied woredas is related to the geological and series of tectonic and erosional processes which have been active during the Tertiary period in the western and southwestern parts of Ethiopia. The extensive fracturing and major displacement along the fracture zones in the late tertiary together with widespread volcanism determined the forms of landscapes in the

southwestern plateau of Ethiopia (Mohr, 1962). The uplift has been spasmodic and thus streams were also adjusted themselves to the new condition. Faults that controlled drainage patterns also affected the topography of the area.

Located in the highlands of southwestern region of Ethiopia, the Omo Nada woreda is generally characterized by chains of volcanic formed hills and gently sloping mountains in the flanks and a more flat and rolling relief at the center of the catchment. Voluminous volcanic eruption has occurred during the tertiary period and lava formed a high plateau landscape, built up in terraces due to successive eruptions and flows.

Figure 12. Typical volcanic landscape in Nada Chala kebele, south west of Nada town indicating chains of trachyte hills at the flanks and a more flat land in the center

Later, the material might have been subjected to erosion and dissection followed by the deposition of the tuffs and later the volcanic ashes probably from shield volcanoes located in the nearby areas such as Wagebeta, and Tepi in the south and southeast and Wachacha in the North. The ashes have undergone several cycles of erosion and transported to the low-lying areas while the other pyroclatic materials were more resistant and have therefore been left as hills jutting out above the general landscape. Though no chronological data is available, from the relatively small thickness of the ash deposit, their flat depositional surface along with the extremely rapid dynamics of the geomorphic processes affecting the area it is imperative to suggest that the deposit is of recent geological origin, most probably quaternary.

Tertiary volcanic basalt and tuff occupies Ethiopian plateau dominantly conglomerates of trap series (Paleocene-miocene) and younger silica rich rhyolites, trachytes, tuff and ignimbrites of Magdala group (Miocene to Pleistocene) floor of rift valley, volcanic rocks, basalts and ignimbrites, of Afar group (Pliocene to Holocene) (Mohr, 1971).

According to Davidson and Rex (1983), approximately 80% of the Omo-Gibe Basin in southwest Ethiopia where the CASCAPE intervention woredas in west Oromia region are also located underlain by Tertiary volcanic rocks. The Authors sub-divided the Tertiary volcanic rocks in to two broad categories namely the pre-rift and post rift vlocanic rocks. The former comprises succession of the oldest main sequence (49 to 35 Ma) and the younger flows (32 to 21 Ma) and the later sequence (19 Ma to present) is made up of the mid Miocene flood basalts, which lie unconformably on tilted pre-rift flows. In parts of the basin where the geological relationships can be established clearly, the flood basalts are overlain by a series of more felsic volcanics, although the latter includes intercalated basalts and pyroclastic rocks.

Davidson (1983) further subdivided Tertiary volcanic rocks of southwest Ethiopia into early flood basalts, lower felsic volcanics ,and the Nazareth group. The lower felsic volcanic rocks comprise a sequence of intercalated acidic, intermediate and basic volcanics was erupted initially onto the flood basalt plateau in the Omo-Ghibe basin. This was then followed by the eruption of great thicknesses of rhyolite and trachyte rocks which occur over large areas in the northern part of the Omo-Ghibe basin, the part of the basin where the Gilgel Gibe catchment lies. Upper felsic volcanics includes thick rhyolites, trachytes and felsic ignimbrites up to 2000 m thick. Where these volcanics have been partially eroded, the central intrusive core often remains as a prominent conical hill or plug.

The nazareth group comprises a series of rhyolite-trachyte plugs, stratoid flows, ignimbrites, pumice, ash fall tuffs and characteristic lacustrine sediments containing coal and lignite deposits along the main Ethiopian Rift and adjacent plateau margins. The Nazareth Group attains a thickness of 200-300 m in the Ethiopian Rift, but is thinner on the adjacent plateau margins. The ages of these rocks range from 10 to 3 million years (Kazmin, 1979; Kazmin et al, 1978, 1981). The Group crops out along the north-east watershed of the Omo-Gibe Basin over a large tract of land stretching from south of Weliso to Welkite-Hosaina-Sodo and Selam Ber, the rift escarpment, and unconformably overlies the early flood basalts (Pv), with minor intercalated basalts being found at the base of the Group.

Deposition of the younger sequences of the Nazareth Group was accompanied by the formation of shield volcanoes of late Pliocene age (2-3 million years) on the Main Ethiopian Rift escarpments (Kazmin et al, 1978, 1980). On the western escarpment, the volcanoes of Wachacha, Yerer,

Gash Megel, Tembero, Damota and others, today form prominent landmarks. These young volcanoes are well preserved with little erosion of the cones and craters, and some contain small crater lakes. Several of these centers, Teza, Ambricho, Wagebessa and Tembero, line on a NNE alignment suggestive of formation along a major fault line. The ejecta from these volcanoes, both trachyte flows and felsic ignimbrites, cover the surface of most of the studied woredas.

According to the recent study by the Geological Survey of Ethiopia (GSE, 2012) the geology of the studied kebeles in Omo nada woreda is dominated by lower pyroclastics (40.3%) followed by Quaternary stratified tuffs (32.3%) as indicated in table 4. Rhyolite and upper basalt flows constitute about 16.2% and 8.1% repectively of the total lithological formation in the CASCAPE intervention kebeles in the wored. Upper basaly flows make up relatively lower proportion (8.1%) of the total geological substrate in the woreda (Geological survey of Ethiopia, 2012). Figure 8 shows the area and percent coverage of the different lithological formation in the studied kebeles of Omo Nada woreda.

When we consider at the kebele level, at the present scale of the geological mapping exercise while the bulk of the surface area of Toli Beyem kebele is covered by the lower pyroclatics, quaternary stratified tuffs and upper basalt flows form the dominant geological substrate in the nada chala and Nada Bidaru kebeles respectively. In the Doyo Yaya kebele, rhyolite flows cover more than half of the surface area extending from the north east to the southeast. This is followed by the quaternary stratified tuffs that occupy bulk of the area of the kebele in the western and northwestern part of the kebele. The quaternary alluvial deposit and lower pyroclastics cover small pocket areas in the southwestern part of the kebele.

Table 4. Area and percent coverage of lithology in CASCAPE intervention kebeles in Omo Nada woreda

Lithology	Area_ha	%
Quaternary alluvial deposit	463	3.0
Upper basalt flows	1247	8.1
Lower pyroclastics	6176	40.3
Rhyolite flows	2481	16.2
Quaternary stratified tuffs	4940	32.3

Figure 13. Rhyolite at a quarry in Doyo Yaya kebele at the Elfeta hill, southeast of Nada showing flow banding

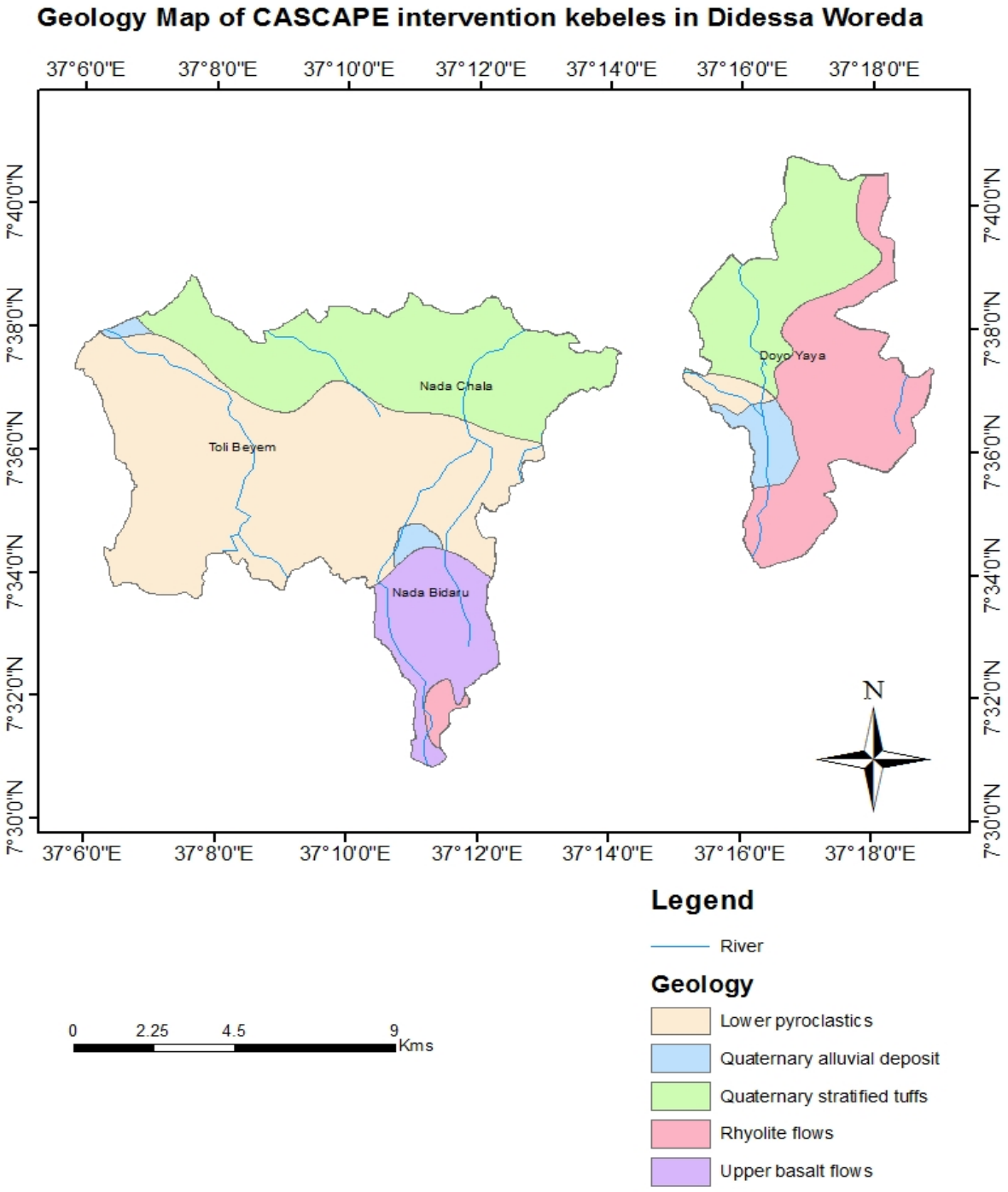

Figure 14. Geological map of CASCAPE intervention kebeles in Omo nada woreda

Similarly, Alemayehu et al (2014) indicated that the geology of the Gilgel Gibe catchment within which Omo Nada woreda is also located is dominated by felsic lavas of trachytic texture and Pyroclastic deposits. The later is subdivided into vitric, lithic and crystal tuffs which were deposited as pyroclastic flows, surges and falls. According to these authors, the rocks in the catchment have generally felsic composition with little chemical variation.

Though it is generally known fact that volcanic rocks in southwest Ethiopia are underlain by the Precambrian basement rocks, no outcrop of the later was observed in Omo nada woreda. Therefore, the geology of the woreda is dominated by the tertiary volcanic rocks.

3.4.2. The soil- landscape

A total of thirty two auger observations and a number of visual observations were made. Seven soil profile investigations were dug and described after proper identification of land units from auger observations (Fig. 15) for soil morphological and environmental characteristics were made.

Using the auger observation, the field visit, the previous studies maps, the topographic maps and slope interpretation the studied kebeles has been classified in to different soil mapping units by considering the dominant soils and land forms. Finally the rectification of the soil mapping units has been made by the laboratory analytical results of the samples collected.

The Soil Map has been compiled primarily from classifying each soil auger site and each soil profile pit according to its soil unit, plotting these data and then grouping them into polygons of similar content.

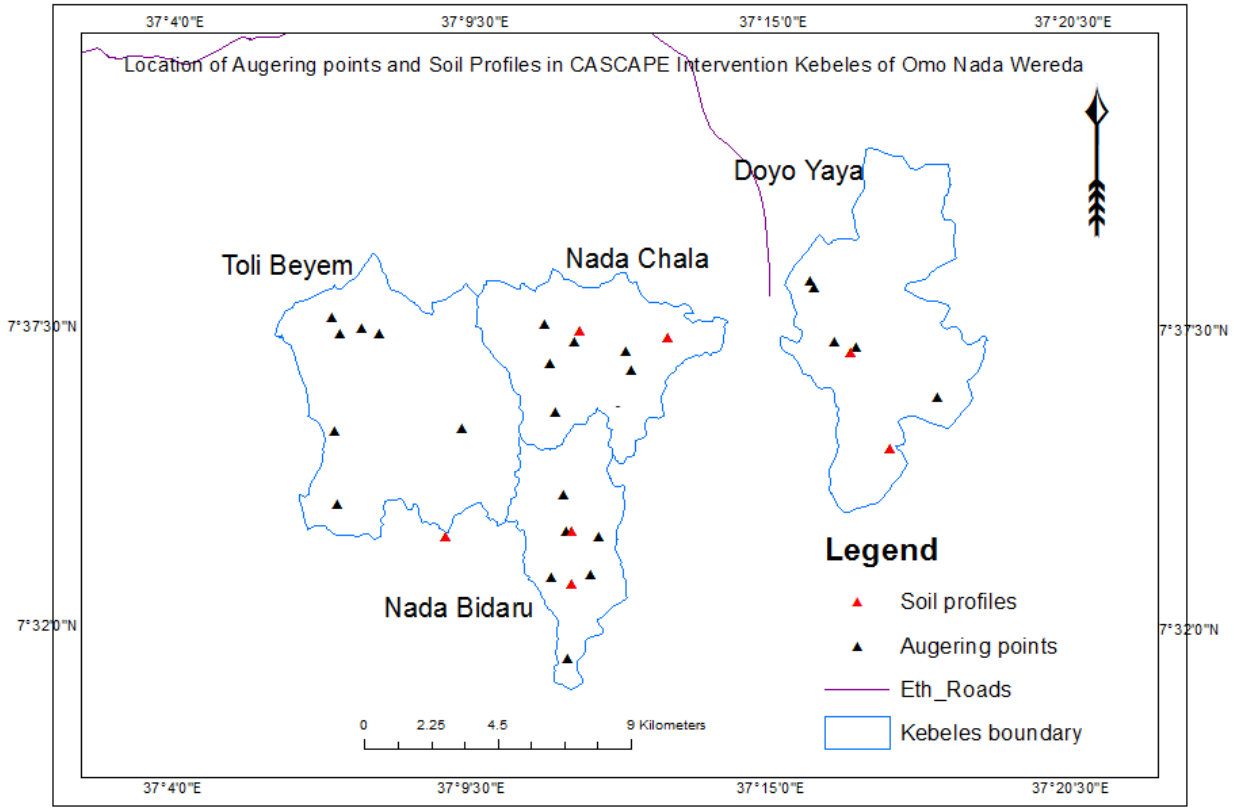

Figure 15. Augure and soil profile locations in Kebeles of Omo Woreda

The soil variation in the woreda mainly depends on the physiographic position. Such a trend in the variability of soils with land form in the various regions of the highlands of Ethiopia has also been established by a number of studies (Belay, 1996, Eylachew, 1999; Abayneh, 2001).

Five mapping units were distinguished in the study area and their distribution and extent are shown in table 5 and the soil map (Fig. 16)

On the high ridges, small hills in the plains and valleys and on upper slopes, Cambisols are the dominant soil types in the four studied kebeles of Omo Nada woreda. These soils cover about 49% of the total area in the four kebeles. In the Doyo yaya woreda large extent of them are found in the middle and upper slopes of Ilfeta and Kiyu hills.

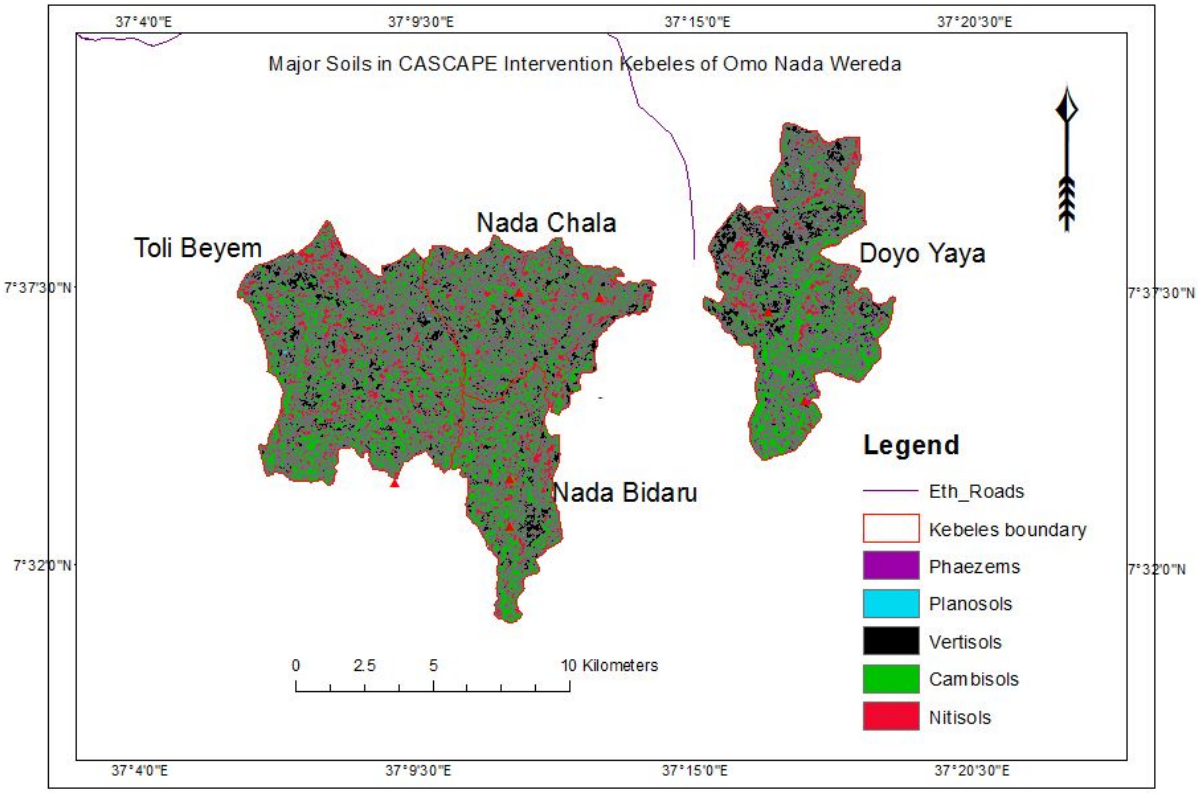

Figure 16. Soil map of CASCAPE intervention kebeles in Omo Nada woreda

In the upper slopes and mesas, Nitisols are the dominant soil types in all the studied kebeles of Omo Nada woreda. These are the second dominant soil types. They cover about 25 % of the total area of the studied kebeles. Agriculturally, Nitisols are the most productive soils in the woreda.

Table 5: Summary of major Soil types and their distribution in the four CASCAPE intervention kebeles of Omo Nada woreda

Soil type	Area coverage (km2)	%
Cambisols	76.72	49.0
Phaezems	3.48	2.2
Nitisols	39.17	25.0
Planosols	4.08	2.6
Vertisols	33.21	21.2

The U shaped valleys are occupied by Vertisols. Next to the Nitisols, Vertisols are the third extensive soil types in the studied kebeles. They cover about 21% of the total area of the studied kebeles.

Small areas in the open slopes and plains are covered by Planosols. The outstanding characteristics of these soils are a strong bleaching of the E horizon and the development of a dense claypan which represents the B horizon. The bleached layer can be explained as the result of pedimentation, i.e. erosion or denudation by scarp retreat, which is a common feature of tectonic basins filled with the waste products of the Tertiary orogeny.

This general type of soil develops from different parent materials, including recent alluvium and various residual materials. Because of the lack of adequate surface drainage and of the water-tight subsoil, Planosols become saturated soon after the beginning of the rainy season, usually in the last two weeks of June and remain in this condition until late September. Water covers large tracts of slightly depressed land and stands on the surface for 3-4 months. The dry seasons are however sufficiently long for a thorough desiccation of the soil. In the classical studies of Planosols genesis, a distinction is commonly drawm between “pedogenic” and “geogenic” processes. The complete profiles of planosols are exposed mainly in road cuts through flat divides between drainage systems.

In the upper slopes, especially in Kuyu hills Phezems covers patchy areas. They constitute only about 2.2% of the total area. They are however quite extensive in Doyo Yaya kebele.

(a) (b)

Figure 17. Representative soil profiles in Omo Nada showing (a) Vertic Planosols, (b) Nitisols

3.4.3. Soil profile descriptions with analytical data

Table 6. Site and profile description and lab analytical data of CASCAPE intervention kebeles in Omo Nada woreda

6.1. Site and profile description of Doyo Yaya Kebele

Site characteristics
Profile code: JIM/OMN/DY/P1
Soil classification: Chromic Luvisols
Location: Doyo Yaya kebele at a specific place called Donga, close to FTC
Coordinates: 309002 m N – 842764 m E
Elevation: 1891 m
Date and author: 15/11/2013; Alemayehu Regassa and Awol Taju
Geology: Volcanic rocks of Tertiary and quaternary age overlie the precamberian rocks
Land form: Undulating to rolling high volcanic plateau
Local physiography: Slightly hilly to the north, slopping river valley to the south
Slope: 5% S, nearly straight along the slope
Land use/Vegetation: Intensive rainfed cultivation of mixed cereals and pulses; Eucalyptus trees around homesteads and farm boundaries, scattered Cordia spps in the farm land; the SLM project has raised fruit trees such as Avocado and Mango delivered to the communities
General information on the soil
Parent material: Basalt
Moisture condition: Dry topsoil with moist subsoil
Drainage: Excessively drained
Ground water: Not encountered, most probably very deep

Surface stones: None
Erosion: Slight sheet erosion
Human influence: The land has been put under continuous cultivation in the past without sufficient fertility management

Profile description

Horizon	Depth (cm)	Description
Ap	0-15	yellowish red (5YR 5/8) moist; sandy clay loam; moderate fine crumb and single grained; friable, slightly sticky and slightly plastic ; many fine random inped tubular pores; many fine and few medium roots; clear smooth boundary to
B	15-40	very dark red (2.5YR2.5/2) moist; clay loam ; moderately weak medium sub angular blocky; friable, sticky and plastic ; many fine interstitial pores; many fine and common medium roots; gradual smooth boundary to
Bt1	40-75	dark reddish brown (2.5YR2.5/4) moist; clay; moderate medium subangular blocky; friable, sticky and plastic ; moderately thick clay cutans on ped faces; many fine random inped tubular pores; common fine and many medium roots; diffuse smooth boundary to
Bt2	75-110	dark red (2.5YR3/2) moist; clay; moderate medium subangular blocky; friable, sticky and plastic; many fine interstitial pores; many clay cutans on all ped faces; few fine and very few very fine roots; gradual smooth boundary to
Bt3	110+	dark red (2.5YR3/2) moist; clay; strong medium subangular blocky; slightly firm, sticky and plastic ; few fine pores; few clay cutans; very few very fine roots

Site characteristics

Profile code: JIM/OMN/DY/P2
Soil classification: Dystric Nitisols
Location: Doyo yaya kebele, lower slope of Ilfeta hill; about 500 m south of Laga Harre river
Coordinates: 842424 m N – 309522 m E
Elevation: 1901 m above sea level
Date and author: 15/11/2013; Alemayehu Regassa and Awol Taju
Geology: Volcanic rocks of Tertiary and quaternary age overlie the precamberian rocks
Land form: Rolling topography. The profile is located on a long colluvial slope
Local physiography: hilly to the south, slopping river valley to the north
Slope: 12%, N long gentle straight slope
Land use/vegetation: At present it is a grazing fallow land and ten years ago cultivated with cereals such as maize, sorghum and teff in rotation. Eucalyptus spps are grown around farm boundaries and in the homesteads and few Cordia spps scattered in the farm lands

General information on the soil

Parent material: Colluvial and residual material from weathered volcanic rocks, probably basalt and trachybasalt, the former being transported from the Ilfeta hill
Moisture condition: Dry in upper horizons and progressively become moist in the subsurface horizons
Drainage: Well drained
Ground water: Deep; no sign of ground water table is encountered in the profile

Surface stones: None
Erosion: Slight rill erosion and shallow gullies
Human influence: Terrace construction, improperly oriented to the slope, thereby accelerating runoff

Profile description

Horizon	Depth (cm)	Description
Ap	0-10	reddish brown (5YR 4/4) moist; clay loam; strong medium granular; soft, friable, slightly sticky and slightly plastic; many medium roots; many fine interstial pores; clear smooth boundary to
AB	10-30	dark reddish brown (5YR 3/3) moist; clay; strong fine and medium sub angular blocky; slightly firm, sticky and plastic; common fine interstitial pores; few fine roots; gradual smooth boundary to
Bt1	30-65	dark reddish brown (5YR 3/3) moist; clay; strong medium and coarse sub angular blocky; hard, very firm, very sticky and very plastic; few soft rounded to sub-rounded dark brown iron and manganese nodules; many distinct shiny ped faces; very few very fine roots; common fine interstitial pores; diffuse smooth boundary to
Bt2	65-110	reddish brown (2.5YR 4/4) moist; clay; strong medium coarse sub angular blocky; hard, very firm, very sticky and very plastic; prominent shiny ped faces; very few Mn nodules; few fine pores; very few very fine roots; gradual smooth boundary to
Bt3	110+	dark red (2.5YR 3/6) moist; very strong very coarse angular blocky; slightly firm, slightly sticky and slightly plastic; intersecting shining ped faces; very few very fine faint yellowish diffuse mottles; few rounded black manganese concretions; few fine pores; no root

Site characteristics

Profile code: JIM/OMN/DY/P3
Soil classification: Phaezems
Location: Doyo Yaya (Kiyu); at the lower slope of rogge hill
Coordinates: 839162 m N – 310858 m E
Elevation: 2271 m above sea level
Date and author: 15/11/2013; Alemayehu Regassa and Awol Taju
Geology: Volcanic rocks of Tertiary and quaternary age overlie the precamberian rocks
Land form: Undulating to rolling high volcanic plateau
Local physiography: Hilly to the west (Kuyu hill), rolling to the east
Slope: 35% NW, on the middle part of a long straight slope
Land use/vegetation: Currently a fallow land used for grazing; two years ago, it has been a cultivated land (teff, maize and wheat are dominant crops cultivated in rotation). Eucalypus spps, Avocado, and coffee are common around homestead. There are reminants of shrubs upslope on the Kiyu hill and along banks of streams
General information on the soil
Parent material: Deeply weathered colluvium and residual material derived from Tertiary rocks, most probably basalts and trachybasalts

Moisture condition: Dry at the top and moist down the profile
Drainage: Well to excessively well drained
Ground water: Not encountered, very deep
Surface stones: None
Erosion: Slight rill erosion and in some areas down slope there are active big gullies
Human influence: Inappropriate tillage practice, ploughing down the slope, accelerating erosion; animal trampling

Profile description

Hor.	Depth (cm)	Description
Ap	0 – 15	dark reddish brown (5YR 3/2) moist; clay loam; soft dry, friable moist, sticky and plastic wet; moderate fine and medium subangular blocky; many fine and common medium pores; many fine roots; smooth gradual boundary to
AB	15 – 40	very dark brown brown (7.5YR 2.5/2) moist; sandy clay loam; hard dry, friable moist, sticky and plastic wet; moderate fine and medium subangular blocky; clay cutans; many fine and common medium pores; many fine roots; gradual smooth boundary to
Bt1	40-75	very dark brown brown (7.5YR 2.5/2) moist; sandy clay loam; soft dry, friable moist, sticky and plastic wet; moderate fine and medium subangular blocky; many fine and few medium pores; few medium spherical quartz fragments; common fine and few medium roots; gradual smooth boundary to
Bt2	75-110	dark reddish brown (5YR 3/2) moist; sandy clay; soft dry, friable moist, sticky and plastic wet; weak fine and medium subangular blocky; many fine and few medium pores; frequent medium spherical weathered quartz fragments; few fine and medium roots

Table 6.2: Physical properties of soil profile in Doyo Yaya

Pedon/Horizon	Depth (cm)	% Particle size distribution			Texture class	Silt/Clay ratio	BD g/cm^3
		Sand	Silt	Clay			
JIM/OMN/DY/P1							
Ap	0-15	18.4	23	58.6	clay	0.39	1.06
AB	15-30	13.2	17.0	70.0	clay	0.24	1.17
Bt1	30-60	15.3	17.0	67.8	clay	0.25	1.01
Bt2	60-80	10.9	23.3	65.8	clay	0.35	1.13
JIM/OMN/DY/P2							
Ap	0-10	22.3	29.4	48.3	clay	0.61	1.08
AB	10--30	15.8	25.3	59.0	clay	0.43	1.03
Bt1	30-65	16.0	23.1	60.9	clay	0.38	1.06
Bt2	65-110	13.7	18.9	67.4	clay	0.28	1.15
Bt3	110+	17.7	16.9	65.4	clay	0.26	1.09
JIM/OMN/DY/P3							
AP	0-15	23.6	31.9	44.6	clay	0.72	1.16
B	15-40	21.3	29.8	49.0	clay	0.61	1.16
Bt1	40-75	17.9	15.1	67.0	clay	0.23	1.18
Bt2	75-110	12.8	19.6	67.6	clay	0.29	1.18
Bt3	110+	10.44	24.0	65.5	clay	0.37	1.21

Table 6.3: Selected chemical properties of soil profiles in Doyo Yaya Kebele

Pedon/ Horizon	Depth (cm)	pH (1:2.5)		ΔpH	EC (ds/m)	OC (%)	TN (%)	C:N ratio	Av.P (mg P_2O_5/ kg soil	Av. S (%)	Micro nutrients (mg/kg soil)			
		H2O	KCl								Zn	Mn	Cu	Fe
JIM/OMN/DY/P1														
Ap	0-15	5.9	5.0	0.9	0.06	1.27	0.13	9.77	0.26	6.37	6.37	17.46	1.07	57.07
AB	15-30	5.4	4.8	0.6	0.05	0.82	0.07	11.71						
Bt1	30-60	5.5	4.7	0.8	0.04	0.59	0.05	11.80						
Bt2	60-80	5.6	4.8	0.8	0.04	0.42	0.04	10.50						
Average		5.6	4.83	0.78	0.05	0.78	0.07	10.95						
JIM/OMN/DY/P2														
Ap	0-10	5.4	4.8	0.6	0.06	1.51	0.15	10.07	10.2	0.46	8.23	57.19	0.75	88.47
AB	10-30	5.2	4.5	0.7	0.04	1.19	0.10	11.90						
Bt1	30-65	5.0	4.5	0.5	0.05	0.80	0.07	11.43						
Bt2	65-110	5.0	4.4	0.6	0.03	0.35	0.04	8.75						
Bt3	110+	5.1	4.4	0.7	0.03	0.29	0.03	9.67						
Average		5.15	4.55	0.6	0.05	0.96	0.09	10.54						
JIM/OMN/DY/P3														
AP	0-15	5.5	4.7	0.8	0.04	1.88	0.16	11.75	10.8	0.29	23.4	61.46	1.32	98.50
B	15-40	5.3	4.7	0.6	0.03	1.62	0.13	12.46						
Bt1	40-75	5.4	4.8	0.6	0.03	1.04	0.10	10.40						
Bt2	75-110	5.5	4.8	0.7	0.02	0.82	0.09	9.11						
Bt3	110+	5.6	4.7	0.9	0.02	0.74	0.08	9.25						
Average		5.5	4.7	0.7	0.03	1.22	0.11	10.59						

Table 6.4. Exchangeable cations and CEC results of soil profiles in Doyo yaya kebele

Horizon	Depth (cm)	Exchangeable cations (cmol (+) kg-1					Cations ratio		CEC (cmol (+) kg-1		BS (%)	ESP (%)
		Na	K	Ca	Mg	sum	Ca/Mg	K/Mg	Soil	Clay		
JIM/OMN/DY/P1												
Ap	0-15	1.63	1.61	14.14	4.99	22.37	2.83	0.32	37.08	55.77	60.3	4.39
AB	15-30	1.47	1.67	12.72	4.24	20.1	3.00	0.39	45.17	60.53	44.5	3.27
Bt1	30-60	1.73	1.74	12.72	4.24	20.43	3.00	0.41	46.09	65.03	44.3	3.76
Bt2	60-80	1.73	1.70	12.72	4.24	20.39	3.00	0.40	46.55	68.62	43.8	3.72
Average		1.64	1.68	13.08	4.43	20.82	2.96	0.38	43.72	62.49	48.2	3.79
JIM/OMN/DY/P2												
Ap	0-10	1.64	1.85	11.76	5.04	20.29	2.33	0.37	47.02	86.58	43.2	3.50
AB	10--30	1.79	1.53	11.76	5.04	20.12	2.33	0.30	41.54	63.29	48.4	4.31
Bt1	30-65	1.79	1.54	12.6	4.20	20.13	3.00	0.37	46.57	71.87	43.2	3.84
Bt2	65-110	1.73	1.83	10.92	4.20	18.68	2.60	0.44	48.39	70.01	38.6	3.58
Bt3	110+	1.92	2.12	11.76	4.20	20	2.80	0.50	41.09	61.30	48.7	4.67
Average		1.77	1.77	11.76	4.54	19.84	2.61	0.40	44.92	70.61	44.42	3.98
JIM/OMN/DY/P3												
AP	0-15	1.71	1.70	17.81	5.94	27.16	3.00	0.29	41.48	78.65	65.5	4.13
B	15-40	1.81	1.32	16.11	5.94	25.18	2.71	0.22	46.09	82.63	54.6	3.92
Bt1	40-75	1.79	1.24	17.12	6.85	27	2.50	0.18	61.87	86.97	43.6	2.89
Bt2	75-110	1.95	1.20	18.14	7.78	29.07	2.33	0.15	56.82	79.91	51.2	3.44
Bt3	110+	1.80	1.12	17.28	6.91	27.11	2.50	0.16	59.63	87.07	45.5	3.02
Average		1.81	1.32	17.29	6.68	27.10	2.61	0.20	53.18	83.05	52.08	3.48

Table 6.5 : Site and profile description of soil profiles in nada Bidaru kebele

Profile code:	JIM/OMN/NB/P1
Soil classification:	Eutric Nitisols
Location:	Nada Bidaru, Garee Bulbuloo
Coordinates:	300086 m N- 836348 m E
Elevation:	2221 m above sea level
Date and author:	19/11/2013; Alemayehu Regassa and Gali
Geology:	Volcanic rocks of Tertiary and quaternary age overlie the precamberian rocks
Land form:	Undulating to rolling high volcanic plateau
Local physiography:	Undulating upland
Slope:	11%, NW
Land use/vegetation:	Cultivation of cereals; major crop are wheat, maize and sorghum; few scattered trees spps on farmlands: *croton machrostachys, cordia africana* and *Eucalyptus spps* around homestead

General information on the soil

Parent material:	Highly weathered basalt
Moisture condition:	Dry at the top and moist in the subsurface horizons
Drainage:	Well drained
Groundwater:	Unknown, no signs of ground water table in the profile
Surface stones:	None
Erosion:	Slight sheet erosion
Human influence:	continuous cultivation and poor soil fertility management

Profile description

Horizon	Depth (cm)	Description
Ah	0-20	dark yellowish brown(10YR 3/4) moist); clay; moderate coarse sub angular blocky; friable ; very sticky and very plastic;common fine and medium roots; few animal burrows ; common fine to coarse pores; clear smooth boundary to
AB	20-35	dark reddish brown (5YR 3/3) moist; clay; strong medium and coarse angular blocky; friable; very sticky and plastic; few distinct clay cutans; pedface; very few black hard mechanical concretion; few fine roots; few animal burrows; common fine and medium pores; gradual smooth boundary to
Bt1	55-60	dark reddish brown (5YR 3/4) moist; clay; strong coarse sub angular blocky; hard, firm, very sticky and very plastic; prominent shiny ped faces; faint diffuse iron and manganese mottlings; many medium coarse pores; very few very fine roots; diffuse smooth boundary to
Bt2	60-100	dark reddish brown (5YR 3/4) moist; clay; strong medium coarse sub angular blocky; hard, very firm, very sticky and very plastic; distinct shiny ped faces decreasing in the horizon below; few fine pores; gradual smooth boundary to
BC	100+	dark reddish brown (5YR 3/4) moist;clay; friable, sticky and plastic; moderate fine and medium sub-angular blocky; common fine and medium roots; many fine and medium pores

Site characteristics

Profile code:	JIM/OMN/NB/P2
Soil classification:	Dystric Cambisols
Location:	Nada Bidaru, *Garee Guutee*
Coordinates:	300078 m N- 834566 m E
Elevation:	2344 m above sea level
Date and author:	19/11/2013; Alemayehu Regassa and Gali
Geology:	Volcanic rocks of Tertiary and quaternary age overlie the precamberian rocks
Land form:	Undulating to rolling high volcanic plateau
Local physiography:	Nearly flat to undulating
Slope:	1%, gentle slope
Land use/vegetation:	Cultivation of leguminous crops mainly faba bean and peas

General information on the soil

Parent material:	Weathered basalts
Moisture condition:	Dry at the top and moist in the subsurface horizons
Drainage:	Well drained
Ground water:	Not encountered, very deep
Surface stones:	None
Erosion:	Slight sheet erosion
Human influence:	Continuous cultivation with out adequate fertilization

Profile description

Hor.	Depth (cm)	Description
Ah	0-8	dark brown (7.5YR 3/2) moist; clay loam; friable; sticky and slightly plastic ; moderate fine and medium sub angular blocky; many fine and medium pores; common fine roots; clear smooth boundary to
AB	8-28	very dark gray (7.5YR 3/1) moist; clay ; moderate fine and medium sub angular blocky; friable; slightly sticky and slightly plastic ; few black rounded hard manganese nodules ; many fine and medium pores; very few fine and medium roots; gradual smooth boundary to
Bt1	28-50	dark reddish brown (5YR 3/3) moist; clay; friable; sticky and plastic; moderate fine and medium sub angular blocky; patchy clay cutans on ped faces; few black manganese nodules; common fine and medium pores; very few fine and medium roots; gradual smooth boundary to
Bt2	50-85	reddish brown (5YR 4/3) moist; clay ; moderate fine and medium sub angular blocky; friable; sticky and plastic; few clay cutans on ped faces; very few fine roots; gradual smooth boundary to

Bt3	85+	strong brown (7.5 YR 5/8) moist; clav ; strong medium angular blocky structure; slightly friable, sticky and plastic; common small hard round black manganese and reddish brown iron concretions; few fine pores; no roots

Table 6.6: Physical properties of soil profiles in Nada Bidaru Kebele

Pedon/Horizon	Depth (cm)	% Particle size distribution			Texture class	Silt/Clay ratio	BD g/cm^3
		Sand	Silt	Clay			
JIM/OMN/NB/P1							
Ah	0-20	27.8	27.6	44.6	clay	0.62	1.03
AB	20-35	19.3	19.1	61.6	clay	0.31	1.08
Bt1	35-60	16.8	17.1	66.1	clay	0.26	1.13
Bt2	60-100	12.6	21.3	66.1	clay	0.32	1.13
BC	100+	13.7	25.3	61.0	clay	0.41	1.14
JIM/OMN/NB/P2							
Ah	0-8	32.1	25.5	42.4	Clay	0.60	1.01
AB	8--28	15.8	23.2	61.0	clay	0.38	1.08
Bt1	28-50	15.3	27.5	57.2	clay	0.48	1.12
Bt2	50-85	16.8	17.1	66.1	clay	0.26	1.15
Bt3	85+	29.4	10.7	59.9	clay	0.18	1.06

Table 6.7: Selected chemical properties of soil profiles in Nada Bidaru

Pedon/Horizon	Depth (cm)	pH (1:2.5)		ΔpH	EC (ds/m)	OC (%)	TN (%)	C:N ratio	Av.P (mg P_2O_5/kg soil	Av. S (%)	Micro nutrients (mg/kg soil)			
		H_2O	KCl								Zn	Mn	Cu	Fe
JIM/OMN/NB/P1														
Ap	0-20	5.6	4.9	0.7	0.06	3.21	0.31	10.35	21.3	1.17	20.8	68.3	1.6	98.0
Bt1g	20-35	5.2	4.6	0.6	0.05	1.55	0.18	8.61						
Bt2g	35-60	5.3	4.5	0.8	0.03	0.98	0.1	9.80						
Bt3g	60-100	5.3	4.5	0.8	0.02	0.57	0.05	11.40						
Bt4g	100+	5.1	4.5	0.6	0.02	0.31	0.03	10.33						
Average		5.3	4.6	0.7	0.04	1.32	0.13	10.10						
JIM/OMN/NB/P2														
Ah	0-8	5.6	4.8	0.8	0.07	3.73	0.4	9.33	19.9	0.87	26.3	67.7	1.3	143.3
AB	8--28	5.9	5.0	0.9	0.06	1.66	0.18	9.22						
Bt1	28-50	5.4	4.8	0.6	0.05	1.25	0.13	9.62						
Bt2	50-85	5.5	4.7	0.8	0.02	0.77	0.09	8.56						
Bt3	85+	5.6	4.8	0.8	0.02	0.38	0.04	9.50						
Average		5.6	4.8	0.8	0.04	1.56	0.17	9.25						

Table 6.8: Exchangeable cations and CEC results of soil profiles in Nada Bidaru kebele

Horizon	Depth (cm)	Exchangeable cations (cmol (+) kg-1					Cations ratio		CEC cmol (+) kg-1		BS (%)	ESP (%)
		Na	K	Ca	Mg	sum	Ca/Mg	K/Mg	Soil	Clay		
JIM/OMN/NB/P1												
Ah	0-20	1.81	1.71	19.50	8.48	31.50	2.30	0.20	47.93	82.80	47.93	3.77
AB	20-35	1.83	0.95	16.96	6.78	26.52	2.50	0.14	56.23	82.80	56.23	3.25
Bt1	35-60	1.84	0.83	15.26	5.09	23.02	3.00	0.16	56.69	82.80	56.69	3.25
Bt2	60-100	1.62	0.82	13.57	4.24	20.25	3.20	0.19	48.39	82.80	48.39	3.35
BC	100+	2.01	0.9	18.48	6.72	28.11	2.75	0.13	37.43	82.80	37.43	5.37
Average		1.82	1.04	16.75	6.26	25.88	2.75	0.16	49.33	82.80	49.33	3.80
JIM/OMN/NB/P2												
Ah	0-8	2.08	2.49	21.20	11.02	36.79	1.92	0.23	40.56	65.47	40.56	5.14
AB	8--28	1.88	2.55	15.12	5.04	24.59	3.00	0.51	38.35	53.36	38.35	4.9
Bt1	28-50	1.95	2.63	13.57	4.24	22.39	3.20	0.62	35.49	54.35	35.49	5.51
Bt2	50-85	2.01	2.77	11.02	4.24	20.04	2.60	0.65	39.63	56.02	39.63	5.07
Bt3	85+	1.94	0.92	12.72	5.09	20.67	2.50	0.18	40.1	64.61	40.1	4.83
Average		1.97	2.27	14.72	5.93	24.90	2.64	0.44	38.83	58.76	38.83	5.09

Table 6.9: Site and profile description of Nada Chala Kebele in Omo Nada Woreda

Site characteristics

Profile code: JIM/OMN/NC/P1
Soil classification: Vertic Planosols
Location: Nada Chala, Garee Sadachaa
Coordinates: 303363 m N- 842940 m E
Elevation: 1823 m
Date and author: 18/11/2013; Alemayehu Regassa and Ahmed
Geology: Volcanic rocks of Tertiary and quaternary age overlie the precamberian rocks
Land form: Valley in a gently undulating landscape with long flat slopes
Local physiography: Undulating upland
Slope: 1%
Land use: A fallow grazing land; it was a teff farm land before 5 years

General information on the soil

Parent material: Colluvial and residual material derived from transported volcanic tephra and mafic materials
Moisture condition: Moist throughout
Drainage: Poorly drained but quickly dries out after the rainy season
Groundwater: None at the time of observation but waterlogged in the rainy season
Surface stones: None
Erosion: Slight sheet erosion
Human influence: Overgrazing

Profile description

Horizon	Depth (cm)	Description
Apg1	0-13	very dark grayish brown (10YR 3/1) moist; sandy loam; massive to very weak granular; friable when moist; non sticky and slightly plastic; common diffuse light brown (10 YR 5/8) distinct mottles ; abundant, very fine to medium roots ; gradual smooth boundary
Eg2	13-40	gray (10YR 5/1) moist ; sandy clay loam; friable; slightly sticky and slightly plastic ; few yellowish brown (10 YR 5/8) mottles ; Common fine interstitial pores; very few fine roots; abrupt and smooth boundary
2Bssg1	40-55	black (10YR 2/1) moist; clay; medium to strong blocky; very sticky and very plastic; very few fine brown (7.5YR 4/4) iron mottles; slight intersecting slickensides; thin clay skins along root channels and larger pores; very few fine roots; few large and many medium rounded and sharp pointed ferromanganese nodules; gradual smooth boundary
2Bssg2	55-85	very dark grayish brown (10 YR 3/2) moist; clay; strong, medium to coarse angular blocky; very sticky and very plastic; many rounded and sub-rounded hard Fe/Mn nodules, generally less than 1 cm across; thin clay skin along cleavage faces; no roots; gradual smooth boundary to
2BC	85+	black (10 YR 2/1, moist); clay; strong fine angular blocky; firm ; sticky and plastic; ; hard iron- manganese concretions; some slickenside ; thin clay skins along root channels ; no roots

Site characteristics

Profile code: JIM/OMN/NC/P2
Soil classification: Rhodic Nitisols
Location: Nada Chala, *Garee Xabaloo*
Coordinates: 300390 m N- 843137 m E
Elevation: 1861 m
Date and author: 18/11/2013; Alemayehu Regassa and Ahmed
Geology: Volcanic rocks of Tertiary and quaternary age overlie the precamberian rocks
Land form: Middle slope between small plateau and valley
Local physiography: Undulating upland
Slope: 13%
Land use: A fallow grazing land and has never been ploughed for the last 30 years

General information on the soil

Parent material: Insitu weathering of mafic rocks, basalt
Moisture condition: Dary at the top and moist down the depth of the profile
Drainage: Well drained
Groundwater: Not encountered, very deep
Surface stones: None
Erosion: Slight sheet erosion
Human influence: Overgrazing, cattle trampling

Profile description

Horizon	Depth (cm)	Description
Ah	0-15	dark reddish brown (7.5YR 3/3) moist; clay loam; strong medium granular; soft, friable, slightly sticky and slightly plastic; many fine interstial pores; many medium roots; clear smooth boundary to
Bt1	15-50	dark reddish brown (5YR 3/3) moist; clay; strong fine and medium sub angular blocky; slightly friable, sticky and plastic; common fine interstitial pores; many medium, reddish brown Fe-oxide mottles and few faint black Mn-oxide mottles; many fine interstial pores; few fine roots; diffuse smooth boundary to
Bt2	50-80	dark reddish brown (5YR 3/3) moist; clay; strong medium and coarse sub angular blocky; hard, very firm, very sticky and very plastic; very few very fine roots; common fine interstitial pores; many distinct shiny ped faces; few dark brown manganese nodules; diffuse smooth boundary to
Bt3	80-110	dark reddish brown (5YR 3/4) moist; clay; strong medium coarse sub angular blocky; hard, very firm, very sticky and very plastic; few fine pores; soft spherical black manganese nodules; gradual smooth boundary to
BC	110+	dark reddish brown (5YR 3/4) moist; coarse angular blocky; slightly hard, sticky and plastic; plane voids;; intersecting shiny ped faces ; very few very fine faint yellowish diffuse mottles; black manganese concretions; no root

Tabler 6.10: Physical properties of soil profiles in Nada Chala Kebele

Pedon/Horizon	Depth (cm)	% Particle size distribution			Texture class	Silt/Clay ratio	BD g/cm^3
		Sand	Silt	Clay			
JIM/OMN/NC/P1							
Ap	0-13	26.4	31.6	42.1	clay	0.75	1.01
Bt1g	13-40	22.2	40.9	36.9	Clay loam	1.11	1.05
Bt2g	40-55	25.0	26.5	48.5	clay	0.55	1.16
Bt3g	55-85	16.1	17.7	66.3	clay	0.27	1.23
Bt4g	85+	18.6	18.1	63.4	clay	0.29	1.15
JIM/OMN/NC/P2							
Ah	0-15	19.5	17.0	63.6	clay	0.27	1.08
Bt1	15-50	20.9	25.7	53.4	clay	0.48	1.10
Bt2g	50-80	20.2	16.8	63.0	clay	0.27	1.08
Bt3g	80-110	16.0	16.8	67.2	clay	0.25	1.14
Bt4g	110+	15.9	16.8	67.3	clay	0.25	1.10

Table 6.11: Selected chemical properties of soil profiles in Nada Chala kebele

Pedon /Horizon	Depth (cm)	pH (1:2.5)		ΔpH	EC (ds/m)	OC (%)	TN (%)	C:N ratio	Av.P (mg P_2O_5/ kg soil	Av. S (%)				
		H_2O	KCl								Zn	Mn	Cu	Fe
JIM/OMN/NC/P1														
Ap	0-13	5.0	4.2	0.8	0.04	1.75	0.16	10.94	10.4	0.34	7.1	30.3	1.6	133.4
Bt1g	13-40	5.4	4.6	0.8	0.03	0.83	0.10	8.30						
Bt2g	40-55	5.4	4.2	1.2	0.07	0.67	0.08	8.38						
Bt3g	55-85	5.7	4.8	0.9	0.09	0.59	0.06	9.83						
Bt4g	85+	7.3	6.3	1	0.17	0.32	0.03	10.67						
Average		5.8	4.8	0.9	0.08	0.83	0.09	9.62						
JIM/OMN/NC/P2														
Ah	0-15	5.3	4.7	0.6	0.05	1.81	0.18	10.06	9.20	0.54	5.7	67.5	1.5	72.9
Bt1	15-50	5.1	4.5	0.6	0.04	1.18	0.10	11.80						
Bt2g	50-80	5.1	4.4	0.7	0.03	0.62	0.07	8.86						
Bt3g	80-110	5.2	4.5	0.7	0.03	0.51	0.05	10.20						
Bt4g	110+	5.2	4.8	0.4	0.03	0.46	0.04	11.50						
Average		5.2	4.6	0.6	0.04	0.92	0.09	10.48						

Table 6.12: Exchangeable cations and CEC results of soil profiles in Nada Chala kebele

Horizon	Depth (cm)	Exchangeable cations (cmol (+) kg-1					Cations ratio		CEC (cmol (+) kg-1		BS (%)	ESP (%)
		Na	K	Ca	Mg	sum	Ca/Mg	K/Mg	Soil	Clay		
JIM/OMN/NC/P1												
Ap	0-13	1.83	0.39	14.28	5.04	21.54	2.83	0.08	35.15	69.24	61.3	5.19
Bt1g	13-40	1.77	0.19	7.34	3.26	12.56	2.25	0.06	31.49	77.75	39.9	5.63
Bt2g	40-55	2.77	1.17	26.16	8.72	38.82	3.00	0.13	48.81	95.69	79.5	5.67
Bt3g	55-85	2.69	1.19	26.16	9.59	39.63	2.73	0.12	51.18	74.18	77.4	5.26
Bt4g	85+	2.25	1.38	43.46	4.78	51.87	9.09	0.29	63.79	98.72	81.3	3.53
Average		2.26	0.86	23.48	6.28	32.88	3.98	0.14	46.08	83.12	67.88	5.06
JIM/OMN/NC/P2												
Ah	0-15	1.71	1.23	13.57	5.09	21.6	2.67	0.24	49.31	67.78	43.8	3.48
Bt1	15-50	1.81	1.49	12.72	5.09	21.11	2.50	0.29	46.09	78.82	45.8	3.92
Bt2g	50-80	1.73	1.56	11.76	5.04	20.09	2.33	0.31	51.59	78.40	38.9	3.36
Bt3g	80-110	1.83	1.39	12.60	4.20	20.02	3.00	0.33	52.96	76.13	37.8	3.45
Bt4g	110+	1.94	1.32	10.92	4.20	18.38	2.60	0.31	47.48	68.17	38.7	4.08
Average		1.80	1.40	12.31	4.72	20.24	2.62	0.30	49.49	73.86	41.00	3.66

Table 6.13: Site and profile description of Toli Beyem Kebele in Omo Nada Woreda

Site characteristics

Profile code: OMN/TB/P1
Soil classification: Vertic Planosols
Location: Toli Beyem, Garee Hullee
Coordinates: 295854 m N- 836182 m E
Elevation: 1771 m above sea level
Date and author: 20/11/2013; Alemayehu Regassa and Ahmed
Geology: Volcanic rocks of Tertiary and quaternary age overlie the precamberian rocks
Land form: Valley in a gently undulating landscape with long flat slopes
Local physiography: Valley bottom, gently undulating
Slope: 1.5%, nearly straight across and along the slope
Land use/vegetation: A fallow grazing land; 15 years ago it was a *teff* farm land; patches of *Eucalyptus* woodlots on either side of the valley, on the hills

General information on the soil

Parent material: Volcanic ash layer over tertiary volcanic material
Moisture condition: Moist throughout
Drainage: Seasonally flooded
Groundwater: None at the time of observation but waterlogged in the rainy season
Surface stones: None
Erosion: Slight sheet erosion
Human influence: Overgrazing

Profile description

Horizon	Depth (cm)	Description
Ah	0-8	pinkish gray (7.5YR 6/2) moist ; clay loam; massive to very weak granular; non-sticky and slightly plastic; very fine reddish yellow (7.5YR 6/8) iron mottles; common fine continuous in ped interstitial pores; many fine and common medium roots throughout; clear smooth boundary to
Eg1	8-25	brown (7.5YR 5/2) moist; silt clay loam; massive to weak platy; friable; slightly sticky and slightly plastic ; few fine strong brown (7.5YR 5/8) mottles ; few medium and fine ferromanganese nodules; thick (2cm) continous layer of common distinct yellowish brown iron and black manganese oxide mottles at the transition to the underlying horizon; many coarse continuous random interstitial pores; common fine, few medium roots; gradual smooth boundary to
Eg2	25-40	gray (7.5YR 5/1) moist; clay; strong, moderate fine and medium sub angular blocky; very sticky and very plastic; few large ferromanganese nodules; vertical pedfaces partly intersecting and shining slickensides; common inped interstitial pores, few very fine and fine roots; abrupt smooth boundary to
2Bssg1	40-50	dark brown (10YRY 3/1) moist); clay; medium to coarse angular blocky; very sticky and very plastic; common slickensides and pressure faces and continuous , thin clay skin along cleavage faces; common fine continuous pores ;very fine to fine , random roots; gradual smooth boundary to
2Bssg2	50-85	black (10YR 2/1, moist); clay; moderate, medium angular blocky; very sticky and very plastic; common slickensides and pressure faces few fine continuous inped pores; no roots; diffuse smooth boundary to
2Bssg3	85+	black (10YR 2/1, moist); clay; moderate fine and medium angular and subangular blocky; slightly hard, very sticky and very plastic; common slickensides and pressure faces; very few very fine inped pores; no roots

Table 6.14: Physical properties of soil profiles in Toli Beyem Kebele

Pedon/Horizon	Depth (cm)	% Particle size distribution			Texture class	Silt/Clay ratio	BD g/cm^3
		Sand	Silt	Clay			
OMN/TB/P1							
Ah	0-8	17.5	36.0	45.2	clay	0.80	1.03
Eg1	8--25	24.1	28.1	47.8	clay	0.59	1.10
Eg2	25-40	63.0	16.4	20.5	SCL	0.80	1.03
Bt1g	40-50	20.3	13.3	66.4	clay	0.20	1.24
Bt2g	50-85	18.9	13.5	67.6	clay	0.20	1.28
Bt3g	85+	21.2	14.4	64.4	clay	0.22	1.16

Table 6.15: Selected chemical properties of soil profiles in Toli Beyem kebele

Pedon/ Horizon	Depth (cm)	pH (1:2.5)		ΔpH	EC (ds/m)	OC (%)	TN (%)	C:N ratio	Av.P (mg P_2O_5/ kg soil)	Av. S (%)	Micro nutrients (mg/kg soil)			
		H_2O	KCl								Zn	Mn	Cu	Fe
OMN/TB/P1														
Ah	0-8	5.4	4.8	0.6	0.04	1.53	2.6	0.15	9.5	0.44	11.0	14.8	1.3	128.6
Eg1	8--25	5.2	4.5	0.7	0.04	1.07	1.8	0.13						
Eg2	25-40	5.3	4.5	0.8	0.04	0.91	1.6	0.10						
Bt1g	40-50	5.04	4.4	0.6	0.08	0.85	1.5	0.08						
Bt2g	50-85	5.1	4.4	0.7	0.13	0.58	1.0	0.06						
Bt3	85+	5.5	4.8	0.7	0.05	0.30	0.5	0.04						
Average		5.3	4.6	0.7	0.06	0.87	1.50	0.09						

Table 6.16: Exchangeable cations and CEC results of soil profiles in Toli Beyem kebele

Horizon	Depth (cm)	Exchangeable cations (cmol (+) kg-1					Cations ratio		CEC (cmol (+) kg-1		BS (%)	ESP (%)
		Na	K	Ca	Mg	sum	Ca/Mg	K/Mg	Soil	Clay		
OMN/TB/P1												
Ah	0-8	2.37	0.48	9.24	3.36	15.45	2.75	0.14	30.59	56.17	50.5	7.76
Eg1	8--25	2.12	0.53	9.15	4.16	15.96	2.20	0.13	27.13	49.23	58.8	7.8
Eg2	25-40	1.99	0.33	7.42	2.47	12.21	3.00	0.13	20.15	82.68	60.6	9.87
Bt1g	40-50	3.21	2.00	13.20	4.40	22.81	3	0.45	55.48	79.04	41.1	5.79
Bt2g	50-85	3.19	2.19	20.42	8.88	34.68	2.30	0.25	52.12	74.14	66.5	6.11
Bt3	85+	2.93	2.04	22.00	8.80	35.77	2.5	0.23	52.61	80.14	68	5.56
Average		2.64	1.26	13.57	5.35	22.81	2.63	0.22	39.68	70.23	57.58	7.15

3.4.4. Synthesis

In this section of the report, synthesis of the soil properties related to the agronomic development is made briefly. Reference is made to Table 5-21 for typical soil morphological description and physico-chemical characteristics.
The dominant agricultural soils in the four studied kebeles, Doyo yaya, Nada Chala, Nada Bidaru and Toli Beyem, are Nitisols and Vertisols covering 46% (25 and 21% respectively). Vertic Planosols occupy patchy flat landscapes interspersed between local hills.

Nitisols dominantly occupy in the upper and middle slope positions. The slope gradient ranges from 5-13%. They are characterized by abundant shiny ped faces which are typical expression of the Nitic properties, a major diagnostic criterion for the classification of Nitisols at the highest level. The shiny ped faces are assumed to be alumino-silica or alumina gel coatings (Sys, 1961).

Vertic Planosols occupy patchy flat landscapes interspersed between local hills. Planosols are soils that are characterized by a coarse textured surface horizon showing signs of periodic stagnation that abruptly overlies dense slowly permeable subsoil with significantly more clay than the surface horizon (Driessen at al., 2001; IUSS Working Group WRB, 2006, 2014). The occurrence of Planosols in flat or depressed topography and the slow permeability of the subsurface horizon results in the wet season and the low water holding capacity of the surface horizon also lead to scarcity moisture to crops in the dry season. Also, the compact subsurface horizon inhibits root growth. Structure of the surface horizon is unstable. Stagnic properties are found where a dense illuviation horizon obstructs downward percolation and the surface soil becomes saturated with water for extended periods of time. Therefore, the range and productivity of crops that can be grown on Planosols is very limited. Therefore Omo Nada, especially, in Nada Chala

kebele , where their occurrence is quite extensive, the major land use is for cattle grazing with some localized patchy areas cultivated with water loving root crops such as tarrow.

Cambisols soils are found on strongly sloping to moderately steep ridges and hills. The slopes range in gradient from nearly level on top of the ridges to 25% on the steep slopes.

The particle size analysis reveals that the texture of Nitisols is clayey throughout with clay content varying from 44.6 - 63.6 % in the surface to 53.4-70% in the subsurface horizons. The higher clay content often observed in the subsurface horizons of many soils may be attributed to illuviation and pedoturbation processes. All the soils have silt/clay ratio above 0.15 indicating that the soils are relatively young with high degree of weathering potential. Silt/clay ratios are relatively higher in the surface horizons and decrease with increase depth in the pedons. The decrease in silt/clay ratio with depth is an indication that subsoils horizons are more weathered than surface horizons.

The bulk density of all the studied profiles in Omo Nada woreda is found to be less than 1.44, which is common in cultivated soils. The low bulk density found in these soils indicates that the soils are not compacted and have more porosity.

From agricultural use point of view, Nitisols have an excellent physical property for crop cultivation. Therefore, they are by far the most agriculturally important soils in southwestern highlands of Ethiopia in general and study woredas in particular.

The soil pH of topsoils of the studied soils is strongly acid to medium with values between 5.0 and 5.9. According to Landon (1991), a pH range of 5.5 to 7.0 is the preferred range for most crops. The acidic soil reaction could

result in excess and toxicity of heavy metals, and deficiency of basic cations (Landon, 1991). The overall trend of the pH values with depth varies considerably and cannot be taken as a characteristic applicable to all the soils.

The organic carbon content in all studied soil samples is found to be very low and regularly decrease with depth. The very low organic carbon content may be attributed to intensive agricultural practices that aggravate organic carbon oxidation (Wakene and Hiluf, 2003). According to Landon (1991) total nitrogen (N) content in topsoils of the studied soils in Omo Nada woreda is low to medium ranging from 0.13 to 0.31% and generally decreases with soil depth. This decrease generally parallels to a decrease in contents of organic carbon, suggesting that the main source of total nitrogen was organic matter.The low nitrogen levels may be attributed to continued nutrient mining by plants. The C : N ratios of the top layer of the studied soils range between 8.61 and 11.65, which is an indication that most soils have good quality organic matter. The values of exchangeable sodium percentage (ESP) in all the soils studied in the woreda are generally below 15%, the critical limit for sodicity (Brady and Weil, 2002).

The CEC of of the total soil and clay fraction after correcting for organic matter is invariably very high. Since the organic matter content of the soils which normally influences the CEC is generally low, the CEC values to the amount and type of clay minerals present in the soils matter.

Exchangeable calcium followed by magnesium formed the dominant cation in the exchange complex throughout the horizons of the representative profiles.But their proportions showed an irregular pattern with depth. On the other hand, the proportions of exchangeable K and Na in the exchange site were found to be insignificant and also showed an irregular variation with

depth of the profile. From these data, it may be pointed out that, whereas toxicity from Na is unlikely to occur but K deficiency is expected according to Landon (1991) ratings. The presence of irregular variation in the exchangeable cations may partly suggest existence of different levels of leaching intensity within the horizons of the profile. It may also partly indicate an existence of different sources of parent materials.

3.5. Soils of CASCAPE intervention Kebeles in Limu Saka woreda

3.5.1. Geomorphology and Geology

The landscape of Limu Saka woreda has a rolling topography: ridges of volcanic origin are dissected by narrow v-shaped valleys. The Ghibe river crosses the woreda. Adjacent to this river large alluvial plains have been formed.

The ridges and small hills in basalt and related tuffs consist of the flat to sloping crests and the slopes (Fig. 12). The former can be of two categories: broad crests which have in general a slope class between 0-8% and narrow crests which have a slope class between 8-15%. Characteristic for the broad crests are very deep red soils. Only some narrow convex crests are characterized by moderately deep and shallow soils. Soil erosion is severe on these narrow crests.

(a)

(b)

Figure 18. Typical landscape of Limu saka woreda showing (a) crests and hills (b) plain land along the Ghibe river

On the sloppy landscapes the steepness varies from 15-40%. The majority of the slopes however have steepness of 15-20%. In these steep to very steep landscapes the soils are dominantly shallow. Large areas along the Gilgel Gibe river valley are covered by alluvial sediments. The slopes in this landscape position are generally less than 1-2%.

The surface rocks out cropping in the study kebeles consists of rhyolites, trachytes, trachytic and rhyolitic tuffs, ignimbrite and basalts which are deposited during the latest phase of the trap series in the Upper-Miocene to Pleistocene. These rhyolites, trachytes and accompanied tuffs are deposited from an acid magma melt.

According to Geological Survey of Ethiopia (GSE, 2012) the geology of the studied kebeles in Limu Saka woreda dominated by Limu lower basalt (37.7%) followed by Limu lower silicics (26.2%). Table7 and Figure 19 shows the area and percentage distribution of the different geological materials in the CASCAPE intervention kebeles of Limu saka woreda. When we consider at the kebele level, Limu lower basalt is the dominant geological substrate in Gejib and Mirkuz kebeles.

Table 7: Area and percent coverage of lithology in CASCAPE intervention kebeles in Limu Saka woreda

lithology	Area_ha	percent
Elluvium	757	5.6
Limu lower basalt	5053	37.7
Gibe lower basalt	36	0.3
Limu lower silicics	3517	26.2
Limu upper silicics	896	6.7
Trachyte flows and plugs	1358	10.1
Arjo lower basalt	402	3.0
Alluvium	174	1.3
Limu upper basalt	1206	9.0

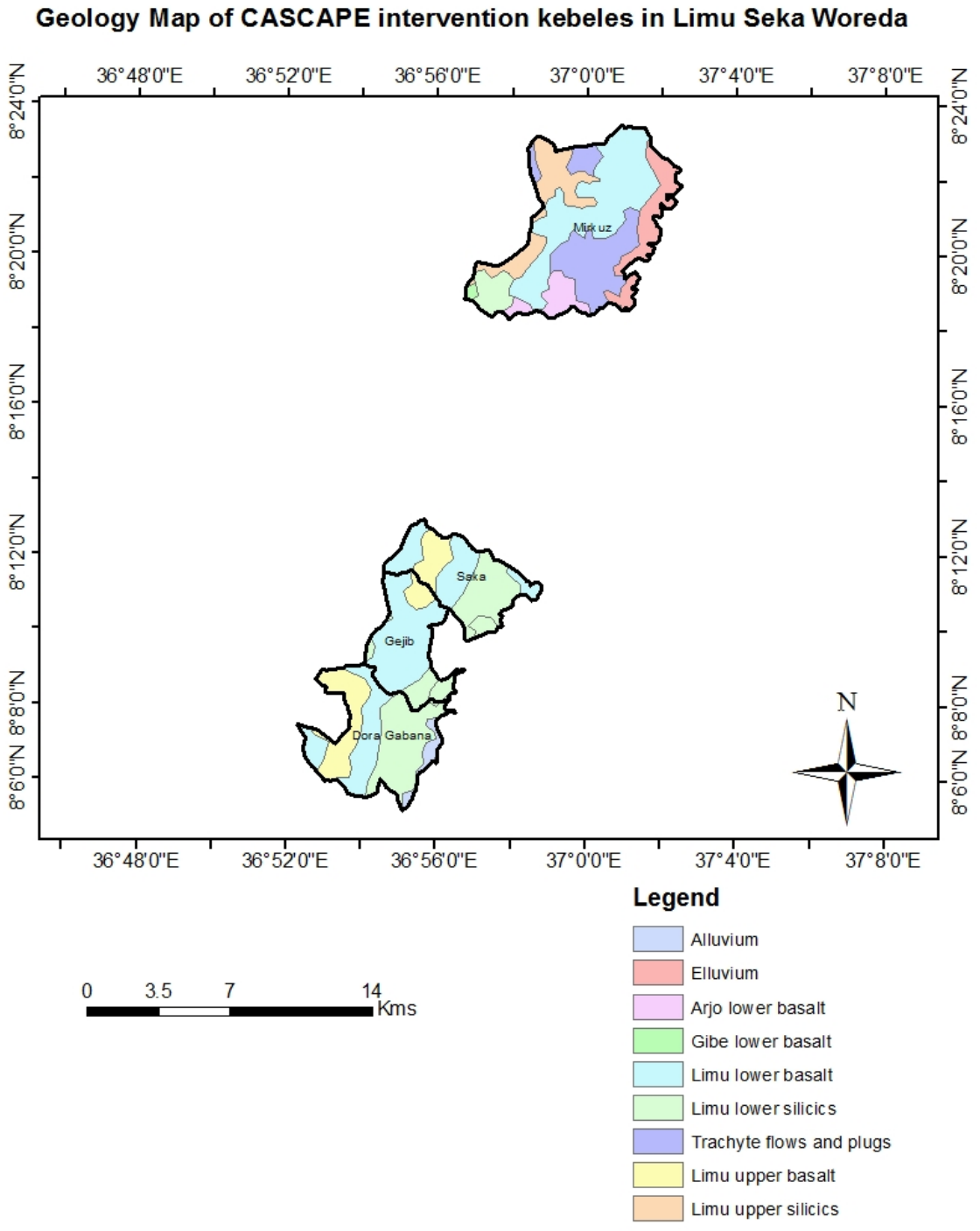

Figure 19. Geological map of CASCAPE intervention kebeles in Limu Saka woreda

Trachyte flows and plugs are also common in Mirkuz kebele while they are not present in the other studied CASCAPE intervention kebeles. In the Dora Gabena kebele, Limu lower silicics is dominant and Limu lower basalt and Limmu basalt cover nearly equal proportion of the area of the kebele. Gibe lower basalt and Limu lower basalt cover equal proportion in the Saka woreda. In all the studied kebeles Limu upper basalt covers the upper hilly topography of the kebeles.

3.5.2. The soil- landscape

Based on landforms, topography, slopes, parent materials, soil morphology and physico-chemical properties four mapping units were distinguished (Fig. 18; Table 8). The soilscapes are mainly related to the physiography of the woreda.

Dissected ridges with complex steep slopes of more than 60% slopes are covered by shallow soils with rock outcrops. The slopes are steep to very steep (over 40%).

Table 8: Summary of major Soil types and their distribution in the four CASCAPE intervention kebeles of Limu Saka woreda

Soil Type	Area (km2)	%
Leptosols	56.04	44.8
Cambisols	6.45	5.2
Nitisols	26.52	21.2
Gleysols	36.03	28.8

The rock out crops makes up 20 to 60% with a complex slope pattern. The land is under natural forest mixed with exotic Eucalyptus trees. The top soils are gravelly and stony (Fig. 20). The soils in these physiographic positions are classified as Leptosols. As the areal extent of such lands in the woreda is quite extensive, soils, dominantly Leptosols occurring in these physiographic positions cover the largest proportion of soils in the woreda. They were found in almost every slope position and gradient and in areas where stones and rocks were closed and/or exposed to the surface. Thus, Leptosols constitute about 44.8% of the soil types in the studied kebeles. Restriction for sustained growth of crops is due to limited rooting depth. Therefore is recommended that these soils are kept under vegetation cover.

 .

Figure 20. Profile of Leptosols indicating the presence of stones at shallow depth

Gently undulating to undulating, slightly dissected slopes, 5-10% slopes are covered with cambisols. These soils cover about 5.2% of the total area of the four kebeles studied in this woreda. They are mainly dominant in the middle slopes of Chalte, Kura, Labu and Gatira volcanic hills which are chains of interconnected hills.

The gently undulating to undulating slopes of varying slopes ranging from 5 to 15% slope gradient are covered by Nitisols (see the typical profile in fig. 20). They are the third most dominant soils interms of area coverage in the four studied kebeles in the woreda. They make up about 21.2 % of the total area of the four kebeles. Nitisols are the most agriculturally important soils.

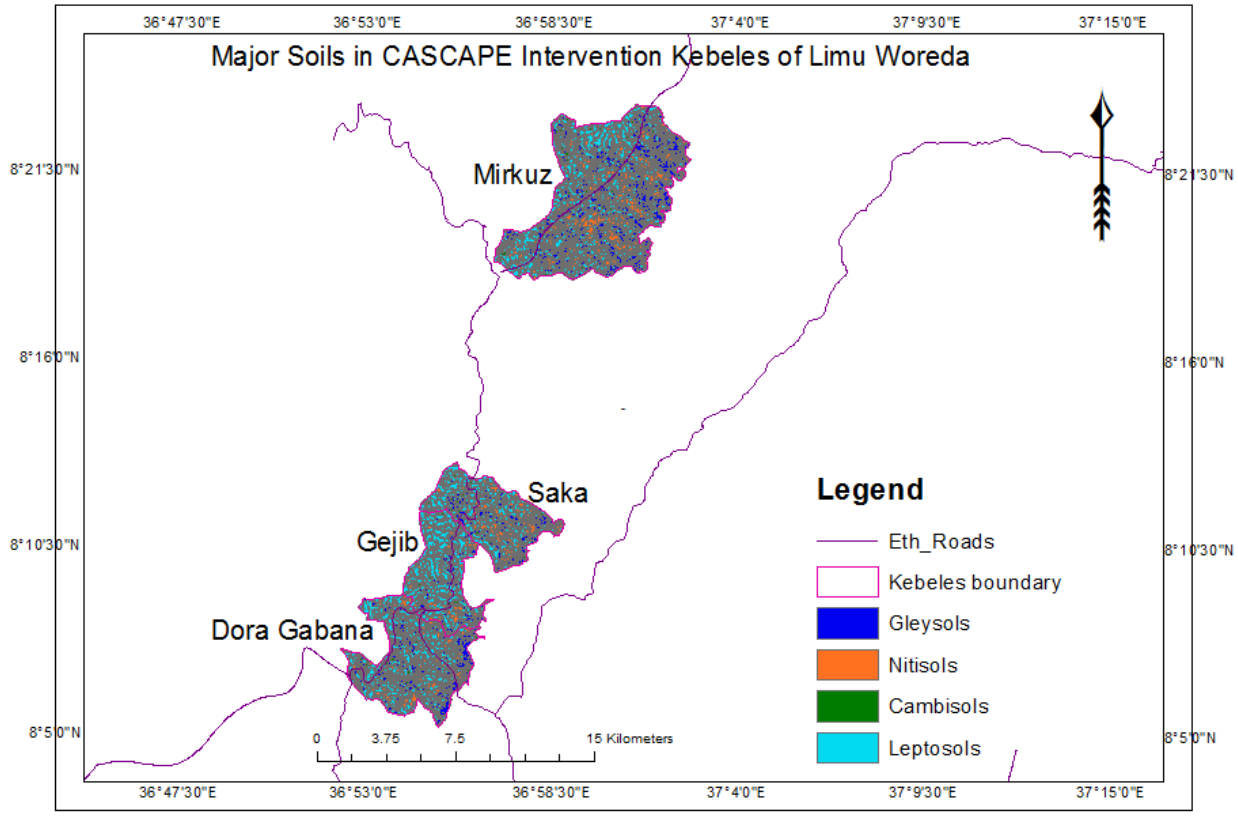

Figure 21. Soil map of kebeles in Limu Saka woreda

They are cultivated with Tefff in the undulating slopes such as on the side slopes of Mille hill in Saka kebele and in the gently undulating slopes in Mirkuz. Nitisols in the upper slopes of local hills of higher gradients of the landscape are prone to erosion if they will be turned to cultivation. They were, therefore, largely used as grazing land with very isolated standing trees. However, it was observed that cultivation was expanding onto these and other higher slope soils of the study area.

In the flat slopes of the low-lying drainage ways and localized depressions with slopes of 0-1%, gleysols are the dominant soil types (typical profile in Fig. 20). In area coverage they are the second extensive soils constituting about 28.8% of the total area of the four kebeles. They are especially extensive in the broad U-shaped valleys adjoining the Ghibe river.

Figure 22. Representative soil profiles in Limu Saka: Left- Nitisols and right Gleysols

3.5.3. Soil profile descriptions with analytical data

Table 9. Site and profile description and lab analytical data of CASCAPE intervention kebeles in Limu Seka woreda

9.1. Site and profile description of Dora Gabana Kebele

Profile code:	JIM/LS/DG/P1
Soil classification:	Stagnic Albic Luvisols
Location:	Dora Gabana, Siidoo plain
Coordinates:	270636 m N- 895080 m E
Elevation:	1619 m above sea level
Date and author:	11/12/2013; Alemayehu Regassa and Miftawu Jemal
Geology:	Volcanic rocks of Tertiary and quaternary age overlie the precamberian rocks
Land form:	Valley in an undulating landscape
Local Physiography:	Plain land between hills
Slope:	1% S, nearly straight
Land use/vegetation:	Farm land, dominant crop being maize; eucalyptus woodlots on the hills and some patches of scattered shrubs

General information on the soil

Parent material	Mixture of colluvial and alluvial deposits, the former upon pedimentation from the surrounding hilly landscape
Moisture condition	Moist throughout
Drainage	Poorly drained
Groundwater	No ground water table was observed but perched water table, stagnating on the clayey subsurface horizon
Surface stones	Nnone
Erosion	Slight sheet erosion
Human influence:	Farm land, dominant crop being maize

Profile description

Hor.	Depth (cm)	Description
Apg	0-10	very dark gray (10YR 3/1) moist; siltv clav; weak fine crumb structure; slightly firm, sticky and plastic; few iron and manganese concretions; common pronounced strong brown mottles; common coarse and medium pores; few coarse and common medium roots; clear smooth boundary to
Eg1	10-35	grayish brown (10YR 5/2) moist; siltv clav; strong medium subangular blocky structure; slightly firm, slightly sticky and slightly plastic; many hard and soft iron and manganese concretions; many medium prominent strong brown (7.5 YR 5/8, moist) mottles; few coarse and many fine pores; very few coarse and common medium roots; diffuse smooth boundary to
Eg2g	35-75	gray (10YR 5/1) moist; siltv clav loam: moderate strong medium parting to fine subangular blocky; slightly firm, slightly sticky and slightly plastic; iron and manganese stains; common fine faint white mottles; few very fine pores; few medium roots; abrupt smooth boundary to
Bt1g	75-115	brown (10YR 6/2) moist; clav: moderate to strong medium subangular blocky structure: friable , sticky and plastic ; few iron and manganese nodules; very fine pores; very few fine roots; diffuse smooth boundary to
Bt2g	115-150	light gray (10YR 7/1) moist ; clav: strong medium subangular and angular blocky structure; slightly firm, sticky and plastic; common medium iron and manganese nodules; common very fine pores; very few fine roots; gradual smooth boundary to

Bt3g	150+	light gray (10YR 7/1) moist ; clay; strong, medium to coarse angular blocky; very sticky and very plastic; very few iron/manganese concretions ; thin clay skin along cleavage faces; no roots

Table 9.2: Physical properties of soil profile in Dora Gabana

Pedon/Horizon	Depth (cm)	% Particle size distribution			Texture class	Silt/Clay ratio	BD g/cm^3
		Sand	Silt	Clay			
JIM/LS/DG/P1							
Ah	0-10	17.5	29.6	52.9	clay	0.56	1.06
Eg1	10--35	43.6	14.6	41.8	clay	0.35	1.02
Eg2	35-75	17.3	33.9	48.8	clay	0.69	1.04
Bt1g	75-115	16.4	27.9	55.7	clay	0.50	1.21
Bt2g	115-150	5.7	23.6	70.7	clay	0.33	1.20

Table 9.3: Selected chemical properties of soil profiles in Dora Gabana Kebele

Pedon /Hor	Depth (cm)	pH (1:2.5)		ΔpH	EC (ds/m)	OC (%)	TN (%)	C:N ratio	Av.P (mg P_2O_5/ kg soil)	Av.S %	Micro nutrients (mg/kg soil)			
		H2O	KCl								Zn	Mn	Cu	Fe
JIM/LS/DG/P1														
Ah	0-10	5.0	4.4	0.6	0.04	2.43	0.27	9.00	14.7	0.36	7.1	75.5	2.8	83.6
Eg1	10--35	4.5	3.8	0.7	0.02	0.97	0.10	9.70						
Eg2	35-75	4.7	3.8	0.9	0.03	0.5	0.04	12.50						
Bt1g	75-115	5.2	4.4	0.8	0.06	0.23	0.02	11.50						
Bt2g	115-150	5.5	4.6	0.9	0.20	0.18	0.02	9.00						
Bt3g	150+	4.9	3.8	1.1	0.03	0.16	0.02	8.00						
Average		5.0	4.1	0.8	0.06	0.75	0.08	9.95						

Table 9.4. Exchangeable cations and CEC results of soil profile in Dora kebele

Horizon	Depth (cm)	Exchangeable cations cmol (+) kg-1					Cations ratio		CEC cmol (+) kg-1		BS (%)	ESP (%)
		Na	K	Ca	Mg	sum	Ca/Mg	K/Mg	Soil	Clay		
JIM/LS/DG/P1												
Ah	0-10	1.83	1.15	11.82	3.38	18.18	3.50	0.34	41.28	62.2	44	4.44
Eg1	10-35	1.83	0.24	10.85	4.17	17.09	2.60	0.06	27.21	57.1	62.8	6.73
Eg2	35-75	1.91	0.32	10.14	3.38	15.75	3.00	0.09	31.68	61.4	49.7	6.03
Bt1g	75-115	1.99	0.28	7.68	3.41	13.36	2.25	0.08	35.26	61.9	37.9	5.63
Bt2g	115-150	2.31	0.76	15.97	6.21	25.25	2.57	0.12	54.49	76.2	46.3	4.25
Bt3g	150+	1.18	0.35	24.86	7.10	33.49	3.50	0.05	48.74	73.9	68.7	2.42
Average		1.84	0.52	13.55	4.61	20.52	2.90	0.12	39.78	65.45	51.57	4.92

Table 9.5 : Site and profile description of soil profiles in Gejib kebele

Site characteristics

Profile code:	JIM/LS/G/P1
Soil classification:	Chromic Luvisols
Location:	Gejib**,** *Garee Kiliifoo*
Coordinates:	272475 m N- 901462 m E
Elevation:	1662 m above sea level
Date and author:	10/12/2013; Alemayehu Regassa and Nazif
Geology:	Volcanic rocks of Tertiary and quaternary age overlie the precamberian rocks
Land form:	Middle slope between small plateau and valley
Local physiography:	Undulating upland
Slope:	12%, long gentle straight slope
Land use/vegetation:	Cultivation of annual and perennial crops. *Teff,* and maize are dominant annual crops while coffee is the main perennial cash crop; *cordia africana, croton macrostachys,* few *acacia spps* and *Eucalyptus species* around home stead

General information on the soil

Parent material:	Basalts and trachybasalt
Moisture condition:	dry in top soil and moist in the subsoil
Drainage:	Well drained
Groundwater:	Not encountered, very deep
Surface stones:	None
Erosion:	Slight sheet erosion
Human influence:	Continuous cultivation; inadequate inorganic fertilizer application

Profile description

Hor.	Depth (cm)	Description
Ap	0-10	yellowish red (5 YR 4/6) moist; clay. medium crump structure; very friable , sticky and plastic ; common fine and medium tubular pores; many fine and very fine roots; common dead roots; few wormcasts; non calcareous; clear smooth boundary to
Bt1	10-40	dark reddish brown (5 YR 3/4) moist; c]ay; subangular blocky structure; friable ; sticky and plastic ; common fine and few medium tubular pores; few fine and very fine roots; non calcareous; gradual smooth boundary to
Bt2	40-80	reddish brown (2.5 YR 5/6) moist; medium subangular blocky structure; slightly firm, sticky and plastic ; common fine and very fine tubular pores; few fine roots; common dead roots; few medium and fine soft manganese concretions, amount increasing with depth; non calcareous; diffuse smooth boundary to
Bt3	80-130	red (2.5YR 4/6); clay; moderate fine to coarse sub angular blocky; friable ; sticky and plastic; few fine roots; many fine and medium pores; diffuse smooth boundary to
Bt4	130+	red (2.5YR 4/6) moist; Clay; no mottle; weak medium angular block structure, hard when dry, friable when moist, slightly sticky and slightly plastic when wet, many fine random tubular pores; very few fine and medium roots

Table 9.6: Physical properties of soil profiles in Gejib Kebele

Pedon/Horizon	Depth (cm)	% Particle size distribution			Texture class	Silt/Clay ratio	BD g/cm^3
		Sand	Silt	Clay			
JIM/LS/G/P1							
Ap	0-10	10.0	30.0	60.0	clay	0.5	1.08
Bt1	10--40	10.5	28.0	61.5	clay	0.46	1.02
Bt2	40-80	11.5	27.7	60.8	clay	0.46	1.05
Bt3	80-130	9.1	29.6	61.3	clay	0.48	1.05
Bt4	130+	11.6	29.5	58.9	clay	0.50	1.07

Table 9.7: Selected chemical properties of soil profiles in Gejib

Pedon/ Hor	Depth (cm)	pH (1:2.5)		ΔpH	EC (ds/m)	OC (%)	TN (%)	C:N ratio	Av.P (mg 2O5/ kg soil)	Av. S %	Micro nutrients (mg/kg soil)			
		H2O	KCl								Zn	Mn	Cu	Fe
JIM/LS/G/P1														
Ap	0-10	4.9	3.8	1.1	0.03	2.17	0.25	8.68	13.5	2.6	1.3	44.5	1.5	56.4
Bt1	10--40	4.3	3.4	0.9	0.02	1.81	0.20	9.05						
Bt2	40-80	4.4	3.5	0.9	0.02	1.55	0.15	10.33						
Bt3	80-130	4.3	3.5	0.8	0.06	0.75	0.09	8.33						
Bt4	130+	4.3	3.6	0.7	0.06	0.44	0.06	7.33						
Average		4.4	3.6	0.9	0.04	1.34	0.15	8.74						

Table 9.8: Exchangeable cations and CEC results of soil profiles in Gejib kebele

Horizon	Depth (cm)	Exchangeable cations cmol (+) kg-1					Cations ratio		CEC cmol (+) kg-1		BS (%)	ESP (%)
		Na	K	Ca	Mg	sum	Ca/Mg	K/Mg	Soil	Clay		
JIM/LS/G/P1												
Ap	0-10	1.97	0.45	5.98	2.56	10.96	2.34	0.18	32.01	40.88	34.2	6.14
Bt1	10-40	1.58	0.21	9.43	3.43	14.65	2.75	0.06	42.88	59.58	34.2	3.7
Bt2	40-80	1.85	0.22	7.65	2.55	12.27	3.00	0.09	31.43	42.91	39	5.88
Bt3	80-130	1.72	0.21	7.59	3.37	12.89	2.25	0.06	33.45	50.36	38.5	5.15
Bt4	130+	1.75	0.23	9.23	3.36	14.57	2.75	0.07	39.22	64.01	37.1	4.47
Average		1.77	0.26	7.98	3.05	13.07	2.62	0.09	35.80	51.55	36.60	5.07

Table 9.9: Site and profile description of Mirkuz in Limu Saka Woreda

Profile code:	JIM/LS/M/P1
Soil classification:	Dystric gleysols
Location:	Mirkuz, lower terrace of Gilgel Gibe river
Coordinates:	283001 m N- 924855 m E
Elevation:	1583 m above sea level
Date and author:	18/11/2013; Alemayehu Regassa and Kalifa
Geology:	Volcanic rocks of Tertiary and quaternary age overlie the precamberian rocks
Land form	Slightly concave valley bottom above flood plain of Ghibe river
Local physiography:	Lower river terrace

Slope: 0%, straight along
Land use/vegetation: Communal grazing land; scattered shrubs and *acacia spps* woodland

General information on the soil

Parent material: Admixture of alluvial and colluvial material over basalts and trachybasalts
Moisture condition: Moist throughout
Drainage: Poorly drained
Groundwater: No ground water observed but there is stagnating perched water table
Surface stones: None
Erosion: Slight sheet erosion
Human influence: Overgrazing, cattle trampling

Profile description

Hor.	Depth (cm)	Description
Ah	0-8	gray (10YR 6/1) moist; silt loam ; weak fine and medium granular structure; friable when moist, sticky and plastic when wet; common fine and many very fine pores; common fine and many very fine roots; clear smooth boundary to
AC	8-20	gray (10YR 6/1) moist; silt loam ; weak medium subanguiar biocky structure; friable when moist, very sticky and very plastic when wet; very few fine and very fine pores; common fine and many very fine, mostly dead, roots; abrupt smooth boundary to
C1g	20-63	yellowish brown (10 YR 5/8), moist; clay loam; weak medium sub angular blocky structure; friable, very sticky and very plastic; common iron manganese mottles and rounded nodules and coatings along root channels; very few fine and very fine pores; common fine and many very fine dead roots; diffuse smooth boundary to
C2g	63-125	grayish brown (10YR 5/2) moist; clay loam; weak medium sub angular blocky structure; friable when moist, very sticky and very plastic when wet; medium yellowish brown (10 YR 5/6) mottles; common soft manganese nodules; very few fine and very fine pores; common fine and many very fine dead roots; diffuse smooth boundary to
C3g	100-120	very dark gray (10YR 3/1) moist; weak medium sub angular blocky structure; friable, very sticky and very plastict; common soft manganese concretions; very few very fine pores; no roots

Site characteristics

Profile code: JIM/LS/M/P2
Soil classification: Eutric Nitisols
Location: Mirkuz,
Coordinates: 300086 m N- 836348 m E
Elevation: 1583 m above sea level
Date and author: 9/12/2013; Alemayehu Regassa and Miftaw Jemal
Geology: Volcanic rocks of Tertiary and quaternary age overlie the precamberian rocks
Land form: Middle slope of rolling topography
Local physiography: Undulating upland
Slope: 8% straight across and along the slope
Land use/Vegetation: At present fallow land, 2 years ago cultivated with maize

General information on the soil

Parent material: Basalt
Moisture condition: Dry in top soil and somewhat moist in the subsoil
Drainage: Well drained
Groundwater: Not encountered, very deep
Surface stones: None
Erosion: Slight sheet erosion

Human influence: Fertilizer application

Profile description

Horizon	Depth (cm)	Description
A	0-12	dark brown (7.5YR 3/4) moist; clay loam; strong medium granular; very friable, slightly sticky and slightly plastic; few fine and very fine interstitial pores; common fine and medium roots; clear smooth boundary to
Bt1	12-30	dark reddish brown (5YR 3/3) moist; clay; strong medium to coarse sub angular blocky; friable; slightly sticky and slightly plastic; prominent shiny ped faces, increasing with depth; common fine and medium pores; many fine and few medium roots; diffuse smooth boundary to
Bt2g	30-90	reddish brown (5YR 4/4) moist; clay; moderate fine to medium angular blocky, slightly firm; very sticky and very plastic; common, medium , distinct bluish black to black mottles many very fine pores, very few very fine roots, diffused smooth boundary to
Bt3	90-145	red (2.5YR 4/6) moist; clay; strong coarse angular blocky; slightly firm, sticky plastic; very few very fine roots; very few fine pores; prominent shiny ped faces;; gradual smooth boundary to
Bt4	145+	red (2.5YR 4/8) moist; clay; moderate medium angular blocky; firm; very sticky, very plastic; very few fine tubular pores; no roots

Table 9.10: Physical properties of soil profiles in Mirkuz Kebele

Pedon/Horizon	Depth (cm)	% Particle size distribution			Texture class	Silt/Clay ratio	BD g/cm^3
		Sand	Silt	Clay			
JIM/LS/M/P1							
Ah	0-8	24.1	26.0	49.9	clay	0.52	1.05
Eg1	8--20	26.1	26.7	47.2	clay	0.57	1.10
Bt1Eg2	20-63	20.7	24.0	55.3	clay	0.43	1.17
Bt2Eg3	63-125	28.0	14.8	57.2	clay	0.26	1.30
Bt3	125+	11.8	25.8	62.4	clay	0.41	1.31
JIM/LS/M/P2							
Ap	0-12	26.0	21.1	52.8	clay	0.40	1.11
Bt1	12--30	15.0	18.1	66.9	clay	0.27	1.10
Bt2g	30-90	12.9	28.7	58.4	clay	0.49	1.17
Bt3	90-145	10.9	28.7	60.5	clay	0.47	1.08
Bt4	145+	13.6	25.3	61.1	clay	0.41	1.06

Table 9.11: Selected chemical properties of soil profiles in Mirkuz kebele

Pedon /Hor	Depth (cm)	pH (1:2.5)		ΔpH	EC (ds/m)	OC (%)	TN (%)	C:N ratio	Av.P (mg P2O5/ kg soil)	Av. S %	Micro nutrients (mg/kg soil)			
		H_2O	KCl								Zn	Mn	Cu	Fe
JIM/LS/M/P1														
Ah	0-8	5.3	4.7	0.6	0.27	3.56	0.39	9.13	24.6	0.3	15.2	6.3	2.0	228.3
Eg1	8--20	5.4	4.8	0.6	0.03	0.89	0.10	8.90						
Bt1Eg2	20-63	5.5	4.8	0.7	0.02	0.63	0.07	9.00						
Bt2Eg3	63-125	5.6	4.7	0.9	0.04	0.6	0.06	10.00						
Bt3	125+	5.0	4.2	0.8	0.11	0.53	0.05	10.60						
Average		5.4	4.6	0.7	0.09	1.24	0.13	9.53						
JIM/LS/M/P2														

Ap	0-12	5.4	4.6	0.8	0.04	2.55	0.25	10.20	9.9	0.45	6.7	61.1	1.9	228.3
Bt1	12--30	5.4	4.2	1.2	0.03	1.44	0.13	11.08						
Bt2g	30-90	5.7	4.8	0.9	0.02	0.77	0.09	8.56						
Bt3	90-145	7.3	6.3	1	0.02	0.48	0.06	8.00						
Bt4	145+	5.3	4.7	0.6	0.01	0.3	0.05	6.00						
Average		5.8	4.9	0.9	0.02	1.11	0.12	8.77						

Table 9.12: Exchangeable cations and CEC results of soil profiles in Mirkuz kebele

Horizon	Depth (cm)	Exchangeable cations (cmol (+) kg-1					Cations ratio		CEC (cmol (+) kg-1		BS (%)	ESP (%)
		Na	K	Ca	Mg	sum	Ca/Mg	K/Mg	Soil	Clay		
JIM/LS/M/P1												
Ah		1.79	0.43	8.32	3.33	13.87	2.50	0.13	32.1	39.9	43.2	5.58
Eg1		1.90	0.29	5.77	2.47	10.43	2.34	0.12	21.5	39.2	48.5	8.83
Bt1Eg2		1.81	0.46	9.15	3.33	14.75	2.75	0.14	29.39	49.2	50.2	6.15
Bt2Eg3		2.10	0.72	11.87	3.39	18.08	3.50	0.21	37.33	61.8	48.4	5.63
Bt3		2.23	0.91	19.69	5.99	28.82	3.29	0.15	42.8	65.7	67.3	5.22
Average		1.97	0.56	10.96	3.70	17.19	2.88	0.15	32.62	51.16	51.52	6.28
JIM/LS/M/P2												
Ap		1.83	0.75	11.76	3.36	17.7	3.5	0.22	38.8	56.8	45.6	4.71
Bt1		1.81	0.60	12.72	4.24	19.37	3	0.14	42.86	56.6	45.2	4.22
Bt2g		1.88	0.46	9.33	3.39	15.06	2.75	0.14	33.18	52.4	45.4	5.67
Bt3		0.98	0.46	9.33	3.39	14.16	2.75	0.14	32.72	51.4	43.3	2.99
Bt4		1.83	0.48	8.40	3.36	14.07	2.5	0.14	39.3	62.7	35.8	4.65
Average		1.67	0.55	10.31	3.55	16.07	2.90	0.16	37.37	55.98	43.06	4.45

Table 9.13: Site and profile description of Saka Kebele in Limu Saka Woreda

Profile code: JIM/LS/S/P1
Soil classification: Dystric Nitisols
Location: Saka**,** *Garee dariixaa*
Coordinates: 270543 m N- 906727 m E
Elevation: 1688 m above sea level
Date and author: 9/12/2013; Alemayehu Regassa and Nasir
Geology: Volcanic rocks of Tertiary and quaternary age overlie the precamberian rocks
Land form Gently slopping crest in an undulating relief
Local physiography: Undulating upland
Slope: 8%
Land use/vegetation: Cultivation of mixed annual and perennial crops; coffee is dominant ; different shade trees such as *acacia spps, cordia spps, albizia guminifera* are scattered in the coffee plantation and *eucalyptus spps* are grown around homesteads

General information on the soil

Parent material: Basalts and trachybasalts
Moisture condition: Dry in top soil and moist in the subsoil
Drainage: Well drained
Groundwater: Not observed
Surface stones: None

Erosion: Slight sheet erosion
Human influence: Fertilizer application

Profile description

Horizon	Depth (cm)	Description
Ah	0-10	dark reddish brown (5YR 3/3) moist ; clay loam, moderate fine crump; friable; slightly sticky and slightly plastic; few fine and very fine pores, common fine and very fine roots, clear smooth boundary to
AB	10-28	dark reddish brown (5YR 3/4) moist; clay; moderate fine sub-angular blocky; firm, slightly sticky and slightly plastic; many coarse roots; common fine and medium pores; abrupt smooth boundary to
Bt1	28-55	dark reddish brown (5YR 3/4) moist; clay; moderate fine to medium angular blocky, firm very sticky and very plastic, very few very fine channels type pores, very few very fine roots, diffused boundary.
Bt2g	55-105	dark reddish brown (5YR 3/4) moist; clay; strong coarse angular blocky; hard, firm, sticky and very plastic; very few very fine roots; very few fine pores; prominent shiny ped face; common, very fine, distinct bluish black to black mottles; clear smooth boundary to
Bt3	105+	dark reddish brown (2.5YR 3/4) moist; clay; moderate medium angular blocky; firm, very sticky, very plastic; very few fine roots, distinct abundant cutans

Site characteristics

Profile code: JIM/LS/S/P2
Soil classification: Dystric Nitisols
Location: Saka**,** at the upper Millee hill
Coordinates: 273162 m N- 906272 m E
Elevation: 1953 m above sea level
Date and author: 9/12/2013; Alemayehu Regassa and Haile Arage
Geology: Volcanic rocks of Tertiary and quaternary age overlie the precamberian rocks
Land form: Near top of a basaltic hill, Mille in a rolling landscape
Local physiography: Undulating upland
Slope: 30%
Land use/vegetation: Intensive cultivation of crops, teff is the dominant followed by maize

General information on the soil

Parent material: Residuum from tertiary basalts and trachybasalts
Moisture condition: Dry in the top and moist in the subsurface horizons of the profile

Drainage: Well drained
Groundwater: Not encountered, very deep
Surface stones: None
Erosion: Slight sheet erosion
Human influence: Continuous cultivation without soil fertility management

Profile description

Horizon	Depth (cm)	Description
Ap	0-12	dark brown (7.5YR 3/4) moist; clay loam; weak fine to medium granular; very friable, slightly sticky, slightly plastic ; many large pores; common, common fine and medium roots; clear smooth boundary to
BA	12-30	dark reddish brown (5YR 3/3) moist; clay; medium to coarse sub angular blocky; soft, firm, slightly sticky and slightly plastic; many coarse roots; many fine continuous random inped interstitial pores ; gradual smooth boundary to
Bt1	30-90	dark reddish brown (2.5YR 2.5/4) moist; clay; weak fine to medium sub angular blocky; friable, very sticky, very plastic; few medium, common interstitial pores; few fine and medium and few coarse roots; prominent shiny face; faint common ped face clay cutans; diffuse smooth boundary to
Bt2	90-145	dark reddish brown (2.5YR 2.5/4) moist; clay; moderate medium angular blocky; firm, very sticky, very plastic; very few fine roots, diffuse smooth boundary to .
Bt3	145+	dark reddish brown (2.5YR 3/4) moist; clay; strong medium angular blocky; sticky, plastic; few fine and medium pores; few fine roots; faint, ped faces

Table 9.14: Physical properties of soil profiles in Saka Kebele

Pedon/Horizon	Depth (cm)	% Particle size distribution			Texture class	Silt/Clay ratio	BD g/cm3
		Sand	Silt	Clay			
JIM/LS/S/P1							
Ah	0-10	33.4	32.8	33.8	Clay loam	0.97	1.03
AB	10--28	24.4	11.7	63.9	clay	0.18	1.15
Bt1	28-55	11.4	20.3	68.3	clay	0.30	1.11
Bt2	55-105	14.0	26.6	59.5	clay	0.45	1.08
Bt3	105+	12.0	28.6	59.4	clay	0.48	1.04
JIM/LS/S/P2							
Ah	0-12	22.6	22.6	54.8	clay	0.41	1.14
BA	12--30	12.7	23.1	64.1	clay	0.36	1.21
Bt1	30-90	12.2	26.4	61.3	clay	0.43	1.12
Bt2	90-145	11.8	28.7	59.5	clay	0.48	1.04
Bt3	145+	11.6	26.6	61.8	clay	0.43	1.06

Table 9.15: Selected chemical properties of soil profiles in Saka kebele

Pedon /Hor	Depth (cm)	pH (1:2.5)		ΔpH	EC (ds/m)	OC (%)	TN (%)	C:N ratio	Av.P (mg P2O5/ kg soil)	Av. S %	Micro nutrients (mg/kg soil)			
		H2 O	KCl								Zn	Mn	Cu	Fe
JIM/LS/S/P1														
Ah	0-10	5.1	4.5	0.6	0.05	3.93	0.46	8.54	27.9	0.58	9.2	24.8	2.4	192.0
AB	10--28	5.1	4.4	0.7	0.02	1.16	0.13	8.92						
Bt1	28-55	5.2	4.5	0.7	0.02	0.63	0.10	6.30						
Bt2	55-105	5.2	4.8	0.4	0.02	0.53	0.07	7.57						
Bt3	105+	5.6	4.9	0.7	0.03	0.2	0.04	5.00						
Average		5.2	4.6	0.6	0.03	1.29	0.16	7.27						
JIM/LS/S/P2														
Ah	0-12	5.6	4.9	0.7	0.06	2.52	0.25	10.08	19.5	0.25	9.7	66.2	3.3	94.0
BA	12--30	5.3	4.5	0.8	0.05	1.21	0.13	9.31						
Bt1	30-90	5.3	4.5	0.8	0.03	0.83	0.09	9.22						
Bt2	90-145	5.1	4.5	0.6	0.04	0.49	0.06	8.17						
Bt3	145+	5.6	4.8	0.8	0.02	0.33	0.04	8.25						
Average		5.4	4.6	0.7	0.04	1.08	0.11	9.01						

Table 9.16: Exchangeable cations and CEC results of soil profiles in Saka kebele

Horizon	Depth (cm)	Exchangeable cations cmol (+) kg-1					Cations ratio		CEC cmol (+) kg-1		BS (%)	ESP (%)
		Na	K	Ca	Mg	sum	Ca/Mg	K/Mg	Soil	Clay		
JIM/LS/S/P1												
Ah	0-10	2.08	0.41	9.24	4.20	15.93	2.20	0.10	33.33	58.5	47.8	6.25
AB	10—28	1.94	1.21	12.72	4.24	20.11	3.00	0.29	35.95	50.0	55.9	5.38
Bt1	28-55	1.86	1.22	11.02	4.24	18.34	2.60	0.29	53.46	75.1	34.3	3.48
Bt2	55-105	2.01	1.37	8.48	3.39	15.25	2.50	0.40	32.26	51.2	47.3	6.23
Bt3	105+	2.03	1.62	9.33	3.39	16.37	2.75	0.48	31.8	52.4	51.5	6.38
Average		1.98	1.17	10.16	3.89	17.20	2.61	0.31	37.36	57.44	47.36	5.54
JIM/LS/S/P2												
Ah	0-12	2.23	2.16	12.84	4.28	21.51	3.00	0.50	46.06	68.21	46.7	4.85
BA	12-30	1.63	0.88	15.96	6.72	25.19	2.38	0.13	37.89	52.59	66.5	4.29
Bt1	30-90	1.94	0.63	12.65	4.22	19.44	3.00	0.15	32.99	49.15	58.9	5.89
Bt2	90-145	2.03	0.56	10.17	3.39	16.15	3.00	0.17	29.01	45.93	55.7	6.98
Bt3	145+	1.96	0.72	9.34	3.40	15.42	2.75	0.21	32.75	51.15	47.1	5.97
Average		1.96	0.99	12.19	4.40	19.54	2.83	0.23	35.74	53.41	54.98	5.60

3.5.4. Synthesis

In this section of the report, synthesis of the soil properties related to the agronomic development is made briefly. Reference is made to the respective tables of analytical data.

The dominant agricultural soils in the four studied kebeles, Mirkuz, Saka, Gwjib and Dora gabana, are Nitisols and Gleysols covering 46% (21.2 and 28.8% respectively). Cambisols and Leptosols occuy moderately to strongly steeply hills and ridges.

Texture of these soils is clayey throughout the profiles. The bulk density of all the studied profiles in Omo Nada woreda is found to be less than 1.44, which is common in cultivated soils. The low bulk density found in these soils indicates that the soils are not compacted and have more porosity.

Similar to the Omo Nada woreda, Nitisols are the most agricultural important soils in Limu saka woreda..

The soil pH in water of topsoils is strongly acid to medium with values between 4.9 and 5.3. The acidic soil reaction could result in excess and toxicity of heavy metals, and deficiency of basic cations (Landon, 1991). The overall trend of the pH values with depth varies considerably, sometimes increasing and sometimes decreasing and cannot be taken as a characteristic applicable to all the soils. The low pH value is likely to increase Al toxicity as this element is normally expected at less than 5.5 pH values. This would in particular a problem where the low pH value occurred within 65 cm from the soil surface in which most crop roots extract their nutrient requirements (Tisdale, et al., 1993)

The organic carbon content in top soils ranges from 2-4% which is rated as low by Landon (1991). The low organic carbon content may be attributed to intensive agricultural practices that aggravate organic carbon oxidation (Wakene and Hiluf, 2003). Also, total nitrogen (N) content in topsoils ranges between 0.25-0.46 which is rated as medium as per the rating by Landon (1991) and decreases with soil depth. This decrease generally parallels to a decrease in contents of organic carbon, suggesting that the main source of total nitrogen was organic matter. The C: N ratios of the top layer of the studied soils range between 8.54 and 9.13, which is an indication that most soils have good quality organic matter. The values of exchangeable sodium percentage (ESP) in all the soils studied in the woreda are generally below 15%, the critical limit for sodicity (Brady and Weil, 2002).

The CEC of the total soil and clay fraction after correcting for organic matter is invariably very high ranges between 32.1 to 41.3 cmol(+) kg^{-1} and 39.9 to 62.2 cmol(+) kg^{-1} respectively. Since the organic matter content of the soils which normally influences the CEC is generally low, the CEC values to the amount and type of clay minerals present in the soils matter.

Exchangeable calcium followed by magnesium formed the dominant cation in the exchange complex throughout the horizons of the representative profiles. But their proportions showed an irregular pattern with depth. On the other hand, the proportions of exchangeable K and Na in the exchange site were found to be insignificant and also showed an irregular variation with depth of the profile. From these data, it may be pointed out that, whereas toxicity from Na is unlikely to occur but K deficiency is expected according to Landon (1991) ratings. The presence of irregular variation in the exchangeable cations may partly suggest existence of different levels of leaching intensity within the horizons of the profile. It may also partly indicate an existence of different sources of parent materials.

3.6. Soils of CASCAPE intervention Kebeles in Gera woreda

3.6.1. Geology and geomorphology

Gera woreda is characterized by mountains, highly rugged and dissected topography with deep slopes and the lowest parts of the area is characterized by valley floor with flat to gentle slopes. The physiographic land feature of the study area is is both of structural and volcanic origin. Escarpments associated with faultlines are also present but less frequent and dramatic.

According to Geological Survey of Ethiopia (GSE, 2012) the geology of the studied kebeles in Gera woreda is simple and consists of Upper trachyte flow (42.8%), Upper basalt flows (30.4%) and Quaternary alluvial deposits (26.9%). They all belong to the tertiary volcanic rocks (Jimma volcanics). The valleys bedrock is overlain by alluvial sediments. These alluvial sediments occupy the broad valleys between the local hills. Jimma volcanic comprises massive rhyolites with alternating trachytes, tuffs, ignimberites, and subordinate basalts. It forms a thick succession of basalts and felsic rocks with basalts dominating the lower part of most section. It has two parts Jimma basalt and Jimma rhyolite which shows a conformable relationship. Jimma rhyolite is the younger one. The Jimma volcanics almost always rest on the Precambrian basement, the unconformity being marked by basal residual sandstone. The basalt flows form an unbroken succession several hundred meters thick in some places. On others felsic rocks are interbeded with basalt flow or form a thick succession just above the basal basalts (Geological survey of Ethiopia, 2012). Table 10 and Figure 23 shows the area and percentage distribution of the different geological materials in the CASCAPE intervention kebeles of Gera woreda. When we consider at the kebele level, Limu lower basalt is the dominant geological substrate in Gejib and Mirkuz kebeles.

Table 10: Area and percent coverage of lithology in CASCAPE intervention kebeles in Gera woreda

lithology	Area_ha	percent
Quaternary alluvial deposit	1877	26.9
Upper trachyte flows	2990	42.8
Upper basalt flows	2122	30.4

Figure 23. Typical landcape features of Gera woreda showing Plain areas abruptly rising into chains of hills adjoining hills

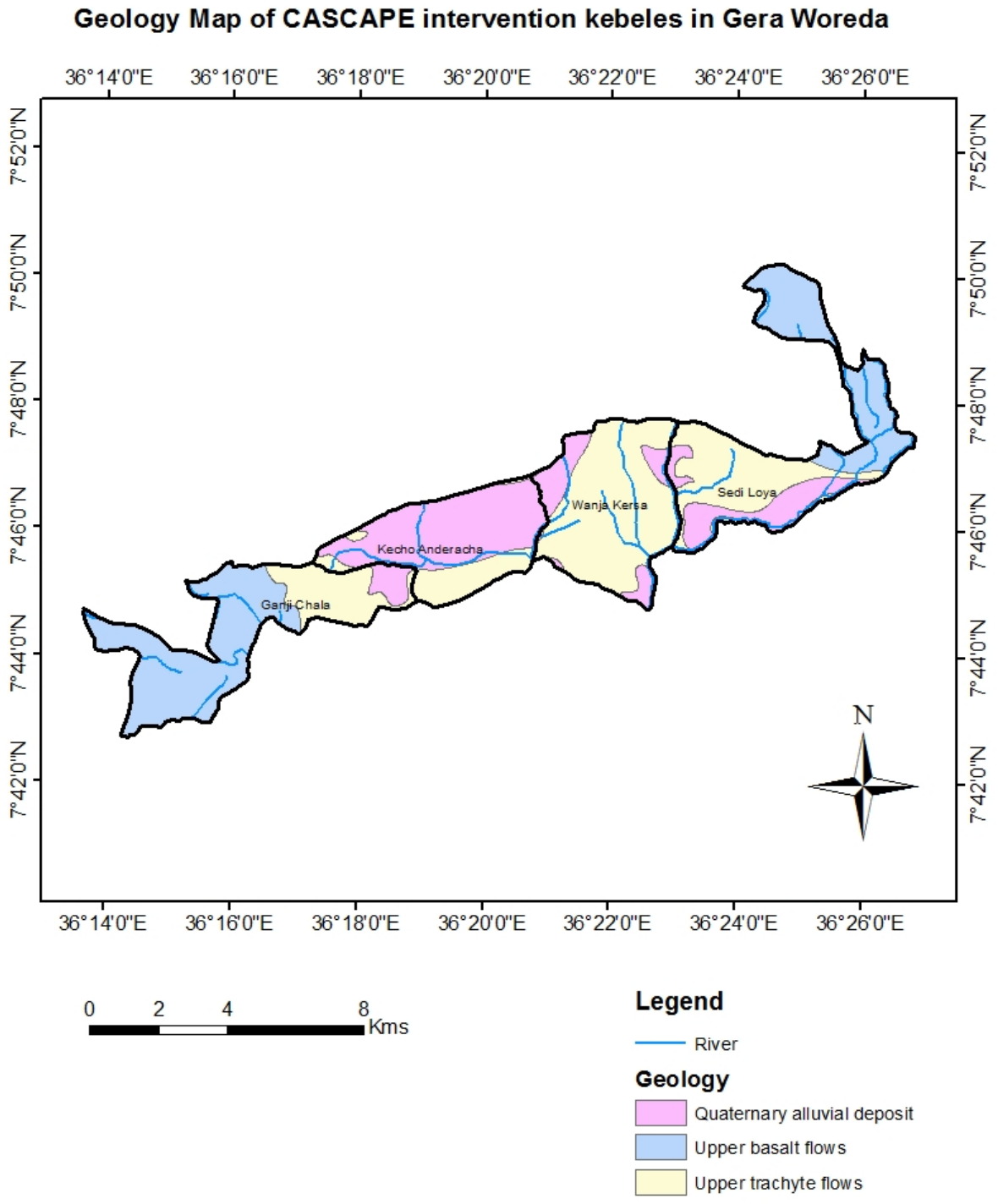

Figure 24. Geological map of CASCAPE intervention kebeles in Gera woreda

3.6.2. The soil- landscape

Soil types and their general distribution in Gera woreda is determined by topography. Seven soil profile investigations were dug and described after proper identification of land units from auger observations (Fig. 14) for soil morphological and environmental characteristics were made.

Leptosols occur on high lying hills and mountains. These areas are covered by natural forests. Dissected ridges with steep slopes (over 50%) are commonly sparsed in Gera. As these landforms form considerably large area in the studied kebeles of the woreda, soil formed in these landscapes, dominantly Leptosols constitute about 50% of the total area of the woreda. Some patchy areas of the middle slopes of the ridges, where erosion is less severe, Cambisols occur with area cover of about 1% (Table 40 and Figure.

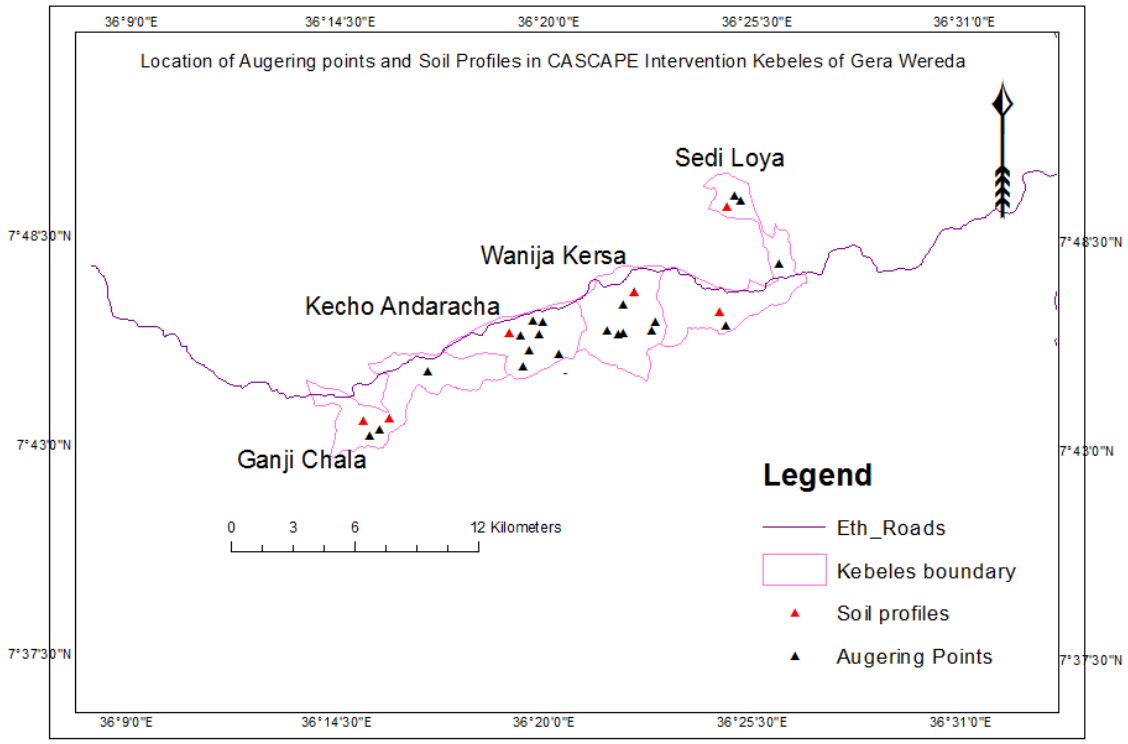

Figure 25. Augure and soil profile locations in CASCAPE intervention kebeles in Gera.

The rock out crops makes up 40% with a complex slope pattern. The land is under natural forest mixed with Eucalyptus tree species. The top soils are gravelly and stony.

Table 11: Summary of major Soil types and their distribution in the four CASCAPE intervention kebeles of Gera Woreda

Soil type	Area (km2)	%
Leptosols	33.95	48.3
Cambisols	0.73	1.0
Nitisols	12.56	17.9
Gleysols	9.87	14.0
Planosols	13.16	18.7

Nitisols occupy the gently undulating to undulating slopes. They are the third most dominant soils interms of area coverage next to Planosols covering 17.9 % and 18.7% respectively.

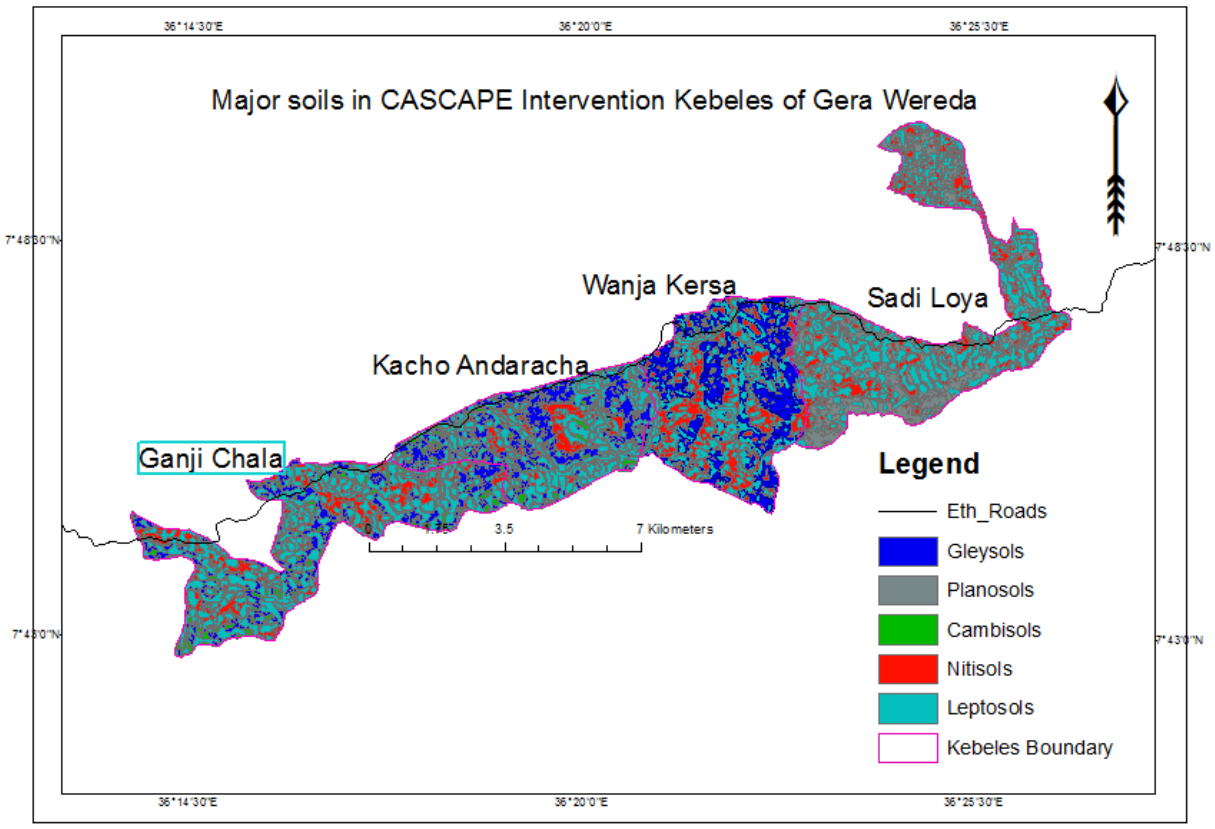

Figure 26. Soil map of CASCAPE intervention kebeles in Gera woreda

In the flat slopes of the low-lying drainage ways and localized depressions with slopes of 0-1%, gleysols are the dominant soil types (typical profile in Fig. 20). In area coverage they constitute about 14.0% of the total area of the four kebeles. They are especially extensive in the broad U-shaped valleys adjoining the Ghibe river.

Hydromorphic soils are very extensive in the flat areas in all the four kebeles. They are however more extensive in the two moddle kebeles vis 6 Kacho Andaracha and Wanja Kersa. In these areas farmers apply a traditional soil management practice called *guie,* burning of sods of soils with some grass piled in heaps (Fig. 24).

Figure 27. Traditional soil burning “guie” on hydromorphic soils in Wanja Kersa kebele, Gera woreda

In Ethiopia, *guie*, ia a traditional practice fitted in a cycle of shifting cultivation with fallow periods of up to 15 years for every 2 years of cultivation (Wolde-Yohannes and Wehrmann, 1975; Pulschen and Koch, 1990). In time however, Abebe (1981) stated that the application of guie has been compromised by increasing population pressure, decreased land holding sizes, and the subsequent inability of farmers to restore soil fertility by letting land lie fallow. In their publication on the traditional application of guie in more extensive cultivation systems, Pülschen and Koch (1990) also argued that the guie practice would be likely to disappear, because of its excessive labor demands and detrimental effects on the physical soil quality.

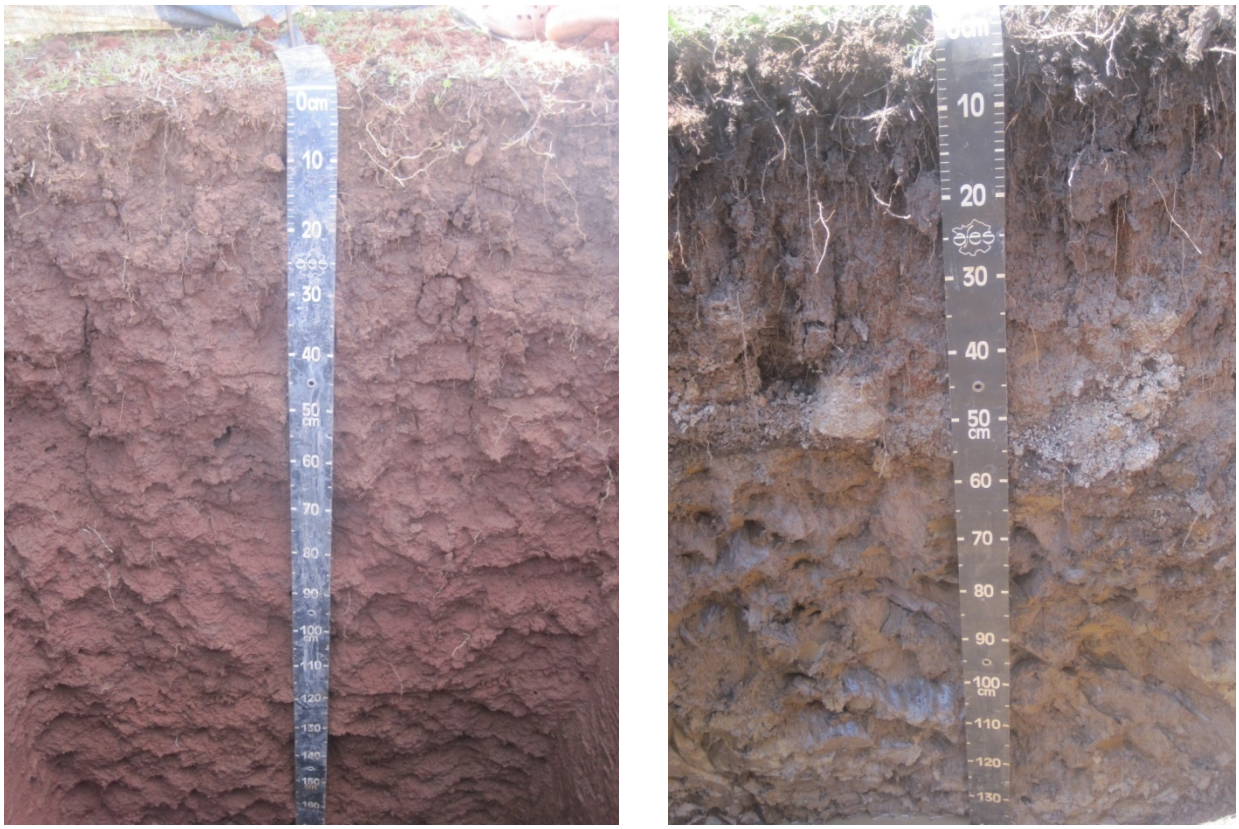

Figure 28. Typical soil profiles in Gera, left Nitisols and right Gleysols

Table 12. Site and profile description and lab analytical data of CASCAPE intervention kebeles in Gera woreda

12.1. Site and profile description of Ganji Chala Kebele

Profile code:	JIM/G/GC/P1
Soil classification:	Pisoplinthic Gleysols
Location:	Ganji Chala, Garee Tuucee, plain land between hills
Coordinates:	198175 m N- 855265 m E
Elevation:	1969 m
Date and author:	18/1/2014; Alemayehu Regassa and Fassil Assefa
Geology:	Volcanic rocks of Tertiary and quaternary age overlie the precamberian rocks
Land form:	U-shaped valley in a gently undulating landscape with long flat slopes
Local physiography:	Plain land between hills
Slope:	1%
Land use:	Farm land, dominant crop being maize

General information on the soil

Parent material	Colluvial material over fine textured alluvium
Moisture condition	Moist throughout
Drainage	Poorly drained, seasonally flooded
Groundwater	None at the time of observation but water logged during the rainy season

Surface stones None
Erosion Slight sheet erosion
Human influence Furrow drainage

Profile description

Hor.	Depth (cm)	Description
Apg	0-2	brown (7.5YR 4/2) moist; moderately fine crump; slightly firm, slightly sticky, slightly plastic; common coarse and medium pores; few coarse and common medium roots; few iron and manganese concretions; clear smooth boundary to
AC	2-23	very dark brown (7.5YR 2.5/2) moist; siltvclav: moderate medium angular blocky; slightly firm, slightly sticky, slightly plastic; few coarse and many fine pores; very few coarse and common medium roots; many hard and soft iron and manganese concretions; non calcareous; clear smooth boundary to
C1g	23-45	strong brown (7.5YR 4/6) moist; clav: moderate medium angular blocky ; firm, sticky, plastic; few very fine pores; few medium roots; many medium prominent strong brown (7.5 YR 5/8, moist) mottles; non calcareous; gradual smooth boundary to
C2g	45-70	dark gray (7.5 YR 4/1) moist; clav: moderate fine and medium angular blocky; very firm , sticky and plastic ; very few fine pores; very few fine roots; iron and manganese stains; non calcareous; gradual smooth boundary to
C3g	70+	gray (7.5 YR 5/1) moist; clav; moderate medium angular blocky ; very firm, sticky and plastic t; common very fine pores; very few fine roots; iron and manganese stains; nony calcareous

Site characteristics

Profile code: JIM/G/GC/P2
Soil classification: Eutric Nitisols
Location: Ganji Chala, Garee Baalii
Coordinates: 196918 m N- 855181 m E
Elevation: 2025 m above sea level
Date and author: 18/1/2014; Alemayehu Regassa and Fassil Assefa
Geology: Volcanic rocks of Tertiary and quaternary age overlie the precamberian rocks
Land form: Hilly terrains of low to moderate relief
Local physiography: Gently undulating to rolling
Slope: 15%
Land use/vegetation: Farm land, dominant crop being maize, disturbed forest different spps with cultivation confined to somewhat better drained valley areas

General information on the soil

Parent material: Tertiary basalts and tuffs
Moisture condition: Dry at the top and moist in the subsurface horizons
Drainage: Well drained
Groundwater: Not encountered, very deep
Surface stones: None
Erosion: Slight sheet erosion
Human influence: Permanent cultivation of both annual crops such as maize and teff, and perennial crops mainly coffee

Profile description

Horizon	Depth (cm)	Description
Ap	0-25	dark brown (7.5YR 3/4) moist; clay loam; weak to moderate sub angular blocky, friable, slightly sticky slightly plastic; many fine and very fine pores; common fine and coarse roots; clear smooth boundary to
Bt1g	25-45	dark reddish brown (5YR 3/3) moist; clay; strong medium to coarse sub angular blocky; soft, firm, slightly sticky and slightly plastic; many coarse roots; common fine and medium pores; abrupt smooth boundary to
Bt2g	45-90	dark reddish brown (5YR 3/4) moist; clay; moderate fine to medium angular blocky, firm very sticky and very plastic, very few very fine channels type pores, very few very fine roots, diffused boundary to
Bt3g	90-125	dark reddish brown (5YR 3/4) moist; clay; strong coarse subangular blocky; firm, sticky and plastic; very few very fine roots; very few fine pores; prominent shiny ped faces; common, very fine, distinct bluish black to black mottles; clear smooth boundary to
Bt4g	125+	dark reddish brown (5YR 4/6) moist; clay; clay; moderate medium angular blocky; firm, very sticky, very plastic; very few fine roots

Table 12.2: Physical properties of soil profile in Ganji Chala

Pedon/Horizon	Depth (cm)	% Particle size distribution			Texture class	Silt/Clay ratio	BD g/cm^3
		Sand	Silt	Clay			
JIM/G/GC/P1							
Ap	0-2	43.3	18.2	38.5	Clay loam	0.47	1.05
AB	2—23	30.4	21.4	48.2	Clay loam	0.44	1.04
Bt1g	23-45	33.3	35.0	31.8	Clay loam	1.10	1.15
Bt2g	45-70	34.7	34.3	31.0	Clay loam	1.11	1.12
Bt3g	70+	33.0	31.9	35.1	Clay loam	0.91	1.23
JIM/G/GC/P2							
Ap	0-25	24.2	18.4	57.4	Clay loam	0.32	1.02
Bt1g	25-45	5.5	30.1	64.4	clay	0.47	1.01
Bt2g	45-90	5.7	31.1	63.2	clay	0.49	1.02
Bt3g	90-125	8.3	28.8	62.9	clay	0.46	1.03
Bt4g	125+	12.8	21.2	66.0	clay	0.32	1.25

Table 12.3: Selected chemical properties of soil profiles in Ganji Chala Kebele

Pedon/Horizon	Depth (cm)	pH (1:2.5)		ΔpH	EC (ds/m)	OC (%)	TN (%)	C:N ratio	Av.P (mg P2O5/ kg soil)	Av. S %	Micro nutrients (mg/kg soil)			
		H2O	KCl								Zn	Mn	Cu	Fe
JIM/G/GC/P1														
Ap	0-2	4.6	3.7	0.9	0.05	2.94	0.31	9.48	16.8	0.37	10.4	61.4	3.0	206.7
AB	2—23	4.8	4.0	0.8	0.03	1.51	0.16	9.44						
Bt1g	23-45	5.1	4.4	0.7	0.03	0.33	0.04	8.25						
Bt2g	45-70	5.3	4.7	0.6	0.02	0.29	0.04	7.25						
Bt3g	70+	5.5	4.8	0.7	0.04	0.19	0.03	6.33						
Average		5.1	4.3	0.7	0.03	1.05	0.12	8.15						
JIM/G/GC/P2														
Ap	0-25	6.2	5.5	0.7	0.09	3.03	0.32	9.47	29.5	1.36	7.7	43.6	1.6	124.0
Bt1g	25-45	5.4	4.3	1.1	0.05	1.18	0.13	9.08						
Bt2g	45-90	4.8	4.0	0.8	0.05	0.33	0.07	4.71						
Bt3g	90-125	4.6	3.9	0.7	0.03	0.17	0.04	4.25						
Bt4g	125+	4.8	3.9	0.9	0.02	0.16	0.02	8.00						
Average		5.2	4.3	0.8	0.05	0.97	0.12	7.10						

Table 12.4. Exchangeable cations and CEC results of soil profiles in Ganji chala kebele

Horizon	Depth (cm)	Exchangeable cations cmol (+) kg-1					Cations ratio		CEC cmol (+) kg-1		BS (%)	ESP (%)
		Na	K	Ca	Mg	sum	Ca/Mg	K/Mg	Soil	Clay		
JIM/G/GC/P1												
Ap	0-2	1.63	0.37	15.35	5.12	22.47	3.00	0.07	40.32	78.23	55.7	4.05
AB	2-23	1.91	0.29	14.48	5.11	21.79	2.83	0.06	44.45	81.43	49	4.29
Bt1g	23-45	1.71	0.22	9.29	3.38	14.6	2.75	0.07	28.01	84.31	52.1	6.1
Bt2g	45-70	1.85	0.20	12.79	4.26	19.1	3.00	0.05	36.15	113.39	52.8	5.13
Bt3g	70+	1.86	0.16	10.18	3.39	15.59	3.00	0.05	35.95	100.71	43.4	5.18
Average		1.79	0.25	12.42	4.25	18.71	2.92	0.06	36.98	91.61	50.60	4.95
JIM/G/GC/P2												
Ap	0-25	0.93	2.51	18.94	6.89	29.27	2.75	0.36	56.61	80.51	51.7	1.64
Bt1g	25-45	1.97	4.06	8.55	3.42	18	2.50	1.19	46.48	65.96	38.7	4.24
Bt2g	45-90	1.82	2.45	8.53	3.41	16.21	2.50	0.72	38.47	58.97	42.1	4.72
Bt3g	90-125	1.98	1.57	7.65	2.55	13.75	3.00	0.62	37.9	59.30	36.3	5.22
Bt4g	125+	2.11	0.62	15.91	5.3	23.94	3.00	0.12	60.53	90.80	39.6	3.49
Average		1.76	2.24	11.92	4.31	20.23	2.75	0.60	48.00	71.11	41.68	3.86

Table 12.5 : Site and profile description of soil profiles in Kacho Andaracha kebele

Profile code:	JIM/G/KA/P1
Soil classification:	Dytric Gleysols
Location:	Kacho Andaracha,Xullaa plain
Coordinates:	203998 m N- 859440 m E
Elevation:	1900 m above sea level
Date and author:	19/1/2014; Alemayehu Regassa and Fassil Assefa
Geology:	Volcanic rocks of Tertiary and quaternary age overlie the precamberian rocks
Land form:	Gently undulating landscape with low ridges and long flat slopes
Local physiography:	flat land
Slope:	1%
Land use/vegetation:	cattle grazing land

General information on the soil

Parent material:	Quaternary deposits of volcanic ash admixture with basalt
Moisture condition:	Moist throughout the profile
Drainage:	Imperfectly to poorly drained
Ground water:	No permanent ground water table observed but seasonally flooded
Surface stones:	Nnone
Erosion:	Slight sheet erosion
Human influence:	Over grazing, cattle trampling

Profile descriptions

Horizon	Depth (cm)	Description
Apg	0-10	black (10YR 2/1) moist; silty loam; weak fine crumby; non-sticky and slightly plastic; mottles; and rusty root channels; common fine, few medium roots; clear wavy boundary to
ABg1	10-40	dark gray (10YR 4/1, moist); silt clay loam; crumby; soft friable, slightly sticky and slightly plastic; common fine yellow (10YR 7/8) mottles ; few fine roots; few medium and fine ferromanganese nodules and concretions; gradual smooth boundary to
Bg2	40-50	light brownish grey (10YR 6/2) moist ; silty clay loam; strong, medium prismatic ; slightly sticky and slightly plastic; abundant coarse strong brown (7.5YR 5/8) mottles; distinct iron and black manganese oxide nodules at the transition to the underlying horizon; few very fine and fine roots; abrupt wavy boundary to
C1g	50-80	dark grey (10YR 4/1) moist; clay; strong fine angular blocky; very sticky and very plastic; few large ferromanganese nodules; very fine to fine , random roots; gradual smooth boundary to
C2g	80+	dark grey (10YR 4/1) moist; clay; strong fine angular blocky; firm, sticky and plastic; prominent hard iron- manganese concretions; thin clay skins along root channels

Table 12.6: Physical properties of soil profiles in Nada Bidaru Kebele

Pedon/Horizon	Depth (cm)	% Particle size distribution			Texture class	Silt/Clay ratio	BD g/cm^3
		Sand	Silt	Clay			
JIM/G/KA/P1							
Ap	0-10	47.7	24.6	27.8	SCL	0.88	1.02
E1g	10--40	25.3	24.9	49.8	Clay	0.50	1.21
E2g	40-50	14.6	28.1	57.3	clay	0.49	1.20
Bt1g	50-80	15.7	16.6	67.7	clay	0.25	1.15
Bt2g	80+	5.8	21.6	72.7	clay	0.30	1.10

Table 12.7: Selected chemical properties of soil profiles in KAcho Andaracha

Pedon/ Hor	Depth (cm)	pH (1:2.5)		ΔpH	EC (ds/m)	OC (%)	TN (%)	C:N ratio	Av.P (mg P2O5/ kg soil)	Av. S %	Micro nutrients (mg/kg soil)			
		H2O	KCl								Zn	Mn	Cu	Fe
JIM/G/KA/P1														
Ap	0-10	4.6	3.9	0.7	0.06	3.52	0.4	8.80	18.3	0.45	5.7	17.6	2.2	212.6
E1g	10--40	4.8	4.0	0.8	0.02	1.02	0.1	10.20						
E2g	40-50	5.0	4.2	0.8	0.02	0.41	0.04	10.25						
Bt1g	50-80	4.6	3.8	0.8	0.03	0.20	0.03	6.67						
Bt2g	80+	4.6	3.6	1	0.04	0.17	0.02	8.50						
Average		4.7	3.9	0.8	0.03	1.06	0.12	8.88						

Table 12.8: Exchangeable cations and CEC results of soil profiles in Kacho Andaracha

Horizon	Depth (cm)	Exchangeable cations cmol (+) kg-1					Cations ratio		CEC cmol (+) kg-1		BS (%)	ESP (%)
		Na	K	Ca	Mg	sum	Ca/Mg	K/Mg	Soil	Clay		
JIM/G/KA/P1												
Ap	0-10	1.72	0.50	11.07	4.26	17.05	2.60	0.12	40.71	102.55	43.1	4.23
E1g	10—40	1.66	0.24	7.46	2.49	11.61	3.00	0.10	27.48	47.95	43.1	6.03
E2g	40-50	1.83	0.27	9.14	3.32	14.29	2.75	0.08	28.01	46.44	52	6.52
Bt1g	50-80	1.95	0.53	11.43	4.40	17.78	2.60	0.12	50.65	73.93	36.2	3.85
Bt2g	80+	2.08	0.76	11.64	4.48	18.2	2.60	0.17	54.49	74.13	34.8	3.82
Average		1.85	0.46	10.15	3.79	15.79	2.71	0.12	40.27	69.00	41.84	4.89

Table 12.9: Site and profile description of Wanja Kersa in Gera

Profile code:	JIM/G/WK/P1
Soil classification:	Eutric Nitisols
Location:	Wanja Kersa, Garee Weychara 2ffa
Coordinates:	210081 m N- 861400 m E
Elevation:	1932m above sea level
Date and author:	19/1/2014; Alemayehu Regassa and Fassil Assefa
Geology:	Volcanic rocks of Tertiary and quaternary age overlie the precamberian rocks
Land form:	Slightly convex, middle slope between small plateau and valley bottom
Local physiography:	Undulating to rolling
Slope:	10%
Land use/vegetation:	Cultivation of mixed annual and perennial crops and some grazing; few scattered trees in the farm land and eucalyptus spps around home stead

General information on the soil

Parent material:	basalt and trachybasalt
Moisture condition:	Dry at the top and moist in the subsurface horizons
Drainage:	Well to excessively drained
Groundwater:	Not encountered, very deep
Surface stones:	None
Erosion:	Slight sheet erosion
Human influence:	Terracing and overgrazing, and cattle trampling

Profile description

Horizon	Depth (cm)	Description
Ap	0-13	dark reddish brown (5YR 3/3) moist ; clay loam, moderate sub angular blocky; friable, slightly sticky and slightly plastic; few fine and very fine pores; common fine to coarse roots; gradual smooth boundary to
AB	13-26	dark reddish brown (5YR 3/3) moist; clay; strong medium to coarse sub angular blocky; soft, firm, slightly sticky and slightly plastic; many coarse roots; common fine and medium pores; abrupt smooth boundary to
Bt1	26-34	reddish brown (5YR 4/4) moist ; clay; moderate fine to medium angular blocky; friable, very sticky and very plastic; common shiny ped faces; few fine pores, few very fine roots; diffuse clear boundary to
Bt2	34-75	dark reddish brown (5YR 3/4) moist; clay; strong coarse angular blocky; hard, firm, sticky and very plastic; very few very fine roots; very few fine pores; prominent shiny ped faces; common, very fine, distinct bluish black to black mottles; diffuse smooth boundary to
Bt3	75-120	dark reddish brown (2.5YR 2.5/2) moist; clay; moderate medium angular blocky; slightly firm, very sticky, very plastic; very few fine roots, diffuse smooth boundary to
Bt4	120+	dark reddish brown (2.5YR 2.5/2) moist; clay; moderate medium angular blocky; slightly firm (moist), very sticky, very plastic; very few fine roots

Tabler 12.10: Physical properties of soil profiles in Wanja Kersa Kebele

Pedon/Horizon	Depth (cm)	% Particle size distribution			Texture class	Silt/Clay ratio	BD g/cm^3
		Sand	Silt	Clay			
JIM/G/WK/P1							
Ap	0-13	43.9	17.3	38.8	Clay loam	0.45	1.07
AB	13-26	20.1	13.0	66.9	clay	0.19	1.02
Bt1	26-34	7.0	21.6	71.4	clay	0.30	1.02
Bt2	34-75	6.4	21.5	72.1	clay	0.30	1.04
Bt3	75-120	4.2	26.9	68.9	clay	0.39	1.02
Bt4	120+	5.2	29.8	65	clay	046	1.05

Table 12.11: Selected chemical properties of soil profiles in Wanja Kersa kebele

Pedon /Hor	Depth (cm)	pH (1:2.5)		ΔpH	EC (ds/m)	OC (%)	TN (%)	C:N ratio	Av.P (mg P2O5/ kg soil)	Av. S %	Micro nutrients (mg/kg soil)			
		H2O	KCl								Zn	Mn	Cu	Fe
JIM/G/WK/P1														
Ap	0-10	4.6	3.9	0.7	0.06	3.52	0.4	8.80	12.6	0.5	6.9	69.6	3.3	133.8
E1g	10--40	4.8	4.0	0.8	0.02	1.02	0.1	10.20						
E2g	40-50	5.0	4.2	0.8	0.02	0.41	0.04	10.25						
Bt1g	50-80	4.6	3.8	0.8	0.03	0.20	0.03	6.67						
Bt2g	80+	4.6	3.6	1	0.04	0.17	0.02	8.50						
Average		4.7	3.9	0.8	0.03	1.06	0.12	8.88						

Table 12.12: Exchangeable cations and CEC results of soil profiles in Nada Chala kebele

Horizon	Depth (cm)	Exchangeable cations cmol (+) kg-1					Cations ratio		CEC cmol (+) kg-1		BS (%)	ESP (%)
		Na	K	Ca	Mg	sum	Ca/Mg	K/Mg	Soil	Clay		
JIM/G/WK/P1												
Ap	0-13	1.68	1.34	11.16	3.43	17.61	3.25	0.39	38.72	74.02	45.5	4.34
AB	13-26	2.39	1.61	10.30	3.43	17.73	3.00	0.47	43.85	54.78	40.4	5.45
Bt1	26-34	1.89	1.71	9.47	3.44	16.51	2.75	0.50	38.36	46.72	43	4.93
Bt2	34-75	1.64	1.85	6.00	2.57	12.06	2.33	0.72	36.32	47.05	33.2	4.51
Bt3	75-120	1.81	2.80	6.00	2.57	13.18	2.33	1.09	33.06	45.95	39.9	5.46
Bt4	120+	1.77	2.19	6.37	2.12	12.45	3.00	1.03	33.68	50.89	37	5.26
Average		1.86	1.92	8.22	2.93	14.92	2.78	0.70	37.33	53.24	39.83	4.99

Table 12.13: Site and profile description of Sadi Loya Kebele in Omo Nada Woreda

Profile code:	JIM/G/SL/P1
Soil classification:	Gleyic Vertic Planosols
Location:	Sadi Loya, Garee Looyyaa 2ffa
Coordinates:	213914 m N- 804754 m E
Elevation:	1896 m above sea level
Date and author:	20/1/2014; Alemayehu Regassa and Fassil Assefa
Geology:	Volcanic rocks of Tertiary and quaternary age overlie the precamberian rocks
Land form:	Numerous small hills grading to flat to gently undulating valleys
Local physiography:	Valley and gently sloping valley sides
Slope:	1%
Land use/veregation:	Cultivation of annual crops mainly maize and teff ; slightly disturbed high forest in the surrounding uphills

General information on the soil

Parent material:	Volcanic ash deposits with admixture of alluvial materials
Moisture condition:	Moist throughout the depth of the profile
Drainage:	Poorly to imperfectly drained
Groundwater:	None up to 100 cm depth, temporary water table during the rainy season
Surface stones:	None
Erosion:	Slight sheet erosion
Human influence:	Surface drainage

Profile descriptions

Horizon	Depth (cm)	Description
Apg	0-13	dark gray (7.5 4/1) moist); silty loam; weak fine crumby; non-sticky and slightly plastic; common yellowish red (5YR 4/6) iron and manganese mottles; common medium roots; clear wavy boundary to
Eg1	13-40	grayish brown (10YR 5/2) moist; silt clay loam; crumby; soft friable; slightly sticky and slightly plastic ;common fine yellow (10YR 7/8) mottles ;many fine and few coarse roots; few medium ferromanganese nodules and concretions; gradual smooth boundary to
Eg2	40-70	dark yellowish brown (10YR 4/6) moist; silty clay loam; strong, medium prismatic ; slightly sticky and slightly plastic; abundant coarse strong brown (7.5YR 5/8) iron and manganese oxide mottles at the transition to the underlying horizon; few very fine and fine roots; abrupt wavy boundary to
2Bssg	70-100	dray (10 YR 5/1) moist; clay; strong fine angular blocky; very sticky and very plastic; few large ferromanganese nodules; common slickensides and pressure faces; very fine to fine , random roots

Site characteristics

Profile code:	JIM/G/SL/P2
Soil classification:	Eutric Nitisols
Location:	Sadi Loya, *Loya Kerebe zone*
Coordinates:	214245 m N- 860483 m E
Elevation:	1917 m
Date and author:	20/1/2014; Alemayehu Regassa and Farid Ahmedin
Geology:	Volcanic rocks of Tertiary and quaternary age overlie the precamberian rocks

Land form: Plateau; gently undulating to rolling isolated hills
Local physiography: Undulating upland
Slope: 13%
Land use/vegetation: Cultivation of annual and perennial crops and scattered trees on farm land and patches of Eucalyptus spps woodlots

General information on the soil

Parent material: Basalt
Moisture condition: Dry at the top and progressively moist with depth
Drainage: Well to excessively drained
Groundwater: Not encountered, very deep
Surface stones: None
Erosion: Slight sheet erosion
Human influence: Continuous cultivation without maintaining the fertility of the soils

Profile description

Horizon	Depth (cm)	Description
Ap	0-10	brown (7.5YR 4/3) moist; clay loam; moderate fine to medium sub angular blocky; very friable ,slightly sticky, slightly plastic; many very fine and fine pores; many, fine and medium roots; clear smooth boundary to
AB	10-30	bark brown (7.5YR 3/2) moist; clay; strong medium to coarse sub angular blocky; soft, firm, slightly sticky and slightly plastic; many coarse roots; common fine and medium pores; gradual smooth boundary to
Bt1	30-60	bark reddish brown (5YR 3/4) moist; weak fine and medium subangular blocky structure; friable, very sticky and very plastic; prominent shiny ped faces; many fine and common medium roots; diffuse smooth boundary to
Bt2	60-105	reddish brown (5YR 4/4) moist; moderate medium angular blocky; firm , very sticky, very plastic; prominent shiny ped faces; very few fine roots; diffuse smooth boundary to
Bt3	105+	Dark reddish brown (5YR 3/4) moist; clay; strong medium angular blocky; sticky, plastic; common shiny ped faces; few fine pores; few fine roots;

Site characteristics

Profile code: JIM/G/SL/P3
Soil classification: Eutric Nitisols
Location: Sadi Loya, Caawura Zone, garee Booree
Coordinates: 214552 m N- 865584 m E
Elevation: 2378 m above sea level
Date and author: 21/1/2014; Alemayehu Regassa and Farid Ahmedin
Geology: Volcanic rocks of Tertiary and quaternary age overlie the precamberian rocks
Land form: Plateau; gently undulating to rolling hilly land
Local physiography: Undulating upland
Slope: 12%
Land use/vegetation: Fallow grazing land, before two years it was cultivated with teff; bushes and shrubs in the valleys along the streams and *eucalyptus woodlots*

General information on the soil

Parent material: Basalt
Moisture condition: Dry at the top and slightly moist down the depth of the profile
Drainage: Well drained
Groundwater: Not encountered, very deep
Surface stones: None
Erosion: Slight sheet erosion
Human influence: Overgrazing

Profile description

Horizon	Depth (cm)	Description
Ap	0-16	brown (7.5YR 4/3) moist ; clay loam; moderate fine to medium sub angular blocky; very friable ,slightly sticky, slightly plastic, many very fine and fine pores; many, fine and medium roots; clear smooth boundary to
AB	16-45	dark reddish brown (5YR 3/2) moist; clay; strong medium to coarse sub angular blocky; soft, firm, slightly sticky and slightly plastic; many coarse roots; common fine and medium pores; gradual smooth boundary to
Bt1	45-60	dark reddish brown (5YR 3/3) moist ; weak fine and medium subangular blocky ; friable , very sticky and very plastic ; prominent shiny ped faces; many fine and common medium roots; diffuse smooth boundary to .
Bt2	60-75	dark reddish brown (2.5YR 3/3) moist; clay; moderate medium angular blocky; firm, very sticky, very plastic; very few fine roots, prominent shiny ped faces
Bt3g	75-130	yellowish red (5YR 4/6) moist; clay; strong medium angular blocky; sticky, plastic; few medium pores; prominent shiny ped faces; few medium bluish black iron and manganese nodules few fine roots

Tabler 12.14: Physical properties of soil profiles in Sedi Loya Kebele

Pedon/Horizon	Depth (cm)	% Particle size distribution			Texture class	Silt/Clay ratio	BD g/cm^3
		Sand	Silt	Clay			
JIM/G/SL/P1							
Ap	0-13	33.5	22.2	44.3	clay	0.50	1.07
E1g	13-40	23.0	26.0	51.0	clay	0.51	1.05
E2g	40-70	43.8	4.3	51.8	clay	0.08	1.17
Bt1g	70-100	16.0	14.6	69.4	clay	0.21	1.20
JIM/G/SL/P2							
Ap	0-10	30.5	17.4	52.1	clay	0.33	1.04
AB	10--30	19.9	10.6	69.5	clay	0.15	1.02
Bt1	30-60	12.8	21.3	65.9	clay	0.32	1.04
Bt2	60-105	10.7	26.6	62.7	clay	0.42	1.07
Bt3	105+	7.7	26.8	65.5	clay	0.41	1.04
JIM/G/SL/P3							
Ap	0-16	39.6	17.3	43.2	clay	0.40	1.06
AB	16-45	9.6	20.5	70.0	Clay	0.29	1.04
Bt1	45-60	8.5	22.6	68.9	clay	0.33	1.10
Bt2	60-75	5.0	27.0	68.0	clay	0.40	1.12
Bt3g	75-130	7.0	30.7	62.3	clay	0.49	1.11

Table 12.15: Selected chemical properties of soil profiles in Sedi Loya kebele

Pedon /Hor	Depth (cm)	pH (1:2.5)		ΔpH	EC (ds/m)	OC (%)	TN (%)	C:N ratio	Av.P (mg P2O5/ kg soil)	Av. S %	Micro nutrients (mg/kg soil)			
		H_2O	KCl								Zn	Mn	Cu	Fe
JIM/G/SL/P1														
Ap	0-13	4.3	3.6	0.7	0.02	3.98	0.43	9.26	22.3	0.44	6.9	60.9	1.0	271
E1g	13-40	4.6	3.9	0.7	0.02	1.15	0.12	9.58						
E2g	40-70	4.7	4.0	0.7	0.02	0.97	0.11	8.82						
Bt1g	70-100	5.1	4.3	0.8	0.02	0.27	0.03	9.00						
Average		4.7	4.0	0.7	0.02	1.59	0.17	9.17						
JIM/G/SL/P2														
Ap	0-10	5.5	4.7	0.8	0.04	3.66	0.33	11.09	15.6	1.11	8.3	60.5	2.11	106.2
AB	10--30	4.9	4.4	0.5	0.03	1.94	0.23	8.43						
Bt1	30-60	4.6	4.1	0.5	0.02	1.54	0.13	11.85						
Bt2	60-105	4.6	4.0	0.6	0.02	1.13	0.10	11.30						
Bt3	105+	4.5	3.9	0.6	0.01	0.35	0.03	11.67						
Average		4.8	4.2	0.6	0.02	1.72	0.16	10.87						
JIM/G/SL/P3														
Ap	0-16	5.3	4.8	0.5	0.04	3.27	0.35	9.34	16.1	0.96	15.7	60.8	3.3	104.0
AB	16-45	5.4	4.7	0.7	0.02	1.12	0.10	11.20						
Bt1	45-60	4.8	4.2	0.6	0.01	0.87	0.07	12.43						
Bt2	60-75	4.6	4.0	0.6	0.01	0.58	0.06	9.67						
Bt3g	75-130	4.7	4.1	0.6	0.01	0.65	0.06	10.83						
Average		5.0	4.4	0.6	0.02	1.30	0.13	10.69						

Table 12.16: Exchangeable cations and CEC results of soil profiles in Toli Beyem kebele

Horizon	Depth (cm)	Exchangeable cations cmol (+) kg-1					Cations ratio		CEC cmol (+) kg-1		BS (%)	ESP (%)
		Na	K	Ca	Mg	sum	Ca/Mg	K/Mg	Soil	Clay		
JIM/G/SL/P1												
Ap	0-13	1.41	0.39	10.11	4.21	16.12	2.40	0.09	41.2	61.85	39.1	3.42
E1g	13-40	1.70	0.25	7.48	2.49	11.92	3.00	0.10	27.1	45.29	44	6.27
E2g	40-70	1.83	0.37	11.17	4.30	17.67	2.60	0.09	37.36	65.56	47.3	4.9
Bt1g	70-100	1.93	0.51	15.94	6.20	24.58	2.57	0.08	48.13	67.91	51.1	4
Average		1.72	0.38	11.18	4.30	17.57	2.64	0.09	38.45	60.15	45.38	4.65
JIM/G/SL/P2												
Ap	0-10	1.78	1.69	12.95	4.32	20.74	3.00	0.39	45.97	64.05	55.7	4
AB	10-30	1.40	1.36	10.18	3.39	16.33	3.00	0.40	43.16	52.60	48.1	4.13
Bt1	30-60	1.47	1.25	10.18	3.39	16.29	3.00	0.37	37.33	48.45	43.7	3.75
Bt2	60-105	1.45	1.00	11.96	4.27	18.68	2.80	0.23	37.79	54.21	43.1	3.9
Bt3	105+	1.41	0.39	10.11	4.21	16.12	2.40	0.09	38.08	56.31	49.1	3.8
Average		1.50	1.14	11.08	3.92	17.63	2.84	0.30	40.47	55.12	47.94	3.92
JIM/G/SL/P3												
Ap	0-16	1.48	1.24	14.61	4.30	21.63	3.40	0.29	39.22	64.86	55.2	3.76
AB	16-45	1.77	1.01	12.85	4.28	19.91	3.00	0.24	38.18	49.11	52.1	4.63
Bt1	45-60	1.69	0.63	9.4	3.43	15.15	2.74	0.18	40.98	55.12	37.0	4.14
Bt2	60-75	1.77	0.47	8.59	3.44	14.27	2.50	0.14	42.96	60.24	33.2	4.13
Bt3g	75-130	1.69	0.46	10.12	3.37	15.64	3.00	0.14	34.37	51.64	45.5	4.91
Average		1.68	0.76	11.11	3.76	17.32	2.93	0.20	39.14	56.19	44.60	4.31

3.6.3. Synthesis

In this section of the report, synthesis of the soil properties related to the agronomic development is made briefly. Reference is made to the respective tables of analytical data.

The dominant agricultural soils in the four studied kebeles, Ganji Chala, Kacho Andaracha, Wanja Kersa and Sedi Loya, are Nitisols, Planosols and Gleysols covering 50.6% (17.9, 18.7 and 14.0% respectively). Cambisols and Leptosols occuy moderately to strongly steep hills and ridges.

Texture of these soils is clayey throughout the profiles. The bulk density of all the studied profiles in Omo Nada woreda is found to be less than 1.44, which is common in cultivated soils. The low bulk density found in these soils indicates that the soils are not compacted and have more porosity.

Except in Kacha andaracha where the bulk of the kebele is made up of hydromorphic soils, Nitisols are the most agriculturally important soils in the Gera woreda.

The soil pH in water of topsoils is strongly acid with values between 4.3 and 4.6. The acidic soil reaction could result in excess and toxicity of heavy metals, and deficiency of basic cations (Landon, 1991). The overall trend of the pH values with depth varies considerably and therefore cannot be taken as a characteristic applicable to all the soils. The low pH value is likely to increase Al toxicity as this element is normally expected at less than 5.5 pH values. This would in particular a problem where the low pH value occurred within 65 cm from the soil surface in which most crop roots extract their nutrient requirements (Tisdale, et al., 1993)

The organic carbon content in top soils ranges from 2.94-3.98% which is rated as low by Landon (1991). The low organic carbon content may be attributed to intensive agricultural practices that aggravate organic carbon oxidation (Wakene and Hiluf, 2003). Also, total nitrogen (N) content in topsoils ranges between 0.31-0.43 which is rated as medium as per the rating by Landon (1991) and decreases with soil depth. This decrease generally parallels to a decrease in contents of organic carbon, suggesting that the main source of total nitrogen was organic matter. The C:N ratios of the top layer of the studied soils range between 8.54 and 9.13, which is an indication that most soils have good quality organic matter. The values of exchangeable sodium percentage (ESP) in all the soils studied in the woreda are generally below 15%, the critical limit for sodicity (Brady and Weil, 2002).

The CEC of the total soil and clay fraction after correcting for organic matter is invariably very high ranges between 38.7 to 40.7 cmol(+) kg^{-1} and 74.02 to 102.5 cmol(+) kg^{-1} respectively. Since the organic matter content of the soils which normally influences the CEC is generally low, the CEC values to the amount and type of clay minerals present in the soils matter.

Exchangeable calcium followed by magnesium formed the dominant cation in the exchange complex throughout the horizons of the representative profiles. But their proportions showed an irregular pattern with depth. On the other hand, the proportions of exchangeable K and Na in the exchange site were found to be insignificant and also showed an irregular variation with depth of the profile. From these data, it may be pointed out that, whereas toxicity from Na is unlikely to occur but K deficiency is expected according to Landon (1991) ratings. The presence of irregular variation in the exchangeable cations may partly suggest existence of different levels of

leaching intensity within the horizons of the profile. It may also partly indicate an existence of different sources of parent materials.

3.7. Soils of CASCAPE intervention Kebeles in Didessa woreda

3.7.1. Geology and geomorphology

The slightly dissected landscape Didessa woreda consists of ridges of volcanic origin which are dissected by a few narrow mostly V-shaped valleys. The majority of the slopes of the ridges have slope classes which vary between 6 and 32%.

The ridges can be categorized into the flat to gently sloping crests and the slopes. The majority of the crests are broad and are characterized by very deep well drained red soils. On some small convex crests erosion processes have led to shallow soils. On the other hand the slope varies in steepness from 10-60%. Sucha located in Goro kebele is the biggest hill (more than 2400 m.a.s.l) in the woreda. However the majority of the slopes vary between 12 and 20%. Since most of these slopes are covered by trees erosion processes are negligible.

Valleys and plain areas of low slope gradient and relief are also widely distributed in the studied kebeles interspersed between the local hills. Large extents of these flat landmasses occur in Sobo and yembero kebeles along Didessa river.

The hard rock within the woreda consists of fine grained basalts and white to grey tuffs. These volcanic rocks belong to the Magdala group. They include rhyolites, trachytes, trachytic nad rhyolitic tuffs, ignimbrite and basalts which are deposited during the latest phase of the trap series in the upper Miocene to Pleistocene. These acidic rocks, rhyolites, trachytes and accompanying tuffs are deposited from the acid magma melt.

According to the report by the Geological Survey of Ethiopia (GSE, 2012), more than half of the surface geology of the CASCAPE intervention kebeles in Didessa woreda is made up of Arjo middle basal which accounts for about 54.3 % of the total surface geology of the four studied kebeles. This is followed by Arjo lower basalt which covers about 22% of the total area of the four kebeles. Trachyte flows and plugs covers about 18.1% of the total aras of the studied kebeles. Table 13 and Figure 29 shows the area and percentage distribution of the different geological materials in the CASCAPE intervention kebeles of Didessa woreda

Table13: Area and percent coverage of lithology in CASCAPE intervention kebeles in Didessa woreda

lithology	Area_ha	%
Arjo middle basalt	7028	54.3
Trachyte flows and plugs	2346	18.1
Gibe lower basalt	724	5.6
Arjo lower basalt	2856	22.0

While Yembero and Mesera kebeles are covered to a large extent by Arjo middle basalt, Goro and Sobo kabeles are covered dominantly by Arjo lower basalt and Trachyte flows and plugs respectively. While dominant in the sobo Kebele , the trachyte flows and plugs cover only pocket areas in the Mesera and yembero kebeles. In contrary, the Arjo middle basalt that covers the bulk areas in the Masara and Yembero kebeles occur only in pocket areas in the Sobo kabele and absent in the Goro kebele.

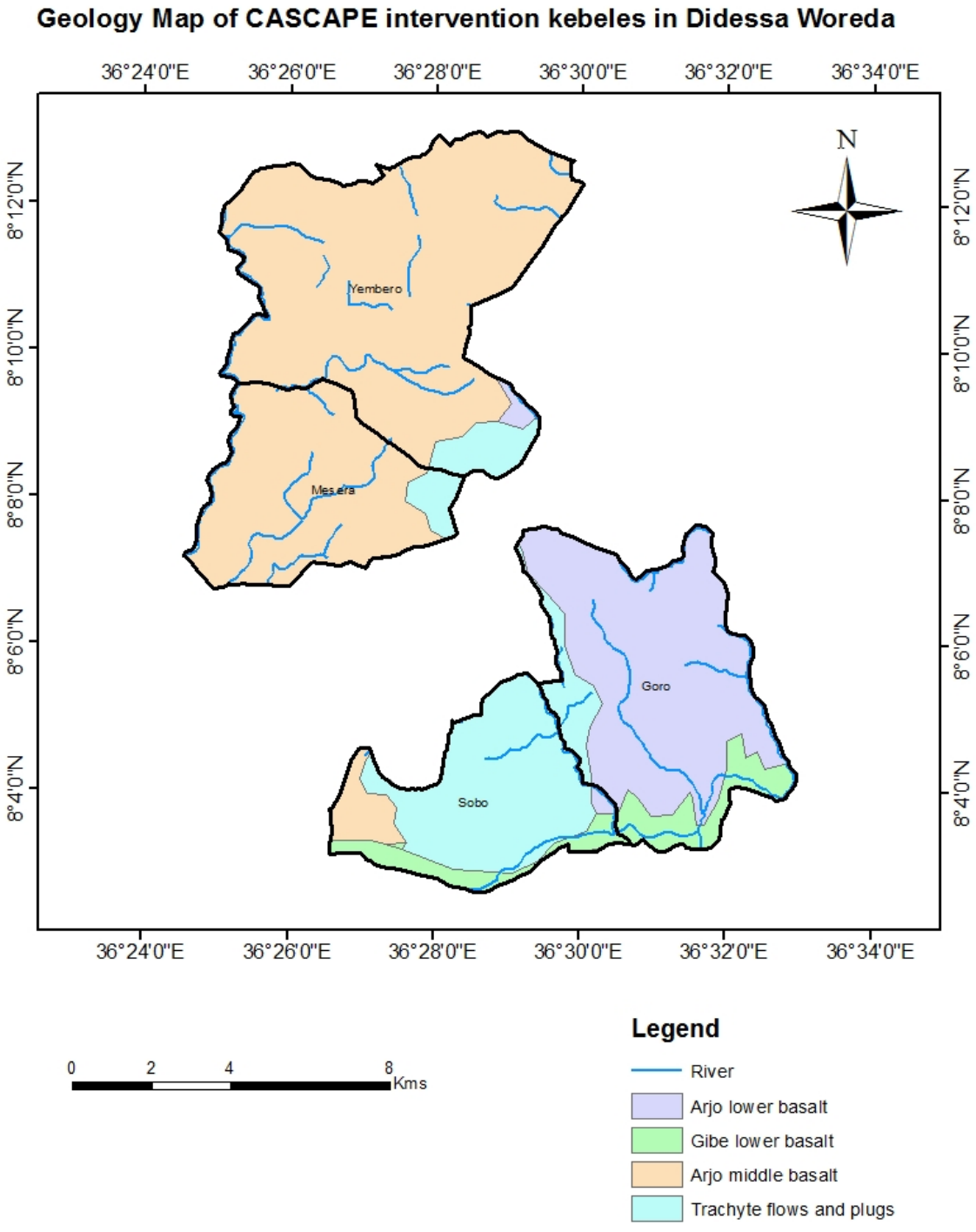

Figure 29. Geological map of CASCAPE intervention kebeles in Didessa woreda

3.7.2. The soil- landscape

Thirty two auger observations coupled with a number of visual observations were made from natural exposures such as roadside cuts and gullies. Six soil profile were dug and investigated (see the locations of the auger observations and soils profiles in Figure 26.From the auger observation, soil profile study and interpretation of the the topographic and slope maps, the studied kebeles have been classified in to different soil mapping units by considering the dominant soils and land forms.

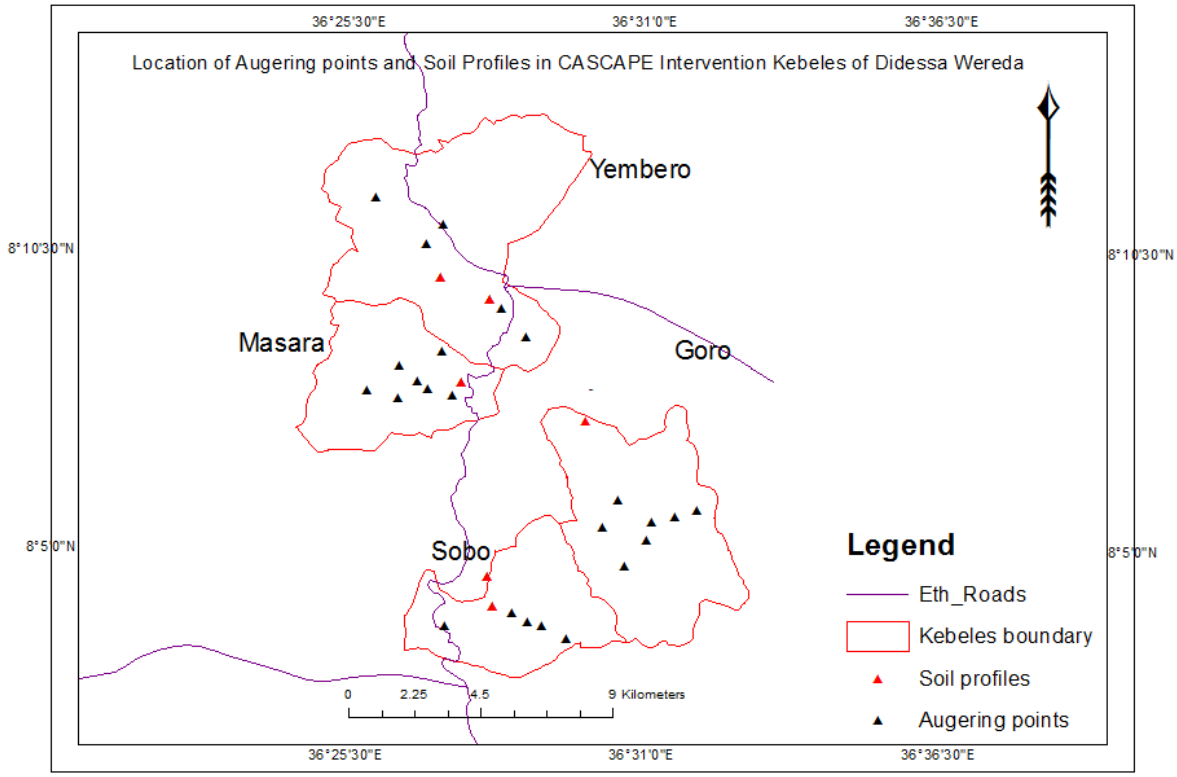

Figure 30. Augure and soil profile locations in Kebeles of Didessa woreda

The Soil Map has been compiled primarily from classifying each soil auger site and each soil profile pit according to its soil unit, plotting these data and then grouping them into polygons of similar content.

The soil variation in the woreda mainly depends on the physiographic position. Five mapping units were distinguished in the study area and their distribution and extent are shown in table 4 and the soil map (Fig. 27)

On the high ridges and top of small hills, Leptosols are the dominant soil reference groups. They constitute about 24.5% of the total area of all the four kebels in Didessa woreda. Cambisols are the dominant soil types in the studied kebeles of Didessa woreda. These soils cover about 32.9% of the total area in the four kebeles.

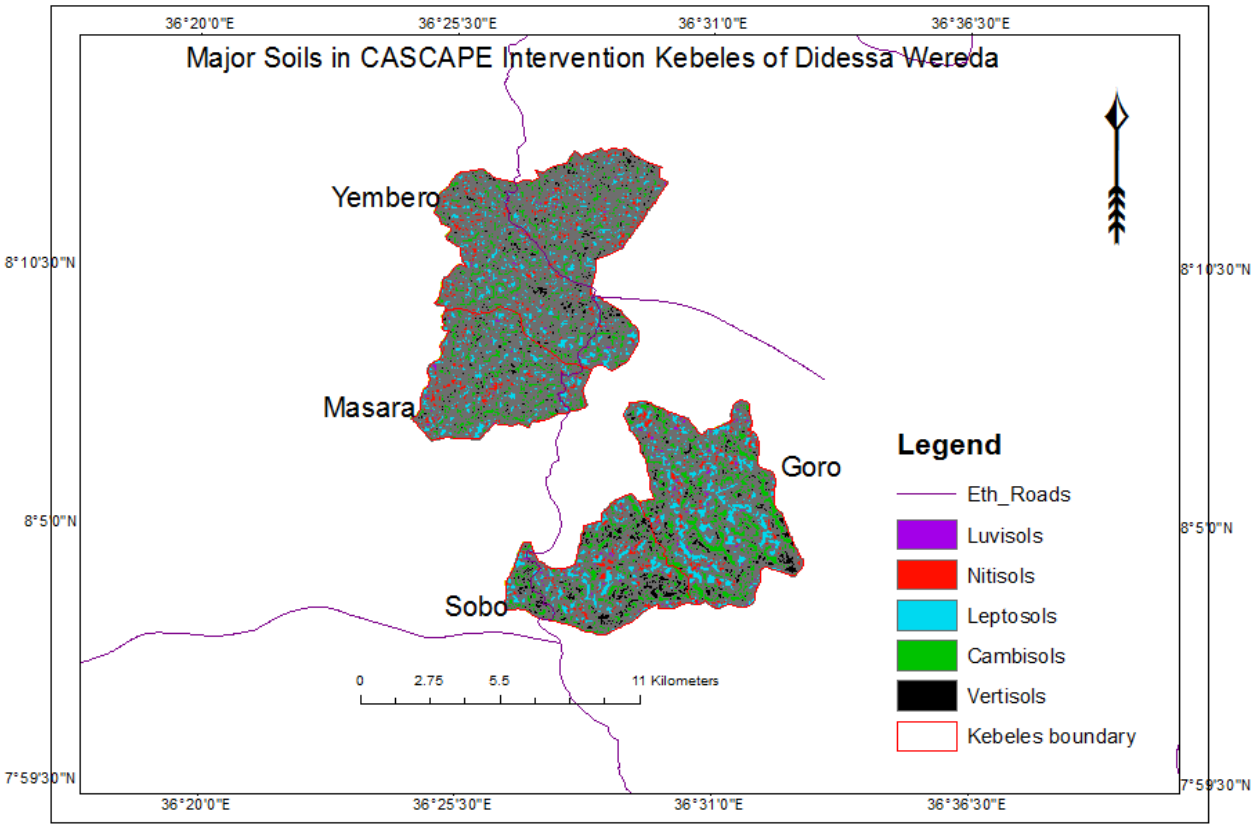

Figure 31. Soil map of kebeles in Didessa

In the upper slopes, Nitisols are the dominant soil types. They constitute about 17.2% of the total area of the four studied kebeles. Nitisols and Cambisols are the most agriculturally important soils in the woreda.

Table 14: Summary of major Soil types and their distribution in the four CASCAPE intervention kebeles of Didessa woreda

Soil types	Area (km2)	%
Leptosols	31.71	24.5
Cambisols	42.68	32.9
Luvisols	6.31	4.9
Nitisols	22.22	17.1
Vertisols	26.64	20.6

The U shaped valleys, open slopes and plains are covered by Vertisols. The make up about 20.6 % of the total area of the four kebeles studied. Vertisols are especially extensive in didessa valleys of Sobo kebele. They are agriculturally highly productive soils.

Table 15 : Site and profile description and lab analytical data of CASCAPE intervention kebeles in Didessa woreda

15.1 : Site and profile description of Goro Kebele

Profile code:	ILU/D/G/P1
Soil classification:	Dystric Luvisols
Location:	Goro, *Garee Agal luuccoo*
Coordinates:	224252 m N- 899077 m E
Elevation:	1984 m above sea level
Date and author:	27/01/2014; Alemayehu Regassa and Nasha Mohammed
Geology:	Volcanic rocks of Tertiary and quaternary age overlie the precamberian rocks
Land form:	Isolated hills, hilly
Local physiography:	Undulating upland
Slope:	12%
Land use/vegetation:	Cultivation, teff and maize are the dominant crops; some digressional areas are used for private cattle grazing; remnants of forests on hills and bush along stream courses

General information on the soil

Parent material:	Basalt
Moisture condition:	Dry at the top and moist in the subsurface horizons
Drainage:	Well drained to excessively drained
Groundwater:	Not encountered, very deep
Surface stones:	None
Erosion:	Slight sheet erosion
Human influence:	Inadequate soil fertility maintenance, soil burning in the valleys

Profile description

Hor.	Depth (cm)	Description
Ap	0-15	dark reddish brown (5YR 3/3) moist; clay loam ; medium granular structure; friable, sticky and plastic; few fine and very fine pores; common coarse and many fine roots; gradual smooth boundary to
Bt1	15-55	dark reddish brown (5YR 3/4) moist; clay; weak medium subanguiar biocky friable, very sticky and very plastic; few fine and very fine pores; common fine and many very fine mostly dead, roots; few wormcasts; non calcareous; diffuse smooth boundary to
Bt2	55-80	dark reddish brown (2.5 YR 3/3) moist; clay; moderate medium subanguiar blocky; friable, very sticky and very plastic; few fine and very fine pores; common fine and many very fine roots; diffuse smooth boundary to
Bt3	80-115	reddish brown (2.5 YR 4/3) moist; clay; friable, very sticky and very plastic; few fine and very fine pores; common fine and many very fine roots; diffuse smooth boundary to
Bt4	115+	reddish brown (2.5 YR 4/4) moist; clav; friable, very sticky and very plastic, few fine and very fine pores; no roots

Table 15.2: Physical properties of soil profile in Goro

Pedon/Horizon	Depth (cm)	% Particle size distribution			Texture class	Silt/Clay ratio	BD g/cm^3
		Sand	Silt	Clay			
ILU/D/G/P1							
Ap	0-15	37.8	12.7	49.5	clay	0.26	1.02
Bt1	15-55	16.8	13.7	69.5	clay	0.20	1.02
Bt2	55-80	14.6	16.9	68.6	clay	0.25	1.04
Bt3	80-115	18.8	15.8	65.4	clay	0.24	1.01
Bt4	115+	9.2	19.0	71.8	clay	0.26	1.05

Table 15.3: Selected chemical properties of soil profiles in Goro Kebele

Pedon /Hor	Depth (cm)	pH (1:2.5)		ΔpH	EC (ds/m)	OC (%)	TN (%)	C:N ratio	Av.P (mg P2O5/ kg soil)	Av. S %	Micro nutrients (mg/kg soil)			
		H2O	KCl								Zn	Mn	Cu	Fe
ILU/D/G/P1														
Ap	0-15	5.4	4.7	0.7	0.03	2.87	0.32	8.97	19.3	0.39	4.3	52.9	1.6	55.1
Bt1	15-55	5.3	4.6	0.7	0.04	1.30	0.13	10.00						
Bt2	55-80	4.9	4.2	0.7	0.03	0.92	0.10	9.20						
Bt3	80-15	4.7	4.1	0.6	0.03	0.76	0.07	10.86						
Bt4	115+	4.5	3.8	0.7	0.03	0.67	0.06	11.17						
Average		5.0	4.3	0.7	0.03	1.30	0.14	10.04						

Table 15.4. Exchangeable cations and CEC results of soil profiles in Goro kebele

Horizon	Depth (cm)	Exchangeable cations cmol (+) kg-1					Cations ratio		CEC cmol (+) kg-1		BS (%)	ESP (%)
		Na	K	Ca	Mg	sum	Ca/Mg	K/Mg	Soil	Clay		
ILU/D/G/P1												
Ah	0-18	1.88	1.03	13.44	5.04	21.39	2.67	0.20	51.59	84.42	41.5	3.65
AB	18-42	1.72	0.76	12.6	5.04	20.12	2.50	0.15	53.41	70.52	37.7	3.21
Bt1	42-74	1.86	1.08	10.92	4.20	18.06	2.60	0.26	54.78	75.19	33	3.4
Bt2	74-122	1.72	1.94	9.24	3.36	16.26	2.75	0.58	44.74	64.43	36.3	3.84
Bt3	122+	1.64	1.18	10.08	4.87	17.77	2.07	0.24	52.5	69.78	33.8	3.13
Average		1.76	1.20	11.26	4.50	18.72	2.52	0.29	51.40	72.87	36.46	3.45

Table 15.5 : Site and profile description of soil profiles in Masara kebele

Profile code ILU/D/M/P1
Soil classification Dystric Nitisols
Location Masara, *Garee Dingarache*
Coordinates 220098 m N- 900039 m E
Elevation 2163 m above sea level
Date and author 26/01/2014; Alemayehu Regassa and Nasir
Geology Volcanic rocks of Tertiary and quaternary age overlie the precamberian rocks
Land form: Isolated hills, hilly
Local physiography: Undulating upland
Slope: 15%
Land use: Cultivation of annual crops, dominantly teff followed by maize

General information on the soil

Parent material: Deeply weathered Basalt
Moisture condition: Dry at the top and moist in the subsurface horizons
Drainage: Well to excessively well drained
Groundwater: Not encountered, very deep
Surface stones: None
Erosion: Slight sheet erosion
Human influence: Continuous cropping without enough fertility management

Profile description

Hor.	Depth (cm)	Description
A	0-18	dark brown (7.5YR 3/4) moist, ; silty clay loam, week fine to very fine sub angular blocky, friable, slightly sticky and slightly plastic, few fine and very fine pores, common fine and medium roots; gradual smooth boundary to
AB	18-42	dark reddish brown (5YR 3/3) moist; clay; strong medium to coarse sub angular blocky; slightly firm, slightly sticky and slightly plastic; many coarse roots; common fine and medium pores; abrupt smooth boundary to
Bt1	42-74	dark reddish brown (5YR 3/4) moist, clay; moderate fine to medium angular blocky, firm very sticky and very plastic; prominent shiny pedfaces; few very fine pores, few fine roots, diffuse smooth boundary to
Bt2	74-122	dark reddish brown (5YR 3/4) moist; clay; strong coarse angular blocky; slightly firm, sticky and plastic; prominent shiny pedfaces; few fine roots; very few fine pores; diffuse smooth boundary to
Bt3	122+	dark reddish brown (5YR 4/6) moist; clay; moderate medium angular blocky; firm, very sticky and very plastic; very few fine roots

Table 15.6: Physical properties of soil profiles in Masara Kebele

Pedon/Horizon	Depth (cm)	% Particle size distribution			Texture class	Silt/Clay ratio	BD g/cm^3
		Sand	Silt	Clay			
ILU/D/M/P1							
Ah	0-18	37.1	17.0	45.9	clay	0.37	1.07
AB	18-42	13.3	18.2	68.5	clay	0.27	1.06
Bt1	42-74	15.6	16.0	68.4	clay	0.23	1.04
Bt2	74-122	14.7	16.0	69.3	clay	0.23	1.05
Bt3	122+	14.1	20.2	65.8	clay	0.31	1.14

Table 15.7: Selected chemical properties of soil profiles in Masara

Pedon /Hor	Depth (cm)	pH (1:2.5)		ΔpH	EC (ds/m)	OC (%)	TN (%)	C:N ratio	Av.P (mg P2O5/ kg soil)	Av. S %	Micro nutrients (mg/kg soil)			
		H2O	KCl								Zn	Mn	Cu	Fe
ILU/D/M/P1														
Ah	0-18	5.1	4.4	0.7	0.06	2.44	0.28	8.71	25.1	1.15	2.6	51.7	0.8	54.6
AB	18-42	4.7	4.1	0.6	0.01	1.37	0.12	11.42						
Bt1	42-74	4.7	4.2	0.5	0.01	1.19	0.10	11.90						
Bt2	74-22	4.7	4.1	0.6	0.01	0.76	0.07	10.86						
Bt3	122+	4.8	4.2	0.6	0.01	0.51	0.04	12.75						
Avergae		4.8	4.2	0.6	0.02	1.25	0.12	11.13						

Table 15.8: Exchangeable cations and CEC results of soil profiles in Nada Bidaru kebele

Horizon	Depth (cm)	Exchangeable cations cmol (+) kg-1					Cations ratio		CEC cmol (+) kg-1		BS (%)	ESP (%)
		Na	K	Ca	Mg	sum	Ca/Mg	K/Mg	Soil	Clay		
ILU/D/M/P1												
Ah	0-18	1.40	1.13	18.66	6.78	27.97	2.75	0.17	38.25	65.03	73.1	3.66
AB	18-42	1.75	0.43	10.27	3.42	15.87	3.00	0.13	41.87	54.12	37.9	4.18
Bt1	42-74	1.90	0.52	12.72	4.24	19.38	3.00	0.12	44.24	58.54	43.8	4.29
Bt2	74-122	1.55	0.38	13.57	5.09	20.59	2.67	0.07	39.63	53.43	52	3.91
Bt3	122+	1.95	0.45	9.33	3.39	15.12	2.75	0.13	41.02	59.60	36.9	4.76
Average		1.71	0.582	12.91	4.58	19.786	2.834	0.124	41.002	58.144	48.74	4.16

Table 15.9: Site and profile description of Sobo in Didessa Woreda

Profile code: ILU/D/S/P2
Soil classification: Dystric Nitisols
Location: Sobo, Zoni Gudo, Garee Abaloo, about 500 m NW of FTC
Coordinates: 221006 m N- 893394 m E
Elevation: 1846 m above sea level
Date and author: 26/01/2014; Alemayehu Regassa and Biyyaa Jihaad
Geology: Volcanic rocks of Tertiary and quaternary age overlie the precamberian rocks

Land form: Isolated hills, hilly
Local physiography: Undulating upland
Slope: 8%
Land use: Farm land

General information on the soil

Parent material: Deeply weathered basalt
Moisture condition: Dry at the top and moist in the subsurface horizons
Drainage: Well drained
Groundwater: Not encountered, very deep
Surface stones: None
Erosion: Slight sheet erosion
Human influence: Terrace construction

Profile description

Hor.	Depth (cm)	Description
Ah	0-15	dark reddish brown (5YR 3/3) moist; clay loam; moderate fine and medium sub angular blocky; friable, sticky and slightly plastic; common fine roots; many fine and medium pores; clear smooth boundary to
AB	15-30	very dark brown (7.5YR 2.5/3) moist; clay ; moderate fine and medium sub angular blocky; friable, sticky and plastic ; many fine and medium pores; very few fine and medium roots; gradual smooth boundary to
Bt1	30-60	Dark brown,(7.5YR 3/4) moist); clay; moderate fine and medium sub angular blocky; friable, sticky and plastic; prominent shiny ped faces; few black hard and soft nodules; common fine and medium pores; very few fine and medium roots; diffuse smooth boundary to
Bt2	60-90	Dark brown (7.5YR 3/4) moist, clay; strong coarse angular blocky; slightly firm, sticky and plastic; very few very fine roots; very few fine pores; prominent shiny ped face; common, very fine, distinct bluish black to black mottles; diffuse smooth boundary to
Bt3	90-120	Dark reddish brown (5YR 3/3) moist; clay; strong medium coarse sub angular blocky; slightly firm, very sticky and very plastic; faint dark brown clay coatings; few fine pores

Site characteristics

Profile code: JIM/D/S/P2
Soil classification: dystric Cambisols
Location: Sobo, Garee Abaloo
Coordinates: 221153 m N- 892409 m E
Elevation: 1846 m above sea level
Date and author: 26/01/2014; Alemayehu Regassa and Biyyaa Jihaad
Geology: Volcanic rocks of Tertiary and quaternary age overlie the precamberian rocks
Land form: Isolated hills, hilly
Local physiography: Undulating upland
Slope: 8%
Land use: Farm land

General information on the soil

Parent material: Weathered basalts and trachybasalts
Moisture condition: Dry at the top and moist in the subsurface horizons
Drainage: Well drained
Groundwater: Not encountered, very deep
Surface stones: Nnone
Erosion: Slight sheet erosion
Human influence: Bad ploughing practice, along the slope thereby facilitating soil to erosion

Profile description

Hor.	Depth (cm)	Description
Ah	0-10	dark brown (7.5 YR 3/2) moist; clay loam; moderate fine and medium sub angular blocky; friable, sticky and slightly plastic ; common fine roots; many fine and medium pores; clear smooth boundary to
Bw	10-35	very dark brown (7.5YR 2.5/2) moist; clay ; weak sub angular blocky; friable, sticky and plastic ; very few fine and medium roots; many fine and medium pores; clear smooth boundary to.
BC	35+	brown,(7.5YR 4/4) moist; clay; weak medium sub angular blocky; friable, sticky and plastic; very few fine roots; common fine and medium pores

Table15.10: Physical properties of soil profiles in Sobo Kebele

Pedon/Horizon	Depth (cm)	% Particle size distribution			Texture class	Silt/Clay ratio	BD g/cm^3
		Sand	Silt	Clay			
ILU/D/S/P1							
Ah	0-15	38.3	17.8	43.9	clay	0.41	1.11
AB	15-30	27.6	11.5	60.9	Clay	0.19	1.11
Bt1	30-60	18.0	15.8	66.2	clay	0.24	1.11
Bt2	60-90	10.3	21.1	68.6	clay	0.31	1.09
Bt3	90-120	10.5	20.0	69.5	clay	0.29	1.07
ILU/D/S/P2							
Ah	0-10	34.4	16.9	48.7	clay	0.35	1.00
Bw	10--35	22.3	16.8	60.9	clay	0.28	1.10
BC	35+	37.2	11.5	51.3	clay	0.22	1.14

Table 15.11: Selected chemical properties of soil profiles in Sobo kebele

Pedon /Hor	Depth (cm)	pH (1:2.5)		ΔpH	EC (ds/m)	OC (%)	TN (%)	C:N ratio	Av.P (mg P2O5/ kg soil)	Av. S %	Micro nutrients (mg/kg soil)			
		H_2O	KCl								Zn	Mn	Cu	Fe
ILU/D/S/P1														
Ah	0-15	5.0	4.3	0.7	0.03	1.46	0.13	11.23	23.3	0.71	5.5	48.9	0.9	67.4
AB	15-30	5.3	4.7	0.6	0.04	1.31	0.10	13.10						
Bt1	30-60	5.4	4.7	0.7	0.04	0.77	0.07	11.00						

Bt2	60-90	5.3	4.8	0.5	0.03	0.56	0.06	9.33						
Bt3	90-120	5.2	4.7	0.5	0.02	0.52	0.04	13.00						
Average		5.2	4.6	0.6	0.03	0.92	0.08	11.53						
ILU/D/S/P2														
Ah	0-10	5.4	4.8	0.6	0.04	3.38	0.41	8.24	30.3	1.2	4.9	54.0	0.7	59.0
Bw	10-35	4.8	4.2	0.6	0.03	1.47	0.18	8.17						
BC	35+	5.0	4.3	0.7	0.01	0.88	0.10	8.80						
Average		5.1	4.4	0.6	0.03	1.91	0.23	8.40						

Table 15.12: Exchangeable cations and CEC results of soil profiles in Sobo kebele

Horizon	Depth (cm)	Exchangeable cations (cmol (+) kg-1					Cations ratio		CEC (cmol (+) kg-1		BS (%)	ESP (%)
		Na	K	Ca	Mg	sum	Ca/Mg	K/Mg	Soil	Clay		
ILU/D/S/P1												
Ah	0-15	1.58	1.31	10.85	4.17	17.91	2.60	0.31	39	77.45	45.9	4.05
AB	15-30	1.68	1.17	12.56	4.19	19.6	3.00	0.28	51.44	76.91	38.1	3.26
Bt1	30-60	1.55	0.97	12.59	5.04	20.15	2.50	0.19	43.33	61.53	46.5	3.58
Bt2	60-90	1.63	1.12	11.78	3.37	17.9	3.50	0.33	37.05	51.09	48.3	4.40
Bt3	90-120	1.64	0.94	12.6	5.04	20.22	2.50	0.19	45.2	62.45	44.7	3.64
		1.62	1.10	12.08	4.36	19.16	2.82	0.26	43.20	65.89	44.70	3.79
ILU/D/S/P2												
Ah	0-10	1.76	0.54	15.19	5.06	22.55	3.00	0.11	39	51.54	61.4	4.80
Bw	10-35	1.73	0.35	8.38	3.35	13.81	2.50	0.10	51.44	59.87	33.3	4.18
BC	35+	1.67	0.25	9.19	3.34	14.45	2.75	0.07	43.33	62.28	41.3	4.78
		1.72	0.38	10.92	3.92	16.94	2.75	0.09	44.59	57.90	45.33	4.59

Table 15.13: Site and profile description of Yembero Kebele in Didessa Woreda

Profile code: ILU/D/Y/P1
Soil classification: Eutric Gleysols
Location: Yembero
Coordinates: 221096 m N- 902861 m E
Elevation: 2166 m above sea level
Date and author: 27/01/2014; Alemayehu Regassa and Nasir Zeinu
Geology: Volcanic rocks of Tertiary and quaternary age overlie the precamberian rocks
Land form: Nearly level plateau with interspersed seasonally flooded valleys
Local physiography: Alluvio- colluvial inland valley
Slope: 1%
Land use: Formerly dry season maize farm land with scattered patches of fallow lands

General information on the soil

Parent material: Mixture of alluvial and colluvially transported basaltic and trachtic material
Moisture condition: Moist throughout the depth of the profile
Drainage: Poorly to imperfectly drained
Groundwater: Not encountered, temporary seasonally stagnating perched water tables
Surface stones: None
Erosion: Slight sheet erosion
Human influence: Traditional soil burning ‘guie’’, inappropriately oriented surface drainage

Profile description

Hor.	Depth (cm)	Description
Apg	0-10	dark gray (10YR 4/1) moist; silt loam; weak fine and medium granular ; friable, sticky and plastic ; yellowish brown (10 YR 5/6, moist) mottles; common iron and manganese coatings along root channels; few fine and very fine pores; common fine and many very fine roots; non calcareous; gradual and smooth boundary to
Cg1	10-40	dark yellowish brown (10YR 3/6) moist; silt clay loam; weak medium subangular blocky ; friable, very sticky and very plastic; common yellowish brown (10 YR 5/6) mottles; very few fine and very fine pores; common fine and many very fine dead roots; diffuse smooth boundary to
Cg2	40-60	gray (10 YR 5/1) moist; clay loam; weak medium subangular blocky ; friable, very sticky and very plastic; common iron coatings along root channels; very few fine and very fine pores; few fine dead roots; many rounded medium iron-manganese nodules; diffuse smooth boundary to
Cg3	60-85	dark grav (10YR 4/1) moist; clav; weak medium subangular blocky; friable, very sticky and very plastic ; many fine to medium yellowish brown (10 YR 5/6) iron manganese mottles, very few very fine in-ped pores; very few very fine dead roots ; diffuse smooth boundary to
Cg4	85+	dark grav (10YR 4/1) moist; clav; weak medium subangular blocky; friable, very sticky and very plastic; yellowish brown (10 YR 5/6) fine to medium iron mottles; very few very fine pores; no root

Site characteristics

Profile code: ILU/D/Y/P2
Soil classification: Eutric Nitisols
Location: Yembero, *Gute II*
Coordinates: 212030 m N- 903011 m E
Elevation: 2166 m above sea level
Date and author: 26/01/2014; Alemayehu Regassa and Nasir Zeinu
Geology: Volcanic rocks of Tertiary and quaternary age overlie the precamberian rocks
Land form: Dissected Plateau
Local physiography: Undulating upland
Slope: 15%
Land use: Mixed cultivation of annual and perennial crops, teff is dominant

General information on the soil

Parent material: Basalt
Moisture condition: Dry at the top and slightly moist in the subsurface horizons
Drainage: Well to excessively drained
Groundwater: Not encountered, very deep
Surface stones: None
Erosion: Slight sheet erosion
Human influence: Insufficient soil fertility maintenance, continuous cropping

Profile description

Hor.	Depth (cm)	Description
Ap	0-2	brown (7.5 YR 4/3) moist; clay loam; moderate fine and medium sub angular blocky; friable, slightly sticky and slightly plastic ; many fine to coarse pores; many fine and medium roots; few termite nests ; clear smooth boundary to
AB	2-35	very dark brown (7.5YR 2.5/2) moist; clay ; strong fine and medium sub angular blocky; friable, sticky and plastic; common fine roots; few termite nests; many fine medium pores; clear smooth boundary to
Bt1	35-85	very dark brown (7.5YR 2.5/2) moist; clay; moderate fine and medium subangular blocky; friable, very sticky and plastic; prominent shiny ped faces; very few black hard and soft nodules; common fine and medium pores; few fine roots; diffuse smooth boundary to
Bt2	85-125	dark reddish brown (5YR 3/4) moist; clay ; moderate fine and medium sub angular blocky; friable, very sticky and plastic; common shiny ped faces; very few small manganese nodules; common fine and medium pores; very few fine roots; diffuse smooth boundary to
Bt3	125+	dark reddish brown (5YR 3/4) moist; clay ; moderate medium angular blocky; slight firm), very sticky, very plastic; very few fine roots, distinct abundant overall cutans

Table 15.14: Physical properties of soil profiles in Yembero Kebele

Pedon/Horizon	Depth (cm)	% Particle size distribution			Texture class	Silt/Clay ratio	BD g/cm^3
		Sand	Silt	Clay			
ILU/D/Y/P1							
Ap	0-10	33.5	11.8	54.7	clay	0.22	1.01
BA	10--40	24.1	24.3	51.7	clay	0.47	1.01
Bt1	40-60	31.6	9.6	59.1	clay	0.16	1.19
Bt2	60-85	29.8	15.7	54.5	clay	0.29	1.21
Bt3	85+	3.7	32.1	64.2	clay	0.50	1.23
ILU/D/Y/P2							
Ap	0-2	23.6	26.2	50.2	clay	0.52	1.04
AB	2--35	15.0	17.4	67.6	clay	0.26	1.01
Bt1	35-85	9.9	28.6	61.6	clay	0.46	1.02
Bt2g	85-125	4.9	31.4	63.8	clay	0.49	1.02
Bt3g	125+	5.3	29.1	65.7	clay	0.44	1.12

Table 15.15: Selected chemical properties of soil profiles in Yembero kebele

Pedon /Hor	Depth (cm)	pH (1:2.5)		ΔpH	EC (ds/m)	OC (%)	TN (%)	C:N ratio	Av.P (mg P2O5/ kg soil)	Av. S %	Micro nutrients (mg/kg soil)			
		H_2O	KCl								Zn	Mn	Cu	Fe
ILU/D/Y/P1														
Ap	0-10	4.4	3.7	0.7	0.05	5.91	0.73	8.10	17.3	1.73	2.1	22.8	0.4	195.8
BA	10-40	4.4	3.8	0.6	0.03	3.28	0.28	11.71						
Bt1	40-60	4.7	4.0	0.7	0.02	1.25	0.13	9.62						
Bt2	60-85	4.6	3.9	0.7	0.02	0.57	0.06	9.50						
Bt3	85+	4.4	3.5	0.9	0.04	0.47	0.04	11.75						
Average		4.5	3.7	0.7	0.03	2.30	0.25	10.14						
ILU/D/S/P2														
Ap	0-2	4.9	4.1	0.8	0.04	4.51	0.35	12.89	22.9	0.36	5.3	51.2	1.4	70.5
AB	2-35	4.8	3.9	0.9	0.03	3.41	0.29	11.76						
Bt1	35-85	4.5	3.8	0.7	0.01	3.11	0.26	11.96						
Bt2g	85-125	4.2	3.6	0.6	0.02	1.22	0.14	8.71						
Bt3g	125+	4.4	3.7	0.7	0.02	0.86	0.10	8.60						
Average		4.6	3.8	0.7	0.02	2.62	0.23	10.78						

Table 15.16: Exchangeable cations and CEC results of soil profiles in Yembero kebele

Horizon	Depth (cm)	Exchangeable cations (cmol (+) kg-1					Cations ratio		CEC (cmol (+) kg-1		BS (%)	ESP (%)
		Na	K	Ca	Mg	sum	Ca/Mg	K/Mg	Soil	Clay		
ILU/D/Y/P2												
Ap	0-10	1.86	0.32	7.70	3.42	13.3	2.25	0.09	38.15	32.45	34.9	4.88
BA	10-40	1.52	0.18	10.92	4.20	16.82	2.60	0.04	42.46	60.08	39.6	3.57
Bt1	40-60	1.74	0.14	7.49	2.50	11.87	3.00	0.06	32.1	46.87	37	5.41
Bt2	60-85	1.46	0.12	9.24	4.20	15.02	2.20	0.03	29.22	49.94	51.4	5
Bt3	85+	1.45	0.31	16.26	5.99	24.01	2.71	0.05	37.22	55.48	64.5	3.9
Average		1.61	0.21	10.32	4.06	16.20	2.55	0.05	35.83	48.96	45.48	4.55
ILU/D/Y/P2												
Ap	0-2	1.39	0.45	16.42	5.18	23.44	3.17	0.09	46.02	60.60	50.9	3.02
AB	2-35	1.75	0.34	12.1	4.32	18.51	2.80	0.08	51.65	58.95	35.8	3.38
Bt1	35-85	1.61	0.32	11.34	4.36	17.63	2.60	0.07	36.49	41.70	48.3	4.42
Bt2g	85-125	1.50	0.33	11.23	3.46	16.52	3.25	0.10	32.87	44.94	50.3	4.57
Bt3g	125+	1.51	0.48	12.84	4.28	19.11	3.00	0.11	30.24	41.46	63.2	4.98
Average		1.55	0.38	12.79	4.32	19.04	2.96	0.09	39.45	49.53	49.70	4.07

3.7.3. Synthesis

Hereunder, evaluation of the investigated soil properties with focus to their implication for agronomic development will done. Reference is made to the respective tables of analytical data.

The dominant agricultural soils in the four studied kebeles, Sobo, Masara, Goro and Yembero are Cambisols, Leptosols, Vertisols and Nitisols covering 32.9%, 24.5%, 20.6% and 17.1% respectively.of the total area of the studied four kebeles in the woreda. Luvisols occur in the gently undulating slopes and cover 4.9%. Cambisols and Leptosols occuy moderately to strongly steep hills and ridges. Vertisols are extensive plain areas along the didessa river. Except the Leptosols, all the dominant soils are intensively used for crop cultivation.

Texture of these soils is clayey throughout the profiles. The bulk density of all the studied profiles in Omo Nada woreda is found to be less than 1.44, which is common in cultivated soils. The low bulk density found in these soils indicates that the soils are not compacted and have more porosity.

The soil pH in water of topsoils is strongly acid with values between 5.0 and 5.3. The acidic soil reaction could result in excess and toxicity of heavy metals, and deficiency of basic cations (Landon, 1991). The overall trend of the pH values with depth varies considerably and therefore cannot be taken as a characteristic applicable to all the soils. The low pH value is likely to increase Al toxicity as this element is normally expected at less than 5.5 pH values. This would in particular a problem where the low pH value occurred

within 65 cm from the soil surface in which most crop roots extract their nutrient requirements (Tisdale, et al., 1993)

The organic carbon content in top soils ranges from 5.0-5.4% which is rated as low by Landon (1991). The low organic carbon content may be attributed to intensive agricultural practices that aggravate organic carbon oxidation (Wakene and Hiluf, 2003). Also, total nitrogen (N) content in topsoils ranges between 0.13-2.87 which is rated as medium as per the rating by Landon (1991) and decreases with soil depth. This decrease generally parallels to a decrease in contents of organic carbon, suggesting that the main source of total nitrogen was organic matter. The C:N ratios of the top layer of the studied soils range between 8.71 and 11.23, which is an indication that most soils have good quality organic matter. The values of exchangeable sodium percentage (ESP) in all the soils studied in the woreda are generally below 15%, the critical limit for sodicity (Brady and Weil, 2002).

The CEC of the total soil and clay fraction after correcting for organic matter is invariably very high ranges between 38.2 to 51.6 cmol(+) kg^{-1} and 32.45 to 84.42 cmol(+) kg^{-1} respectively. Since the organic matter content of the soils which normally influences the CEC is generally low, the CEC values to the amount and type of clay minerals present in the soils matter.

Exchangeable calcium followed by magnesium formed the dominant cation in the exchange complex throughout the horizons of the representative profiles. But their proportions showed an irregular pattern with depth. On the other hand, the proportions of exchangeable K and Na in the exchange site were found to be insignificant and also showed an irregular variation with depth of the profile. From these data, it may be pointed out that, whereas toxicity from Na is unlikely to occur but K deficiency is expected according to Landon (1991) ratings. The presence of irregular variation in

the exchangeable cations may partly suggest existence of different levels of leaching intensity within the horizons of the profile. It may also partly indicate an existence of different sources of parent materials.

3.8. Soils of CASCAPE intervention Kebeles in Bedele Zuria woreda

3.8.1. Geology and Geomorphology

The Bedele area has a landscape configuration in which there exists a number of superimposed trachyte and basalt plateaus surrounded by lower planation surfaces on basement rock, dissected to various degrees of steepness. In the western part of the area recent volcanic ash sheets are present locally, blanketing the residual weathering mantle.

Within the broad geomorphic unit, three major landscapes can be identified, the plateau plains which are moderately elevated, moderately dissected hills and sideslopes with great range of elevation and low land plains (Dhidhessa valley).

The plateau landscape consists of different relief forms from depression flat area upto hilly plain. The moderately dissected hills and sideslopes are composed of undulating or gentle sideslopes upto very steep sideslope or incised valley. The dissected hills and side slopes are further extended to the low land Didessa valley.

The geological formation of Bedele area belongs to two forming groups, namely the Ashangi group of Paleocene-Oligocene-Miocene age which is mainly occupying the plateau and moderately dissected hills and side slopes and lower complex undifferentiated of the low land plains of Didessa valley. The Ashangi group consists of predominantly alkaline basaly with

interbedded pyroclastics and rare rhyolite erupted from fissures. The lower complex undifferentiated area includes rocks which probably belong to one or other groups.

According to the geological Survey of Ethiopia (GSE, 2012), except for the banshure kebeble, all the other three kebeles are made up of a single geological formation, the Arjo lower basalt that makes up about 87.8 % of the total area of the four studied kebeles. The low land area of banshure kebele is covered by Gibe lower basalt which makes up about 12.0 % of the total areas of the four kebeles. Table 16 and Figure 32 shows the area and percentage distribution of the different geological materials in the CASCAPE intervention kebeles of Bedele woreda

Table 16: Summary of major Soil types and their distribution in the four CASCAPE intervention kebeles of Gera woreda

lithology	Area_ha	percent
Gibe lower basalt	881	12.0
Trachyte flows and plugs	43	0.6
Arjo lower basalt	6439	87.5

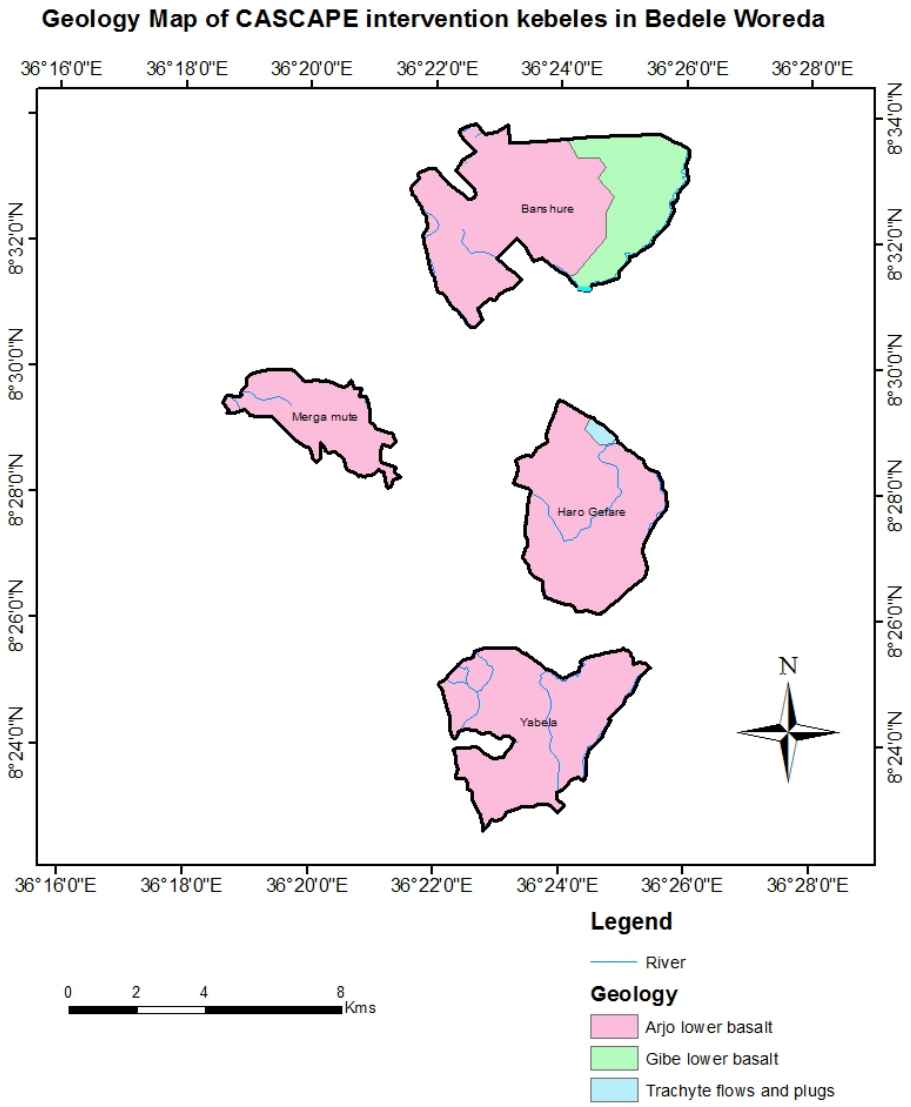

Figure 32. Geological map of CASCAPE intervention kebeles in Bedele woreda

3.8.2. The soil- landscape

Soil mapping units produced from auger observations and representative soil profile investigation revealed that landform controls much of the soils distribution in the landscape.

About thirty two auger holes and seven soil profiles were investigated to characterize the soils and determine the spatial distribution of the soils in the landscape. The location of the auger observations and soil profiles are indicated in figure 28.

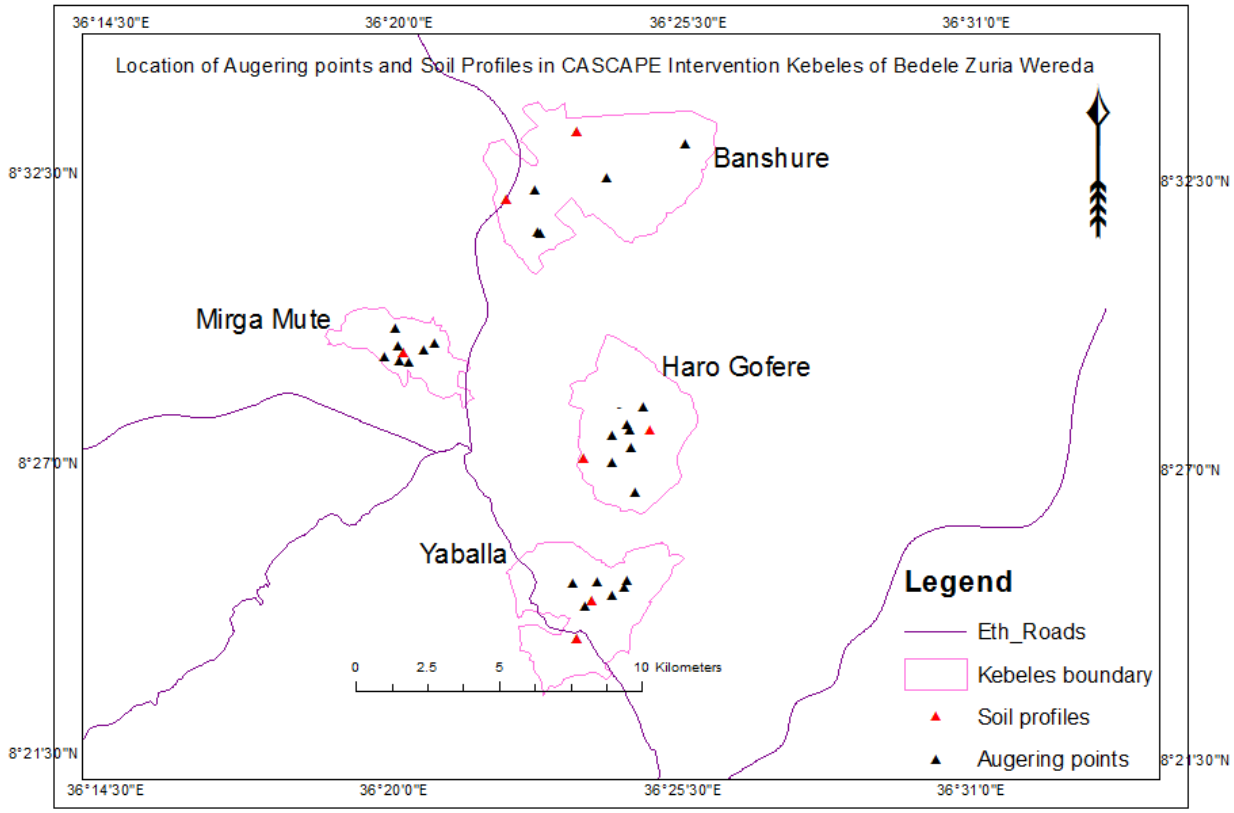

Figure 33. Location of auger and soil profiles in CASCAPE intervention kebeles in Bedele Zuria woreda

The soils in Bedele Woreda may be divided into two groups on the basis of topography and drainage, namely, (1) those developed on flat topography under poor drainage conditions, and (2) those developed on rolling topography under conditions of good drainage.

In the plateau and moderately dissected hills and sideslope the predominant soils are Cambisols and Leptosols that constitute about 31.6% and 23.7% of the total area of the four studied kebeles in the woreda respectively.

Leptosol are soils limited in depth by continuous hard rock with in 25cm from the soil surface or overlying material with a calcium carbonate equivalent of more than 40 percent within 25cm from the soil surface or containing less than 10 percent (by weight) fine earth to a depth of 75cm or from the soil surface and having no diagnostic horizons other than mollic, umbric, ochiric, yermic or Vertic horizon.

Nitisols and Vertisols are the second most widespread type of soils in the landscape covering respectively 17.2% and 23.1 % of the total area of the four Kebeles in the woreda.

Most of the arable land consists of well drained upland with flat or slightly undulating topography which supports one growing season under rainfall conditions. Nitisols, being the most agriculturally suitable soils dominantly occur in the rolling to gently sloping landscape extending from plateau. Vertisols occupy the lowland plains of Didessa valley. They are most extensive in the kora agroecology of Banshure kebele. Soil map of the studied kebeles are indicated in figure 28.

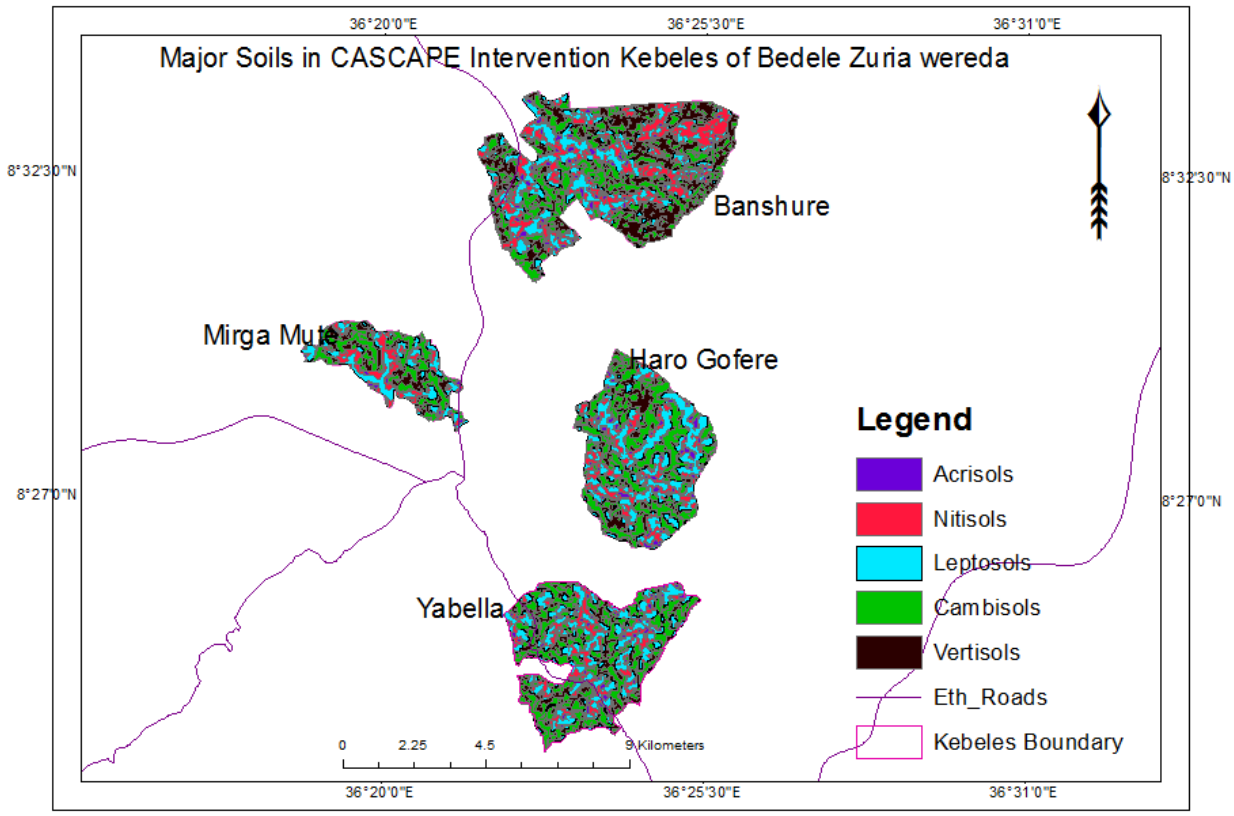

Figure 34. Soil map of Bedele woreda

Table 17 : Site and profile description and lab analytical data of CASCAPE intervention kebeles in Bedle

17.1. Site and profile description of Banshure Kebele

Profile code:	ILU/B/B/P1
Soil classification:	Dystric Luvisols
Location:	Banshure, *Garee Kulee*
Coordinates:	212626 m N- 946691 m E
Elevation:	1709 m above sea level
Date and author:	25/01/2014; Alemayehu Regassa and Gutata
Geology:	Volcanic rocks of Tertiary and quaternary age overlie the precamberian rocks
Land form:	Dissected hills grading to lowland plains
Local physiography:	Gently sloping plain gradually rising to steeply sloping upland
Slope:	12%
Land use:	Cultivation of mixed annual and perennial crops dominantly maize and *Teff*

General information on the soil

Parent material:	Basalts and trachybasalts
Moisture condition:	Dry in top and moist in the subsurface horizons
Drainage:	Well to excessively drained drained
Groundwater:	Not encountered, very deep
Surface stones:	Few medium to large stones
Erosion:	Slight sheet erosion

Human influence: Continuous cultivation of annual crops with little to zero fertilizer application, poor soil fertility management,

Profile description

Hor.	Depth (cm)	Description
Ap	0-7	dark brown (7.5 YR 3/2) moist; clay; medium subangular blocky; slightly firm, sticky and plastic; common fine and medium tubular pores; many fine and very fine and few coarse roots; few termite casts; non calcareous; gradual smooth boundary to
AB	7-25	strong brown (5 YR 3/2) moist; c]ay; medium subangular blocky; slightly firm, sticky and plastic; common fine and few medium tubular pores; few termite gallaries; few fine and very fine roots; non calcareous; gradual smooth boundary to
Bt1	25-54	dark brown (7.5 YR 3/3) moist; cjay; moderately strong medium subangular blocky structure; slightly firm when moist, sticky and plastic when wet; common; common fine and very fine tubular pores; few fine roots; non calcareous; diffuse smooth boundary to
Bt2	54-98	dark reddish brown (5YR 3/3) moist; moderately fine angular blocky friable, slightly sticky and slightly plastic; very fine random tubular pores, few fine, very few medium and coarse roots, few soft black manganese nodules, non-calcareous, diffuse gradual boundary to
Bt3	98-120	dark brown (7.5YR 3/3)moist; clay; weak medium angular blocky; friable,slightly sticky and slightly plastic;many fine random tubular pores; very few fine and medium roots, non calcareous

Site characteristics

Profile code: ILU/B/B/P2
Soil classification: Dystric Nitisols
Location: Banshure**,** South of Gabriel hill
Coordinates: 210162 m N- 944310 m E
Elevation: 1880 m above sea level
Date and author: 28/01/2014; Alemayehu Regassa and Gutata
Geology: Volcanic rocks of Tertiary and quaternary age overlie the precamberian rocks
Land form: Plateau, gently slopping
Local physiography: Undulating upland
Slope: 6 %
Land use: cultivation of cereal crops dominantly maize, sorghum and teff

General information on the soil

Parent material: Basalts and trachybasalts
Moisture condition: Dry in top soil and moist in the subsoil
Drainage: Well drained
Groundwater: Not encountered, very deep
Surface stones: None
Erosion: Slight sheet erosion
Human influence: Insufficient fertility management

Profile description

Hor.	Depth (cm)	Description
Ap	0-15	dark brown to brown (5 YR 4/4) moist; clay; medium and fine subangular blocky; slightly firm, sticky and plastic; fine to medium pores; many fine and very fine roots; many dung beetle cast and termite gallaries; non calcareous; gradual smooth boundary to
AB	15-55	dark reddish brown (5 YR 3/3) moist; c]ay; strong medium subangular blocky; slightly firm, sticky and plastic; common shiny ped faces; common fine and few medium tubular pores; few fine and very fine roots; few termite casts; non calcareous; gradual smooth boundary to
Bt1	55-90	dark reddish brown (5YR 3/4) moist; clay; moderately strong medium subangular blocky; slightly firm when moist, sticky and plastic; prominent shiny ped faces; common fine and very fine pores; few fine roots; few soft manganese concretions; non calcareous; diffuse smooth boundary to
Bt2	90-140	dark reddish brown (2.5YR 3/4) moist; clay; coarse sub angular blocky; slightly firm, sticky and plastic; common fine and very fine pores; few fine roots; prominent shiny ped faces; non calcareous; diffuse smooth boundary to
Bt3	140+	dark reddish brown (2.5YR 2.5/4) moist, strong coarse angular blocky; slightly firm, sticky and very plastic; very few very fine roots; very few fine pores; prominent shiny face; common, very fine, non calcareous

Table 17.2: Physical properties of soil profile in Banshure

Pedon/Horizon	Depth (cm)	% Particle size distribution			Texture class	Silt/Clay ratio	BD g/cm^3
		Sand	Silt	Clay			
ILU/B/B/P1							
Ap	0-7	14.0	26.5	59.6	clay	0.44	1.06
AB	7--25	22.5	15.5	62.0	clay	0.25	1.03
Bt1g	25-54	4.5	30.0	65.5	clay	0.46	1.07
Bt2g	54-98	5.6	26.7	67.8	clay	0.39	1.01
Bt3g	98-120	3.1	29	68	clay	0.43	1.03
ILU/B/B/P2							
Ah	0-15	15.5	17.1	67.4	clay	0.25	1.15
AB	15-55	17.3	12.7	70	clay	0.18	1.13
Bt1	55-90	5.5	24.4	70.1	clay	0.35	1.03
Bt2	90-140	5.5	24.4	70.1	clay	0.35	1.01
Bt3	140+	4.6	26.5	68.9	clay	0.38	1.01

Table 17.3: Selected chemical properties of soil profiles in Banshure Kebele

Pedon /Hor	Depth (cm)	pH (1:2.5)		ΔpH	EC (ds/m)	OC (%)	TN (%)	C:N ratio	Av.P (mg P2O5/ kg soil)	Av. S %	Micro nutrients (mg/kg soil)			
		H_2O	KCl								Zn	Mn	Cu	Fe
ILU/B/B/P1														
Ap	0-7	5.6	4.7	0.9	0.04	2.84	0.26	10.92	28.5	3.78	7.9	34.5	1.4	66.1
AB	7-25	5.5	4.7	0.8	0.03	1.78	0.20	8.90						
Bt1g	25-54	5.4	4.5	0.9	0.02	1.37	0.12	11.42						
Bt2g	54-98	5.3	4.4	0.9	0.02	1.00	0.11	9.09						
Bt3g	98-120	5.2	4.4	0.8	0.03	0.91	0.08	11.38						
Average		5.4	4.5	0.9	0.03	1.58	0.15	10.34						
ILU/B/B/P2														
Ah	0-15	5.5	4.6	0.9	0.06	3.85	0.31	12.42	21.4	1.13	7.5	55.6	2.2	67.6
AB	15-55	5.5	4.6	0.9	0.03	1.43	0.13	11.00						
Bt1	55-90	5.5	4.6	0.9	0.03	1.06	0.10	10.60						
Bt2	90-140	5.6	4.7	0.9	0.03	0.99	0.09	11.00						
Bt3	140+	5.5	4.7	0.8	0.03	0.42	0.04	10.50						
Average		5.5	4.6	0.9	0.04	1.55	0.13	11.10						

Table 17.4. Exchangeable cations and CEC results of soil profiles in Banshure kebele

Horizon	Depth (cm)	Exchangeable cations (cmol (+) kg-1					Cations ratio		CEC (cmol (+) kg-1		BS (%)	ESP (%)
		Na	K	Ca	Mg	sum	Ca/Mg	K/Mg	Soil	Clay		
ILU/B/B/P1												
Ap	0-7	1.55	1.4	20.1	7.85	30.9	2.56	0.18	58.29	81.36	53	2.67
AB	7--25	1.53	1.05	19.36	7.04	28.98	2.75	0.15	28.98	36.74	100	2.42
Bt1g	25-54	1.78	1.18	20.24	7.92	31.12	2.56	0.15	70.3	100.00	44.3	2.53
Bt2g	54-98	1.49	1.03	19.36	7.04	28.92	2.75	0.15	66	92.33	43.8	2.26
Average		1.59	1.17	19.77	7.46	29.98	2.66	0.16	55.89	77.61	60.28	2.47
ILU/B/B/P2												
Ah	0-15	1.56	1.53	16.26	5.14	24.49	3.16	0.30	53.03	59.09	46.2	2.95
AB	15-55	1.66	1.17	15.26	5.09	23.18	3.00	0.23	61.3	80.43	37.8	2.71
Bt1	55-90	1.4	0.93	12.72	4.24	19.29	3.00	0.22	56.69	75.73	34	2.47
Bt2	90-140	1.6	1.21	12.72	4.24	19.77	3.00	0.29	49.31	65.49	40.1	3.25
Average		1.56	1.21	14.24	4.68	21.68	3.04	0.26	55.08	70.19	39.53	2.85

Table 17.5 : Site and profile description of soil profiles Haro Gefere kebele

Profile code:	ILU/B/HG/P1
Soil classification:	Dystric Acrisols
Location:	Haro Gafare, *Garee Somboo,Lalo 800*m west of Bedele - *Qoolloo Sirrii* town
Coordinates:	212886 m N- 935284 m E
Elevation:	1984 m above sea level
Date and author:	28/01/2014; Alemayehu Regassa and Ibrahim
Geology:	Volcanic rocks of Tertiary and quaternary age overlie the precamberian rocks
Land form:	Plateau
Local physiography:	Gently undulating upland
Slope:	3%
Land use:	Cultivation of annual crops: maize, *teff* and sorghum are dominant

General information on the soil

Parent material:	Basalt and trachybasalt
Moisture condition:	Dry at the top and slightly moist in the deeper subsurface horizons
Drainage:	Excessively well drained
Groundwater:	Not encountered, very deep
Surface stones:	None
Erosion:	Slight sheet erosion
Human influence:	Continuous cultivation, poor soil fertility management

Profile description

Hor.	Depth (cm)	Description
Ap	0-13	reddish brown (5YR 4/4) moist; clay loam; medium and fine subangular blocky; friable, slightly sticky and slightly plastic; cmmon medium and fine pores; common fine and medium roots; common termite casts; non calcareous; gradual smooth boundary to
AB	13-33	reddish brown (5YR 4/4) moist; clav ; medium angular blocky structure; slightly firm, sticky and plastic;; few medium and common fine pores; common fine roots; many termite gallaries; non calcareous; gradual smooth boundary to
Bt1	33-62	brownishvellow (2.5YR 3/3) moist; clav; medium subangular blocky; very sticky and very plastic; fine and verv fine pores; few fine roots; few termites casts; non calcareous; diffuse gradual boundary to
Bt2	62-85	dark reddish brown (2.5YR 3/4) moist; clav; medium subangular blocky; slightly firm, very sticky and very plastic; common fine and very fine pores; few fine roots; non calcareous; diffuse smooth boundary to
Bt3	85+	dark reddish brown (2.5YR 2.5/3) moist; clav; medium sub angular blocky; friable, very sticky and very plastic; few very fine pores; few fine roots; non calcareous

Site characteristics

Profile code:	ILU/B/HG/P2
Soil classification:	Dystric Cambisols
Location:	Haro Gafare, *Garee Siiso, 350*m west of Bedele – Haroo Xaaxessaa *Kebele*
Coordinates:	214511 m N- 935673 m E
Elevation:	1980 m above sea level
Date and author:	28/01/2014; Alemayehu Regassa and Ibrahim
Geology:	Volcanic rocks of Tertiary and quaternary age overlie the precamberian rocks

Land form: Flat topped hills and sloping to steeply sloping landforms
Local physiography: Undulating upland
Slope: 3%
Land use: Cultivation of annual crops: teff, maize and sorghum

General information on the soil

Parent material: Basalt and trachybasalt
Moisture condition: Dry at the top and moist in the subsurface horizons
Drainage: Well drained
Groundwater: Not encountered, very deep
Surface stones: Many medium to large surface stones
Erosion: Slight sheet erosion
Human influence: Continuous cropping. The major crops are maize, sorghum and teff.

Profile description

Hor.	Depth (cm)	Description
Ap	0-10	Dark brown (7.5YR 3/2) moist; silty clay loam; many medium to coarse gravel; weakly developed structure; slightly firm, non sticky and non plastic; few fine and medium pores; few coarse roots; clear broken boundary to
AB	10-25	Strong brown (7.5YR 4/6) moist; clay loam; weakly developed coarse angular blocky; many coarse fragments; slightly firm, slightly sticky and slightly plastic; common fine to medium pores; few medium to coarse roots; gradual irregular boundary to
Bw	25-65	Brown (7.5YR 4/4) moist; clay loam; friable, slightly sticky and slightly plastic; medium angular blocky; few fine to medium pores; very few fine roots; gradual smooth boundary to
BC	65+	Brown (7.5YR 4/4) moist; clay loam; friable, slightly sticky and slightly plastic; medium angular blocky; few fine to medium pores; no roots

Table 17.6: Physical properties of soil profiles Haro Gefere Kebele

Pedon/Horizon	Depth (cm)	% Particle size distribution			Texture class	Silt/Clay ratio	BD g/cm^3
		Sand	Silt	Clay			
ILU/B/HG/P1							
Ap	0-13	30.2	19.0	50.8	clay	0.37	1.06
AB	13-33	25.0	16.9	58.1	clay	0.29	1.03
Bt1	33-62	9.1	29.6	61.3	clay	0.48	1.03
Bt2	62-85	10.7	24.2	65.2	clay	0.37	1.04
Bt3	85-125	30.8	16.8	52.4	clay	0.32	1.04
ILU/B/HG/P2							
AP	0-10	42.6	24.0	33.4	Clay loam	0.72	1.03
AB	10--25	30.9	16.8	52.4	clay	0.32	1.13
Bw	25-65	20.5	19.9	59.6	clay	0.33	1.17
BC	65+	18.7	28.2	53.2	clay	0.53	1.13

Table 17.7: Selected chemical properties of soil profiles in Haro Gefere kebele

Pedon /Hor	Depth (cm)	pH (1:2.5)		ΔpH	EC (ds/m)	OC (%)	TN (%)	C:N ratio	Av.P (mg P2O5/ kg soil)	Av. S %	Micro nutrients (mg/kg soil)			
		H_2O	KCl								Zn	Mn	Cu	Fe
ILU/B/HG/P1														
Ap	0-13	4.3	3.6	0.7	0.03	2.02	0.25	8.08	27.4	1.88	7.9	35.3	1.0	31.0
AB	13-33	4.1	3.7	0.4	0.02	1.78	0.19	9.37						
Bt1	33-62	4.2	3.7	0.5	0.02	1.58	0.15	10.53						
Bt2	62-85	4.3	3.7	0.6	0.03	1.08	0.10	10.80						
Bt3	85-125	4.0	3.2	0.8	0.04	0.40	0.04	10.00						
Average		4.2	3.6	0.6	0.03	1.37	0.15	9.76						
ILU/B/HG/P2														
AP	0-10	4.8	4.0	0.8	0.04	2.50	0.28	8.93	23.3	0.13	6.7	53.0	1.1	63.9
AB	10-25	4.9	4.1	0.8	0.02	1.55	0.19	8.16						
Bw	25-65	5.1	4.5	0.6	0.02	0.8	0.09	8.89						
BC	65+	5.0	4.2	0.8	0.01	0.43	0.04	10.75						
Avergae		5.0	4.2	0.8	0.02	1.32	0.15	9.18						

Table 17.8: Exchangeable cations and CEC results of soil profiles in Haro Gefere kebele

Horizon	Depth (cm)	Exchangeable cations (cmol (+) kg-1					Cations ratio		CEC cmol (+) kg-1		BS (%)	ESP (%)
		Na	K	Ca	Mg	sum	Ca/Mg	K/Mg	Soil	Clay		
ILU/B/HG/P1												
Ap	0-13	1.48	0.33	10.92	4.20	16.93	2.60	0.08	38.8	38.8	43.6	3.81
AB	13-33	1.39	0.26	11.76	4.20	17.61	2.80	0.06	38.35	38.35	45.9	3.62
Bt1	33-62	1.37	0.25	11.76	4.20	17.58	2.80	0.06	31.5	31.5	55.8	4.35
Bt2	62-85	1.64	0.27	12.60	4.20	18.71	3.00	0.06	36.07	36.07	51.9	4.56
Bt3	85-125	1.22	0.27	11.76	4.20	17.45	2.80	0.06	29.22	29.22	59.7	4.19
Average		1.42	0.28	11.76	4.20	17.66	2.80	0.06	34.79	34.79	51.38	4.11
ILU/B/HG/P2												
AP	0-10	1.88	1.23	9.15	3.33	15.59	0.37	0.37	30.75	30.75	50.7	6.12
AB	10--25	1.64	1.02	12.6	4.20	19.46	0.24	0.24	48.39	48.39	40.2	3.4
Bw	25-65	1.79	0.52	12.48	4.16	18.95	0.13	0.13	52	52	36.4	3.44
BC	65+	1.77	0.96	7.49	3.33	13.55	0.29	0.29	39.34	39.34	34.4	4.51
Average		1.77	0.93	10.43	3.76	16.89	0.26	0.26	42.62	42.62	40.43	4.37

Table 17.9: Site and profile description of Mirga Mute Kebele in Bedele Woreda

Profile code:	ILU/B/MM/P1
Soil classification:	Dystric Luvisols
Location:	Mirga Mute**,** Garee Dhibbisaa, about 500 m NW from Muxxee hill
Coordinates:	206545 m N- 938985 m E
Elevation:	2033 m above sea level
Date and author:	28/01/2014; Alemayehu Regassa and Ummer
Geology:	Volcanic rocks of Tertiary and quaternary age overlie the precamberian rocks
Land form:	Plateau
Local physiography:	Gently undulating upland
Slope:	6 %
Land use:	Cultivation of annual crops such as maize, *Teff* and sorghum

General information on the soil

Parent material:	Basalt and trachybasalt
Moisture condition:	Dry in top soil and moist in the subsoil
Drainage:	Well drained
Groundwater:	Not encountered, very deep
Surface stones:	None
Erosion:	Slight sheet erosion
Human influence:	Continuous cultivation without fertility management

Profile description

Hor.	Depth (cm)	Description
Ap	0-17	brown (7.5YR 4/4) moist; clav loam; moderate coarse and medium subangular blocky; friable, slightly sticky and slightly plastic; common medium and many fine pores; few medium and fine roots; non calcareous; gradual smooth boundary to
AB	17-40	dark reddish brown (5 YR 3/4) moist; clay loam; moderate coarse and medium parting into fine subangular blocky; slightly friable, slightly sticky and slightly plastic; common medium and many fine pores; few medium and fine roots; non calcareous; gradual smooth boundary to
Bt1	40-70	dark reddish brown (2.5YR 3/4) moist; clay loam; coarse and medium subangular blocky structure; friable, slightly sticky and slightly plastic ; patchy broken thin cutans; few medium and common fine and very fine pores; few fine roots; non calcareous; diffuse smooth boundary to
Bt2	70-102	reddish brown (2.5 YR 4/4) moist; clay; moderate medium and fine subangular blocky; friable, sticky and plastic; common clay cutans; common fine and very fine and few medium pores; few fine and very fine roots; few worm casts; non calcareous; abrupt and gradual smooth boundary to
Bt3	102-150	red (2.5YR 4/6) moist; clav: medium subangular blocky; friable, sticky and plastic; few very fine pores; no roots;

Tabler 17.10: Physical properties of soil profiles in Mirga Mute Kebele

Pedon/Horizon	Depth (cm)	% Particle size distribution			Texture class	Silt/Clay ratio	BD g/cm^3
		Sand	Silt	Clay			
ILU/B/MM/P1							
Ap	0-17	27.6	22.7	49.7	clay	0.46	1.04
AB	17-40	11.8	20.4	67.8	clay	0.30	1.03
Bt1	40-70	3.65	30.0	66.4	clay	0.45	1.02
Bt2	70-102	10.1	24.3	65.6	clay	0.37	1.01
Bt3	102-150	6.4	26.6	67.0	clay	0.40	1.02

Table 17.11: Selected chemical properties of soil profiles in Mirga Mute kebele

Pedon /Hor	Depth (cm)	pH (1:2.5)		ΔpH	EC (ds/m)	OC (%)	TN (%)	C:N ratio	Av.P (mg P2O5/ kg soil)	Av. S %	Micro nutrients (mg/kg soil)			
		H2O	KCl								Zn	Mn	Cu	Fe
ILU/B/MM/P1														
Ap	0-17	4.7	3.8	0.9	0.02	3.08	0.31	9.94	26.6	047	9.4	29.0	1.3	38.3
AB	17-40	4.8	4.0	0.8	0.02	1.32	0.15	8.80						
Bt1	40-70	5.0	4.3	0.7	0.03	0.82	0.11	7.45						
Bt2	70-102	5.0	4.2	0.8	0.03	0.58	0.06	9.67						
Bt3	102-150	4.6	3.8	0.8	0.02	0.34	0.03	11.33						
Average		4.8	4.0	0.8	0.02	1.23	0.13	9.44						

Table 17.12: Exchangeable cations and CEC results of soil profiles in Mirga Mute kebele

Horizon	Depth (cm)	Exchangeable cations cmol (+) kg-1					Cations ratio		CEC cmol (+) kg-1		BS (%)	ESP (%)
		Na	K	Ca	Mg	sum	Ca/Mg	K/Mg	Soil	Clay		
ILU/B/MM/P1												
Ap	0-17	1.62	0.26	12.84	5.14	19.86	2.50	0.05	33.5	46.08	59.3	4.83
AB	17-40	1.69	0.21	12.84	4.28	19.02	3.00	0.05	54.43	73.50	34.9	3.11
Bt1	40-70	1.62	0.26	12.84	4.28	19	3.00	0.06	46.99	66.55	40.4	3.45
Bt2	70-102	1.61	0.23	12.60	4.20	18.64	3.00	0.05	35.61	51.23	52.3	4.51
Bt3	102-150	1.64	0.21	11.02	4.24	17.11	2.60	0.05	39.63	57.36	43.2	4.14
Average		1.64	0.23	12.43	4.43	18.73	2.82	0.05	42.03	58.94	46.02	4.01

Table 17.13: Site and profile description of Yaballa Kebele in Bedele Woreda

Profile code:	ILU/B/Y/P1
Soil classification:	Eutric Acrisols
Location:	Yaballaa**,** *Garee* Lemman Lammaa, Haro, 500m west of the main road
Coordinates:	212630 m N- 928984 m E
Elevation:	1907 m above sea level
Date and author:	28/01/2014; Alemayehu Regassa and Umer Abdu
Geology:	Volcanic rocks of Tertiary and quaternary age overlie the precamberian rocks
Land form:	Plateau
Local physiography:	Gently undulating upland
Slope:	6 %
Land use:	Cultivation of crops such as maize, *Teff* and sorghum

General information on the soil

Parent material:	Basalts and trachybasalts
Moisture condition:	Dry in top soil and moist in the subsoil
Drainage:	Well to excessively drained
Groundwater:	Not encountered, very deep
Surface stones:	Many small to medium sized scattered stones
Erosion:	Slight sheet erosion
Human influence:	Continuous cultivation, poor soil fertility management

Profile description

Hor.	Depth (cm)	Description
Ap	0-15	strong brown (7.5YR 4/6) moist; clay loam; coarse, medium and fine subangular; friable, slightly sticky and slightly plastic:, medium and fine pores; common medium and fine roots; few termite gallaries; non calcareous; clear and smooth boundary to
AB	15-48	reddish brown (5YR 4/4) moist; clayloam; medium coarse subangular blocky; friable, slightly sticky and slightly plastic ; few medium, common fine and very fine pores; few fine and very fine roots; few termite casts; non calcareous; gradual smooth boundary to
Bt1	48-80	yellowish brown (5YR 3/4) moist; clay; strong medium and fine subangular blocky; slightly firm, sticky and plastic; common thin clay skins on ped faces; very few medium, common fine and very fine pores; few fine and very fine roots; non calcareous; diffuse smooth boundary to
Bt2	80-110	dark reddish brown (2.5YR 3/4), moist; clay; moderately strong medium and fine subangular blocky; friable, sticky and plastic; ; very few fine and few very fine pores; very few fine and few very fine roots; non calcareous

Site characteristics

Profile code:	ILU/B/Y/P2
Soil classification:	Eutric Cambisols
Location:	Yaballaa**,** *Garee* Bambaa, Shobee
Coordinates:	213159 m N- 930302 m E
Elevation:	1937 m above sea level
Date and author:	28/01/2014; Alemayehu Regassa and Umer Abdu
Geology:	Volcanic rocks of Tertiary and quaternary age overlie the precamberian rocks
Land form:	Gently slopping
Local physiography:	Undulating upland
Slope:	6 %

Land use: *Teff* farm land

General information on the soil

Parent material: Basalts and trachybasalts
Moisture condition: Dry in top soil and moist in the subsoil
Drainage: Excessively drained
Groundwater: Not encountered, very deep
Surface stones: None
Erosion: Slight sheet erosion
Human influence: Continuous cultivation, inadequate fertilizer application

Profile description

Hor.	Depth (cm)	Description
Ap	0-15	brown (7.5YR 5/4) moist; sandy clay loam; weak fine sub angular blocky; friable, slightly sticky and slightly plastic; few fine random tubular pores; many fine and medium, few coarse roots; non calcarous, cleat smooth boundary to
AB	15-40	reddish brown (5YRYR 4/3) moist; clay loam; weak sub angular blocky ; friable, slightly sticky and slightly plastic; few fine random tubular pores; many fine and medium rare coarse roots, non calcareous; gradual smooth boundary to
Bw	40-85	reddish brown (5YR 4/4) moist; clay loam; weak coarse prismatic to coarse angular blocky; slightly firm, slightly sticky and slightly plastic; few fine random tubular pores; few fine and medium roots, gradual smooth boundary to
BC	85+	reddish brown (5YR 4/4) moist; clay loam, weak medium angular block structure, slightly friable, slightly sticky and slightly plastic;, many fine random tubular pores; very few fine and medium roots, non calcareous

Tabler 17.14: Physical properties of soil profiles in Yaballa Kebele

Pedon/Horizon	Depth (cm)	% Particle size distribution			Texture class	Silt/Clay ratio	BD g/cm^3
		Sand	Silt	Clay			
ILU/B/Y/P1							
Ap	0-15	23.4	20.2	56.4	clay	0.36	1.01
AB	15-48	10.4	26.8	62.9	clay	0.43	1.07
Bt1	48-80	7.6	31.9	60.5	clay	0.53	1.07
Bt2	80-110	6.7	27.3	66.1	clay	0.41	1.05
ILU/B/Y/P2							
Ap	0-15	48.2	21.7	30.0	SCL	0.72	1.12
AB	15-40	48.2	21.7	30.0	Clay loam	0.32	1.10
Bw	40-85	31.5	22.8	45.7	clay	0.33	1.06
BC	85+	34.4	20.8	44.8	clay	0.53	1.05

Table 17.15: Selected chemical properties of soil profiles in Toli Beyem kebele

Pedon /Hor	Depth (cm)	pH (1:2.5)		ΔpH	EC (ds/m)	OC (%)	TN (%)	C:N ratio	Av.P (mg P2O5/ kg soil)	Av. S %	Micro nutrients (mg/kg soil)			
		H_2O	KCl								Zn	Mn	Cu	Fe
ILU/B/Y/P1														
Ap	0-15	4.3	3.6	0.7	0.03	2.14	0.25	8.56	21.2	0.85	0.8	27.3	0.7	36.3
AB	15-48	4.3	3.6	0.7	0.01	1.60	0.19	8.42						
Bt1	48-80	4.8	4.1	0.7	0.03	1.16	0.10	11.60						
Bt2	80-110	4.9	4.2	0.7	0.05	0.34	0.03	11.33						
Average		4.6	3.9	0.7	0.03	1.31	0.14	9.98						
ILU/B/Y/P2														
Ap	0-15	4.5	3.7	0.8	0.02	1.65	0.22	7.50	17.0	0.2	1.3	44.9	0.3	56.7
AB	15-40	4.4	3.7	0.7	0.01	1.03	0.10	10.30						
Bw	40-85	4.3	3.7	0.6	0.02	0.60	0.07	8.57						
BC	85+	4.3	3.7	0.6	0.02	0.29	0.03	9.67						
Average		4.4	3.7	0.7	0.02	0.89	0.11	9.01						

Table 17.16: Exchangeable cations and CEC results of soil profiles in Yaballa kebele

Horizon	Depth (cm)	Exchangeable cations (cmol (+) kg-1					Cations ratio		CEC (cmol (+) kg-1		BS (%)	ESP (%)
		Na	K	Ca	Mg	sum	Ca/Mg	K/Mg	Soil	Clay		
ILU/B/Y/P1												
Ap	0-15	1.68	0.36	11.02	4.24	17.3	2.60	0.08	38.25	54.70	45.2	4.39
AB	15-48	1.36	0.28	11.87	4.24	17.75	2.80	0.07	31.34	40.92	56.6	4.35
Bt1	48-80	1.64	0.27	12.72	4.24	18.87	3.00	0.06	32.26	46.71	58.5	5.09
Bt2	80-110	1.63	0.26	11.76	4.20	17.85	2.80	0.06	29.22	42.39	61.1	5.56
Average		1.58	0.29	11.84	4.23	17.94	2.80	0.07	32.77	46.18	55.35	4.85
ILU/B/Y/P2												
Ap	0-15	1.22	0.40	12.36	4.12	18.10	3.00	0.10	30.9	84.33	58.6	3.94
AB	15-40	1.43	0.30	12.48	4.16	18.37	3.00	0.07	32.56	96.53	56.4	4.39
Bw	40-85	1.57	0.27	13.31	4.16	19.31	3.20	0.06	33.91	69.82	56.9	4.64
BC	85+	1.56	0.30	15.81	5.82	23.49	2.72	0.05	32.1	69.42	73.2	4.85
Average		1.45	0.32	13.49	4.57	19.82	2.98	0.07	32.37	80.03	61.28	4.46

3.8.3. Synthesis

Synthesis of the soil properties related and their implication to the agronomic development is briefly made hereunder. Reference is made to The respective tables for reference

Texture analysis result indicated that that the studied soils in all the kebels are clayey throughout with a clay content varying from 44.6 - 63.6 % in the surface to 53.4-70% in the subsurface horizons. The higher clay content often observed in the subsurface horizons of many soils may be attributed to illuviation and pedoturbation processes. All the soils have silt/clay ratio above 0.15 indicating that the soils are relatively young with high degree of weathering potential. Silt/clay ratios are relatively higher in the surface horizons and decrease with increase depth in the pedons. The decrease in silt/clay ratio with depth is an indication that subsoils horizons are more weathered than surface horizons.

The bulk density of all the studied profiles in Bedele Zuria woreda is found to be less than 1.44, which is common in cultivated soils. The low bulk density found in these soils indicates that the soils are not compacted and have more porosity.

The soil pH of topsoils of the studied soils is strongly acid to medium. According to Landon (1991), a pH range of 5.5 to 7.0 is the preferred range for most crops. The acidic soil reaction could result in excess and toxicity of heavy metals, and deficiency of basic cations (Landon, 1991). The overall trend of the pH values with depth varies considerably and cannot be taken as a characteristic applicable to all the soils.

The organic carbon content in all studied soil samples is found to be very low and regularly decrease with depth. The very low organic carbon content may be attributed to intensive agricultural practices that aggravate organic

carbon oxidation (Wakene and Hiluf, 2003). According to Landon (1991) total nitrogen (N) content in topsoils of the studied soils in Bedele Zuria woreda is low to medium and generally decreases with soil depth. This decrease generally parallels the decrease in contents of organic carbon, suggesting that the main source of total nitrogen was organic matter.The low nitrogen levels may be attributed to continued nutrient mining by plants.

The CEC of of the total soil and clay fraction after correcting for organic matter is invariably very high. Since the organic matter content of the soils which normally influences the CEC is generally low, the CEC values to the amount and type of clay minerals present in the soils matter.

Exchangeable calcium followed by magnesium formed the dominant cation in the exchange complex throughout the horizons of the representative profiles.But their proportions showed an irregular pattern with depth. On the other hand, the proportions of exchangeable K and Na in the exchange site were found to be insignificant and also showed an irregular variation with depth of the profile. From these data, it may be pointed out that, whereas toxicity from Na is unlikely to occur but K deficiency is expected according to Landon (1991) ratings. The presence of irregular variation in the exchangeable cations may partly suggest existence of different levels of leaching intensity within the horizons of the profile. It may also partly indicate an existence of different sources of parent materials.

4. Conclusion and recommendation

In this soil survey work it has been found out that topography and landform are important elements dictating variability in the soil types in the study areas. Canyons and deeply incised streams are the dominant land forms in the Kebeles of Omo nada, Didessa and Bedele Zuria woredas. In the kabeles of Limu Seka and Gera woredas, U shaped valleys constitute the largest proportion. The dominant slope class in all woredas is 5-10%. In Omo Nada woreda, nada chala kebele has the largest proportion of flat to very gently sloping land (0-2%). Doyo yaya has the largest proportion of land with steep slope (>30%). In Gera woreda, Kacho Andaracha and Wanja Kersa woredas have by far the greater proportion of land with flat to gently sloping topography and the proportion of steep slopes (>30%) is invariably small in all the four studied kebeles of Gera woreda. Considerably large proportions of the landscape in all kebeles of didessa woreda have strongly sloping (10-15%) topography. In Bedele woreda, Banshure Kebele has the largest proportion of land with gently sloping topography (2-5%) while the larger percentage of the land in Haro Gefere and Yaballa kebeles is strongly sloping (10-15%).

Leptosols and Cambisols are the dominant soil types in the hilly and mountainous landforms. On such areas gulley erosion is a serious problem and appropriate soil and water conservation practices are recommended. On the other hand, Vertisols and gleysols, tend to be the dominant soils of the smaller swamps and depressions which occur on the lava plains. Planosols occur on the flats between the steeper rises in the numerous depressions that are subjected to seasonal water inundation. Nitisols and Luvisols occur in the gently undulating to rolling topographic positions in all the woredas.

Soils of the studied kebeles showed a fairly narrow range of soil properties. The texture is clayey through out the majority of the lay content increases with depth. The drainage status is moderately to well drained. The reaction of the soil is generally acidic which may be the result of the long years continuous use of such as Urea and DAP soil acidifying nature and aggravate cation losses and ultimately causes acidification of soils. To reclaim the acidity problem of the soils liming is recommemded. Moreover, instead of using inorganic fertilizers alone it is advisable to combine with organic fertilizers such as farm yard manre as the later, besides being source of nutrients, improve physical and chemical characteristics of soil, water holding capacity, CEC and biological activities of the soil. The EC and ESP value of all mapping units is low and thus salinity and sodicity effects are negligible. The content of organic matter was found to be low to medium and decreases with depth. Appropriate agricultural land management is recommended. The content of total nitrogen was low to medium and decreased regularly with depth of the profile. The decrease of total nitrogen with depth generally parallels to a decrease in contents of organic carbon, suggesting that the main source of total nitrogen was organic matter. The high temperature and relative humidity conditions of southwestern Ethiopia favour rapid decomposition andmineralization of organic matter which could explain thelow levels of organic carbon in the soils. Available phosphorus is low to medium due to high p-fixation capacity associated with the acidity of the soils. Therefore, crop cultivation in these soils would be limited by low P status in addition to other potential limiting factors mentioned earlier, as a result of which application and management of P is required. The CEC of the soils is very high due to the high clat content. BS saturation is low due to intensive leaching resulting from the high rainfalls in the area.

5. References

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6. Annex

Annex 1. Auger Observation points of CASCAPE intervention woredas in West Oromia region

Woreda	Auger		coordinates (UTM)			
	kebele	Auger code	N	E	Field classification	
		JIM/OMN/DY/A1	329640	837229		Nitisols
		JIM/OMN/DY/A2	310858	839162		Luvisols
	Doyo Yaya	JIM/OMN/DY/A3	309522	842424		nitisols
		JIM/OMN/DY/A4	309002	842764		Nitisols
		JIM/OMN/DY/A5	312447	840903		leptosols
		JIM/OMN/DY/A6	308309	844628		vertisols
		JIM/OMN/DY/A7	308177	844841		vertisols
		JIM/OMN/DY/A8	309742	842611		nitisols
Omo Nada	Nada Chala	JIM/OMN/NC/A1	303363	842940		Planosols
		JIM/OMN/NC/A2	300390	843137		Nitisols
		JIM/OMN/NC/A3	299204	843386		vertisols
		JIM/OMN/NC/A4	301935	842476		nitisols
		JIM/OMN/NC/A5	299535	840406		leptosols
		JIM/OMN/NC/A6	299369	842062		nitisols
		JIM/OMN/NC/A7	302130	841800		Planosols
		JIM/OMN/NC/A8	300205	842770		Nitisols
	Nada Bidaru	JIM/OMN/NB/A1	299815	837609		nitisols
		JIM/OMN/NB/A2	299902	836349		nitisols
		JIM/OMN/NB/A3	300078	834566		cambisols
		JIM/OMN/NB/A4	300086	836348		Nitisols
		JIM/OMN/NB/A5	299949	832063		leptosols
		JIM/OMN/NB/A6	301025	836202		nitisols
		JIM/OMN/NB/A7	300719	834884		vertisols
		JIM/OMN/NB/A8	299422	834805		nitisols
	Toli Beyem	JIM/OMN/TB/A1	292168	837278		planosols
		JIM/OMN/TB/A2	295854	836182		planosols
		JIM/OMN/TB/A3	292266	843079		luvisols
		JIM/OMN/TB/A4	293575	843072		fluvisols
		JIM/OMN/TB/A5	292085	839761		cambisols
		JIM/OMN/TB/A6	296389	839844		nitisols
		JIM/OMN/TB/A7	291990	843589		vertisols

		JIM/OMN/TB/A8	293006	843229		vertisols
	Mirkuz	JIM/LS/DG/A1	280549	924160		nitisols
		JIM/LS/DG/A2	277323	921565		nitisols
		JIM/LS/DG/A3	280732	923975		nitisols
		JIM/LS/DG/A4	280282	923917		nitisols
		JIM/LS/DG/A5	283001	924855		planosols
		JIM/LS/DG/A6	279837	926477		leptosols
		JIM/LS/DG/A7	282932	922931		vertisols
		JIM/LS/DG/A8	283346	925859		planosols
	Saka	JIM/LS/S/A1	271983	907027		nitisols
		JIM/LS/S/A2	270605	906972		nitisols
		JIM/LS/S/A3	270543	906727		nitisols
		JIM/LS/S/A4	272932	907022		nitisols
		JIM/LS/S/A5	276327	905563		Planosols
		JIM/LS/S/A6	273162	906272		Nitisols
		JIM/LS/S/A7	273358	906873		luvisols
		JIM/LS/S/A8	274723	905375		luvisols
	Gejib	JIM/LS/G/A1	272967	901890		Luvisols
		JIM/LS/G/A2	273118	901397		Nitisols
Limu Saka		JIM/LS/G/A3	271164	902575		leptosols
		JIM/LS/G/A4	272475	901462		acrisols
		JIM/LS/G/A5	270605	895080		planosols
		JIM/LS/G/A6	270581	903597		leptosols
		JIM/LS/G/A7	272502	900258		vertisols
		JIM/LS/G/A8	271169	901558		nitisols
	Dora	JIM/LS/DG/A1	270636	895080		planosols
		JIM/LS/DG/A2	270228	896563		fluvisols
		JIM/LS/DG/A3	270417	899838		nitisols
		JIM/LS/DG/A4	268346	896563		fluvisols
		JIM/LS/DG/A5	268613	900774		luvisols
		JIM/LS/DG/A6	271821	897098		planosols
		JIM/LS/DG/A7	272269	897778		fluvisols
		JIM/LS/DG/A8	286022	899947		nitisols
	Ganji Chala	JIM/G/GC/A1	200030	857590		nitisols
		JIM/G/GC/A2	197681	854746		nitisols
		JIM/G/GC/A3	197250	854472		fluvisols
		JIM/G/GC/A4	198175	855265		nitisols
		JIM/G/GC/A5	196918	855181		nitisols
	Kacho andaracha	JIM/G/KA/A1	203998	859440		Planosols

		JIM/G/KA/A2	204943	858604		Gleysols
		JIM/G/KA/A3	205471	859378		leptosols
		JIM/G/KA/A4	206384	858392		nitisols
		JIM/G/KA/A5	205142	860035		fluvisols
		JIM/G/KA/A6	204668	857820		nitisols
Gera		JIM/G/KA/A7	204546	859329		planosols
		JIM/G/KA/A8	205654	859974		nitisols
	Wanja kersa	JIM/G/WK/A1	209525	860789		Nitisols
		JIM/G/WK/A2	209517	859436		luvisols
		JIM/G/WK/A3	210081	861400		luvisols
		JIM/G/WK/A4	210081	861400		Nitisols
		JIM/G/WK/A5	211069	860005		cambisols
		JIM/G/WK/A6	209307	859374		fluvisols
		JIM/G/WK/A7	208755	859558		nitisols
		JIM/G/WK/A8	210938	859571		nitisols
	Sadi Loya	JIM/G/SL/A1	214576	864576		nitisols
		JIM/G/SL/A2	214953	866073		Nitisols
		JIM/G/SL/A3	213914	804754		Planosols
		JIM/G/SL/A4	214245	860483		Nitisols
		JIM/G/SL/A5	214552	865584		Nitisols
		JIM/G/SL/A6	214495	859779		planosols
		JIM/G/SL/A7	215232	865848		nitisols
		JIM/G/SL/A8	217110	862797		cambisols
	Sobo	ILU/D/S/A1	221006	893394		Nitisols
		ILU/D/S/A2	221153	892409		cambisols
		ILU/D/S/A3	219547	891718		nitisols
		ILU/D/S/A4	222375	891884		regosols
		ILU/D/S/A5	223681	891288		vertisols
		ILU/D/S/A6	222838	891751		luvisols
		ILU/D/S/A7	221829	892198		nitisols
	Masara	ILU/D/M/A1	217950	899500		nitisols
		ILU/D/M/A2	219461	901088		luvisols
		ILU/D/M/A3	220098	900039		nitisols
		ILU/D/M/A4	218602	900085		fluvisols
		ILU/D/M/A5	218979	899808		nitisols
		ILU/D/M/A6	219819	899576		cambisols
Didessa		ILU/D/M/A7	218016	900583		nitisols
		ILU/D/M/A8	216876	899775		nitisols
	Goro	ILU/D/G/A1	224252	899077		nitisols

		ILU/D/G/A2	224905	895103		vertisols
		ILU/D/G/A3	226575	895269		cambisols
		ILU/D/G/A4	227369	895450		nitisols
		ILU/D/G/A5	228146	895649		nitisols
		ILU/D/G/A6	225649	893764		nitisols
		ILU/D/G/A7	225467	896029		cambisols
		ILU/D/G/A8	226410	894640		cambisols
	Yembero	ILU/D/Y/A1	221096	902861		Planosols
		ILU/D/Y/A2	221461	902551		nitisols
		ILU/D/Y/A3	219489	905423		Nitisols
		ILU/D/Y/A4	212030	903011		Fluvisols
		ILU/D/Y/A5	219399	903611		fluvisols
		ILU/D/Y/A6	218943	904750		nitisols
		ILU/D/Y/A7	217225	906323		cambisols
		ILU/D/Y/A8	222301	901563		cambisols
	Banshure	ILU/B/B/A1	211265	943200		leptosols
		ILU/B/B/A2	211352	943145		gleysols
		ILU/B/B/A3	211148	944654		leptosols
		ILU/B/B/A4	210162	944310		Nitisols
		ILU/B/B/A5	213459	947669		vertisols
		ILU/B/B/A6	212626	946691		Nitisols
		ILU/B/B/A7	216440	946284		vertisols
		ILU/B/B/A8	213653	945083		Nitisols
	Mirga Mute	ILU/B/MM/A1	206437	938710		nitisols
		ILU/B/MM/A2	206545	938985		Acrisols
		ILU/B/MM/A3	206766	938661		nitisols
		ILU/B/MM/A4	207250	939059		cambisols
		ILU/B/MM/A5	207631	939284		vertisols
Bedele		ILU/B/MM/A6	205900	938834		leptosols
		ILU/B/MM/A7	206385	939232		luvisols
		ILU/B/MM/A8	206264	939820		fluvisols
	Haro gefere	ILU/B/HG/A1	214511	935673		cambisols
		ILU/B/HG/A2	212886	935284		Acrisols
		ILU/B/HG/A3	214495	936262		cambisols
		ILU/B/HG/A4	213867	936097		nitisols
		ILU/B/HG/A5	214360	936456		cambisols
		ILU/B/HG/A6	214943	937068		leptosols
		ILU/B/HG/A7	213838	935142		acrisols
		ILU/B/HG/A8	214674	934112		luvisols

	Yaballa	ILU/B/Y/A1	213159	930302		cambisols
		ILU/B/Y/A2	212630	928984		Acrisols
		ILU/B/Y/A3	212902	930103		cambisols
		ILU/B/Y/A4	213864	930508		cambisols
		ILU/B/Y/A5	214307	930772		acrisols
		ILU/B/Y/A6	212506	930894		cambisols
		ILU/B/Y/A7	213317	930979		nitisols
		ILU/B/Y/A8	214373	931026		acrisols

Annex 2. Studied soil profiles in CASCAPE intervention Woredas of West Oromia region

No	Woreda	Kebele	Profile No	Coordinates (UTM)		Classification (WRB, 2006)
				Northing	Easting	
		Doyo Yaya	JIM/OMN/DY/P1	309002	842764	Cutanic Luvisol (Epidystric, Clayic, Rhodic)
			JIM/OMN/DY/P2	309522	842424	Luvic Nitisol (Dystric, Rhodic)
			JIM/OMN/DY/P3	310858	839162	Luvic Phaezem (Clayic)
		Nada Chala	JIM/OMN/NC/P1	303363	842940	Vertic Planosol (Albic, Eutric, Clayic)
1	**Omo Nada**		JIM/OMN/NC/P2	300390	843137	Acric Nitisol (Dystric)
		Nada Bidaru	JIM/OMN/NB/P1	300086	836348	Luvic Nitisol (Dystric, Rhodic)
			JIM/OMN/NB/P2	300078	834566	Haplic Cambisol (Eutric, Clayic)
		Toli Beyem	JIM/OMN/TB/P1	295854	836182	Vertic Planosol (Albic, Eutric, Clayic)
		Mirkuz	JIM/LS/M/P1	283001	924855	Luvic Gleysol (Dystric, Clayic)
			JIM/LS/M/P2	280732	923975	Luvic Nitisol (Dystric, Rhodic)
		Saka	JIM/LS/S/P1	270543	906727	Luvic Nitisol (Dystric, Rhodic)
2	**Limu saka**		JIM/LS/S/P2	273162	906272	Luvic Nitisol (Dystric, Rhodic)
		Gejib	JIM/LS/G/P1	272475	901462	Cutanic Luvisol (Clayic)
		Dora	JIM/LS/DG/P1	270636	895080	Stagnic, Albic Luvisol (Rubtic, Clayic)
		Ganji Chala	JIM/G/GC/P1	198175	855265	Pisoplinthic Gleysol (Dystric, Clayic)
			JIM/G/GC/P2	196918	855181	Luvic Nitisol (Dystric, Rhodic)
3	**Gera**	Kacho Andaracha	JIM/G/KA/P1	203998	859440	Luvic Gleysol (Dystric, Clayic)
		Wanja Kersa	JIM/G/WK/P1	210081	861400	Luvic Nitisol (Dystric, Rhodic)
		Sadi Loya	JIM/G/SL/P1	213914	804754	Endogleyic, Plinthic, Vertic Planosol (Eutric, Clayic)
			JIM/G/SL/P2	214245	860483	Luvic Nitisol (Dystric, Rhodic)
			JIM/G/SL/P3	214552	865584	Luvic Nitisol (Dystric, Rhodic)
		Sobo	ILU/D/S/P1	221006	893394	Luvic Nitisol (Dystric, Rhodic)
			ILU/D/S/P2	221153	892409	Haplic Cambisol (Dystric, Clayic)
		Masara	ILU/D/M/P1	220098	900039	Luvic Nitisol (Dystric, Rhodic)
4	**Didessa**	Goro	ILU/D/G/P1	224252	899077	Cutanic Luvisol (Clayic)

		Yembero	ILU/D/Y/P1	221096	902861	Plinthic Gleysol (Dystric, Clayic)
			ILU/D/Y/P2	212030	903011	Luvic Nitisol (Dystric, Rhodic)
		Banshure	ILU/B/B/P1	210162	944310	Nitic Luvisol (Epidystric, Clayic)
			ILU/B/B/P2	212626	946691	Luvic Nitisol (Dystric, Rhodic)
5	**Bedele**	Mirga Mute	ILU/B/MM/P1	206545	938985	Cutanic Luvisol (Clayic)
		Haro Gefere	ILU/B/HG/P1	214511	935673	Haplic Acrisol(Epieutric, Clayic)
			ILU/B/HG/P2	212886	935284	Haplic Cambisol (Dystric, Clayic)
		yaballa	ILU/B/Y/P1	213159	930302	Haplic Acrisol(Epieutric, Clayic)
			ILU/B/Y/P2	212630	928984	Haplic Cambisol (Dystric, Clayic)

Annex 3. Slope map of the CASCAPE intervention woredas in West Oromia region

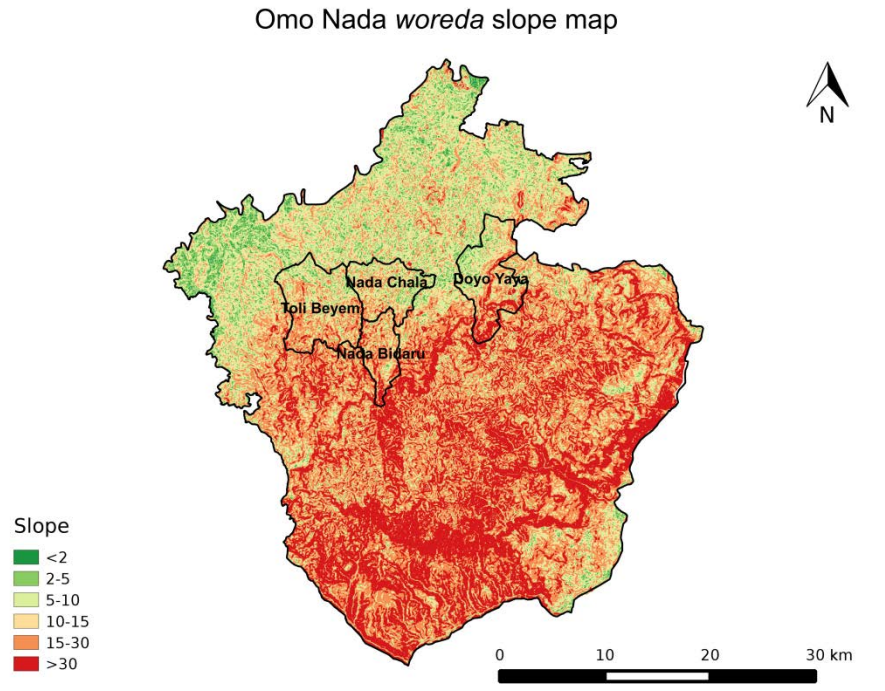


Figure: Slope map of Omo nada Woreda

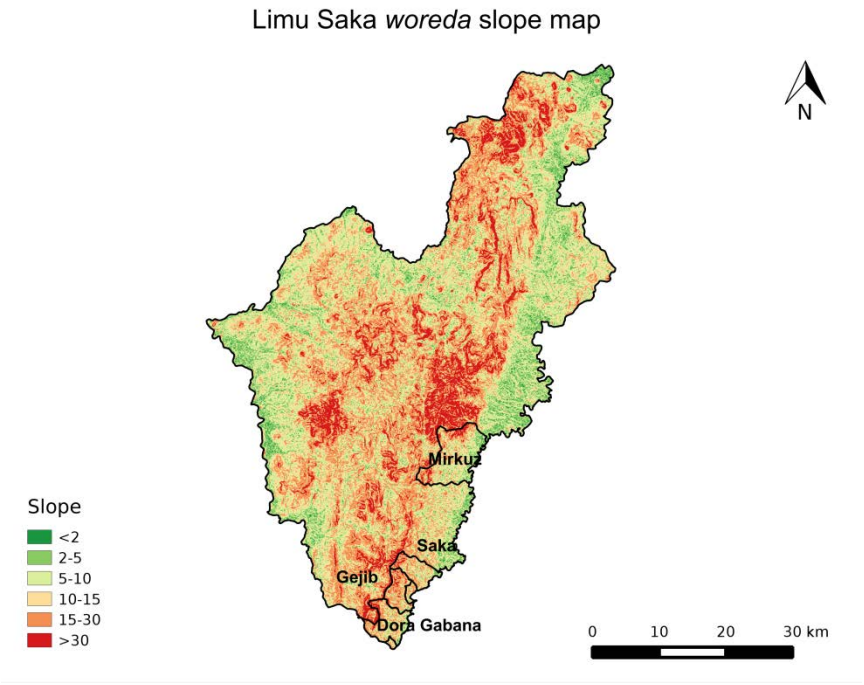


Figure: Slope map of Limu Saka Woreda

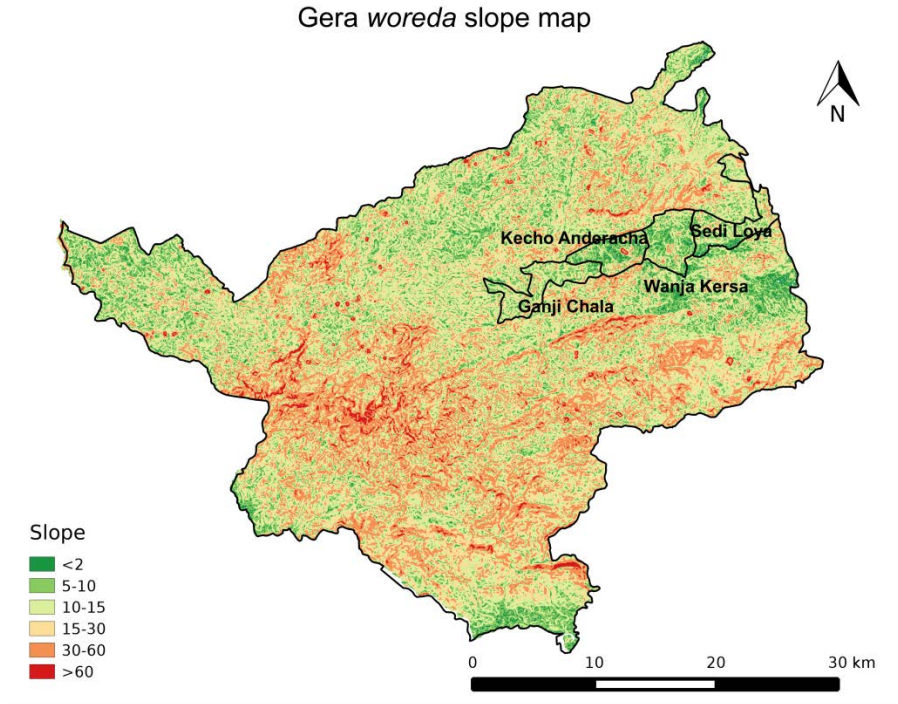


Figure: Slope map of Gera woreda

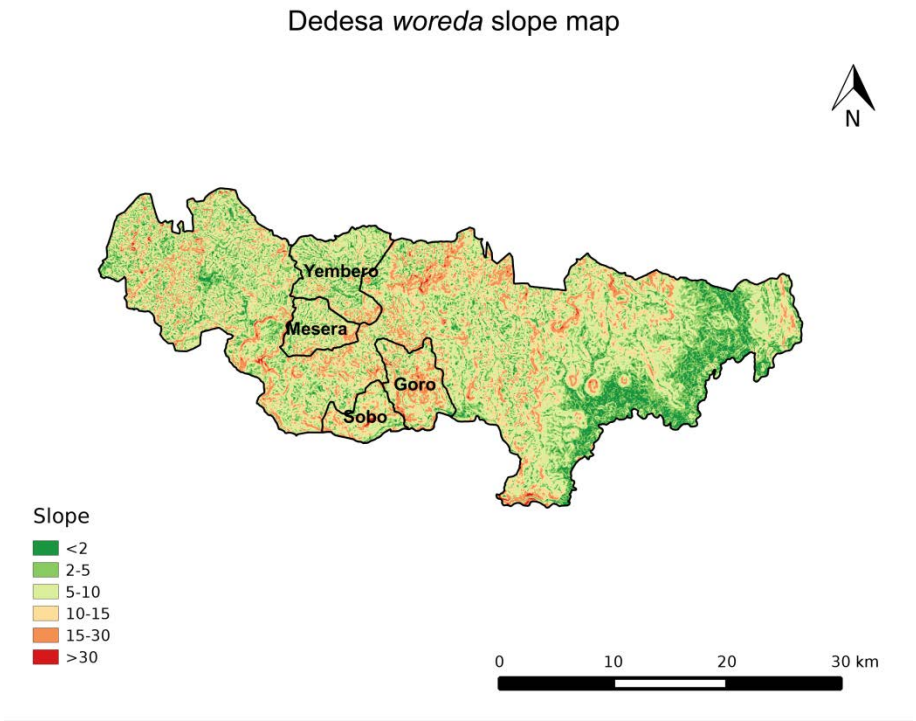


Figure : Slope map of Didessa Woreda

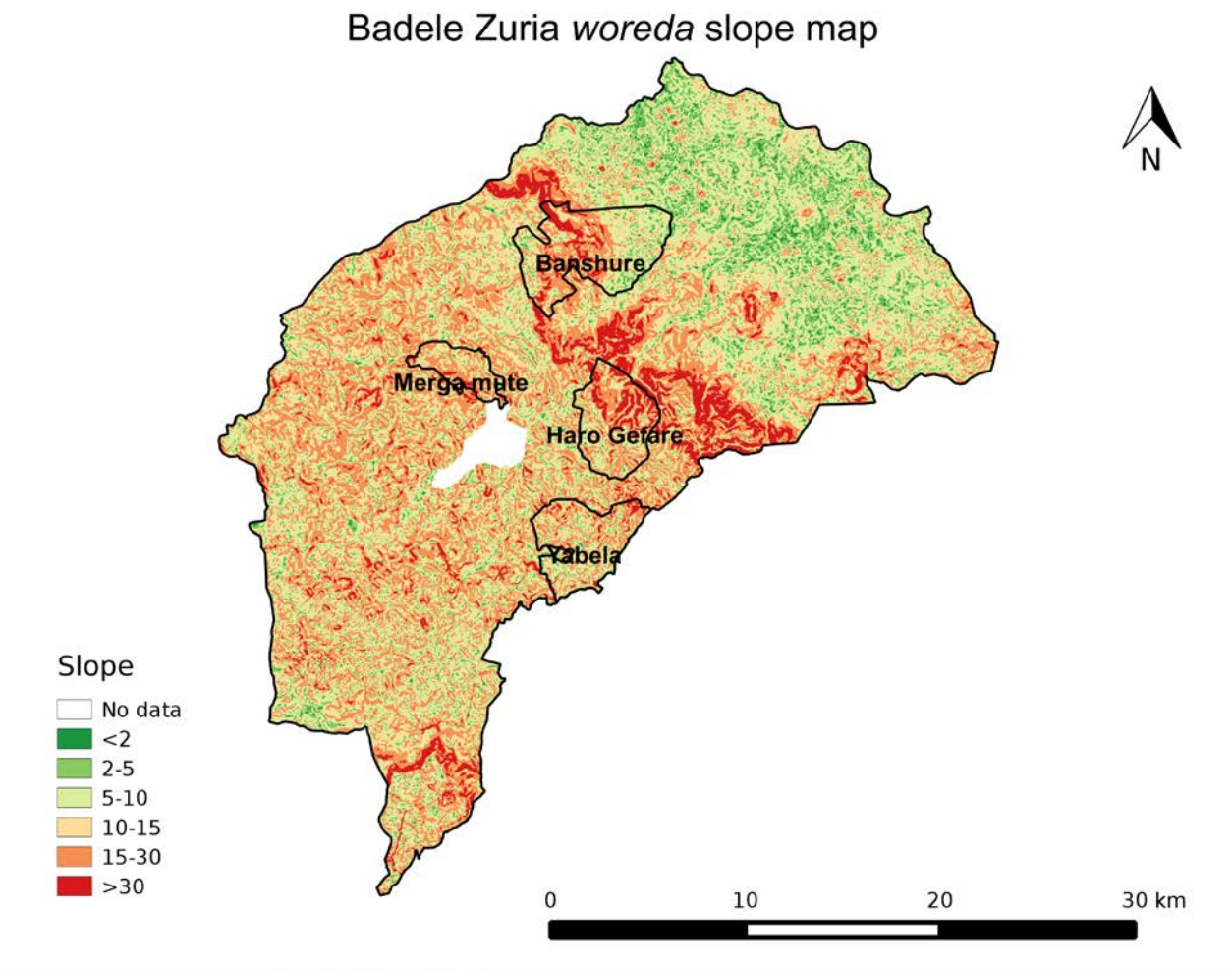
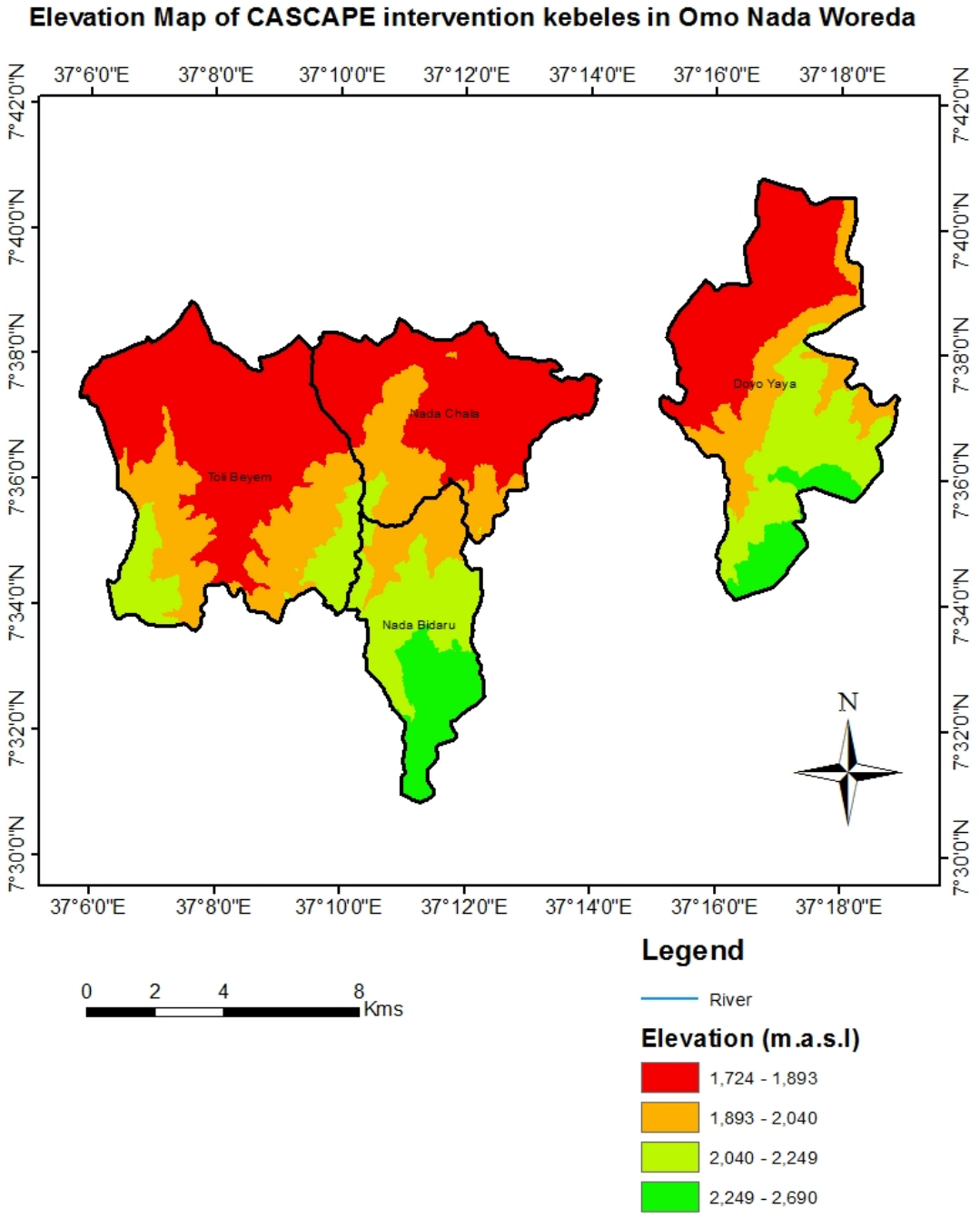


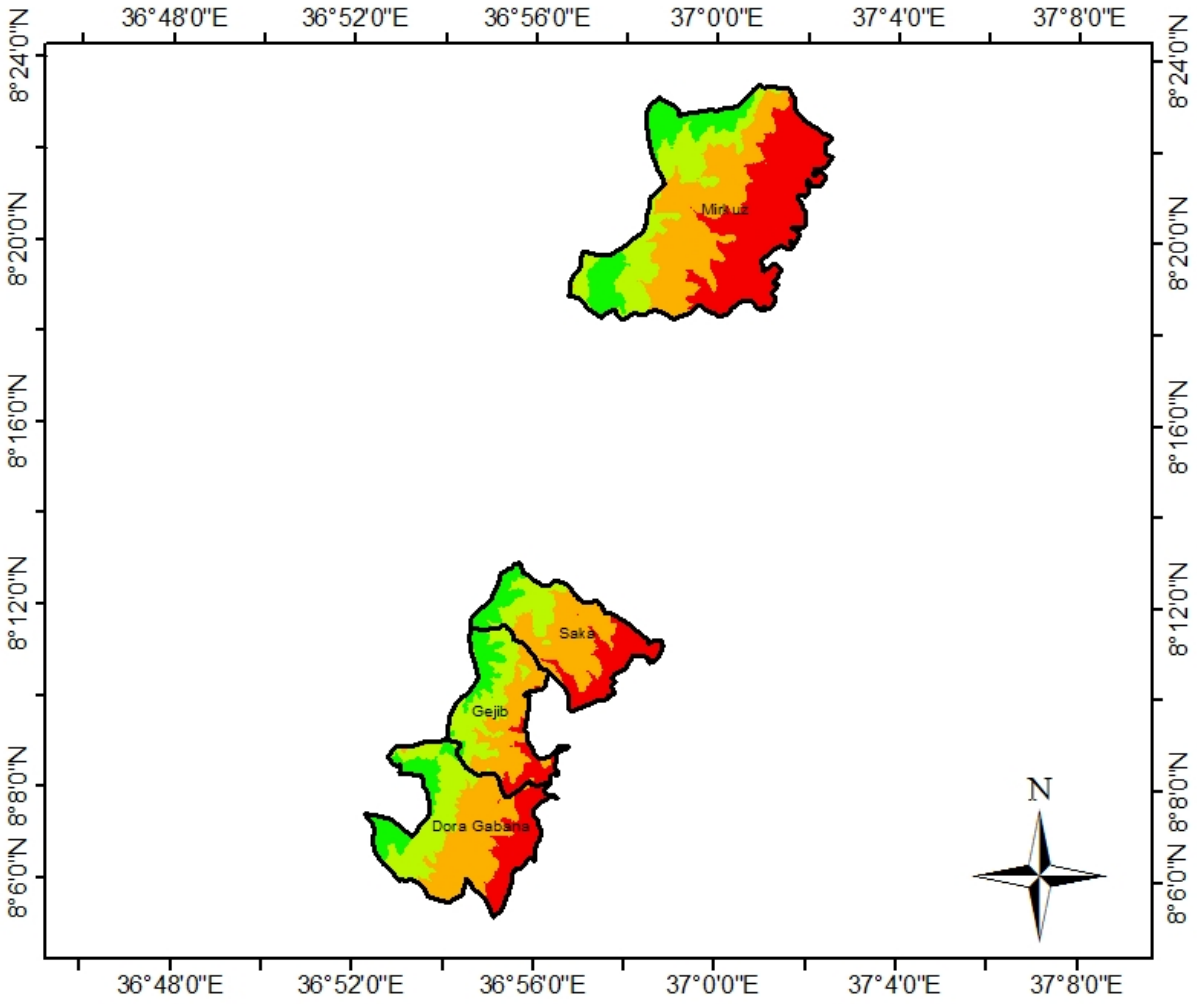
Fig: Slope map of Bedele Zuria woreda

New Figure of soil distributiobn

Annex 4. Elevation map of the CASCAPE intervention woredas in West Oromia region



Elevation Map of CASCAPE intervention kebeles in Limu Seka Woreda

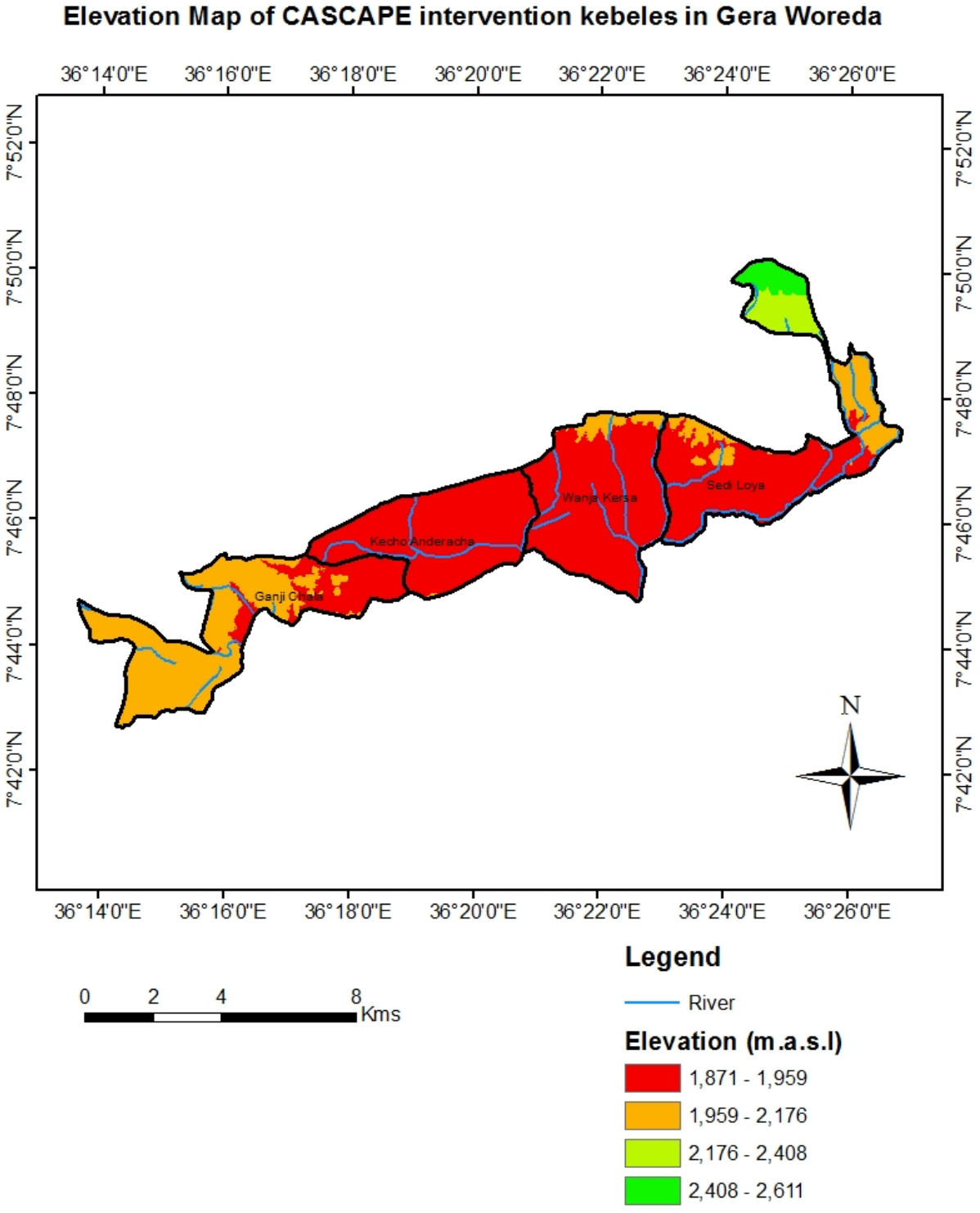


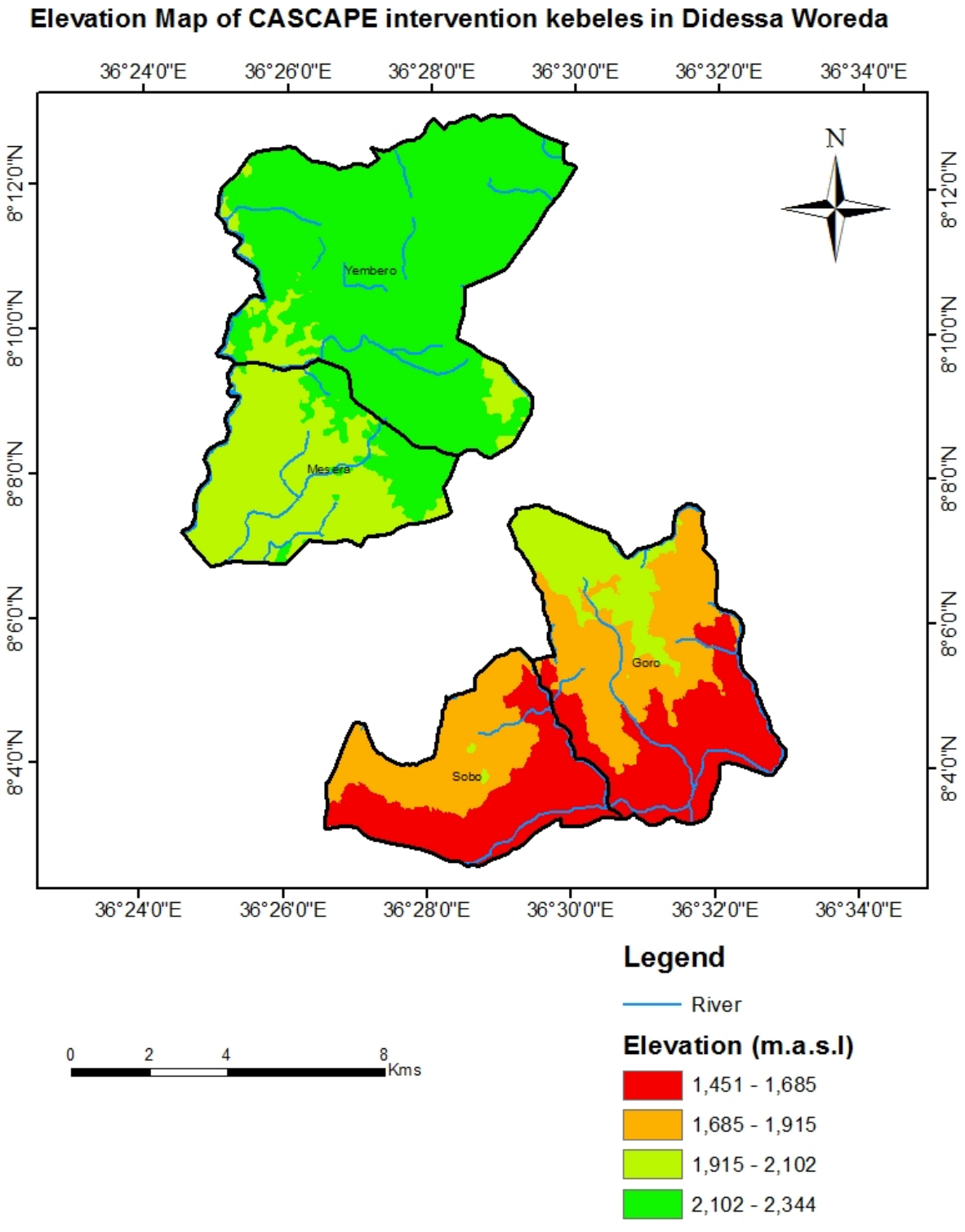
0 3.5 7 14 Kms

Legend

Elevation (m.a.s.l)

- 1,564 - 1,664
- 1,664 - 1,764
- 1,764 - 1,883
- 1,883 - 2,186


Elevation Map of CASCAPE intervention kebeles in Gera Woreda
36°14'0"E
36°16'0"E
36°18'0"E
36°20'0"E
36°22'0"E
36°24'0"E
36°26'0"E
7°52'0"N
7°50'0"N
7°48'0"N
7°46'0"N
7°44'0"N
7°42'0"N
Wanja Kersa
Sedi Loya
Kecho Anderacha
Ganji Chefa
N
0 2 4 8
Kms
Legend
River
Elevation (m.a.s.l)
1,871 - 1,959
1,959 - 2,176
2,176 - 2,408
2,408 - 2,611


Elevation Map of CASCAPE intervention kebeles in Didessa Woreda
36°24'0"E
36°26'0"E
36°28'0"E
36°30'0"E
36°32'0"E
36°34'0"E
8°12'0"N
8°10'0"N
8°8'0"N
8°6'0"N
8°4'0"N
N
Yembero
Mesera
Goro
Sobo
Legend
River
Elevation (m.a.s.l)
1,451 - 1,685
1,685 - 1,915
1,915 - 2,102
2,102 - 2,344
0
2
4
8
Kms

Elevation Map of CASCAPE intervention kebeles in Bedele Woreda