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EXECUTIVE SUMMARY

The present study is initiated in order to provide essential soils and land related information (i.e., on land qualities and soil physical and chemical characteristics for irrigation development) during feasibility study. This helps to identify potentials and constraints of the area and assigning the lands for its best use through land evaluation. Hence, the soil survey of Calle small scale irrigation project was undertaken and mapped at scale of 1:10,000 and the fieldsoil surveyalso conductedon gross command area of 145 hectares.

1. INTRODUCTION

Agriculture is the mainstay of Ethiopian's economy. It employs 85 percent of the population and accounts for about 45 percent of the Gross Domestic Product (GDP) and over 90% of the national export earnings. In fact, due to the dominant traditional system of farming, improper land use system, ever increasing population, and unbalanced climatic condition, agriculture production is very low. The use of improved technology has been among the lowest, and until very recently, the mode of agriculture has been solely rain-fed where only less than 5% of the total cropped area is currently irrigated. Farther more natural resources degradation is a major deterrent to agricultural production and productivity. Agricultural growth is realized more through increasing productivity per unit of land, giving emphasis to specialized, high value product rather than relying on the expansion of cultivable land. Thus, to improve the agricultural production and productivity in the country, the Government of Ethiopia has given more attention to the development of infrastructure and effective institutions for facilitating agricultural growth.

Agricultural production through adopting pressurized irrigation for the development of irrigated agriculture and livestock development should be based on physical resources assessment and sustainable resources management. Soil, among others, is an irreplaceable land resource that influences crop suitability and choice of land utilization types; hence every irrigation project should be pro-accompanied by an intensive soil study to ensure selection of land for irrigation development and other agricultural practices.

The assessment of soil suitability for irrigated agriculture usually requires, detailed land resources inventory and its behavior under future system of crop managements. The changes associated with the introduction of irrigation are generally greater than those under rain fed agricultural practices and accurate prediction requires a thorough knowledge of soils of the command area. The objective of the soil study is to provide detailed information on soils of the potential irrigable command areas in order to use the information for development of irrigation development projects.

Calle irrigation project is found in Oromia Regional State, Arsi Zone, Shirka District and Sole Chisa kebele. So that Soils of Calle Small Scale Irrigation Project area was conducted at feasibility level of the study taking into account the following objectives as required under the Terms of Reference (TOR).

2. OBJECTIVES

2.1 General Objective

The general objective of the soil survey study is to provide detailed information on soils of the potential irrigable command areas in order to use the information for development of irrigation development projects.

2.2 Specific Objectives

- ❑ Determine the nature and distribution of different soil types over the project area (i.e., appraisal of the project site soil resources),
- ❑ Supply scientific basis and to establish a generally accepted soil unit which help for management,
- ❑ Carry out a detailed soil survey within the area identified to establish a common framework in developing the area,
- ❑ Create awareness on the distribution of soil types, so that management could be developed accordingly (i.e., evaluating land suitability (based on land qualities and characteristics) to obtain suitable classification for different kind of land use

3. METHODOLOGY

Assessment of soil suitability for irrigated agriculture requires detail evaluation and characterization because changes associated with the introduction of irrigation are generally much greater than those under rainfed agriculture. Thus, every activity was carefully conducted to examine soils distribution, types and all related factors. Following suggestions in the TOR to use FAO Guidelines, soil survey and land evaluation approaches are considered FAO guidelines. procedures are distribution in the project area. Soil survey works were performed in three phases Summary of activities performed at each phase is highlighted as follows:

3.1 Pre-field study

Previous study documents relevant to the project area were thoroughly reviewed and tentative field visit has been carried out. Before the actual field survey the necessary survey formats such as Field soil survey guidelines, standard description sheets for auger boring, profile pits, hydraulic conductivity and infiltration rate tests formats have been duplicated during this stage. Slope map have been generated for the study area from Aster-DEM as a base map. And preliminary soil boundary larger than the actual size was delineated. Then soil auger observation points of 200x200 m grid were distributed on a base map of 1:10,000. The location of profile pits and site tests were decided in the field based on soil types identified with soil auger description.

3.2 Field Work

Feasibility level soil surveying in the project area was carried out in April 2018 during which 10 auger hole observations, 3 profile pits for detail analysis, infiltration and hydraulic conductivity analyses were made. The augering result description has been made for every 200 x 200m grid along transect (i.e., one auger site per 10ha). and as found feasible supplementary free survey was carried out to ensure proper inspection of geomorphological units, to exclude unsuitable land and to verify soil boundaries, wherever found necessary.

Survey approaches followed standard soil survey procedures and classified according to the FAO Guidelines for Soil Description (2006) and World Reference base for Soil Resource (2006). The system is used because it provides detail information on soil qualities and soil characteristics for the assessment of land performance when used for specific purpose.

Soil profile pits were dug to 200cm depths at representative sites, following transect lines. Soil samples were taken from each significant natural horizon's, for full physical, chemical, bulk density and available water holding capacity analyses and/or determination. in-situ infiltration (using double ring infiltrometer in triplicate at the representative profile pits) and hydraulic conductivity tests (using inverse auger hole method) were carried out. All observations were recorded on soil description sheets at each observation site and the following surface/ external characteristics and information were recorded.

- Land form and its use and/or land cover,
- Location of the site using hand GPS,
- Soil colour using Munsell color charts,
- Parent material, presence of micro-topography, surface features (cracks, crust, stoniness, etc),
- Erosion hazard (by estimation), flooding problem, etc.,
- Presence of carbonates using 10% HCl
- General pattern of drainage,
- Land use (i.e., the kind of crops grown and other plant species),

Moreover, some internal characteristics such as soil depth, texture, nodules (such as iron, manganese, etc) mottling, etc., were further evaluated. During profile pit analysis more information was recorded (i.e., from each horizon structural development and form, consistence, porosity (using magnifying hand lens), roots, cutans, slickenside, etc.

From the analysis It is noted that, textural class determination by hand feel method in the field is different than the result in the laboratory. Under such condition where there are differences between laboratory and field evaluation by hand feel method values of the laboratory results have been considered. Undisturbed core samples were sent to the laboratory for the determination of water holding capacity. All field observation points (auger holes and profile pits) had been plotted in the digitized soil map units, and observations within similar soil unit were used to characterize the mapping unit.

Table 3-1 Soil Survey Data Collected During Field Work

Data type	Number of observations
Total augers observation points	10
Total soil pits observed	3
Infiltration, hydraulic conductivity test sites	2
Total sample soils for laboratory analysis	12

3.3 Post Field Work

Some of the major activities carried out were: detail scrutiny of field, laboratory and supporting documents; interpretation of obtained data, establishment of land suitability analysis and diagnostic criteria, preparation of soil and land suitability management units, etc. Some of the major activities carried out are highlighted hereunder.

3.3.1 Laboratory Analysis and Results Interpretation

Samples analysed in the laboratory were carried out on air dried fine earth fraction (<2mm) based on the procedures specified. Each parameter analyzed was based on standard procedures and methods,

- Soil particle size distribution (texture) following hydrometer procedure,
- Bulk density (gm/cm³), on dry weight basis from pF ring samples.
- Soil pH in H₂O and 1M KCl at a soil to solution ratio of 1:2.5,
- EC (ms/cm) at a soil to water ratio of 1:2.5 using EC meter.
- Exchangeable Na, K, Ca, Mg (meq/100gm of soil) following ammonium acetate leachate using Atomic Absorption Spectrophotometer (AAS),
- Cation exchangeable capacity (CEC) (meq/100gm of soil) following ammonium acetate method at pH 7,
- Organic carbon (%) (walkley and Black method),
- Total nitrogen, N (kjeldahl method) ,

- Available phosphorous, p (Olson) mg p₂O₅ kg/soil,
- Free CaCO₃ (by acid neutralization method),
- Exchangeable sodium percentage, ESP (deduced from CEC and exchangeable Na),
- Calcium: magnesium ratio:Ca:Mg (deduced from exchangeable ca and Mg),

4. DESCRIPTION OF THE PROJECT AREA

4.1 Location

Calle irrigation project is found in Oromia Regional State, Arsi Zone, Shirka District and Sole-chisa kebele. The command area is failed in an altitude range between 2114-2141 masl which is characterized by plain to gentle slope lands. More over the project site is far 9 km distance from district capital.

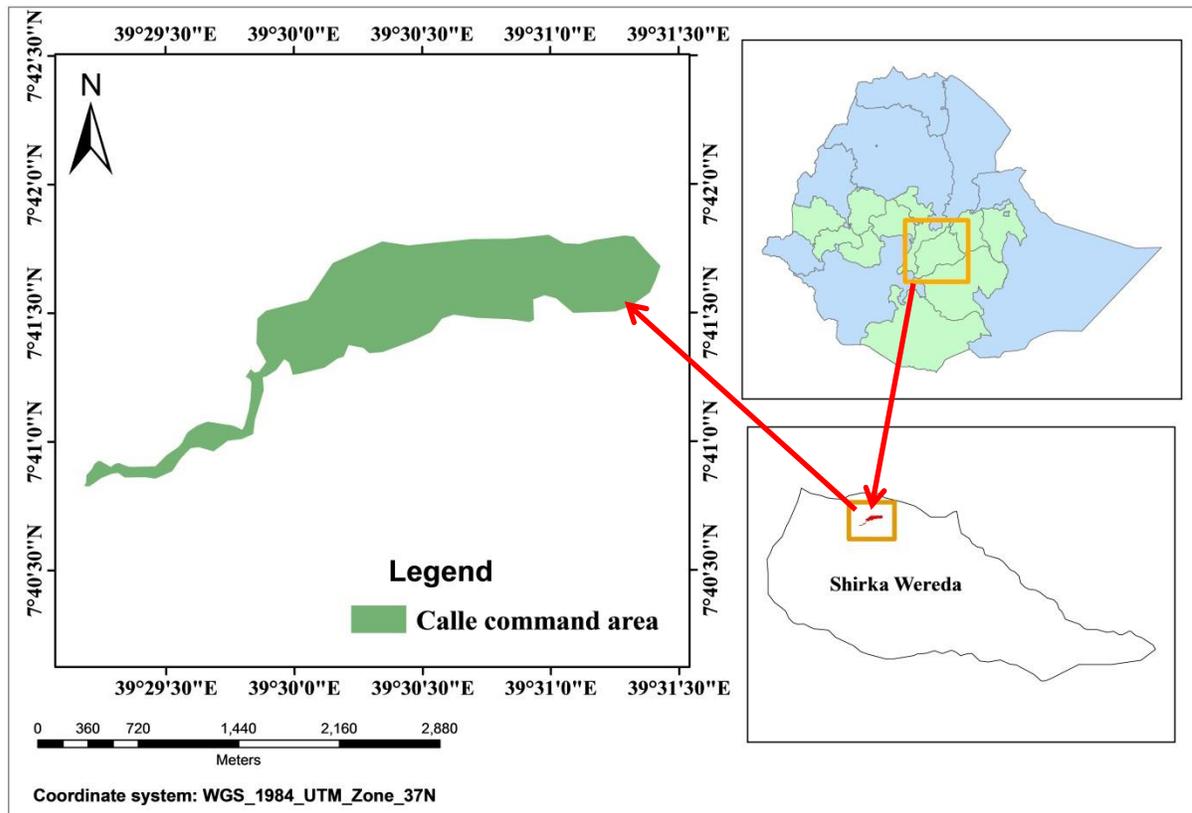


Figure 1-1 Map of Calle command area

4.2 Climate

Climate is the important factor determining the success or failure of agriculture. It influences agricultural operations from sowing of a crop to the harvest and particularly rain fed agriculture depends on the mercy of the weather. The crops are to be sown at the optimum period for maximum yield. In dry lands, the time of receipt of rainfall decides the sowing date. The study of climate helps to minimize the crop losses due to excess rainfall, cold/heat etc. It helps in forecasting pests and diseases, choice of crops, irrigation and other intercultural operations through short, medium and long-range forecasts.

Climate helps to identify places with same climatic conditions (Agro climatic zones). This will enable to adopt suitable crop production practices based on the local climatic conditions. It also helps in the introduction of new crops and varieties, which are more productive than the native crops, and varieties. Ticho meteorological Station is the nearest station from which the climatic data were inferred.

4.3 Rainfall

Precipitation refers to the water (moisture) received in the form of rain, snow, hail, fog, dew or a combination of them. However, rainfall is the most important form of precipitation in the tropics and subtropics in which its efficiency is measured by its yearly amount, distribution and duration.

The area is characterized by bi-modal rainfall pattern that extends from April to Mid-November with dry spell period in mid-November to mid-march. However, as it was described by the farmers, the rainfall of the area is characterized by late onset and early offset as well as inadequate in its amount. Even though the area is characterized by bimodal rainfall pattern, the moisture obtained during the short rainy season is not enough for crop production. Therefore, the total average annual rain fall is calculated to be **1265mm**. Maximum rainfall occurred in the month of August which is 165mm as shown in Table 4-1.

Table 4-1: Monthly Rain and Effective Rain Fall of Project Area

Month	Rain(mm)	Eff rain(mm)
January	46	42.6
February	87	74.9
March	135	105.8
April	155	116.6
May	101	84.7
June	95	80.6
July	157	117.6
August	165	121.4
September	144	110.8
October	103	86
November	54	49.3
December	23	22.2
Total	1265	1012.5

4.4 Temperature

The prevailing temperature considerably influences selection of crops and their growing periods. Optimum temperature plays an important role on the growth period and the production of crops. The mean maximum annual temperature of the area is 20.11^oc and the mean minimum annual temperature is 7.53^oc, in which the highest mean maximum temperature and a mean minimum temperature were recorded in January and May months respectively as illustrated in Table 4-2 below. Thus, in command area mostly low to moderate temperature ranges are occurred which is favorable for the growth of various crops in the area.

Table 4-2: Minimum, Maximum and Monthly Average Temperature

Months	Min Tem(°c)	Max Tem(°c)	Average Temp(°c)
January	6.2	20.9	13.55
February	7.2	21.6	14.4
March	8	21.2	14.6
April	8.9	20.2	14.55
May	9	20.7	14.85
June	8.1	20.8	14.45
July	8.4	19.5	13.95
August	8.1	19.1	13.6
September	8.1	19.3	13.7
October	7.5	18.7	13.1
November	5.9	19.2	12.55
December	5	20.2	12.6
Average	7.53	20.11	

4.5 Land use

The vegetation cover of the area is changing, due to the expansion of farm land and increasing uncontrolled tree cutting for fire wood and construction. A good indicator is that cultivation in steep areas was observed during site observation on some irrigation schemes. Indigenous trees are mostly replaced by eucalyptus species which are becoming dominant in farm lands. The figure below is driven from satellite images.

Table 4-3: Land Use Type In District and Study Kebele

No	Land use	District Area in (ha)	Area (%)	Kebele Area in (ha)	Area (%)
1	Arable land	27244	40.4	0	0
1	Cultivated land	21566	32.0	686	86.4
2	Grazing land	1472	2.2	2	0.3
3	Forest land	12622	18.6	100.7	12.7
4	Settlement	3937	5.8	0	0
5	Other uses	648	1.0	5	0.6
	Total	67489	100	793.7	100

Source: *Shirka District Agricultural Development Office*

4.6 Topography

Topography is an important factor for the planning of any irrigation project as it influences method of irrigation, drainage, erosion, and cost of land development, mechanization, labor requirement, and choice of crops. Topographically most of the cultivated lands of the project area are found between levels to gently undulating lands. The command area begins after a few kilometers of ideal canal with in the villages around their homesteads crossing roads and different structures. In general, the command area divided in to three slope classes namely, 0-3, 3-8 and 8-15percent.

Table 4-4: Slope Class and Area Coverage of Command Area

SN	Slope class	Area in (ha)	Area in (%)
1	0-3	23.69	23
2	3-8	30.9	30
3	8-15	48.41	47
	Total	103	100

4.7 Geology of the Command Area

This unit constitutes most part of the main canal of the irrigation area in which its higher dotted relief increases eastward. The flank of this elongated dotted ridge has higher steep slope and dies to plain to gently sloping command area, southern part of the ridge area. Reddish brown color of west to east trending and elevated land feature with sequences of dotted hills on left flank of the irrigation area. Basalt is the dominant unit in this undifferentiated volcanic unit. Reddish Scoria, engulfed globular basalt within the groundmass and highly fractured and weathered light gray tuff also exists in association in substantial amount. Moderate to high degree of fracturing and weathering is frequent in this undifferentiated volcanic unit.

The command area of the irrigation area is characterized by soil layer, tuff and the lower basalt. Black cotton soil dominated the middle and lower portion of the command area, while the upper part is dominated by reddish brown soil associated with granular fragments of basalt, which fall from the hill side of the fractured undifferentiated volcanic unit. The pale yellowish tuff of loosely consolidation is sandwiched between the upper soil layer and the beneath basaltic lithology.

4.8 Land use

The land use pattern of Shirka district has exhaustively utilized the arable land mainly for rain fed agriculture. According to the data collected from Shirka district agricultural office the area is allocated for crop production in which rain fed cultivated land contribute 39% of the total Sole-chisa kebele area. Currently the cultivable land contributes about 86.4% or an area of 793.7 ha.(Table 4-5).

Table 4-5 Land use type in district and study kebele

No	Land use	District Area in (ha)	Area (%)	Kebele Area in (ha)	Area (%)
1	Arable land	27244	40.4	0	0
2	Cultivated land	21566	32.0	686	86.4
3	Grazing land	1472	2.2	2	0.3
4	Forest land	12622	18.6	100.7	12.7
5	Settlement	3937	5.8	0	0
6	Other uses	648	1.0	5	0.6
	Total	67489	100	793.7	100

Source: Agricultural Development Office

4.9 Farming system

Farming system is the function of natural resources and agricultural experiences applied to sustain the livelihood of the people in a given agro-ecosystem. In the context of the project area, lowland cereals based mixed farming system is a dominant smallholder agricultural production system. The land preparation mainly the ploughing is carried out by oxen. The farming system is dominated by annual cereal crops where vast area of the crop fields is covered by wheat and barley which are typical high land crops. Usually the farmers are using simple farm hand tools for cultivation and weeding. The dominant farming system to some extent applies fertilizer for selected crops.

4.9.1 Crop production

The rain fall pattern around project area is bi-modal, mid-February–mid-May (short) and mid-June–mid-October (long) rainy seasons. At present, the short rainy season is not effective for agricultural production because of the climatic disturbance. The study area is endowed with favorable climate, soil and topography for cultivation of diverse crops. Maize is the most widely grown crops in the study area mainly maize, sorghum, wheat, barley, beans and small vegetables which are commonly cultivated crops and used for food purpose and Chat also grown in the district and it serve as a cash crop.

Table 4-6 Crop type and yield of rain fed agriculture in district 2009/2010

S.N	Crop type/input type	Unit	Yield/ha	Price/Qt)	Remarks
1	Cereals				
	Maize	Kun	45	650.00	Used selected and local seeds
	Wheat	Kun	30	1200.00	Used selected and local seeds
	Barely	Kun	18	1100.00	Used local seeds
	Sorghum	Kun	22	700.00	Used local seeds
2	Pulses				
	Horse bean	Kun	8	1700.00	Used local seeds
	Pea	Kun	7	1700.00	Used local seeds
3	Root crops				
	Potato	Kun	80	350.00	Used selected and local seeds
4	Vegetables				
	Cabbage	Kun	120	1200.00	Used selected seeds
	Pepper	Kun	20	4000.00	Used selected seeds
	Carrot	Kun	80	1600.00	Used selected seeds
	Onion	Kun	60	1500.00	Used selected and local seeds
	Garlic	Kun	35	3000.00	Used local seeds
	Tomato	Kun	85	1000.00	Used selected seeds
5	Cash crops				
	Sugar cane	Pcs	-	16.00	Used local seeds
	Chat	kg	-	100.00	Used local seeds

Source: District agricultural development office

4.10 Soil Erosion and Conservation Status

Soil erosion is widespread, but there is considerable variation in the degree of erosion from place to place in the study area. Erosion is most serious in the study area such that most areas are covered with gullies and bare surfaces. These features are good indicators of severe soil erosion in the woreda.



Photo 4-1 Soil erosion along the farm land

Soil erosion, on the other hand, is the movement of soil from one part of the land to another through the action of wind or water. Thus, soil erosion by water is caused by raindrop impact surface sealing, and crust formation leading to high runoff rate and amount, high runoff velocity on long and undulating slopes, and low soil strength of structurally weak soils with high moisture content due to frequent rains. Soil erosion by wind is caused by lack of vegetation cover, dry pulverized soils, strong wind speeds, and poor land management practices such as continuous tillage and over grazing.

According to the woreda agricultural development office annual report, the major causes for soil erosion are the steepness of the land surface, improper land use systems (poor farming practice and expansion of agriculture to sensitive forest and grasslands), poor soil and water conservation practices on farming and eroded lands.

The main soil and water conservation structural measures used on croplands comprise diversion ditches (cut-off drains), retention (infiltration) ditches, terraces and waterways. Supportive cultural measures such as grass or vegetative material for stabilizing the structures are also applied in project area.

5. SOIL CLASSIFICATION

Soil is one of our most natural resources. It is the heart of terrestrial ecology, and understanding of the soil system is key to success and environmental harmony of any human use of the land. To a great degree, the quality of the soil determines the nature of plant eco-systems and the capacity of land to support animal life and society, nature and properties of soil discussed with the general principles of:

- ❑ Classification of soils in terms of diagnostic and characteristics, which to the greatest extent possible is measurable and observable in the field..
- ❑ Selection of diagnostic and characteristics takes into account their relationship with soil forming process.
- ❑ World reference base is used as a guideline to be comprehensive and which enables to accommodate fair classification approach(i.e., it allows precise characterization and classification of individual soil profiles)

The parent material of the Calle project area undifferentiated volcanic unit. Soils of the survey area has been categorized/classified with the individual soil type specific criteria using to differentiate the soils to the lowest possible level. Soil classification was in accordance to FAO and the World Reference Base for soils Resources classification approaches, which are mostly based on recognition of diagnostic horizons, properties, materials, etc.

Soil classification of the project area is based on field morphological characteristics, which can be observed and measured or inferred from field observations. Furthermore, physical and chemical properties such as textural classes, content of calcium carbonate, physiological position, drainage characteristics of that particular soil, soil depth, etc were used to specifically define the soil. The major soils in and distinguished characteristics of the study area is dominated by Pellic Vertisols and Eutric-Cambisol.

5.1 Pellic Vertisols

Dominantly level to nearly level, very deep, moderately well drained, fine textured soils, of flat to almost flat lands found along the bank of the river. This soil is suitable for irrigated and rain fed farming. Most of the area is cultivated. This soil is well suited to most cultivated and vegetable crops considered in this project.

The very low nutrient status, especially phosphorous, and soil acidity are the main limitations to crop growth at present and in the future, keeping tillage to minimum, using cover crops, incorporating crop residues into the soil, plowing at proper soil moisture level, and rooting crops help maintain tilth and increase organic matter content of the soil. As observed this soil responds well to irrigation and is one of the better sites.

Vertisols stand apart from the other two soils by a vertic horizon, with high clay content and intersecting slickensides. Cambisols are associated vertic integrades, which occur in higher landscape position than vertisols, in the surveyed area. The colour differences noted between the Vertisols (as stated above as pellic and chromic type) are often indicative of differences in drainage status. The more reddish hue or stronger chroma of relatively better drained vertisols reflect higher contents of free iron oxides. Hence, this type of soils is observed in the lower elevation of the command area (pit 1&2).



Photo 5-1 Major soil type of the command area

5.2 Eutric Cambisols

Eutric-Cambisols are represent soils which showed minimum degree of soil development characterized by a certain development of their structure or by colors indicating moderately pronounced alteration and development features. Marks of alteration are evidenced by a recognizable soil structure, absence of rock structure, stronger chroma, redder hue or higher clay content with respect to the underlying layer(s). They do not have appreciable quantities of illuviated clay, organic matter, aluminium and/or iron compounds. Cambisols are generally considered as soils conditioned by a limited age, however this is not necessarily the case.

The main characteristic is the presence of a horizon of alteration, which in Cambisols must be seen as a 'minimum B-horizon' with beginning soil formation, a cambic horizon. A cambic horizon can also occur in other major soil groups but there it is not a differentiating characteristic because other properties are given higher priority for example gleyic properties in Gleysols. Many Cambisols are in a transitional stage of development from a young soil to a mature soil. Nonetheless, a cambic horizon can be quite stable, viz. where the environment counteracts pedogenetic change, e.g. by low temperatures or even permafrost, or by low precipitation, or impeded drainage, or highly calcareous or weathering-resistant parent materials, or by a continuous supply of ions to replenish ions lost by leaching, or by a slow but continuous rate of erosion that is in equilibrium with weathering processes.

In practice, a cambic horizon is any section of a soil profile situated between a humus-enriched surface horizon and a relatively unaltered substratum. It has soil structure rather than rock structure and differs from the substrate in color and/or clay content.

On the other hand, it is not well possible to sum up all mineralogical, physical and chemical characteristics of Cambisols in one generalized account because Cambisols occur in such widely differing environments. However, most Cambisols contain at least some weatherable minerals in the silt and sand fractions. They occur in regions with a precipitation surplus but in terrain positions that permit surface discharge of excess water. Cambisols are medium textured and have good structural stability, high porosity, and good water holding capacity and good internal drainage. In most cases Cambisols have a neutral to weakly acid soil reaction, a satisfactory chemical fertility and an active soil fauna. Thus this type of soils is found in the higher elevation of the command area (pit - 3).



Photo5-2 Soil color in the higher elevation of the command area

6. SOIL PHYSICAL AND CHEMICAL CHARACTERISTICS

6.1 Physical Characteristics

Soil physical properties profoundly influence how soils functions in an eco-system and how they can best be manged. The physical properties discussed in this report related to the solid particles of the soil and the manner in which they are agregated. Moreover, the physical or morphological characteristics of the horizons (layers) of a soil profile are visually observed, measured and recorded in the field. These characteristics include: colour, texture, structure, clay skins, consistence, horizon boundaries, roots, pores, etc.

6.1.1 Soil Color

Soil color was measured under dry moist conditions by determining the Hue, Value and Chroma of the soils using Munsell soil color chart. It is the most obvious features of the soils that can be easily identified. It relates to specific chemical, physical and biological properties of the soil. Soil color of the survey area is mainly related to drainage and to lesser extent, to parent material. Therefore, soil color of the command soil is characterized by black, brown and gray-brown for PellicVertisols while for Eutric-Cambisols has brown and gray color was observed.

6.1.2 Soil Depth

The effective soils depth is the depth of the soil that can be effectively exploited by the plant root. It is limited by clay pan, hard pan or by permanent water table. Soil depth is important for evaluation of land for agriculture and land suitability classification. Soil depth of the project area has good soil depth for crop development of crops (0-100cm). Moreover, the command soils for both soil types have dominantly moderately to deep soils characteristics and do not pose any serious constraint in so far as plant rooting depth is concerned.

6.1.3 Texture

The basic property of Pellic Vertisols that endows them with a high moisture-holding capacity is their clay content, which commonly lies between 53 to 75 %, and the texture of the surface soil is lighter and the clay content increases with increasing depth towards the subsoil. In addition, the property of Eutric Cambisols showed slightly clay-loam to clay properties (Table 6-1).

Table 6-1: Soil Texture Class of Command Area

S N	Field Id	Depth (cm)	Coordinate			Particle size distribution percentage			
			X	Y	Z	Sand %	Silt %	Clay %	Soil Class
1	Pit 1	0-35	556074	850069	2123	31	38	31	Clay loam
		35-70				27	38	35	Clay loam
		70-102				31	22	37	Clay loam
		102-200				25	34	41	Clay
2	Pit 2	0-30	557320	849982	2125	27	20	53	Clay
		30-60				25	16	59	Clay
		60-100				21	4	75	Clay
		100-200				21	8	71	Clay
3	Pit 3	0-20	556420	850208	2144	37	32	31	Clay loam
		20-50				21	24	55	Clay
		50-100				21	22	57	Clay
		100-200				21	22	57	Clay

6.1.4 Soil Structure

The soil structure of the top soil for PellicVertisols showed angular blocky and fine to medium structure. Similarly, sub angular and angular blocky structures found in sub soil. In general, soils of such character with medium angular and sub angular blocky structure are suitable for the growth of most crops and these soils are good for irrigated agriculture if soil moisture is properly managed. On the other hand, Eutric-Cambisols has granular sub angular/blocky structure is observed in soil profile.

6.1.5 Consistence

Similar to the above-described morphological properties, soil consistence within horizons and among profiles also showed variability under moist and wet conditions especially for verity soils. In PellicVertisols offer extremes of consistence they are very hard when dry and very sticky and plastic when wet and Extreme hardness when dry and stickiness and loss of traffic ability when wet, permit tillage and seedbed preparation only within a very narrow range of moisture contents. Moreover, Eutric Cambisols has friable to firm, sticky and slightly plastic nature.

6.1.6 Soils drainage

The concept of soil drainage refers to the frequency and duration of periods when the soil is free of saturation, or partial saturation by water. Soil drainage is usually reflected by the colors of soil materials. Most of the drainage of the soils of the survey area falls under moderate drainage class. In addition, Cambisols is characterized by well to moderately drained.

6.1.7 Bulk Density (BD)

Bulk density is determined by the dry weight of 100ml undisturbed core sample taken at field in moist conditions. Due to the relatively higher organic matter content of the surface soils, the bulk densities in the surface soil have lower values than subsurface soils. The overall bulk density values indicate that the soils in the study area are not compact and thus do not restrict root crops development and water movement. The bulk density of the soils in the study area is found between the range of 1.36 and 1.50gm/cm³ and the average value being 1.43gm/cm³. This showed that Ideal bulk densities for plant growth.

6.1.8 Porosity

While bulk density per se is a satisfactory measure of the state of compaction of a soil, knowledge of the soil particle density allows the porosity and void ratio to be calculated; the latter two being of more interest to crop production and consolidation of soils respectively. An adequate supply of soil solution and soil air especially oxygen to plant roots is essential for plant growth. Soil solution and air are stored and transported within the soil pores. Also plant roots exist in the soil pores found out that sandy soils with a total pore space less than 40% are liable to restrict root growth. Accordingly, porosity nature of the project soil was found in between 49% and 53% for clay loam and clay texture respectively.

6.1.9 Infiltration Characteristics

This is the vertical intake of water into a soil, usually at the soil surface. Its measurement forms a vital part of many surveys involving irrigation development or soil conservation, for instance in determining the most efficient method(s) of application of irrigation water, crop water demands and in runoff calculations. It is also an important component of the hydrologic cycle crucial to most hydrologic processes e.g. soil water content, runoff and soil. Knowledge of infiltration process is therefore a prerequisite for efficient soil and water management. Infiltration rate is dependent on many factors among them vegetation, slope, bulk density and initial soil moisture. Infiltration rate is mainly governed by conditions at or near the soil surface. Numerous formulations have been proposed over the years in repeated attempts to express infiltration rate as a function of time or of the total quantity of water infiltrated into the soil. Therefore, the command soil infiltration rate is failed in 0.8 and 0.5 cm/h for clay loam and clay type respectively.

6.1.10 Hydraulic Conductivity

The hydraulic conductivity of a soil is the ability of a soil to conduct water. It defines the volume of water which will pass through unit cross-sectional area of a soil in unit time, given a unit difference in water potential (hydraulic head). It is of considerable importance since it gives an indication of the rate of movement of water to plant roots, the flow of water to drains and wells and the evaporation of water from the soil surface. Comparison made of the hydraulic conductivity rates of different soil horizons gives a guide to water movement and possible drainage problems within soil profiles. The water retention function is primarily dependent upon texture and structure. Storage of water by soils is a result of attractive forces between the solid and liquid phases. The solid (matrix) forces enable the soil to hold water against forces or processes such as gravity, evaporation, uptake by plant roots. Therefore, based on soil laboratory result the project soil was failed in 1.25m/day for clay and 1.35m/day clay loam, which is failed in moderate hydraulic conductivity ratings.

Table 6-2: Hydraulic Conductivity Ratings

Hydraulic conductivity	Rate
< 0.2 m/day	Very slow
0.2 – 0.5 m/day	Slow
0.5 – 1.4 m/day	Moderate
>1.4 m/day	Moderately rapid to rapid

Source: Landon, 1990

6.1.11 Field Capacity (FC)

Field capacity (FC) of a soil is the maximum water content the soil will hold following free drainage. FC is the upper limit of available soil moisture under irrigation. It does not therefore correspond to a fixed soil-water potential, but instead represents the condition of each individual soil after the larger pores have drained freely under gravity. The field capacity of the soils of the study area falls in between of 27 to 35%. The following table shows the field capacity results of the study area versus texture.(Annex 2).

Table 6-3: Field Capacity Results Versus Soil Textures of Study Area

S. N	Soil Texture	Field capacity (%)
1	Clay	35
2	Clay loam	27

6.1.12 Permanent Wilting Point

Permanent wilting point (PWP) is the soil moisture content at which plants can no longer obtain enough moisture to meet evapo-transpiration requirements and remain wilted unless water is added to the soil. In other way round, the permanent wilting point (PWP) is arbitrary defined as the soil moisture content at which the leaves of sunflower plants wilts permanently, i.e. when they do not recover their turgor if subsequently placed in a saturated atmosphere. The permanent wilting point is taken as the lower limit of available water so that water in drier soil is assumed to be not available to plants. The PWP of project area soils has 13 and 17% for clay-loam and clay type respectively.

6.2 Soil Chemical Characteristics

In general, chemical properties of the soil influence the planning of agronomic development activities that are best suited to the proposed irrigation project. As the level of elements measured in soils vary according to laboratory methods and procedures and spectrum of field crops that have different nutrient requirement and toxicity tolerance level, there is no worldwide accepted single criteria used for the interpretation of laboratory results. However, the following summary criteria should be regarded as a general one based on literature in compliance with the applied laboratory methods and procedures. Its main use is to evaluate the natural fertility of soils and to indicate its potential, abundance or otherwise deficiency in the project irrigation area. The chemical soil analysis of the surveyed area was analyzed in Oromia Water Works Design and Supervision Enterprise Soil Laboratory Centre. The laboratory result summarized as follows (Table6-4)

Table 6-4: Summary of Soil Fertility Laboratory Test Result

S N	Fiel d Id	Depth (cm)	pH (H ₂ O)	E.C ds/m	O.M (%)	T.N (%)	Av.P (ppm)	BS (%)	C.E. C (meq /100g)	Exchange bases				Textural
										Mg ⁺⁺	Ca ⁺⁺	Na ⁺	K ⁺	
1	Pit 1	0-35	7.2	0.139	2.13	0.11	0.04	89	51.9	9.39	35.68	0.12	0.82	Clay loam
		35-70	7.1	0.109	3.29	0.15	0.98	82	51.7	8.99	34.45	0.11	0.39	Clay loam
		70-102	7.1	0.119	2.1	0.10	1.22	88	52.7	9.38	36.58	0.16	0.29	Clay loam
		102-200	7.0	0.117	2.47	0.14	0.00	87	55.2	9.66	37.76	0.28	0.35	Clay
2	Pit 2	0-30	7.7	0.254	2.41	0.11	1.32	91	73.7	5.83	59.85	0.06	1.33	Clay
		30-60	7.8	0.298	2.21	0.11	0.05	94	74.1	8.03	60.81	0.15	0.49	Clay
		60-100	7.9	0.328	1.89	0.10	0.03	97	71.5	10.8	57.27	0.60	0.44	Clay
		100-200	7.9	0.331	1.08	0.05	0.01	97	66.2	10.7	51.97	0.87	0.50	Clay
3	Pit 3	0-20	7.7	0.203	2.19	0.11	2.00	73	53.6	9.05	28.29	0.06	1.51	Clay loam
		20-50	7.1	0.152	2.03	0.13	4.26	73	57.0	8.63	31.04	0.17	1.55	Clay
		50-100	7.5	0.191	1.71	0.09	0.02	77	60.4	9.33	34.76	0.27	1.95	Clay
		100-200	7.8	0.207	1.61	0.08	1.76	78	53.6	9.93	37.39	0.43	2.11	Clay

Hence, based on the collected results from the laboratory analysis, both the upper and the lower soils horizons are identified as follows.

6.2.1 Soil Reaction pH

The soils pH of the study area recorded 7.2 to 7.7 pH values on the top soils (i.e., 0 to 35 cm soil depth), which falls within moderately alkaline and 7.1 to 7.8 in the sub soil (i.e., 35-70 soil depth) rated as topsoil. It should be noted that When the pH level is found in between 7 and 8.5 the availability of phosphorous and micronutrients with the exception of Mb. Therefore, proper attention should be given based on the crop to be grown and application of natural and artificial fertilizer is essential.

6.2.2 Electrical Conductivity (E.C)

This is a measure of the total soluble salt concentration in the soil solution. A high degree of correlation exists between the EC and osmotic pressure of soil-water extract. If its amount is greater than 4ds/m, the soil is to be saline and difficult for crop production. Therefore, the laboratory results confirmed that the E.C values for topsoil recorded 0.13 to 0.2ds/m (i.e., 0 to 35 cm soil depth) and 0.1 to 0.2ds/m in the sub soil (i.e., 35-70 soil depth). Thus, the soil of the command area is none saline and optimum for all crops growth.

6.2.3 Organic Matter (OM)

According to the analytical data the percent organic carbon ranges in the top soil between 2.1 to 2.4 (rated as medium range) and from 2.0 to 3.29 percent for the sub-soils (rated as medium to high). Hence to maintain the organic matter content of the soil, regular application of crop residues and manure is recommended.

6.2.4 Total nitrogen (T.N %)

The laboratory analyses data show that the range of total nitrogen in the top soil is from 0.11 to 0.13 percent, low to high. For the sub soils, the range is from 0 to 0.13 percent which is found in low to high category. In general proper soil management, follow-up and regular application of nitrogenous fertilizer may be required based on crops to be grown.

6.2.5 Available phosphorus (Av.P)

The amount of available phosphorus in the command area soil showed 0.11mg/Kg on topsoil and 0.1 to 0.15mg/kg which is found in low category. Thus fertilizer response is most likely. A large buildup of available nutrient is needed. Starters and banding will improve the efficiency of the fertilizer used.

6.2.6 Base saturation (BS %)

Base saturation is calculated as the sum of exchangeable bases divided by the CEC of the soil. In most cases the percentage of a base saturation is greater than 80, which indicates that exchange capacity is saturated by bases, while very rare in the exchangeable capacity is hydrogen and aluminium elements. The base saturation present for all the samples ranges between 73 to 91 percent for top and 73 to 94 percent for sub-soils. Although, the fertility levels corresponding to these base saturation values are rated high for both type of command area soils.

6.2.7 Cation exchange capacity (C.E.C)

The C.E.C of the project soil is recorded 51.9 to 73.7 meq/100g on the top soils (i.e., 0 to 35 cm soil depth), and 51.7 to 74.1 meq/100g in the sub soil (i.e., 35-70 soil depth which is failed within the range very high category. Thus these soils are good for agriculture.

6.2.8 Exchangeable magnesium (Mg⁺⁺)

Laboratory results indicated that exchangeable magnesium was recorded 5.83 to 9.39 and 8.0 to 8.99 meq/100g) on top and sub soils respectively i.e found within in high to very high category.

6.2.9 Exchangeable calcium (Ca⁺⁺)

The overall content of exchangeable calcium of the command area soils are found 28.25 to 59.85 on top soil and 31 to 60 meq/100g values on sub soils which is found within the range of very high category. This shows that the soil status is found to be good with the proportion of the rest cations is applied in the soil

6.2.10 Exchangeable sodium (Na⁺)

The content of exchangeable sodium of the study area recorded the values of 0.06 to 0.12 on top soil and 0.11 to 0.17 meq/100g on sub soils which is found within range of low category.

6.2.11 Exchangeable potassium (K⁺)

The content of exchangeable potassium of the study area recorded the values of 0.82 to 1.51 on top soil and 0.39 to 1.55 meq/100g on sub soils which is found within range of high to very high. Therefore, these indicate that a response to K fertilizer application is highly unlikely.

6.3 Soil Fertility Result Evaluation on Upper and Lower Horizons

The chemical features of the sampled results are evaluated for both, upper and lower horizons of the selected pits within the command area. The rates are evaluated as very low, low, normal, high and very high as specified in the following (Table6-5).

Table 6-5: Evaluation summary on upper and lower horizons of samplesoils

SN	Properties	Rates achieved									
		Very low		Low/moderate		Normal to medium		High		Very high	
		H1	H2	H1	H2	H1	H2	H1	H2	H1	H2
1	pH	x	x								
2	E.C	x	x								
3	O.M			x	x						
4	T.N									x	x
5	Av.P	x	x								
6	C.E.C									x	x
7	Ex.bas.										
	Mg ⁺⁺									x	x
	Ca ⁺⁺									x	x
	K ⁺				x			x			
	Na ⁺			x	x						

The above Table 6-5 shows the trend of increasing or decreasing of the evaluated parameters through the soil profiles. (H1) indicates upper horizon and (H2) indicates the lower soil profile or soil horizons. Thus, as it is shown in the above Table 6-5, the upper horizons/profiles are relatively better for crop production.

7. Description of Soil Mapping Units

Soils are natural bodies on the earth surface and occur on different types of landforms. They are not discrete bodies, but continuous entities, which merge into each other across the terrain. Therefore, soils form an integral part of the SOTER unit. To map and classify the soil units of the command area division of the major landforms has been made at 2 units of generalization. The structure of the division shows their inter-relationships as well as the characteristics by which they differ. On this basis homogenous terrain units are distinguished at each level of generalization. A particular combination of land form and lithology can be then hierarchically further sub-divided and delineated on the basis of soil characteristics. Lithology gives the petrographic nature of hard rock or origin of soft cover formations from which the soils have been developed.

In distinguishing criteria for mapping units balanced approach is set to maintain detailed information, that can be identified as soil mapping units and be mapped with an acceptable degree of accuracy that the project requires. A soil inventory is required before a land classifier can rate land as to its suitability for irrigation. This soil information may be obtained from an existing soil survey map or by performing a soil survey. Soil map units the command area can be described as follows:

7.1 Soil Map Unit-1

Observation Number	(Pit-1 & 2)
Total Area	116 ha
Soil Classification (FAO):	Pellic-Vertisol
Parent Material:	Piedmont alluvium derived from basic volcanic rocks.
· Elevation:	2123 and 2125 masl
· Slope:	2-4 %
· Land use/vegetation:	Fallow, dry-farmed sorghum
· Climate:	Sub humid warm tropical
· Moisture Condition:	Moist throughout
· Groundwater Level	None
· Runoff:	None
· Drainage Class:	Imperfect
· Permeability:	Very slow
· Internal Drainage:	Very slow

- Flooding: None
- Rockiness: None
- Stoniness: None
- Erosion: Slight Sheet
- Surface Cracking: 80 cm deep

Soil Profile Description:

0-35/0-30cm; Very dark gray (10YR3/1)(moist) clay-loam; extremely hard (dry), extremely firm (moist), sticky, and plastic (wet); strong medium and coarse angular blocky structure; many fine tubular pores; 2-5% slightly rounded basalt gravel and stones; many medium and coarse roots; non calcareous; pH= 7.2/7.7.; clear and smooth on:

35-70/30-60cm; Black (2.5Y2/0)(moist) clay-loam; extremely firm (moist), sticky and plastic (wet); strong coarse and very coarse angular blocky structure; few very fine tubular pores; 2-5% slightly rounded basalt gravel and stones; few very fine and fine roots; common moderately developed non intersecting slickenside; non calcareous; pH=7.1/7.8; gradual and wavy on:

102-102/60-100cm; Very dark gray (10YR3/1)(moist) clay-loam; (moist) ; moderate to strong medium angular blocky structure; few fine tubular pores; 2-54 slightly rounded basalt gravel; no roots; many moderately developed intersecting slickensides; slightly calcareous and few lime mycelia; pH= 7.1/7.9 and EC=0.11/0.3ds/m; diffuse and irregular on:

102-200/100-200cm; Very dark grayish brown (10YR3/2-3)(moist) clay; friable (moist); moderate medium angular blocky structure; very few tubular pores; 2-57. Slightly rounded basalt gravel; calcareous and few lime mycelia; pH= 7.1/7.9 and EC=0.11/0.3 ds/ m.

7.2 Soil Map Unit-2

Observation Number:	(Pit-3)
Total Area	29 ha
Soil Classification (FAO):	Eutric Cambisol
Parent Material:	Alluvium derived from basic volcanic rocks
· Elevation:	2144 m asl
· Slope:	5 %
· Land use/vegetation:	Dry-farmed sorghum and maize
· Climate:	Sub humid warm tropical
· Moisture Condition:	Slightly moist throughout
· Groundwater Level	None
· Runoff:	Medium
· Drainage Class:	Mod. well,
· Permeability:	Slow
· Flooding:	None
· Internal Drainage:	Medium
· Rockiness:	None
· Stoniness:	3-15 %
· Erosion:	Moderate sheet
· Surface Cracking:	None

Soil Profile Description:

0-20cm; Very dark grayish brown (10YR3/2)(moist) clay-loam and dark grayish brown (10YR4/2)(dry) loam; hard (dry), non sticky and non plastic (wet); moderate coarse sub angular blocky and crumb structure, partly massive; many very fine to medium tubular pores; 2-57. Slightly rounded basalt gravel; many very fine to medium roots; non calcareous; pH=7.7 and EC=0.2 ds/m; ; abrupt and smooth on:

20-50cm; Very dark grayish brown (10YR3/2)(moist) clay friable (moist); moderate coarse sub angular blocky structure; many very fine and fine tubular pores; 2-5% slightly rounded basalt gravel; many very fine roots; non calcareous; pH=7.1 and EC=0.1 ds/ m; diffuse and smooth on:

50-100cm; Very dark grayish brown (10YR3/2)(moist) loam; friable (moist); moderate medium and coarse sub angular (blocky structure; many very fine and fine tubular pores; 2-5% slightly rounded basalt gravel; few very fine roots; non calcareous; pH=7.1 and EC=0.11 ds/ m; clear and smooth on:

102-200cm, Grayish brown (10YR3/2)(moist) clay containing slightly rounded basalt gravel and stones.

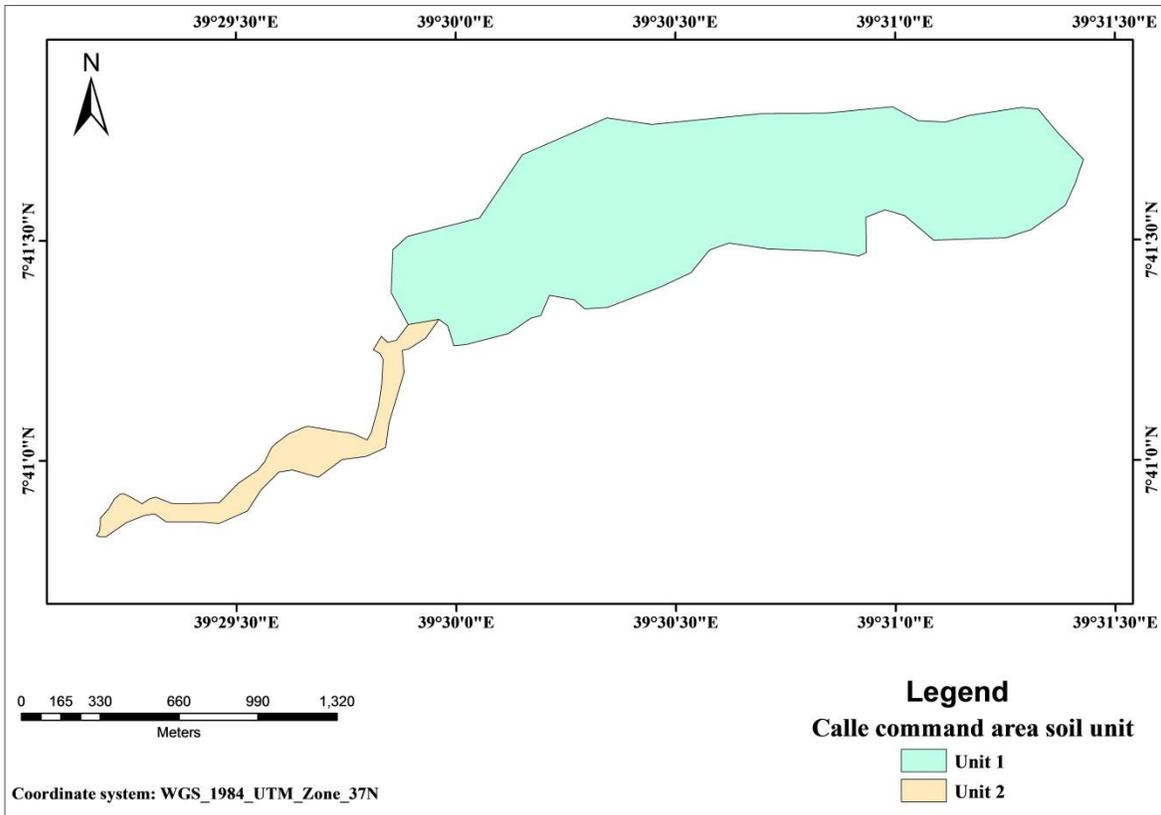


Figure 7-1 Soil units map of the command area

8. LAND EVALUATION

A fuller use of land and water resources by the development of irrigation facilities could lead to substantial increases in food production in many parts of the world. The process whereby the suitability of land for specific uses such as irrigated agriculture is assessed is called land evaluation. Land evaluation provides information and recommendations for deciding 'Which crops to grow where' and related questions. Land evaluation is the selection of suitable land, and suitable cropping, irrigation and management alternatives that are physically and financially practicable and economically viable. The main product of land evaluation investigations is a land classification that indicates the suitability of various kinds of land for specific land uses, usually depicted on maps with accompanying reports.

The land evaluation study has been conducted based on the FAO Framework for land evaluation scheme. The methodology outlined in the FAO Soil Bulletin No.55, Guideline for Land Evaluation for Irrigated Agriculture (FAO, 1985) and Soil Bulletin No 32, A Framework for Land Evaluation has been followed.

The land suitability of a land unit for irrigated agriculture based on the different Land Utilization Type (LUTs) considered are determined by comparing the land use requirements for surface and/or overhead irrigated agricultural development with the land qualities and/or characteristics (actual environmental conditions) of the land unit. The values of each land quality/characteristic are checked against the class limits of land use requirements for irrigated agricultural development (for each LUTs separately). Thus suitability assessments of the land unit are made for each land use requirements separately.

The overall suitability of the land unit are then determined on the basis of the suitability ratings, referred to as partial suitability of the individual land use requirements for the LUTs under consideration separately. The most commonly used method is to assign the suitability class according to the suitability rating of the most limiting condition. For instance, a land unit, which is moderately suitable (S2m) for the production of the LUTs in terms of moisture availability (m), and marginally suitable (S3r) in terms of soil depth (r), is classified as marginally suitable (S3r).

8.1 Land Suitability Classes

Land suitability is a measure of how well the qualities and/or characteristics of a land unit match with the requirements of a particular form of LUTs. The suitability of the land for specific use has been defined by rating the land qualities of land units, which are relevant to specific land utilization types

The suitability of land for irrigated agriculture has been determined by rating land quality of each soil-mapping unit, which is relevant to the land utilization type. In this way the limitation of each land unit has been identified for the land use under consideration.

The FAO Framework encompasses the following four levels of land suitability classes. At highest level there are two suitability orders, Suitable (S) and Not Suitable (N). **Suitable** land is land on which sustained use of the kind under consideration is expected to yield benefits, which "justify the inputs and development costs, without unacceptable risk of damage to land resources. **Not Suitable** indicates that the land has qualities that appear to preclude sustained use of the kind under consideration. At second level the suitability orders are divided into three classes. These are: Class S1, Highly Suitable; Class-S2, Moderately Suitable; Class-S3, Marginally Suitable; Class-N1, Marginally Not Suitable; and class N2, Permanently Not Suitable. Table 7-1 gives the definition and application of these classes Table 7-2.

Table 8-1: Land suitability classification levels

Order	Class	Name	Definition
S		Suitable	The land can support the land use. Benefits justify inputs without unacceptable risk of damage to land resources.
	S1	Highly Suitable	Land without significant limitations. The potential yield level expected is 85% or more of optimum yield.
	S2	Moderately Suitable	Land having limitations that either reduce productivity or increase the inputs needed to sustain productivity levels compared with those needed on S1 land. The potential yield level expected is 60-85% of the optimum yield.
	S3	Marginally suitable	Land with limitations so severe that benefits are seriously reduced and/or the inputs required to sustain productivity are such that this cost is only marginally justified. The potential yield level expected is 40-60% of the unsuitable optimum yield.
N		Unsuitable	Land that cannot support the land use sustainable, or land on which benefits do not justify inputs
	N1	Currently unsuitable	Land with limitations to sustained use that cannot be overcome at currently acceptable cost
	N2	Permanently unsuitable	Land with limitations to sustained use that cannot be overcome

This type of land suitability classification levels represents those used by the FAO but some modifications and updating have been made by different authors based on research results on some definition about yield level, factor ratings, etc based on, however, on FAO system.

8.2 Land suitability limitations sub-classes

At third level there are a number of classes which reflect the kind of limitations that restrict the suitability of land for specific land use. Sub-classes reflecting a requirement or limitation are denoted by a letter suffix, these are s, t or d indicating a soil, topographic or drainage deficiency respectively. The sub-class codes are defined specifically for the six LUTs under consideration based on surface and overhead systems of irrigated agricultural development with medium to high input level. Table 7-2 gives the definitions and applications of these sub-classes

Table 8-2: Land Suitability Limitations for Sub-Classes

Sub-Class	Description
C	Climate (Temperature regime): Land units having either very low or very high temperatures below or above the critical temperatures, which may cease the plant growth and may have adverse effect on rate of plant growth, depending on the type of plants and varieties to be grown. Thus adaptable crops should be carefully selected for evaluation.
M	Moisture availability: Land units having soil moisture deficiencies, there is a need for an increased amount and frequency of irrigation and/or selection of draught-resistant crop varieties. Overhead irrigation may be more cost effective.
D	Oxygen availability: Land units having soil drainage deficiencies, ascribed to poor soil drainage that may be due to high ground water table, flooding, slow infiltration, slow permeability, slow surface drainage (low physiographic position) or some combination of these. Sub-soiling, diversion ditches and under drainage may be required. Selection of more tolerant crops like rice can be another solution.
N	Nutrient retention: Land units having poor capacity of soil to retain added nutrients as against loses caused by leaching, ascribed to low CEC, and these by organic matter. Thus, additional input is required to conserve organic matter and improve soil structure and require fertilizer application.
Z	Nutrient availability: Land having poor capacity to supply crop with nutrients, ascribed to pH, nutrient availability is 7.0 to 7.9 which is moderately alkaline by fixation.
R	Rooting condition: Land units with limited effective soil depth (effective depth is a depth to a limiting horizon having high amount of gravels, hard pan or toxic layers) and restrictive root penetration having massive, columnar or coarse sized structure coupled with very firm consistence and high amount of stones or gravels. Land having restrictive effective soil depth and/or penetrability, which impairs germination and hinders mechanical cultivation.
W	Workability: Land units with poor workability, ascribed to massive clays, poor organic matter content, very firm consistence and occurrence of high amount of stones and gravels in the surface layers.
K	Potential for mechanization: Land units having unfavorable slope steepness, rock hindrances, presence of large amount of surface stones and plastic heavy clays, which affects mechanized agricultural operations by any kind of implements.
T	Land preparation and clearance: Land having topographic limitations ascribed to unfavorable slope angel, micro-relief coupled with excess rock out crops and denser vegetation covers, which needs a higher initial land development cost, requiring land leveling (or short channel lengths and drop structures), grading, terracing, clearances of rock hindrances and vegetation clearances
E	Erosion hazard: Land having an increased water erosion risk under irrigation. Conservation practices and surface drainage control are required.

9. CONCLUSIONS AND RECOMMENDATIONS

- ❑ The soil of the command area is well drained and has got good moisture retention capacity, moderately deep to very deep effective soil depth which is suitable for most of the crop varieties and fertilizer requirements need to be reworked through research based experiments.
- ❑ The EC and cation and anion value has no indication of inducing salinity and sodicity problem to develop the land for irrigated agriculture. PH of soil is recorded somewhat moderately alkaline. If the pH level is found between the range of 7 to 8.5 the availability of phosphorous and boron decreases and deficiency of other micro-nutrients may be liable. However, the only limiting factors on both soil units are low values of phosphorous availability. Even though phosphorous availability is found in the lower limit of the normal range and this also require frequent utilization of compost, mulching and farm yard manures.
- ❑ A total area of 145 ha is gross commendable by gravity irrigation within the study area, assuming that the river diversion weir will be built at the planned weir site. Out of these 145 ha, a total area of 87.55 ha is classified as highly suitable (S1) when drainage or slopes are not limiting factors and an area of 15.45 ha is classified as moderately suitable for irrigation development (S2). In total 42 ha are classified as currently unsuitable for irrigation development (N1).
- ❑ A total area of 87.55 ha is classified as highly suitable for irrigation development. This area includes the low lying alluvial lands along the Challe river (land units 1&2). These lands are highly suitable for irrigation development under the assumption that investments will be carried out:
- ❑ Topsoil amelioration and bunding will be carried out wherever necessary. Crops which rate as highly suitable under irrigated conditions are: maize, onion, carrot and potato.
- ❑ The land and soils of this unit pose almost no limitations to irrigated agriculture, if the above mentioned land improvements are carried out. Only crops which are sensitive to water stress may suffer limited yield decline.

- Presently, an area of about 42 ha from the grosscommand area, characterized by gully, stony, steep slope etc... This is judged to be under-utilization of the land. It is recommended to give opportunities to move in to grazing activities to land with a lower suitability for irrigation development.
- A total area of 15.45 ha is classified as moderately suitable for irrigation development. This area includes part of the higher piedmont slopes (land units 2). These lands are moderately suitable for irrigation development under the assumption, that wherever necessary' topsoil amelioration will be effectuated and (minor) flood protection works will be constructed.
- A total area of 42 ha is classified as marginally suitable for irrigation development. This area includes part of the higher piedmont slopes (land unit 2). Limitations to crop performance are severe and of several types: steep slope, erosion problems and others deficiencies for certain crops. Continuation of rain fed agriculture may prove to be a more feasible option than irrigated agriculture.
- In the present study it is assumed that irrigation water is not a limiting factor, both in a quantitative and a qualitative sense. No barriers seem to exist for the construction of primary irrigation channels. Basic soil infiltration rates, estimated soil perm abilities and available soil water holding capacities are suitable for irrigation development. Furrow irrigation is recommended as irrigation application technique.
- It is possible that triple cropping under irrigation and rain fed agriculture that will be practiced and also adequate crop rotations will be adopted. Fertilizers, pesticides etc. are assumed to be available. The three growing seasons cover the following periods of the Year
 - From mid February to mid-May belg
 - From mid June to end of October mehir
 - From Novemberto mid- February irrigation

The rainfall distribution is such that in many years supplementary irrigation at the end of growing periods or between two short growing periods will be sufficient to create two growing seasons per year of adequate length.

- ❑ One other land improvement, i.e. the construction of drainage system in Vertisols (units 1), is assumed to be part of the irrigation and drainage package. Without a drainage system, the land suitability of the best land will be reduced due to the buildup of water logging problems.
- ❑ There is one, possibly overruling, constraint to irrigation development which must be considered carefully. The Challe river is a river which carries a large sediment load from the catchment during peak flows. The rate at which a weir and other structures would lose efficiency by filling up with sediments is high. Careful study of water shade management plan is strongly recommended. Hence, the simple (and in the light of the a band application of suitable soil and water conservation activities make the argumentation possibly and realistic assumption is made, that irrigation water can be commanded from the diversion weir without limitation

Annex 1: CalleSoil Laboratory Test Result

	Company Name: OROMIA WATER WORKS DESIGN AND SUPERVISION ENTERPRISE						Doc. No.: DSESWL /133 & 138/10		
	Doc. Title: Soil Analysis Laboratory Result						Page No.: 3 of 4		
Name of Customer : BBG Engineering PLC									
Project : Calle Small Scale irrigation				Location - Shirka Woreda, Arsi Zone, Oromia Region					
LAB NO	Field Code	Depth Cm	p ^H -Water 1:2.5	E.C ds/m	M.Content %	Particle Size Distribution			TEXTURAL CLASS
						Sand %	SILT %	CLAY %	
1841 /18	Pit - 1	0-35	7.2	0.139		31	38	31	Clay loam
1842 /18		35-70	7.1	0.109		27	38	35	Clay loam
1843 /18		70-102	7.1	0.119		31	32	37	Clay loam
1844 /18	Pit - 2	102-200	7.0	0.117		25	34	41	clay
1845 /18		0-30	7.7	0.254		27	20	53	clay
1846 /18		30-60	7.8	0.298		25	16	59	clay
1847 /18	Pit - 3	60-100	7.9	0.328		21	4	75	clay
1848 /18		100-200	7.9	0.331		21	8	71	clay
1849 /18		0-20	7.7	0.203		37	32	31	Clay loam
1850 /18		20-50	7.1	0.152		21	24	55	clay
1851 /18		50-100	7.5	0.191		21	22	57	clay
1852 /18		100-200	7.8	0.287		21	22	57	clay
LAB NO	Na	K	Ca	Mg	SUM	CEC	BS	EX. Acidity	Ex. Al ³⁺
	Cmol(+)Kg ⁻¹						%	Cmol(+)Kg-1	
1841 /18	0.12	0.82	35.68	9.39	46.01	51.9	89		
1842 /18	0.11	0.39	34.45	8.99	43.94	53.7	82		
1843 /18	0.16	0.29	36.58	9.38	46.41	52.7	88		
1844 /18	0.28	0.35	37.76	9.66	48.05	55.2	87		
1845 /18	0.06	1.33	59.85	5.83	67.07	73.7	91		
1846 /18	0.16	0.49	60.81	8.03	69.48	74.1	94		
1847 /18	0.60	0.44	57.27	10.85	69.16	71.5	97		
1848 /18	0.87	0.50	51.97	10.71	64.05	66.2	97		
1849 /18	0.06	1.51	28.29	9.05	38.90	53.6	73		
1850 /18	0.17	1.55	31.04	8.63	41.39	57.0	73		
1851 /18	0.27	1.95	34.76	9.33	46.31	60.4	77		
1852 /18	0.43	2.11	37.39	9.93	49.86	63.6	78		
LAB NO	T.N	O.C	O.M	C/N	Av.K	Av.P	P ₂ O ₅	F.C	P.W.P
	%					PPM	PPM	%	
1841 /18	0.11	1.24	2.13	11		0.04	0.09		
1842 /18	0.15	1.91	3.29	13		0.98	2.24		
1843 /18	0.10	1.22	2.10	12		1.22	2.79		
1844 /18	0.14	1.43	2.47	10		0.00	0.00		
1845 /18	0.11	1.40	2.41	13		1.32	3.02		
1846 /18	0.11	1.28	2.21	12		0.05	0.11		
1847 /18	0.10	1.10	1.89	11		0.03	0.07		
1848 /18	0.05	0.63	1.08	13		0.01	0.02		
1849 /18	0.11	1.27	2.19	12		2.00	4.58		
1850 /18	0.13	1.18	2.03	9		4.26	9.76		
1851 /18	0.09	0.99	1.71	11		0.02	0.05		
1852 /18	0.08	0.94	1.61	12		1.76	4.03		
Remark _____									
Checked By <u>Fikru Asrat</u> Signature <u>[Signature]</u> Date <u>24/07/18</u>									
Approved By <u>Hassen Ahmed Mune</u> Signature <u>[Signature]</u> Date <u>24/07/18</u> Laboratory Service Process Manager									
									
Tel: +251 11 439 4863/ 2162/ 2470 Fax: +251 11 439 2020 P.O.Box: 870/1250									

Annex 2: Representative Physical Properties of Soil

Soil Texture	Infiltration 1/and Permeability cm/hpf	Total pore space% N	Apparent specific gravity γ_s	Field capacity %FC	Permanent Wilting %PWP	Total Available Moisture		
						Weight% $P_w = FC - P_w$	Volume $P_v = P_w \gamma_s$	cm/m $d = P_w / 100 \gamma_s$
Sand	5 (2.5-25)	38(32-42)	1.65(1.551.80)	9 (6-12)	4 (2-6)	5 (4-6)	8 (6-10)	8 (6-10)
Sandy-loam	2.5 (1.3-7.6)	43(40-47)	1.50(1.401.60)	14 (10-18)	6 (4-8)	8 (6-10)	12 (9-15)	12 (9-15)
Loam	1.3 (0.8-2.0)	47(43-49)	1.4(1.5-1.50)	22 (18-26)	10 (8-12)	12 (10-14)	17 (14-20)	17 (14-20)
Clay-loam	0.8 (0.25-1.5)	49(47-51)	1.35(1.301.40)	27 (23-31)	13 (11-15)	14 (12-16)	19 (16-22)	19 (16-22)
Silty-clay	0.25 (0.03-0.5)	51(49-53)	1.3(1.30-1.40)	31 (27-35)	15 (13-17)	16 (14-18)	21 (18-23)	21 (18-23)
Clay	0.5 (0.01-1.0)	53(51-55)	1.25(1.201.20)	35 (31-39)	17 (15-19)	18 (16-20)	23 (20-25)	23 (20-25)

Note: - Normal ranges are shown in parentheses.

Source: - Israelson and Hanson (1962), publishers J. Wiley and Sons, New York.

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