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ABBREVIATIONS AND ACRONYMS

DEM	Digital Elevation Model
ECe	Electrical Conductivity
AAS	Atomic Absorption Spectrophotometer
FAO	Food and Agriculture Organization
GIS	Geographical Information System
GPS	Geographic Positioning System
ha	Hectare
masl	Meters above Sea Level
OC	Organic Carbon
OM	Organic Matter
IR	Infiltration Rate
SMU	Soil Mapping Unit
TN	Total Nitrogen
WRB	World Reference Base for Soil Resources
Na	Sodium
Ca	Calcium
K	Potassium
ESP	Exchangeable sodium Percentage
SSIP	Small Scale Irrigation Project
Mg	Magnesium
Al	Aluminum
LUT	Land utilization type
LUR	Land use requirements
LC	Land Characteristics
LQ	Land Qualities

SUMMARY

The soil Survey of the Worbate Small Scale irrigation Project (Worbate SSIP) conducted at feasibility level to use the information obtained as a basis for confirming/rejecting the irrigation potential, crop selections, irrigation designs and agricultural input requirements.Field auger observation, profile description and soil sampling for laboratory analysis (Both Physical and Chemical Properties), field setting of infiltration rate and hydraulic conductivity were conducted on representative sites.

On the basis of soil chemical characteristics (CEC, Ph, BS% .etc) and soil physical characteristics (depth, slope, soil texture and soil type) characteristics a total of 14 soil mapping units (SMU) were identified. On the basis of profile morphology and development, and nature of the soil material and profile phisical and chemical properites the soils of the study area are identified as Cambisols, Lexisol and, Leptosol.

The targeted project *has* **230.99** ha of Gross area, and Net Irrigable area is **204 ha**. Water Harvesting is the source to irrigate the area by canal using gravity. The proposed crops that can be cultivated by using surface irrigation are 5 (Low land Maize, Low Land Sorghum, Haricot bean, Tomato, Onion,) Crops. The results of the suitability evaluation of the project area for surface irrigation, indicates that Total area of **89.73**.ha of land is found to be (S2) Moderatly suitable for surface irrigation. An area amounting to **123.12 ha** is found to be (S3) marginally suitable for surface irrigation development. And **18.13ha** is not suitable for surface irigation(N) The areas identified as moderately and marginally suitable for surface irrigation are constrained by slope.depth, texture and chemical reaction (Ph) and nutrient availability (Avp and organic matter).

The result indicated that some, 11.55 moderatly Suitable(S2) ,201.30 ha (S3) marginally suitable for Maize cultivation by surface irrigation.For Sorghum Some 11.55ha is Highly suitabile Some 78.18 ha Moderatly Suitable(S2) and 138.71 ha Marginally suitable (S3) Olso for Haricot bean some 12.30 ha of land is moderately suitable(S2), 216.14 ha marginally suitable (S3) respectively. For Tomato Some 11.55ha Higly suitable and 216.9 marginaly suitable (S3),for Onion,some 11.55 ha is Highly Suitable,Some 122.17 moderatly suitable (S2), and some 94.72 ha marginaly suitable. The major limitations that downgraded the suitability level of the area to marginally subclass are Slope, Texture, Depth and Soil Chemical Reaction in the study area.

Olso have low nutrient availability like organic matter availabile phosphorus (Av.p) are correctable constrients

Worbate irrigation soil survey report is presented in one volume that includes maps and information as:-Physical environment;Method of investigation and activities carried out;Result of the soil survey and analysis of soils in the study area Description of the identified soil mapping unit; and relevant appendixes are included A total of observations (74 augers and 4 Profile pits) were describes for the study area. The detail level soil survey study enabled the identification of 14.soil mapping units (SMU). It is hoped the information provided in this report helps in assembling and using data for the area of landsuitability map.

To undertake theLand Evaluation, land utilization types (LUT) for surface irrigation methods were identified first. Accordingly, a total of nine LUTs for surface irrigation methods were therefore identified. These LUTs include banana, cabbage, haricot bean, Lowland maize, onion, Sorghum, tomato, pepper, mango and papaya production for surface irrigation, For these LUT land use requirements (LURs) were then geared up. These land use requirements were carried out basing some critical land characteristics that strongly have an effect on the growth and development of crops. These are atmospheric temperature, slope, flooding, soil texture, soil depth, ECe, ESP, SAR, pH, Caco3, OCand CEC of the soil.

1. INTRODUCTION

1.1 Back Ground

The soil survey and land evaluation of the Worbate Small Scale Irrigation Project conducted at feasibility level to assess in detail the physical and chemical characteristics of the soils in the project area and to evaluate the suitability of the area for surface irrigation and crop types.The project area is located in the Oromia Region,Borena zone Gommole District. Residentes are dominantly pastoralists With food security Problem with Livestock production (Cattle, Camels, GoatsandSheep) This report presents the results of detailed, soil survey carried out at feasibility level and the land evaluation exercise for the suitability of surface irrigation and selected crop types. The project area has food security problem

1.2. General Objective

The main objective of the soil survey is to provide detail information on land and soils of the study area (Worbate SSIP) at feasibility level which may form as a basis for confirming/rejecting the irrigation potential (all or part of area), crop selections, irrigation designs, and agricultural input requirements such as fertilizer applications etc. suitability for irrigation. The study also focuses on identifying the various topographic forms, soil types, present land use assessment and evaluating the existing land use pattern and serve as a basis for assessment of land and crop

1.3 Specific objective

- To determine the distribution of different soil types over the project area
- To provide basic soil data to facilitate irrigation design work to be carried out in the project area.
- To offer detailed soil information of the command area as a ground for ratifying or rejecting the soils potential for surface irrigated agriculture.
- Produce soils and land suitability maps at scale of 1:10,000.

1.4 Structure of the Report

The results of the study is presented by standard narrative approaches, which include soil distribution and land suitability classification and other relevant information.

The report covers:

- Phyical environment ,
- Method of investigations and activities carried out,
- Result of the soil survey and analysis of soils present in the study area,
- Soil mapping units/soil management , etc.
- Land evaluation

And relevant appendix are included as follows:

- Appendix A: Soil physical and chemical analytical data for representative soilprofiles
- Appendix B: typical profile pits explanation for each representative soil type,
- Appendix C: in situ soil physical test results for representative soil type

To make the report clear and readable the report on land suitability part is prepare in a separate volume as Part II.

2. THE PHYSICAL ENVIRONMENT OF THE AREA

2.1. Location and Accessibility

The study area, Worbate Small Scaleirrigation project, is Located in the Oromia Regional State, Borena Zone Gommole wereda. Irrigation to be used from woerbate. More precisely it falls in between 553393 to556074 UTM N and 436630 to 439395 UTM E. The targeted area of the project is 230.99 ha. The altitude of the area ranges from 1428-1472 masl. The project area is acceceble via Finfinee-Yaaballo-asphalt road, 500km south East and 30km Dray weather Road to Worbate

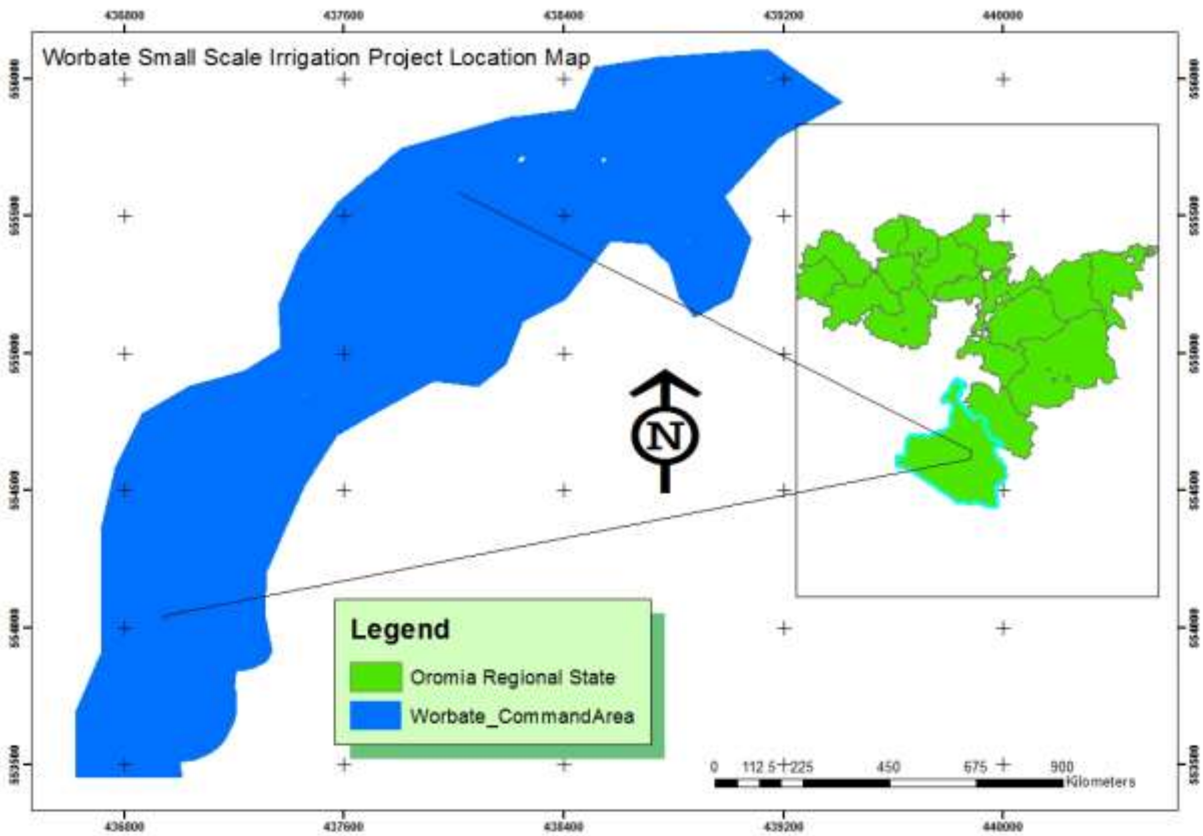


Figure: 1Location Map of Worbate Small scale irrigation project

2.2. Climate

Temperature is one of the dominant climatic elements, which determines the distribution of vegetation, soil and farming system of a certain area. The temperature is inversely related to the altitude in most cases.

The mean maximum temperature in the area is recorded in the month of February (29.28 ^{o}C) and the highest mean minimum is recorded in the month of April (15.91 ^{o}C). The mean maximum temperature ranges between 23.90 ^{0}c (July) and 29.28 ^{0}c (February) and the mean minimum ranges from 12.67 ^{0}c (December) to 15.91 ^{0}c (April).

Generally, the temperature of the study area is suitable for agricultural crops proposed for irrigated agriculture.

.2.3. Rainfall

The rainfall pattern of the study area is bimodal. The total annual rainfall of the study area is about 811.4 mm. The rainfall distribution and amounts vary from year to year. The moist months of the project area are mid March to end March and mid September to end October and the dry months are from end October to mid beginning March and end May to mid September

2.4Physiograpy and Geology

The geology of the study area is mainly composed of *Based on the present study, the project area is found being characterised by alluvial soil overburden deposits of considerable thickness and the basement metamorphosed rock / GRANITE units*

Alluvial deposits

The deposit is found overlaying the volcanic rock units in the area. These are mainly organic soil material and River deposits.

The organic soil material is found covering extensive part of the project area mainly covering the poorly drained plain land mass of the project area. Reddish brown sand deposition

2.3.1 Landscape and Soils

The properties of soil vary from place to place, but its variation is not random. Natural soil body are the result of climate and living organism (fauna and flora) acting on parentmaterials, with topography or local relief exerting a modifying influence and with time required for soil forming processes to act. For the most part soils are the same whenever all elements of the five factors are the same. Under similar environment in different place, soils are similar.Climate influences soil development by affecting the degree of weathering. Climate and time are related, in that climatic (weathering) effects are most pronounced on stable surfaces, while on such surfaces past rather than current climates may account for the soil conditions. Thus, in areas where the climate is wetter, weathering and decomposition are pronounced giving rise to deep and well developed soils such as Luvisols and cambisol. In areas where drier climates prevail, evaporation exceeds precipitation and accumulation rather than leaching occurs, so calcic and salt affected soils are dominant. Topography plays an important role in soil genesis, primarily through modification due to the impact of climate. Thus, on steeper slopes water runs off rapidly retarding soil development. Where topography is steeper, soils are shallower and at the initial stages of soil profile development, because erosion has not given them time to develop. Soils developed on recent alluvial and colluvial deposits are often only at an initial stage of development, or are not developed at all, as evidenced by their weak structure and stratification resulting in Fluvisols. In flat, nearly flat, and undulating topography in lower landscape positions, imperfect to poorly drained soils, such as Vertisols are formed.

The influence of organisms is manifested in the amount of organic matter in the soils. Organisms also have an appreciable impact on weathering, and are critical to the recycling and release of plant nutrients.

The Study Area comprisesIn flat, nearly flat, and undulating topography in lower landscape positions the middle and lower catchment of Worbate River and its tributaries.Deep reddish brownSandy loam textured soils (*Cambisols*, Lixisol and *Leptosol*) are the most widespread soils developed on 0-8% slope mainly from Granite and Aluvium parent matterial, amounting to almost 78% of the Study Area.

Table 1: Land form and Slope

Slope%	Area (ha)	Area (%)	Remark
0-2	15.47	6.69	
2-5	108.23	46.85	
5-8	90.92	39.36	
8-15	13.83	5.98	
>15	2.54	1.09	
Total	230.99	100	

2.3.2 Vegetation and Land Use

The major farming system of the study area is pastoralism and therefore, the land use of the study area is mainly for browsing and grazing purpose. A very few patchy areas of cultivated lands are also observed in the study area. The vegetation of the study area is open bush and shrubs dominated by acacia species.

Extensive Graizing and browsing with Cattles, camels,goat and sheeps are the dominant land use of the project area.(>90% of the Command area is open bush and shrub land There is No Cultivatin in the project area).

(The vegetation cover is dense near to Dam site and Worbateriver).

Table 2: Land use land cover of Worbate irrigation project

Land use	Area (ha)	Area(%)
Settlementand others	2.99	1.29
Shrub and Bush Land	228	98.71
Total area	230.99	100

3. REVIEW OF PREVIOUS STUDIES

3.1. Genale Dawa River Basin Master Plan project

A soil survey of Genale Dawa river basen master plan project was carried out by Lahmayer international (Germany) and Yeshiber Concelt (Ethiopia) at a recoinacence level and a soil unit association map prepared at1:250,000 scale.The recoinacense soil surveys identified 13 Mayor Soil groups, 28 soil units and 61 soil mapping units.in the river basen.in the surveythe majorsoil groups and soil units were classified bassed on the soil property observed in the field and from the laboratory results.Luvisol,cambisol,Calsisol,Fluvisol,Leptosol Nitosol,Acrisol, Gleysoland vertisol identified in the soil survey activity.Among many soil survey works carried out in Bale Zone in the past, the soil survey that included the proposed command area is the Genale-Dawa River basin master Plan Development Project. This study was conducted at reconnaissance level at a scale of 1:250, 000. In this study, previous studies at a pre-reconnaissance, reconnaissance, semi-detailed and detailed level were reviewed. The review concentrated on the evaluation of their objectives and methodology, their output in terms of data, maps and findings and the means to use them. Satellite imageries and national topographical maps were interpreted by GIS experts. A base map was compiled at 1:250, 000 scale from an overlay of national topographical maps, geomorphology and soils, land use and land cover, slope and geology.

A systematic verification survey was planned for the areas previously surveyed and mapped at different scales instead of repeating the conventional survey. The methodology of field survey was mainly through a network survey with additional free survey in different landform units depending on the complexity of the soil pattern, accessibility and potential of the area for development. Auger observations were carried out along the roads at 2 km intervals in most of the areas and at 1.5 km in potential areas to check and delineate soil types. Additional traverse auger observations were made in some complex soil patterns to check variability. About 1 to 2 pit were dug per mapping units/soil units and FAO pit description guidelines and FAO/UNESCO ISRIC classification method were used for description of the soil profiles and soil classification respectively. In heterogeneous areas additional mini pits of about 0.5 to 0.6 m were dug.

Based on the field and laboratory physical and chemical analysis of the soils, according to the study, identified soil types are Cambisol, Leptosol ,Luvisol and nitisol,

3.2. Borana Integrated Land Use Planning Soils of the Dawa Sub Basin Project

This project conducted by oromia water works design and suppervision enterprice
Based on soil genesis, morphology and other profile and surface characteristics such as effective soil depth, color, texture, structure, consistency, slope, micro topography, drainage, stoniness and flooding together with soil chemical properties the soil of Dawa Sub Basin is classified in to the following eight major soils i.e. Luvisols, Cambisols, Fluvisols, Leptosols, and Nitisols.

Soil augerfield observation, profile description and laboratory results were compiled and analyzed using appropriate methods. The soils were identified, classified and characterized based on physical and chemical parameters following FAO/UNESCO/ISRIC/WRB methods. Potential and limiting factors have been identified to make land suitability evaluation. The report and soil map of theDawa Sub Basin has been presented on 1:50,000 Scale map.in this study identifaid cambisol, Lixisol,Leptosol and Chromic Luvisol in the project area.

3.3. Soil and Geomorphologymap of Ethiopia, 1984

Ethiopian soil and geomorphology map is presented at a scale of 1:1000, 000 and mostly used in the development of a master land use Plan for the country.Soils information was based on the interpretation of available surveys, field traverses; Land sat derived data and agro climatic information. These data were combined, as landscape units, in a Geomorphology and Soils map at 1:1,000,000 scale with extended legend. The FAO system of classification is used in the description of soi1types. Though the soil types were identified for the whole Ethiopian landscape, the scale level at which the soil was studied, doesn’t permit to evaluate and plan for a particular catchment at scale greater than 1:1,000,000.

4. METHODOLOGY OF INVESTIGATION

4.1. Scope of the survey

The TOR calls for soil survey (investigate, analyze and map the distribution of soil type) of the project area and use of the information obtained as a basis for confirming/rejecting the irrigation potential, crop selections, irrigation designs and agricultural input requirements. Therefore, the survey is designed to conform to the following standards in the TOR:-

- Standard soil Description is to a depth of 2 m unless restricted by lithic contact. Auger observations are to 1.2 m unless restricted by barrier layers.
- Soil samples (undisturbed and disturbed) be collected from generic horizons for the analysis of the chemical and physical properties, and moisture characteristics.
- Standard infiltration and hydraulic conductivity tests on representative sites be carried out as the soil conditions permit.
- Soil and land characteristics description shall be according to FAO guidelines (1985; 1990).

The methodology to be followed for the soil survey is designed to conform to the scope of the study. The overall survey procedure will consist of three stages, namely **pre-field stage**, **fieldwork**, and **post-field work**. The data to be collected and activities undertaken in each stage, and the soil parameters to be analyzes are listed in the subsequent section.

4.2. Pre-fieldwork

The base map used in the field prepared from Land- sat image digitized/ interpreted by slope at a scale of 1:10,000. In addition the slope and contour map of the basin has been derived from ASTER Digital Elevation Model (DEM) of 30 m resolution created contour lines at 5m intervals.

Auger hole observations sites were predetermined on 200 m by 200 m grids and approximate location of profile pits, infiltration and hydraulic conductivity testing sites were laid on the base map and the necessary data recording sheets and equipment were made available.

4.3. Fieldwork

4.3.1 Auger observation

Auger observation was done to the depth of 1.2 m unless encounter by rock or water table. At each auger hole a mini-pit of 0.6 m deep was hand dug which enables identification of major soils on the bases of their physical appearance of the subsoil. Auger-hole observations made by fixed grid technique that transects laid at 200m apart and auger observations made along every 200 m each grid transects. Atotal of 74 auger holes observation has been made, All observation with their geographic coordinate for every Auger point is given in Appendix table3.

4.3.2. Soil profile description

Depending on soil mapping unit classified and defined from auger bores (mainly depth, texture and slope, 12representative soil profiles were located and dug to the depth of 2.0 m and described in accordance with the FAO "Guidelines for Soil Description". Data was recorded on a standardized profile description sheet to ensure completeness and uniformity of data collection. On-site, every profile pit description was preliminarily classified according to the "World Reference Base for Soil Resources" (2006) and (2014) final classification was made in the office after chemical analyses completed. A total of 4 soil profil pits were dug and sampled. These samples were sent to the Oromia Water Works Design and Supervision Enterprise Laboratory Service for further physical and chemical analysis. Profile description data with their coordinate are given appendix table2and3.

4.3.3 Physical tests

For measurement of water content at various bars to determine soil available water capacity (AWC) 2 undisturbed soil core samples were collected from major horizons of representative soil profile and the samples were sent to Oromia Water Works Design and Supervision Enterprise Laboratory Service (OOWWDSELS).The core samples were analyzed for bulk density on dry weight basis and moisture content at (FC and PWP) by pressure plate extraction and the results are presented in appendix table7.

Infiltration rate and Hydraulic conductivity test was determined in triplicates (8 to 10 m apart).Atotal of 1 representative sites by the double ring infiltrometer method and inverse Auger-hole Test method, respectively (FAO, 1979). Location of auger observation points and soil profile pits are presented in Figure 6 and 3. Observation of auger and profile pits descriptions are also presented in appendix table2.

The soil survey data collected during field work is summarized in table 2 below and locations and distribution of the observations and description sites are shown in Figure 2 and 3 bellow.

Table 3 Soil survey data collected during the field work

S/N	Status	Number of observations
1	Total augers observation points	74
2	Soil profile description	4
3	Soil samples	8
4	Infiltration and hydraulic conductivity	0
5	Undisturbed core samples	2

All observations recorded on soil description sheets at each observation site, and the following surface/ external characteristics and information recorded.

- Steepness, length and direction of slopes;
- Land form and its use and/or land cover;
- Location of the site elevation using GPS;
- Soil color using Munsell soil color chart;
- Parent material, presence of micro-topography, surface features (E.g. cracks, crust, stoniness, etc,);
- Erosion hazard (by estimation), flooding problem, etc;

General pattern of drainage, Land use (i.e., the kind of crop 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, roots cutans, slickenside, etc. From the analysis, it is noted that, textural class determination by hand fill method in the field is slightly underestimated than the clay content result in the laboratory. Under such condition where there are differences, values of the laboratory results have been considered.

4.3.4. Post Fieldwork

After completion of the fieldwork, field data compilation and encoding, field and laboratory data interpretation and report writing was conducted. The satellite image interpretation units were rectified on the basis of field observation and a legend was developed for the mapping units. Soil mapping units have been established based on slope, soil depth and soil unit. A total of 14 SMU were identified on the basis of the above three criteria.

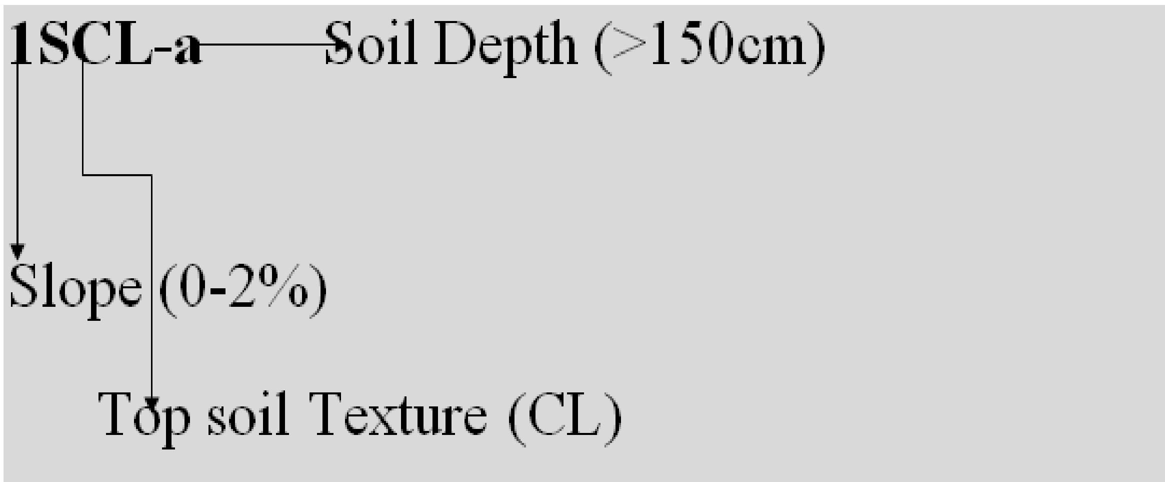
Table 4: Soil properties used for the definition of SMU

Slope		**Texture**		**Depth**	
%	**Map Symbol**	**Class**	**Map Symbol**	**Cm**	**Map Symbol**
0-1	1	Clay loam	CL	>150	a
1-2	2	Sandy Clay Loam	SCL	100-150	b
2-4	3	Clay	C		
4-6	4	Loam	L		
6-8	5	Silty loam	SIL		
8-15		Clay	C		

Accordingly based on slope, top soil texture and soil depth of the study area 16 soil mapping units (SMU) were identified on the command area. Thus, SMU were represented by three symbols (e.g. 1SCL-a = Flat land (0-2% slope) with Clay loam texture and having very deep soil profile).

Soil Mapping Units

Example :



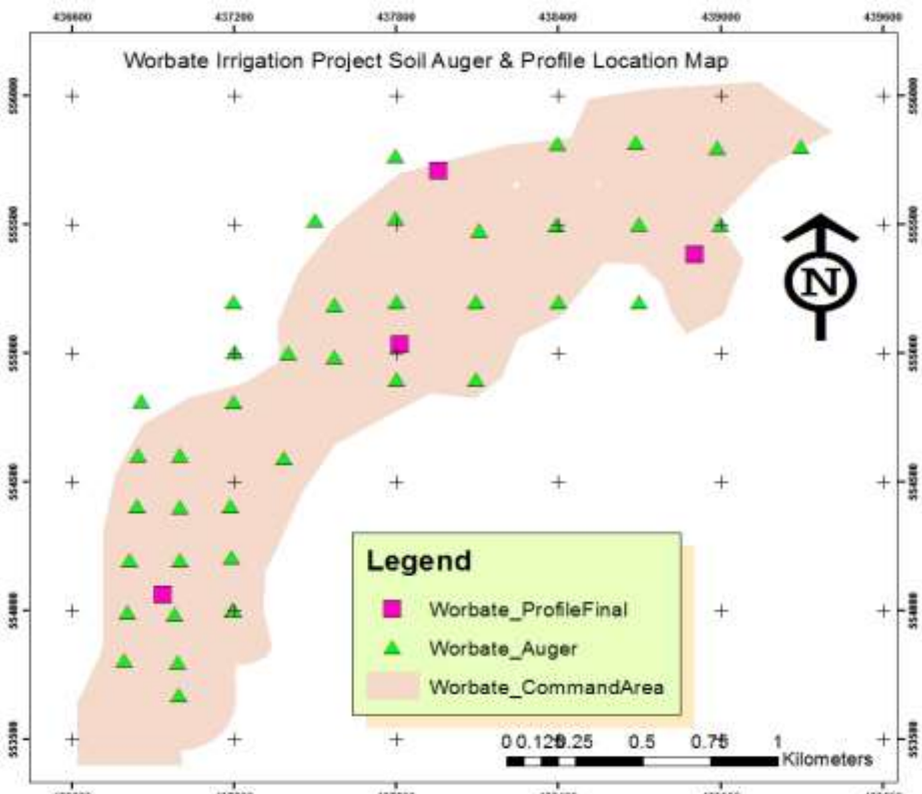


Figure 2: Location of Soil Auger and Profile Pits

4.4 Laboratory Analysis

The soil samples were air-dried, ground and sieved through a 2-mm sieve and analyzed for particle size distribution, pH (H2O), electrical conductivity(EC), organic carbon, total nitrogen, available phosphorus, exchangeable cations and cation exchange capacity (CEC). Soil analyses were performed in the OOWWDSE soil testing laboratory.

Soil pH was measured potentiometrically in 1:2.5 soils to water suspension (w/v) by using glass calomel combination electrode method (Van Reeuwijk, 1993). Electrical conductivity (EC) was determined at a soil/water ratio of 1:5. Organic carbon percentage was determined by the wet digestion method of Walkely and Black method (2000). Total nitrogen percentage was determined following the Kjeldahl method (Gupta, 2000). Available phosphorus was determined following the Olsen (sodium bicarbonate) method as described in Van Reeuwijk (1993). Cation exchange capacity (CEC) was determined by saturation with NH_4OAc at pH 7 and subsequent replacement of NH_4^+ by NaCl extraction. Exchangeable basic cations (Na^+, Ca^{2+}, Mg^{2+}, K^+) from the ammonium leachate.Ca and Mg were read with the help of atomic absorption spectrophotometer (AAS), and K and Na by flame photometer.

Available potash, K (Morgan’s solution and flame photometer), Free calcium carbonate, $CaCO_3$ (filtration and titration with NaOH), Exchangeable Sodium Percentage (ESP

The percentage base saturation (PBS) was computed using the formula

$$PBS = \frac{(K + Na + Ca + Mg)}{CEC} * 100 \qquad \text{(Rowell, 1997)}$$

The contributions of each exchangeable cation to the exchange site of soils were obtained by dividing value of each cation by value of CEC and multiplied by 100 for each horizon. Apparent CEC of clay was estimated by dividing CEC by percent clay expressed as percentages (Buol *et al.* 1997).Bulk density (BD) was determined on oven-dry weight basis of core samples. Water content at field capacity and permanent wilting point (0.33 and 1.5 MPa, respectively) was determined by pressure plate extractor. Soil analyses were performed in the OOWWDSE soil testing laboratory.

The field data and laboratory analytical results as input for final findings of the study accordingly. Consequently based on the final interpreted data, particularly the laboratory analytical results, classification of major soil groups and soil units has been amended. The final soil map and report have been prepared based on data and sample test results obtained from laboratory. The prepared soil map is at the scale of 1:10,000 which contain the slope, soil unit comprising with the dominant soils. Profile pits and auger location points as shown on the map. The preparation of the soil maps was done by the use of GIS software. The soil data bases were generated are:

- Soil auger observation & profile description locations (geo-referenced)
- Soil profile &site description
- Soil auger & site description
- Soil laboratory analytical results
- Soil characteristics/land quality for land evaluation
- Soil maps (in GIS)

5 SOILS OF THE PROJECT AREA

5.1. General

Soil types have been defined on the basis of soil physical properties (such as texture, depth, color, slope etc…) and soil chemical characteristics (CEC, pH and BS% etc…). Although there was some variability in soil physical properties such as in soil color and texture over short distance, they are very limited in their area extents.

5.2. Major Soil Types in the Project Area

Based on soil genesis, morphological and other profile and surface characteristic such as effective soil depth, color, texture, structure, consistency, slope, micro topography, drainage, and stoniness, flooding together with soil chemical properties the soil of theWorbate Irrigation Project is classified in to the following five major soils, i.e. Cambisols, Lixisol and Leptosol. Soil auger field observation, profile description and laboratory soil sample test results were compiled and analyzed using appropriate methods.

The soils were identified, classified and characterized based on physical and chemical parameters following FAO/UNESCO/ISRIC/1998(WRB 2014) methods. Potential and limiting factors have been identified to make land suitability evaluation. The report and soil map of the Worbate Irrigation Project has been presented on 1:10,000 scale maps.

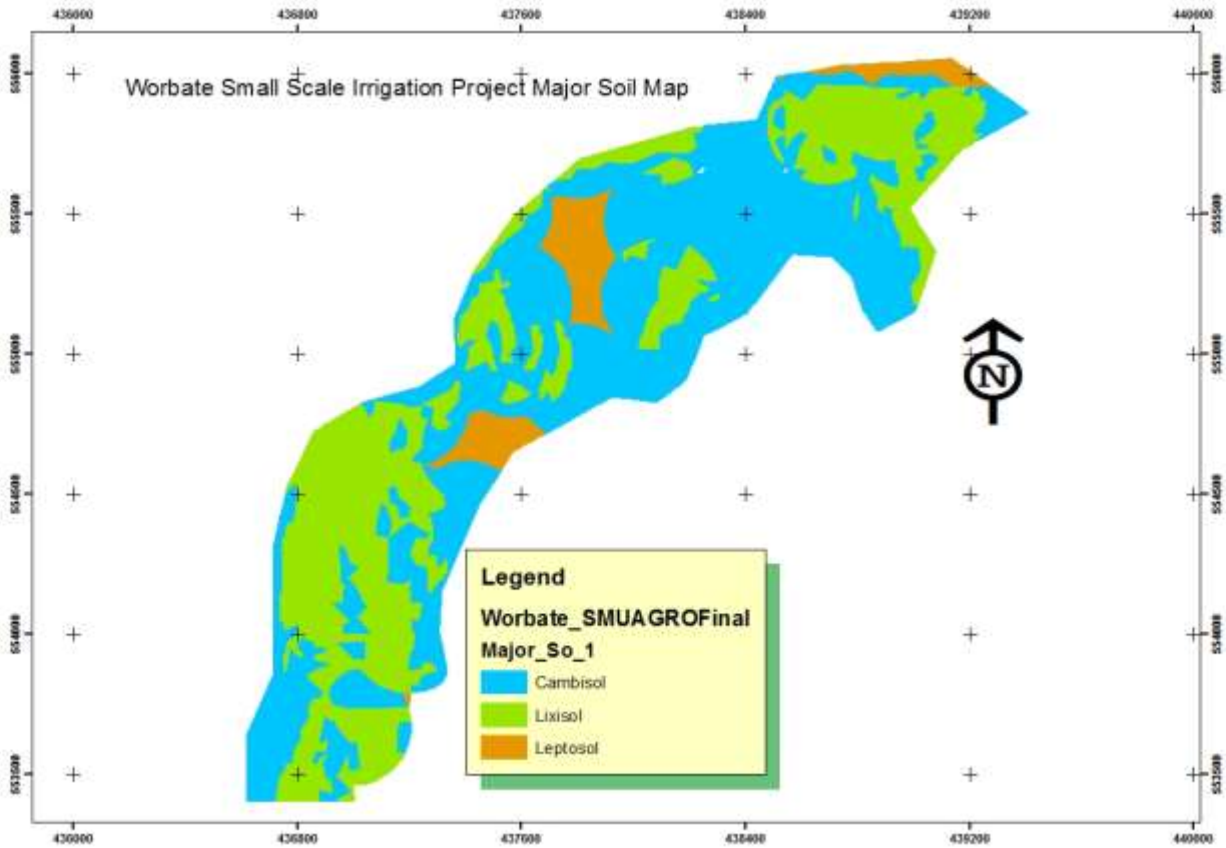


Figure 3 major soil map

5.2.1. Lixisol (Rhodic, Eutric)

Lixisols comprise soils that have a higher clay content in the subsoil than in the topsoil as a result of pedogenetic processes (especially clay migration) leading to an argic subsoil horizon. Lixisols have a high base saturation and low-activity clays at certain depths. Lixisols are soils with a pedogenetic clay differentiation (especially clay migration) between topsoil with a lower and subsoil with higher clay content, low-activity clays and a high base saturation at some depths; from Latin lixivia, washed-out substances. Lixisols occur in a wide variety of parent materials, notably in unconsolidated, strongly weathered and strongly leached, finely textured materials (WRB, 2014).

Lixisols of the study area are found from Plain land (0-2%) slope up to slope land 5-8% slope Well Draind and Deep soils Sandy clay loam textuer on the top Dark Redish brown (5YR 4/6 Dry); and Very Dark Redish Brown (5YR3/4) colored, Slightly acid with Ph 6.0 to 6.4 , high base saturation persentage(69%) Medium CEC leve17.5Meq/100gm Low available Phosphorus. The total area of Lixisols is 89.73 ha covering 38.74% of the total area.

Soil profile Description. **Profile code:** Or*P-3* **Status:** *PS*

Date: *26/01/19*	**Long. In utm (E):***438100*
Author(s):*Ararsa/Leta*	**Lat. in utm (N):***555821*
Region *Oromia*	**Elevation:** *1424m*
Zone:*borena*	**Parent material:** *GR*
Wereda:*Gomolle*	**Rock Type:**
Soil classification FAO Lixi	**Effective soil depth:** *deep*
Human influence:*SC, VU*	**Rock out** N
	Crops:
Land LP	**Depth to bed rock:***none*
Regional slope:	**Surface coarse** few
Position:*lower*	**Micro topography:***termite mound*
Slope class:*0-2*	**Surface sealing:** *None*
Slope aspect:*North-Southu east*	**Drainage class:** *W/W*
Slope gradient:	**Drainage external:***well*
Slope form:*U*	**Drainage internal:**
Slope length:	**Ground water:** *none*
Surface cracks: *none*	**Flooding:** *none*
Dissection:	**Moisture condition:**Dray
Erosion *Rill*	**Land cover:**
Fertilizers:*Unknown*	**Land use:** *HE1*
Existing crops: *N*	**Vegetation types:** *Haroresa*

0-30cm clear and smooth boundary; moist moisture status; dark brown (5YR3/4) Moist color, no mottling, Clay Loam, few fine coarse fragment, strong fine to medium Sub angular structure; No crack; very friable When moist, sticky and plastic when wet; no cutans; no cementation; no mineral nodules; common Fine medium, few medium to coarse roots; common fine medium fine coarse pores; non calcareous

30-100cm gradual and smooth boundary; Dark Redish Brown2.5YR4/4 moist moisture status; dark red (2.5YR3/4) Moist, no Mottling, sandy clay , common fine coarse fragment, weak fine to medium granular structure; fine crack; Very friable when moist, slightly sticky and slightly plastic when wet; no cutans; no cementation; no mineral Nodules; few fine medium, few medium to coarse roots; common fine medium fine coarse pores; non Calcareous.

5.2.2. Cambisols (Chromic, and LepticCambisol, eutric)

Cambisols are moderately developed soils characterized by slight or moderate weathering of parent material and by the absence of appreciable quantities of accumulated clay, organic matter having moderately developed Cambic B horizon or a Mollic horizon overlying subsoil which has a base saturation (by 1M NH4OAc) of less than fifty percent (<50 per cent for dystric Cambisols and >50 per cent for Eutric Cambisols) Cambisols are soils those lacks hydromorphic and permafrost within 100 cm and 200 cm of the surface respectively. In the study area identified Eutric Cambisols. (See soil mapping unit description)

Cambisols of the study area are sub divided in to Leptic Cambisols (Aridic), Haplic Cambisols (Eutric)

The Cambisols in the study area are Modaratly acid with low pH ranging from 5-8 in the top soil and pH ranging 5.6 to5.9 in the sub soils.

The CEC values of the soils are low to very high ranging from 12.0-26.28 Cmol (+) Kg^{-1}in the top soils and medium to very high ranging from 18.8-27.9Cmol (+) Kg^{-1} in the sub soils. Base saturation percent is medium to high ranging from 45-85 and 46-74 percent in the top soils and the subsoil respectively.

The calcium carbonate content of soils is traceen topsoil and in sub soil. Organic carbon percent is very low ranging from 0.74-1.09 % in the top soils and 0.49-0.66% in the sub soils rated as very low the total nitrogen percent is Low (0.06-0.09) in the top soils and 0.04-0.05% rated as low in the sub soils. It requires No fertilizer application. The available P in the soils is low in the top soils and sub soils AvP<5.Cambisol en the Study area cover 125.66 ha or 54.40% of the total area.

Soil profile Description **Profile code:** *ORP-4* **Mapping unit:** **Status:** *PS*

Date: *26/01/19*	**Long. In utm (E):** *438903*
Author(s): *Leta/Ararsa*	**Lat. in utm (N):** *555385*
Region *Oromia*	**Elevation:** *1432m*
Zone: *Borena*	**Parent material:** *BT*
Wereda: *Gommole*	**Rock Types:**
Soil classification FAO *Cambisol*	**Effective soil depth:** *Moderatly Deep*
Human influence: *VU*	**Rock out** N
	Crops:
Land LL	**Depth to bed rock:** *80cm*
Regional slope:	**Surface coarse** N
Position: *Medium*	**Micro topography:** *TM, AB, AT*
Slope class: *2-5%*	**Surface sealing:**
Slope aspect:	**Drainage class:** *W/W*
Slope gradient:	**Drainage external:** *Well*
Slope form: *U*	**Drainage internal:**
Slope length:	**Ground water:** *none*
Surface cracks: *none*	**Flooding:** *none*
Dissection:	**Moisture condition:** 0-80cm dry
Erosion sheet *and splash*	**Land cover:**
Fertilizers: *Unknown*	**Land use:** *GL2*
Existing crops: *N*	**Vegetation types:** *HERER*

0-20cm Clear smooth boundary; dry moisture status; (5YR4/3)dry colour;(5YR3/3)moist colour; none mottling; clay loam texture; none coarse fragement; weak,fine &,medium ,sub- angular blocky structure; none crack;slightly hard,friable (moist), sticky and plastic(wet) consistency; none cutanic features; non-cemented & non-compacted; none mineral nodules;many, fine to medium root;:many, fine to medium pores;none calcareous.

20-80cm dry moisture status; (2.5YR4/6) dry colour;red(2.5YR3/4) moist colour; none mottling; sand clay loam texture;common, fine to medium coarse fragement; moderate,fine & medium , sub- angular blocky structure; nonecrack;hard(dry)' friable (moist), sticky to sticky and plastic to plastic (wet) consistency; none cutanic features; non-cemented & non-compacted; none mineral nodules;common,fine & medium, root;many,fine to medium pores; nonecalcareous. >80cm coarse and gravels. Argic diagnostic horizon (surface), Cambic (sub-surface

5.2.3. Leptosols (EskeletikLeptosol (eutric)

Leptosols are soils having continuous hard rock within 25 cm from the soil surface; or a Ochric horizon with a thickness between 10 and 25 cm directly overlying material with a calcium carbonate equivalent of more than 40 percent, or less than 10 percent (by weight) fine earth from the soil surface down to a depth of 75 cm; and no diagnostic horizons other than a mollic, ochric, umbric or yermic horizon. Leptosols are very shallow soils over continuous rock and soils that are extremely gravelly and/or stony. Leptosols are azonal soils and particularly common in mountainous regions (FAO, 2001, WRB, 2006).

Leptosols of the study area are found as Ochric Leptosols (Eutric) having an area of 15.6 ha occupying 6.77% of the total area

6. SOIL PHYSICAL ANDCHEMICAL PROPERTIES

6.1 Soil Physical Properties

6.1.1 Effective Soil Depth

The effective soil depth is that the thickness of the loose soil above a limiting layer which is impermeable for roots and/or percolating water. Deep well drained soil shows a root penetration until below 150 cm for most crops, however, root penetration might be stopped at shallower depth because of root restricting physical or chemical soil properties (presence of cemented, toxic, compacted or indurate layers, hard rock or gravel layers). The soil survey result shows that the dominant soils of Worbate Irrigation Project are deep to very deep (50-100cm to 100-150 cm respectively), no limitation for normal rooting for most cultivated crops, grazing herbages, bushes and shrubs.

Table 5: Effective soil depth and area coverage of the area

Depth (cm)	Area (ha)	Ha (%)
100-150	89.73	76.64
50-100	67.32	13.22
25-50	58.33	8.67
0-25	15.59	1.40

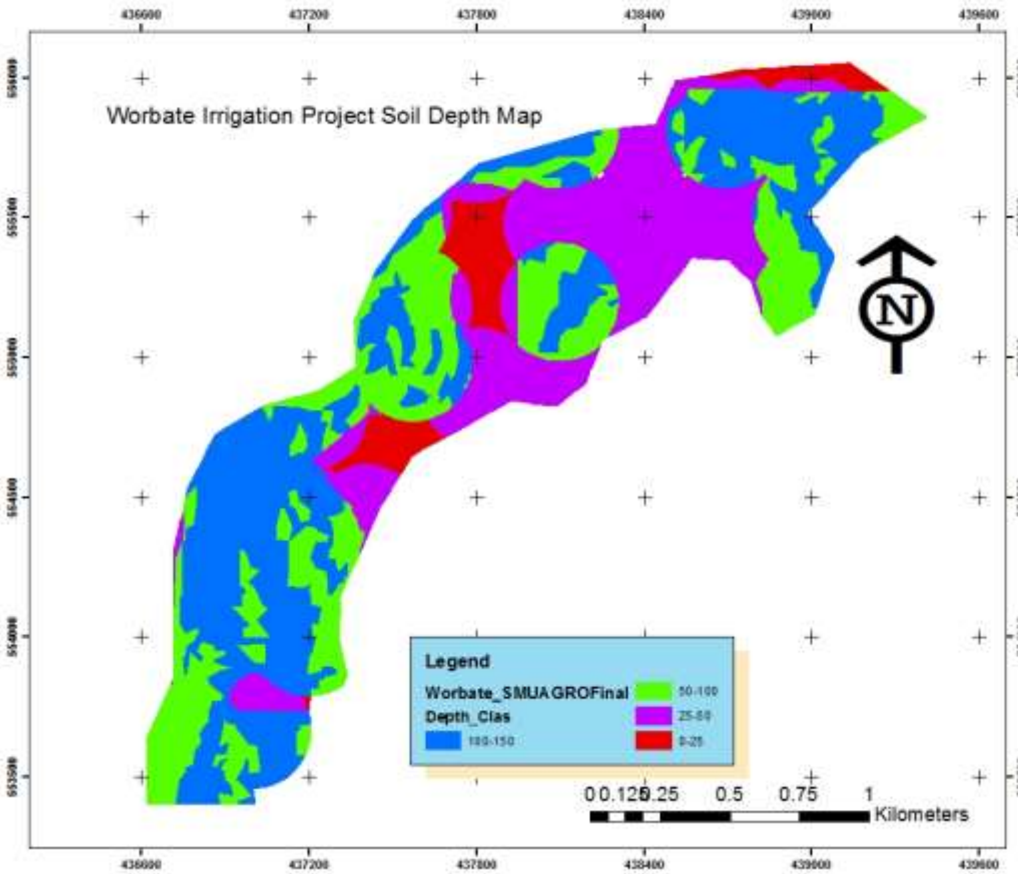


Figure 4: Depth map

6.1.2. Soil Structure

Soil structure is the natural arrangement of soil particles in discrete soil units (aggregates or peds) that result from the pedogenic process. Soil structure is described in terms of grade, size and types of aggregates.

Structure may be weak, moderate or strong and the aggregates may be platy, blocky, prismatic, granular etc…

Soil structures have been assessed from visual observation of soil peds taken from each horizon medium sub angular blocky type. Classification of structure follows the FAO Guidelines for Soil Description (2014).

The Cambisolas (Mollic), moderate, medium sub angular blocky structure both in the surface and sub surface and Leptosols (Eutric) weak to medium moderate sub angular blocky structure and Lixisol have dominantly moderate to weak, fine to medium sub angular blocky structure in their surface soils and moderate to strong, medium to coarse sub angular block structure in their sub soils. Soil structure of almost all soil types is moderately developed medium size and sub-angular blocky.

6.1.3. Consistence

Lixisol friable to very friable when moist, slightly sticky and slightly plastic when wet. The consistence of other soils varies with their textural composition and accordingly the Loam and sandy clay loam textures have dry consistence of slightly hard, friable consistence when moist and slightly stick and plastic when wet.

6.1.4. Texture

The proportions of sand, silt and clay are used to determine the textural class of the soil. It is important in that, it helps determine the capacity of the soil to retain moisture and air, both of which are necessary for plant growth.Top Soils texture of the Project area are dominantly Sandy Clay Lom and Sandy Loam for Lixisol and Cambisol respectively. Laboratory analysis of soil texture show that clay percentage increases down soil profile especially in Lixisols . However the clay percentage in Cambisols is not uniform in the soil profile.

6.1.5. Soil Color

Soil color was measured under dry and moist condition by determining the hue, value and chroma of the soil using Munsell color chart. The soil color of the survey area is mainly related to drainage and the parent material. Accordingly, well drained and moderately well drained soils of the project are dark redish brown (5YR4/3and 3/3) to red (2.5YR4/6) while wel drained.

6.1.6. Soil Drainage

Soil drainage relates the frequency and duration of periods when the soil is free of saturation or partially saturated. The soil drainage classes reflect the effect of climate, landscape and soil. Rainfall, seepage, internal vertical and lateral water movement and external surface run-off and run-on affect soil drainage. Based on this, soil drainage is classified as well drained, moderately well drained, imperfectly drained, Soils of the study area have well drained in Cambisol area and moderately drained to well-drained in Lixisol. Soil condition which vary depending on their varying properties affecting drainage such as water transmission, soil depth, soil chemistry, slope gradient, etc.

6.1.7 Infiltration rate

Infiltration refers to the vertical intake of water into a soil, usually at the soil surface, and measurements rate form a vital part many survey involving irrigation development or soil conservation (Landon, 1991).

Infiltration rate is mainly affected by texture of the soil and other properties of the soil such as organic matter content and structure of the soil. The soils of the study area have a mean infiltration rate of **3.5cm/hr-6.5cm/hr** and this implies that soils of the project area have a **moderate** infiltration rate.

6.1.8. Hydraulic Conductivity

The hydraulic conductivity or permeability of a soil 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. The measurement of hydraulic conductivity is done for comparison of hydraulic conductivity rates of different soil horizons, particularly as a guide to water movement and possible drainage problems within soil profiles (Landon, 1991). The tests were carried out by inverse auger-hole method, near/at the representative soil profile. The results indicate that hydraulic conductivity of **2.5 m/day** for soils of the study area. The result indicates that, the water movement is to **moderate**to**moderately rapid**.this is because plant root penetration and crack formed down to the soil profile.Hydraulic conductivity is affected by texture and structure of the soils.

6.1.9. Bulk Density

Bulk density is the overall density of soil (i.e. the mass of mineral soil divided by the overall volume occupied by soil, water and air); it should be distinguished from the density of the solid soil constituents. Bulk density of clay, is 1.5 g/cm^3, clay loam normally range from 1.42 to 1.44 g/cm^3 depending on their conditions and bulk density ofSilty loam is 1.54 g/cm3. The bulk density of the soils in the study area varies between **1.71and 1.51 g/cm^3**. The result shows that the bulk density of soils of the study area is in normal range and it is not causing hindrance to root penetration as such.

Table 6: Bulck density results versus soil textures of the study area

S/N	Rep.Profile	Surface Texture	Bulck density(gm/cm3)
1	OrbP-1	Sandy Loam	1.71

6.1.10. Field capacity (FC)

Field capacity of a soil is the maximum water content the soil will hold following free draining by gravity force.Field capacity (FC) is the term used to describe the maximum water content that the soil will hold following free drainage. 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 (Landon, 1991). The field capacity of the soils of the study area falls in the range of **20.5% in** the top soil and **19.4% to23.7%** in the sub soils.

6.1.11. Permanent wilting point (PWP)

Permanent wilting point is the soil moisture content at which plants can no longer obtain enough moisture to meet evapotranspiration requirements and remain wilted unless water is added to the soil. Permanent wilting pointis the moisture content level at which the plants are water stressed and irreversibly wilt. If water is continually taken-up by plants and no additional water is added to the soil in the form of precipitation or irrigation water, the medium and small soil pores will be emptied of water. With time, the plant will eventually wilt when it cannot extract more water. The soil is said to be at the permanent wilting point when plants can no longer exert enough force to extract the remaining soil water. At the permanent wilting point, water is held in the soil at about 1.5 MPa (15 bars). The permanent wilting points of the soils of the study area fall in the range of **6.9%** in the top soil and **11.9** in the sub soil.

Table 7: permanent wilting point results versus soil textures of the study area

S/N	Rep.Profile	Surface Texture	Permanent wilting point (%) (15 bar)
1	OrP-1	Sandy loam	6.9

6.1.12. Available water capacity (AWC)

Available water capacity is the volume of water retained between field capacity and permanent wilting point. However, not all available moisture is accessible to plants due to imperfect drainage, hydraulic conductivity of the soil, impenetrable depths, and root concentration at different depths and stage of plant growth. About 50-70% of available moisture is considered readily available water (RAW). Readily available moisture is considered 60% of total available water as a rule. In general principle results of AWC <120mm/m, 120-180 mm/m and >180 mm/m has low, medium and high rate for irrigation suitability respectively.

Based on laboratory analysis of FC, PWP and bulk density on undisturbed core samples, value of AWC was determined for the dominant major soil type of the command area. Calculation for the AWC is done as follows using the formula:

6.1.13. Available water capacity (AWC) and readily available water Capacity (RAWC)

Available water capacity (AWC) is the volume of water retained between field capacity and permanent wilting point. Not all the water held between the field capacity and permanent wilting point can be considered as equally available to plants. A rule of thumb is that the total readily available water capacity (TRAWC) value is half to two thirds of **the total available water** capacity of a profile (Landon, 1991). Calculation of AWC is done by the following formula.

$$\text{AWC} = \frac{(FC - PWP)\ x\ horizondepth\ x\ BD}{100}$$

Table 8: shows the average available water capacity (AWC) and readily available water capacity (RAWC) value for the Representative profile of the soils of the study area.

Depth	cm	BD	FC	PWP	FC-PWP	AWC cm	AWC-mm	TAWC
0-30	30	1.71	13.2	6.9	6.3	3.2319	32.319	97.42
30-60	30	1.5	18.1	11.9	6.2	2.79	27.9	
60-100	40	1.5	18.1	11.9	6.2	3.72	37.2	
							97.419	

The above values were derived from the representative samples for the study area. The medium values of the available water capacity may be because of the higher organic matter content of the soils, good structure etc.

6.1.14 Porosity

Total porosity gives a general indication of (dry) soil compaction. In clayey soils a total pore space of about 50% or less may indicate some compaction. The data confirm the field observations that, when dry, all the soils are hard. However, when moist (under irrigation) the Luvisols become very friable. The Fluvisols remain firm.The data indicate some compaction in the study area but not serious problem.

Air filled porosity is the total porosity minus the volume of moisture held at field capacity. Pores that are not filled by water contain air, and an estimate of their volume can give an indication of the aeration and drainage status of the soil. Very indicatively, a value of the study area indicates < 10% air capacity may indicate anaerobic conditions. In practice, though, the limit depends on soil temperature, continuity of pores, cracks, microbial activity and oxygen consumption by the plant; plants can receive oxygen through stems and roots.

As expected, the Luvisols .Lexisols and Cambisols are all well-aerated at field capacity, but the Fluvisols are not. However, even whenMedium cracks are filled and the Fluvisols have swelled, roots (those below about 20 cm) can extract sufficient oxygen from minor cracks that remain unsaturated

Table 9 **: Total porisity and Air-filled porosity**

profile No.	Soil units	Bulk density, g/cm^3			Total porosity, %			Air-filled porosity, %		
		topsoil	0.3–0.6m	0.6–1.0m	topsoil	0.3–0.6m	0.6-1.0m	topsoil	0.3–0.6m	0.6-1.0m
OrbP-1	Lx	1.51	1.71	1.72	35.47	43.39	43.39	22.27	25.29	26.29

Biological features such as krotovinas, termite burrows, insect nests, worm casts and borrows of large animals in terms of abundance and kinds. Biological features of the study area is common by animal borrows and few earth worm casts and many termite burrows on Redish brown soils according to profile description and surfce obsrvation.

6.1.16. Erosion Status

The erosion status of the command area is slight to moderate for the level lands up to 5% slope and moderate for Slopes >8%. This status of erosion of the command area is shown by the existence of some sheet and rill and Gully erosion active in the comand area and not observed modern soil and water conservation practices.

6.1.17. Flooding

For the majority of the soil mapping unitsthe flooding Status of the command area is generally none, there is no evidence of flooding hazareed, except River side (river buffer zone)

6.1.18 Deep Boring

To Check the depth of impervious layer/horizone, Soil salinity and the fluctuation of the water table of the study area two deep boring were made between 3.0m and 4.0m depth .Saline soils have an ECe of >4.0ds/m sodic or (alkali) soils have an ESP>15. The laboratory result of the study area indicates none of the soil profile or auger analysis even of deep horizons, indicate any Soil salinity orsodicity problem,

6.2. Soils Chemical Properties

6.2.1. Soil Reaction (pH)

Soil pH is important, as it is an indicator of acidity, neutrality or alkalinity in the soil. PH helps to determine the availability of nutrients to plants and toxicity of macro and micronutrients in the soil that ultimately control plant growth. PH water values do not have precise significance but some generalizations can nevertheless be made for interpretation purposes. Generally the pH water tolerance limits for different plants vary, but for most commercial crops a neutral range (PH Water value 6.6-7.3.) is most suitable. The soil pH significantly affects the availability of most of the chemical elements important to plants and microbes.

The overall pH value of the project area in soil-water suspension varies from **5.6-6.4**with an average of **5.9** .which increase from top to sub soil. This range of soil pH is termed as moderatly acid to slightly acid soil. But in the study area there is low almunium toxisity for soil of the study area with detail study Liming is recomended for neutralized the soil reaction or to increse the Low Ph with organic fertilizer application and crop rotation practices.

6.2.2. Electrical Conductivity EC and (ECe)

The Electrical conductivity (EC) measurement of a soil solution is an indicator of the amount of soluble salts in the soil. EC value of greater than 4 mmhos/ cm is considered not favorable for most crops. Electrical conductivity (EC) values of the study area varied from **0.03 to 0.15** dS m^{-1} and in accordance with the EC rating, the soils of the study area were non-saline. Similarly, according to definition set by U.S. Salinity Laboratory Staff (1954) none of the samples were saline and the values were even lower than the suggested cut of point, 4 dS m^{-1}. This is due to rainfall that significantly exceeds evapotranspiration and results in leaching of soluble ions and prevents accumulation of salt. Plants growing in these areas do not have the problem of absorbing water because of the lower osmotic effect of dissolved salt contents.

The range of **ECe** measured for the soil of the study area is very low varying from **0.11-0.28 dS**/m with anaverage of **0.18 dS/**m en the top soil and 0.1 to 0.4 in to the sub soil.Generally soil with EC value of less than 4dS/m is considered as salt free soil and hence soil of the project area is not affected by salinity and no effect on the growth of plant as the value observed is below the permissible limit.

6.2.3. Organic Carbon (OC) or Organic Matter (OM)

The organic carbon contents of soils of the study area are in the range of **0.49**% **to 1.17%** with average of **0.77**% which it is rated as very low level to low level of organic carbon content.The determination of organic matter (OM) is conducted to evaluate availability of plant nutrients and physical condition of the soil. Soil organic matter consists of plant, animal and microbial residues in various stage of decay. Organic matter contains about five present (5 per cent) of total nitrogen, so it serves as a storehouse for reserve nitrogen. But the nitrogen in organic matter is in inorganic form and not immediately available for plant use, since decomposition usually occurs slowly. Organic matter results to dark color of many soils, holds water 20 times of its weight, provides aggregation and has high CEC.

The organic matter content of the study area are in the range of **0.84%to 2.02%**the average organic matter content of the soils of the study area is **1.32%** and is rated as medium level. Generally, in all soils, organic carbon content decreases from top to sub soil indicating relatively better accumulation of decomposable organic materials in the surface horizons than in the subsurface.

6.2.4. Total Nitrogen

The total nitrogen is an indicator of the total amount of the different form of nitrogen such as organic nitrogen, NO_3, NO_2, and NH_4 ions. Apart from nitrogen fertilizer applications, the only other source of nitrogen in soil is the breakdown and humification of organic matter, and atmospheric nitrogen fixation by leguminous plants.

Results show that generally total nitrogen ranges from **0.04 to 0.1%** percent with an average of 0.07% which indicate that the total nitrogen content is high in the study area**.**

6.2.5Carbon to Nitrogen Ratio (C: N)

C:N ratio is an indicator of the process of transformation of organic nitrogen to available nitrogen such as ammonium nitrite and nitrate. A minimum acceptable C: N ratio is a value less than 10:1 and C:N ratio of greater than 14:1 is considered as poor humification and low N. The C: N ratio of soils in the study area varies from **10 to 12**

6.2.6. Available Phosphorus

Phosphorus is present in the soil in both organic and inorganic forms, the inorganic form is usually more important as a plant nutrient. The phosphorus availability to plants differs between different forms of phosphorus in the soil. Available phosphorus is the form of phosphorus, which is readily available to the plant. However, phosphorous is generally low in total amount in the soil and is low in solubility, because it is fixed by Aluminum and Iron at low PH and Calcium at high PH.

The available phosphorus content of the soils of the project area varies from**0.74**ppm to **2.90ppm** with average of **1.86ppm**where the value is low in top soil. Generally the available phosphorus of the soils of the soil mapping units is rated as lower.

6.2.7. Cation Exchange Capacity (CEC)

The Cation Exchange Capacity (CEC) measured as meq/100g soil is important indication or criteria in soil classification and can be used as an overall assessment of the potential fertility of the soils and possible response to fertilizer. CEC is often used as characteristics in determination of nutrient retention for land quality assessment in land evaluation. The higher the CEC, the greater will be the ability to retain cations. It should be noted that CEC values critically depend on pH. The overall values of CEC lie in the range of **12** meq/100g soil to **47** meq/100g. CEC on average **26.7**meq/100g medium value, this value between these ranges is rated as low to very high which in turm mean is good agricultural soilin terms of plant nutrition.

6.2.8 Base Saturation Percentage (BSP)

Base saturation is frequently used as an indicator of soil fertility and it is also used in soil classification. Base saturation is the proportion of CEC accounted by exchangeable bases (Ca, Mg, K and Na) and is considered as an index of soil fertility. The soil with BSP value of less than 50 per cent is considered as Dystric (infertile) and those with above 50 per cent are considered as Eutric (fertile) in FAO classification.

The calculated BSP of the project area was found between**51% to 72%**average**62%**indicating very high value. In other words, such higher levels of BSP mean that the exchangeable complex is saturated with exchangeable cations.

6.2.9. Exchangeable Calcium (Ca)

Normally calcium deficiency in a plant nutrient occurs only in soils of low CEC at PH of 5.5 or less, Calcium also effectively deficient at high PH level when there is excessive sodium content. Large input of potassium fertilizer or high natural potassium may however inhibit plant uptake of calcium in the soil having more neutral reaction. If other factors are conducive a level of 6 meq/100g soil of exchangeable calcium is generally sufficient to ensure crop production (FAO, 1979). The value of exchangeable calcium in the study area is **1.15**cmol (+)/kg soil to **15.42**cmol (+)/kg soil with average value of **6.68** cmol (+)/kg soil, which indicate that very high level

6.2.10. Exchangeable Magnesium (Mg)

Exchangeable magnesium which is greater than 3cmol (+)/kg soil is believed to be adequate for plant nutrition. The amount of exchangeable magnesium reported for the soils of the study area varies from **5.31 to 20.29cmol (+)/kg** soil with average value of **11.39cmol(+)/kg** soil. The result shows that the level of Mg is high to very high

6.2.11. Exchangeable Potassium (K)

Potassium is an important plant nutrient and a great deal of study has been made of the amounts believed necessary for adequate plant growth. Values less than 0.1cmol (+)/kg soil are considered deficient, from 0.1 to 0.2cmol (+)/kg intermediate and greater than 0.2cmol (+)/kg adequate.

Soils of the study area have exchangeable K value ranging from **0.12 to 0.90 cmol (+)/kg** soil. Which indicates that the level of K is medium to high .the average value is **0.51 cmol (+)/kg**

6.2.12. Exchangeable Sodium (Na)

Sodium is not an essential plant nutrient; but some plants for potassium substitute can utilize it. On the other hand, when sodium is present in the soil in significant quantities, particularly in proportion to the other cations present it can have an adverse effect to both plant nutrition and physical conditions of the soils; however, no structural degradation was observed during the present filed work.The value of the measured exchangeable Na falls in the range of **0.13 to 0.20cmol(+)**/kg of soil, with mean value of **0.17 cmol(+)/kg** of soil indicating lower Na content of the soil and have no any adverse effect on growth of crops and physical properties of soil.

6.2.13. Exchangeable Sodium Percentage (ESP) and Sodium Adsorpation Ratio

Exchangeable Sodium Percentage (ESP) indicates Sodicity in the soil. Soils with ESP<15 is generally non-Sodic requiring no amendments, whereas soil with ESP> 15 are Sodic and requires amelioration method.

The result of laboratory analysis and the derived ESP value for the soil of the command area showson the top soil **0.28% to 1.38%** with avegage value of **0.81**% it is below the allowable limit and there is no sodicity problem in the study area and no need of amendments. Sodic soils have an ESP >15, the ECe is <4 dS m^{-1}, and the lower limit of thesaturation extract SAR is 13.

6.2.14 Calcium carbonete

The calcium carbonate equivalent of >15 per cent is used in the FAO definition of Calcic horizon. High level of calcium carbonate >15 per cent affect the physical and chemical characteristics of a soil besides normal root penetration. The term Calcaric which refers to soils which are calcareous (show strong effervescence with 10 per cent HCL), in most of the fine earth or which contain more than 2% carbonate equivalent. The calcium carbonate content of most of the soils in the study area **is trace** that the soils are free of Calcium Carbonate and not affect the soil conditions.

6.2.15. Potassium to Magnesium Ratio (K: Mg)

If the ratio of potassium to magnesium is more than 2:1, magnesium uptake may be inhibited. The ratio of K: Mg recorded for the project area is between 0.04 and 0.29(Average value is 0.16: 1, indicating an optimum situation for production of most field crops, vegetables and fruits.

6.2.16. Calcium to Magnesium Ratio (Ca: Mg)

The ratio of calcium to magnesium (Ca: Mg) in most soils of the project area is moderate 2.07 to 3.84 With Average of 2.92 Which indicate that the level is less favorable to high favorable.

6.2.17. Potassium to Cation Exchangeable Capacity Ratio (K: CEC)

If the ratio of K: CEC is less than two per cent, it suggests a minimum level to avoid K deficiency and soils with more than 25% ratio is considered to be potassium rich soil. The minimum K: CEC ratio of the soil units in project area is anaverage0.03.

Table 10: Description of Soil physical and chemical properties by major soils

	MAJOR SOIL			
Soil Physical & chemical Properties	Horizon	LEXISOL	CAMBISOL	LEPTOSOL
Ph	**top** **sub**	**6.1** **6.4**	**6.0** **5.8**	**5.9** **-**
Ec	**Top** **sub**	**0.1** **0.05**	**0.05** **0.06**	**0.14** **-**
Na	**top** **sub**	**0.15** **0.18**	**0.16** **0.19**	**0.15** **-**
K	**Top** **sub**	**0.90** **0.9**	**0.78** **0.77**	**0.44** **-**
Ca	**top** **sub**	**5.94** **7.4**	**2.75** **3.2**	**4.15** **-**
Mg	**top** **sub**	**2.7** **2.3**	**2.41** **3.39**	**2.61** **-**
CEC	**Top** **sub**	**17.5** **47.7**	**14.5** **23.0**	**14.5** **-**
B S%	**Top** **sub**	**69** **52**	**56** **64**	**55** **-**

	MAJOR SOIL			
Soil Physical & chemical Properties	Horizon	LEXISOL	CAMBISOL	LEPTOSOL
ESP	**top** **sub**	**1.1** **2.2**	**1.23** **1.50**	**1.70** **-**
TN	**top** **sub**	**0.04** **0.03**	**0.04** **0.03**	**0.08** **-**
OC	**top** **sub**	**0.44** **0.2**	**0.5** **0.27**	**1.0** **-**
OM	**top** **sub**	**1.15** **0.42**	**0.87** **0.46**	**1.72** **-**
AvP	**top** **sub**	**1.27** **1.5**	**3.68** **2.41**	**2.07** **-**
Caco3	**top** **sub**	**0.00** **0.00**	**-**	**0.00**
Texture	**top** **sub**	**SCL** **SCL**	**SL** **SL**	**SL** **-**
Depth		**100-150**	**50-100&25-50**	**0-25**

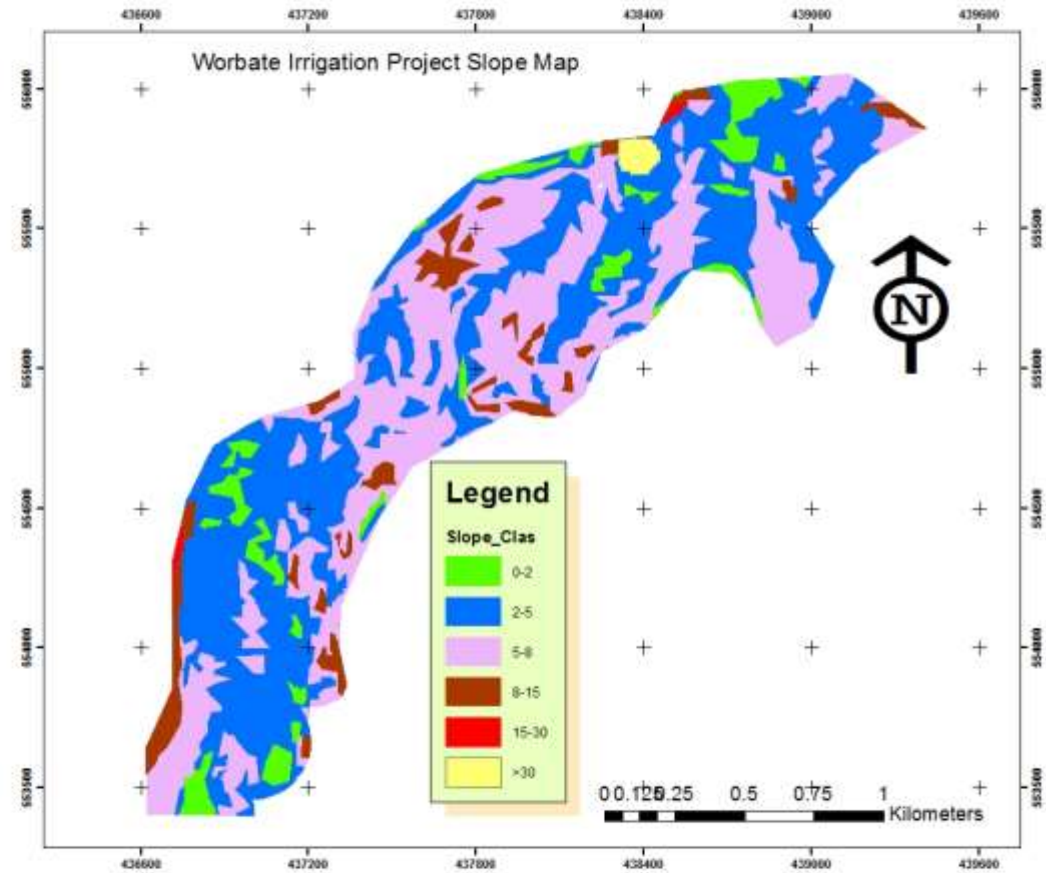


Figure 5: Slope Map

7. DESCRIPTION OF SOIL MAPPING UNITS

7.1. General

The soils of the project area are mapped and described based on their similar soil characteristics and constraints. The soils of the study area have been classified in to 16 soil mapping units. The soil mapping units were classified based on soil phase's criteria. The dominant characteristics considered in mapping the soil unit are like slope, soil type, soil drainage, depth to water table, soil texture and soil physical and chemical properties. Based on this, the following soil mapping units were identified.

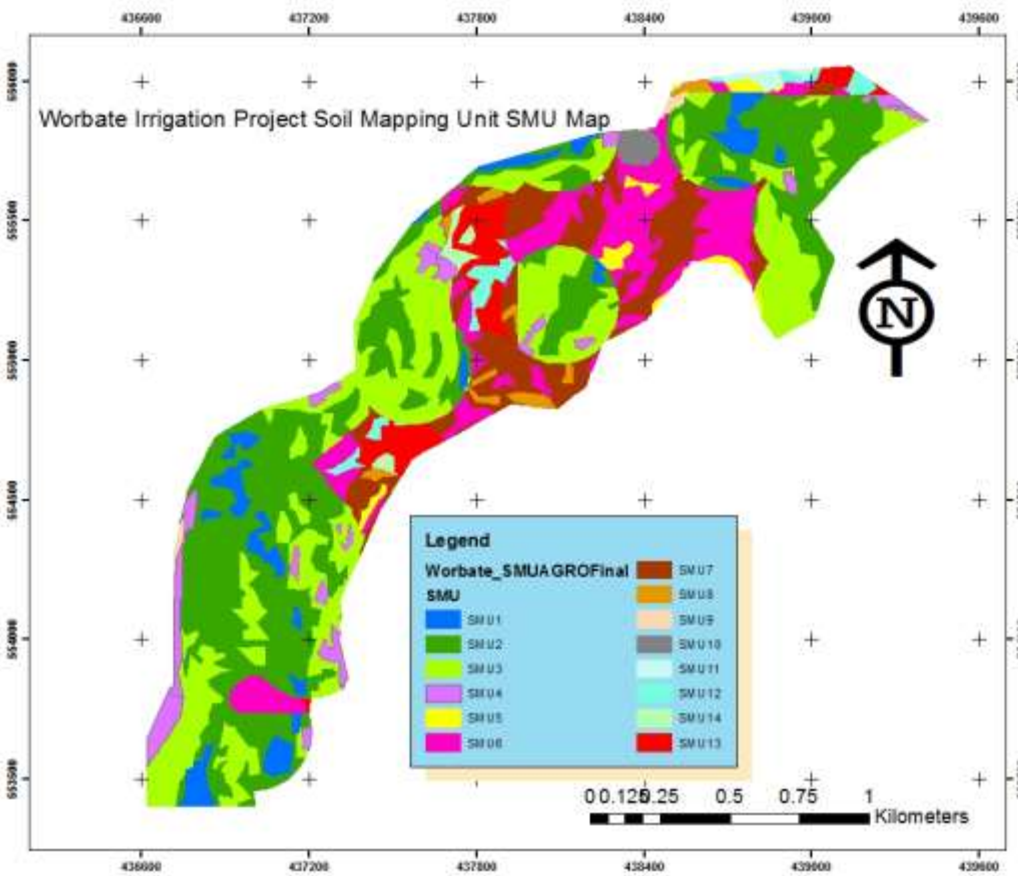


Figure 6Soil mapping unit (SMU Map)

Table 11: Area or (distribution) percentage of major soil groups.

Major Soil Group(Fao,1988)	Identified soil	Area(ha)	Ha(%)
Cambisol	Leptic,eutric,Cambisol	125.66	54.4
Lixisol	Rhodic Lexisol eutric	89.73	38.84
Leptosol	Eskeletic Eutric Leptosol	15.65	6.77
		230.99	100

7.2. Soil Mapping unitsDescription:

1SCL (Lx, eu) -a(SMU1)

This mapping unit refers to soils developed on 0-2% slope with very deep profile (100-150cm). The soils are moderately well drained with moderate, medium sub angular blocky structure and have Sandy Clay L oam (SCL) texture.

The pH value is 6.1 in the top soil and 6.4 in the sub soil indicating that the soil is Slightly acid The over all organic carbone content of this soil unit is 1.17% in the top soil and 0.55% in sub soil, which indicates Low to Very Low level of organic matter content. Total nitrogen content ranges 0.13% in the top and 0.1 % in sub soil which shows high level status of the total nitrogen. This soil mapping unit has low available phosphores (0.65ppm in the top soil &1.02ppm in the sub soil), Medium to high CEC level (17.5&47.7Meq/100g of soilin top and sub soil respectively) and very high base saturation percentage (69% in the top soil and 51% in the sub soil. The soils in this mapping unit have high Ca2+ and are none calcareous. The soil unit is Rhodic and Eutric Lixisol.The total extent of this mapping unit is 11.55 ha.

2SCL (Lix, eu)-a(SMU2)

This mapping unit refers to soils developed on 2-5 % slope with deep profile (100-150cm). The soils are moderately well drained with moderate, medium sub angular blocky structure and have Sandy Clay Loam (SCL) texture.

The pH value is 6.1 in the top and 6.4 in the sub soil indicating that the soil is Slightly acid The overall organic carbon content of this soil unit is 1.17 % in the top soil and 0.55% in sub soil, which indicates low(topsoil) to very low(sub soil) level of organic matter content. Total nitrogen content ranges 0.22% in the top and 0.06% in sub soil which shows High level of the total nitrogen. This soil mapping unit has low lable available phosphorus (2.70ppm in the top soil &2.18ppm in the sub soil), CEC high level (30.4&27.18 Meq/100g of soil in top and sub soil respectively) and high base saturation percentage (71 in topand 80sub soil. The soil in this mapping unit have High Ca2+ and none calcareuse.The soil unit is eutric Lixisol The total extent of this mapping unit is 78.58 ha

3SL (Cm, eu)-a(SMU3)

This mapping unit refers to soils developed on 5-8 % slope with modaratly deep profile (50-100cm). The soils are Moderatly wel drain with moderate, medium sub angular blocky structure and haveSandy Loam (SL) texture.

The pH value is 5.8 in the top soil and6.1 in the sub soil, which indicating that the soil is modaratly to slightly acid. The over all organic carbone content of this soil unit is 2.36% in the top soil and 0.26% in sub soil, which indicates very Low level of organic matter content. Total nitrogen content ranges 0.22% in the top and 0.09 % in sub soil which shows highto medium level status of the total nitrogen. This soil mapping unit has very low available phosphorus (4.0ppm in the top soil &3.98ppm in the sub soil), medium CEC level (20.7&10.66Meq/100g of soil in top and sub soil respectively) and high base saturation percentage (57% in the topand 59 subsoil. The soils in this mapping unit have High Ca2+ and are nonecalcareous.The soil units is Cambisol The total extent of this mapping unit is 58.02 ha

4SL (-b(SMU4)

This mapping unit refers to soils developed on 8-15 % slope with moderatly deep profile (50-100cm). The soils are well drained with fine & medium sub angular blocky structure and have SandyLoam (SL) texture.

The pH value is 5.9in the top and 6.1 in the sub soil, which indicating that the soil is modaratly to slightly acid. The overall organic carbone content of this soil unit is 0.53% in the top soil and 0.33% in sub soil, which indicates very low level of organic matter content. Total nitrogen content ranges 0.04% in the top and 0.03 % in sub soil which shows medium level status of the total nitrogen. This soil mapping unit has low available phosphorus (2.02ppm in the top soil & 2.84ppm in the sub soil), medium CEC level (16.1&17.0Meq/100g of soil in top and sub soil respectively) and high base saturation percentage (65 inthe topand77 subsoil. The soils in this mapping unit have high Ca2+ and are none calcareous. The soil units is Cambisol.The total extent of this mapping unit is 9.23 ha

1SL(Cm)-d(SMU5)

This mapping unit refers to soils developed on 0-2% slope with very deep profile (25-50cm). The soils are imperfectely to moderately well drained with strong & medium sub angular blocky structure and have Sandy Loam (SL) texture.

The pH value is 5.8 in the top soil and6.2in the sub soil, which indicating that the soil is slightly acid. The overall organic carbon content of this soil unit is 1.74% in the top soil and 0.50 % in sub soil, which indicates very low to low level of organic matter content. Total nitrogen content ranges 0.14% in the top and.0.06% in sub soil which shows high level status of the total nitrogen. This soil mapping unit have low available phosphorus in the top and in the sub soil (0.80 ppm in the top soil &2.90 ppm in the sub soil), Medium to high CEC level 18&47 Meq/100g of soil in top and sub soil respectively) and high base saturation percentage (69%and 75% both in the top and subsoil. The total extent of this mapping unit is 2.87.This soil mapping unit is Cambisol.

2SL (Cm, eu)-a(SMU6)

This mapping unit refers to soils developed on 2-5% slope with shallow profile (25-50cm). The soils are moderately well drained with moderate & medium sub angular blocky structure and have Sandy loam (SL) texture.

. The pH value is 5.9 in the top soil and6.1 in the sub soil, which indicating that the soil is Very slightly acid. The overall organic carbon content of this soil unit is 0.8% in the top soil and 0.49 % in sub soil, which indicates very high to high level of organic matter content. Total nitrogen content ranges 0.08% in the top and 0.04 % in sub soil which shows high level status of the total nitrogen. This soil mapping unit have low available phosphorus (1.02 ppm in the top soil &0.12 ppm in the sub soil), medium CEC level (12&18 Meq/100g of soil in top and sub soil respectively) and high base saturation percentage (51% in the top and 72%subsoil. The soils in this mapping unit have high Ca2+ and are None calcareous. The soil units is eutric Lixisol. The total extent of this mapping unit is 26.19 ha

3SCL (Cm, eu)-a(SMU7)

This mapping unit refers to soils developed on 5-8 % slope with shallow profile (25-50cm). The soils are well drained with stronge& medium sub angular blocky structure and have Sandy Clay Loam (SCL) texture.

The pH value is 5.9 in the top soil and 6.2 in the sub soil, which indicating that the soil is slightly acidic. The overall organic carbon content of this soil unit is 1.74% in the top soil and 0.5% in sub soil, which indicates very Low level of organic matter content. Total nitrogen content ranges 0.14% in the top and 0.07 % in sub soil which shows high level status of the total nitrogen. This soil mapping unit have High level of available phosphorus in the top soil (15.18 ppm in the top soil &6.5ppm in the sub soil), mediumCEC level 12.01&18 Meq/100g of soil in top and insub soil respectively) and highLevel base saturation percentage (69% in the top and 72% subsoil. The soils in this mapping unit have high Ca2+ and are none calcareous. The soil units areCambisol.The total extent of this mapping unit is 23.69 ha

4SL (Cm, eu)-a(SMU8)

This mapping unit refers to soils developed on 8-15 % slope with very deep profile(25-50 cm). The soils are moderately well drained with medium subangular blocky structure and have Snndy Loam (SL) texture.

The pH value is 5.9 in the top soil and 6.2 in the sub soil, which indicating that the soil is Slightly acid. The over all organic carbone content of This soil unit is 4.05% in the top soil and 20.7 % in sub soil, which indicates very high to high level of organic matter content. Total nitrogen content ranges 0.46% in the top and 0.1 % in sub soil which shows high level status of the total nitrogen. This soil mapping unit have high to medium level of available phosphorus (24.4 ppm in the top soil & 1.2 ppm in the sub soil), medium to very high CEC level (12 &45 Meq/100g of soil in top and sub soil respectively) and high base saturation percentage (52% in the top and 72% subsoil. The soils in this mapping unit have high Ca2+ and are none calcareous.The soil units is Cambisol.The total extent of this mapping unit is 3.03.ha

6SL (Cm, eu)-a(SMU9)

This mapping unit refers to soils developed on 15-30 % slope with shallow profile (25-50cm). The soils are well drained with moderate & medium sub angular blocky structure and have Sandy Loam (SL) texture.

The pH value is 5.8 in the top soil and5.9 in the sub soil, which indicating that the soil is Strongly acid. The overall organic carbon content of this soil unit is 0.66% in the top soil and 0.65 % in sub soil, which indicates very low to high level of organic matter content. Total nitrogen content ranges 0.05% in the top and 0.03 % in sub soil which shows medium level status of the total nitrogen. This soil mapping unit have low level of available phosphorus (0.38 ppm in the top soil & 0.24 ppm in the sub soil), midum CEC level (12&18Meq/100g of soil in top and sub soil respectively) and high base saturation percentage (52% in the top and 75% subsoil. The soils in this mapping unit have high Ca2+(18) and are None calcareous.The soil units is Cambisol.The total extent of this mapping unit is 0.82ha

6SL (Cm, eu)-a(SMU10)

This mapping unit refers to soils developed on >30 % slope witt Shallow profile (25-50 cm). The soils are well drained with moderate & medium sub angular blocky structure and have Sandy Loam (SL) texture.

The pH value is 5.8 in the top soil and 5.9 in the sub soil, which indicating that the soil is Strongly acid. The overall organic carbon content of this soil unit is 0.66% in the top soil and 0.65 % in sub soil, which indicates very low to high level of organic matter content. Total nitrogen content ranges 0.05% in the top and 0.03 % in sub soil which shows medium level status of the total nitrogen. This soil mapping unit have low level of available phosphorus (0.38 ppm in the top soil & 0.24 ppm in the sub soil), medium CEC level (12& 18Meq/100g of soil in top and sub soil respectively) and high base saturation percentage (69% in the top and 72% subsoil. The soils in this mapping unit have high Ca2+(18) and are Nonecalcareous.The soil units is Cambisol.The total extent of this mapping unit is 1.038ha

1SL (Lp, eu)-a(SMU11)

This mapping unit refers to soils developed on 0-2 % slope with Shallow profile (0-25 cm). The soils are well drained with moderate & medium sub angular blocky structure and have Sandy Loam (SL) texture.

The pH value is 5.8 in the top soil and 5.9 in the sub soil, which indicating that the soil is Modaratly acid. The overall organic carbon content of this soil unit is 0.66% in the top soil and 0.65 % in sub soil, which indicates very low to high level of organic matter content. Total nitrogen content ranges 0.05% in the top and 0.03 % in sub soil which shows medium level status of the total nitrogen. This soil mapping unit have low level of available phosphorus (0.38 ppm in the top soil & 0.24 ppm in the sub soil), very high CEC level (12& 18Meq/100g of soil in top and sub soil respectively) and Medium base saturation percentage (45% in the top and 46% subsoil. The soils in this mapping unit have high Ca2+(18) and are Nonecalcareous.The soil units is Cambisol.The total extent of this mapping unit is 1.13 ha

2SL (Lp, eu)-a(SMU12)

This mapping unit refers to soils developed on 2-5 % slope with Shallow profile (0-25 cm). The soils are well drained with moderate & medium sub angular blocky structure and have Sandy Loam (SL) texture.

The pH value is 5.8 in the top soil and 5.9 in the sub soil, which indicating that the soil is Modaratly acid. The overall organic carbon content of this soil unit is 0.66% in the top soil and 0.65 % in sub soil, which indicates very low to high level of organic matter content. Total nitrogen content ranges 0.05% in the top and 0.03 % in sub soil which shows medium level status of the total nitrogen. This soil mapping unit have low level of available phosphorus (0.38 ppm in the top soil & 0.24 ppm in the sub soil), medium to high CEC level (11.2& 16.9Meq/100g of soil in top and sub soil respectively) and Medium base saturation percentage (45% in the top and 46% subsoil. The soils in this mapping unit have high Ca2+(18) and are Nonecalcareous.The soil units is Cambisol.The total extent of this mapping unit is 3.85 ha

3SL (Lp, eu)-a(SMU13)

This mapping unit refers to soils developed on 5-8 % slope with Shallow profile (0-25 cm). The soils are well drained with moderate & medium sub angular blocky structure and have Sandy Loam (SL) texture.

The pH value is 5.8 in the top soil and 5.9 in the sub soil, which indicating that the soil is Modaratly acid. The overall organic carbon content of this soil unit is 0.66% in the top soil and 0.65 % in sub soil, which indicates very low to high level of organic matter content. Total nitrogen content ranges 0.05% in the top and 0.03 % in sub soil which shows medium level status of the total nitrogen. This soil mapping unit have low level of available phosphorus (0.38 ppm in the top soil & 0.24 ppm in the sub soil), mediumCEC level (12& 18Meq/100g of soil in top and sub soil respectively) and Medium base saturation percentage (45% in the top and 46% subsoil. The soils in this mapping unit have high Ca2+(18) and are Nonecalcareous.The soil units is Cambisol.The total extent of this mapping unit is 9.14 ha

4SL (Lp, eu)-a(SMU14)

This mapping unit refers to soils developed on 8-15 % slope with Shallow profile (0-25 cm). The soils are well drained with moderate & medium sub angular blocky structure and have Sandy Loam (SL) texture.

. The pH value is 5.8 in the top soil and 5.9 in the sub soil, which indicating that the soil is Modaratly acid. The overall organic carbon content of this soil unit is 0.66% in the top soil and 0.65 % in sub soil, which indicates very low to high level of organic matter content. Total nitrogen content ranges 0.05% in the top and 0.03 % in sub soil which shows medium level status of the total nitrogen. This soil mapping unit have low level of available phosphorus (0.38 ppm in the top soil & 0.24 ppm in the sub soil), very high CEC level (12& 18Meq/100g of soil in top and sub soil respectively) and Medium base saturation percentage (45% in the top and 46% subsoil. The soils in this mapping unit have high Ca2+(18) and are Nonecalcareous.The soil units is Cambisol.The total extent of this mapping unit is 1.56 ha

8.0 CONCLUSIONS AND RECOMMENDATIONS

8.1. Conclusions

The detailed survey of the soils of the study area Worbate irrigation project has shown that the soils of the study area have good agricultural potential if properly managed and utilized. Most of the physical properties of the soils are very good for most of agricultural production of crops. Some of the ideal physical properties of the soils are Sandy Clay loam and sandy loam texture, the moderate to weak, fine to medium sub angular blocky structures can be mentioned, high Level of Persentage base saturation.The soils also have no adverse chemical properties that can hinder the production of agricultural crops. The soils have problems of Acidity and fertility

The limitations of the soils investigated are grouped in to two as correctable and non-correctable. The correctable limitations are the low level of organic matter of most soils, the low levels of plant nutrients such as available phosphorous, total nitrogen etc. One of the non-correctable limitations of the soils Moderatly Acidity 5.8 to 6.1 with average 5.9 pH in the top soil (Low Ph level) shallow to mderately deep effective depth of the soils and slope Greater than 15%.

8.2.2. Recommendations

Potentials and limitations of the soils of the study area those crops that can be suitable should be selected through crop suitability evaluation. The non-correctable limitation for most of the soils is Low Ph level moderatly acidity problem) for this Problem Recommended Lime Application and organic fertilizer (compost) use the effective depth of the soils varying from very shallow to moderately deep. Therefore, during crop selection for suitability evaluation, those crops which are shallow to medium rooted should be selected.

The low fertility condition of the soils reflected by the low levels of organic matter for most of the soil mapping units, total nitrogen, and available phosphorous should be avoided by modern practices. This can be done through addition of organic matter (compost) and artifial fertilizers (nitrogeneous and phosphate fertilizers) and by carrying out the overall intgrated nutrient management to alleviate the fertility constraints of the soils.

The correctable physical and chemical constraints which will be identified during evaluation of the selected crops should be corrected for optimum production of the crops. The suitability evaluation of those crops which may fit into the existing situation of the soils can minimize the limitations of the soils (proper crop selection).

There is 2-4 termite mund per hectar in the command area traditional or biological and chemical control of termite exspantion needed.

- Liming to improve the soil PH
- Application of organic fertilzer like compost, and/or chemical fertilzer improves the availability of phousphrous and improve the not suitable land for surface irrigation to highly and moderately suitability class.

Some of the soil mapping units can be affected by sheet, rill and gully erosion. This can be controlled through careful planning and implementation and integrated Watershed Development. Technologies such as proper erosion control mechanism, such as afforestation, plantation of cover grasses, contouring and conservation structures can be incorporated specific to site condition

9. LAND EVALUATION

9.1. Introduction

Land evaluation is the process of the assessment of land performance when used for specified purpose (FAO, 1984). Although its precise role varies in different circumstances, it is always an integral part of the process of land use planning. Land evaluation involves the interpretation of basic surveys of climates, soils, vegetation and other aspects of land in terms of the requirements of alternative kinds of land use. These may be major kinds of land use such as irrigation agriculture, rainfed agriculture, livestock production, forestry, etc., or land utilization types described in more detail.

The suitability of the land is assessed, classified and presented for each kind of use. Land evaluation occupies a central and coordinating position within the project. It provides the means by which the basic surveys of natural resources geomorphology, climate, soils and vegetation are assessed with respect to their potential for different kinds of land use, both actual and potential.

Thus the land evaluation has been the process through which the basic surveys of resources have been translated into potential for development. The output from the evaluation provides a major basis for land use planning at the regional and national level.

The study area, Worbate Large scale irrigation project, is one of the selected area for the irrigation developements. This project area is one of the most important potential areas for all developmental activities, especially for crop development.

9.2. General objective

The general objective of the study is to assess and delineate potentially suitable from non suitable land units for irrigation indicating constraints for use of the land.

9.3. Specific objectives:

The specific objective of this part of the land evaluations includes;

- To identify area of land suitable for irrigation agriculture development that is simultaneously confirmed to be technically feasible, economically viable, and socially acceptable

- Identification of the study area resource potentials and constraints for irrigated agriculture.
- Classification of land into suitability classes and subclasses according to limitations;

Suggesting alternative suitable uses.

9.4. Scope of work:

- Prepare land unit maps
- Compare the major land quality of the study area with land use environmental requirement of LUTs considered.
- Land suitability assessment of the study area for irrigation agriculture development based on LUTs considered.
- Prepare land suitability map at 1:10,000 scales for the LUTs considered

9.5. Procedures Followed

First, identification of land utilization types (LUTs): surface irrigation Based on these land utilization types, full data on land mapping units in terms of their land characteristics and land qualities (FAO, 1976, 1983; Dent & Young, 1981) were collected. This phase is concerned with surveys to collect data on land resources. The collected information on land resources is used to demarcate land mapping units. These land mapping units, whose land characteristics and qualities are described and are known, form the area of land units in the suitability evaluation (FAO, 1983, 1984, 1985).

In the second step the land use requirements for each land utilization type were defined (FAO, 1983; 1984; 1985). The land use requirements of each land utilization type were defined in terms of all forms of their requirements.

In the third step, matching of land qualities and/or land characteristics, with the requirements of land utilization types (FAO, 1983; 1984; 1985) were made. In determining the suitability classes the maximum limitation method was employed to combine individual ratings. The maximum limitation method is based on the law of the minimum, which considers the least favourable land characteristics and/or qualities limit the land use. This implies that any other amendments of the land would not improve its quality unless the most severe limiting factor is eliminated or at least reduced. Then, it distinguishes land suitability classes on the basis of the most severe limiting land characteristic (FAO, 1983).

In the fourth stage combining individual class determining factor ratings to obtain a tentative land suitability classification for each LUT on each land unit through the maximum limitation method was executed.

Finally, mapping of provisionally irrigable and non irrigable area were made as the final outcome.

Table 12:*FAO Land Suitability Classification Levels (FAO, 1983) (After Ir.C.Sys 1991 and H.Huizing, ITC 1992,)*

Class	Designation	Definition
S1	Highly suitable	Land having no significant limitations to sustained application of a given use, or only minor limitations that will not significantly reduce productivity or benefits and will not raise inputs above an acceptable level. The potential yield level expected is 85% or more of optimum yield.
S2	Moderately suitable	Land having limitations which in aggregate are moderately severe for sustained application of a given use. The limitations will reduce productivity or benefits and increase required inputs to the extent that the overall advantage to be gained from the use, although still attractive, will be appreciably inferior to that expected on Class S1 land. The potential yield level expected is 60-85% of the optimum yield.
S3	Marginally suitable	Land having limitations which, in aggregate, are severe for sustained application of a given use and will so reduce productivity or benefits, or increase required inputs, that this expenditure will be only marginally justified. The potential yield level expected is 40-60% of the unsuitable optimum yield.
N1(S4)	Currently not suitable	Land otherwise suitable (S1 to S3) for sustained application of a given use but having a limitation(s) which, although possibly surmountable in time, cannot be corrected with existing knowledge at currently acceptable cost. The limitation(s) is so severe as to preclude successful sustained use of the land in the given manner at present.
N2	Permanently not suitable	Land having limitations that appear so severe as to preclude any possibilities of successful sustained use of the land in the given manner.

9.6. Land Use Requirement for Surface Irrigation

Surface irrigation is the most common method of irrigation and accounts for 95% of irrigation in the world. Soils with high infiltration rate are commonly not suitable to surface irrigation, because even distribution of irrigation water is difficult to maintain without short furrows. As a result the loamy soils may be considered as marginally suitable, despite the potential optimum nutrient and moisture holding capacity. High bulk density hinders root penetration in fine textured soils, if compacted.

In general soils of the area are occurring on very gentle slope and the soils are clay to Sandy loam in texture and prone to water logging (for clay soil). Thus the land is Moderately to marginally suitable for surface irrigation. See Table : 18 below

Table 13: Land use requirement and critical class limits for surface irrigation

S/N	*Limiting factors*	*Suitability Classes*				
		S1	*S2*	*S3*	*S4*	*N*
1	*Slopes (%)*	*0 - 2*	*2-5*	*5-8*	8-15	*>15*
2	*Drainage*	*W*	*MW*	*I*	*P&E*	*VP*
3	*Depth (cm)*	*>120*	*60-120*	*30-60*	*30-60*	*<30*
4	*Soil texture*	*SL-CL*	*CL-C*	*LS & HC*	*S*	*VCS*
5	*Structure*	*SAB*	*AB*	*Platy*	*Massive*	-
6	*Salinity (ds/m)*	*<4*	*4-8*	*8-12*	*12-16*	*>16*
7	*ESP (%)*	*<10*	*10-15*	*15-20*	*>20*	*>20*
8	*CEC (meq/100g)*	*>20*	*5-20*	*1-5*	*<1*	*<1*
9	*OM (%)*	*3-5*	*2.5-3*	*2-2.5*	*1-2*	-
10	*Total N (%)*	*>0.5*	*0.2-0.5*	*0.1-0.2*	-	*<0.1*
11	*Av.P (ppm)*	*>15*	*10-15*	*8-10*	*2-8*	*<2*
12	*C/N*	*10-12*	*6-10*	*<6*	*<6*	-
13	*pH*	*5.5-7*	*5-5.5 & 7-8*	*4.5-5 & 8-8.5*	*8.5-9*	*<4.5 &>9*

S/N	Limiting factors	*Suitability Classes*				
		S1	*S2*	*S3*	*S4*	*N*
14	*Fertility index*	*High*	*Moderate*	*Low*	*Very low*	-
15	*IR (Cm/hr)*	*0.5-3.5*	*0.1-0.5*	*6.5-10.0*	*10-25*	*<0.1, >25*
16		-	*3.5-6.5*	-	-	-
17	*HC (m/day)*	*>1.5*	*1.5-0.5*	*0.5-0.2*	*<0.2*	-
18	*AWC (mm/m)*	*>150*	*100-150*	*75-100*	*50-75*	*<50*

9.7. Land Utilization Types (LUTs)

The main objective of this land evaluation study is to select optimum land use type for each land units(SMU) identified in the study area. Land evaluation defines the suitability of a specific area of land (land unit) for specific LUT under stated system of management and input level.

The major kind of land use considered for the evaluation is irrigated agricultural development in the command area, using surface irrigation systems. A number of land utilization types (LUTs) were identified and defined in terms of their produce.

The present land evaluation thus has been providing a systematic overview of the physical limitations of these land uses. This intern provides a useful indication on opportunity and type of improvements required to improve the systems. The purpose of the present land evaluation is to assess in qualitative terms, the biophysical suitability of the land for the land utilization types. The results of the physical analysis will be used in the subsequent planning phase to identify constraints, opportunities and assess the economic viability of changes in management and input levels.

The major kind of land use considered for the land cultivation is irrigated agriculture development in the study area particularly in the command area using surface irrigation system. A number of LUTs were identified and defined interims of their response to irrigation, socio-economic situation, marketavailability, expected advantage of the government for national and regional agricultural development.Furthermore, in defining and describing the LUTs for irrigated crop production the main management level selected is intermediate management levels were considered:

An intermediate level of management involves the use of improved hand tools and/or draught animals. If accessible, it employs some fertilizer and pesticide applications and simple conservation methods to reduce productivity losses from land degradation. It includes cultivation of a combination of presently grown and improved cultivars of crops on permanently arable rainfed lands and use of supplementary irrigation in the form of spate/ runoff flood farming.

The following potential LUTs have been considered in the command area under the prepared project area:

1. Irrigated Low land sorghum cultivation
2. Irrigated Low land maize cultivation
3. Irrigated vegetable cultivation (Cabbage, Tomato, Pepper, Onion)
4. Irrigated Haricot bean cultivation

The evaluation has been carried out assuming moderately inputs management levels, moderate capital investment and high labor intensity. Thus, the LUTs can be defined, as medium input level of fertilizer and herbicide, moderate capital investment, medium to high labor intensity, 100% private property, with moderate management level by using surface irrigation and improved agronomic cultural practices, for local consumption and market orientation.

Table 14: Description of management levels

Attribute	Levels of management		
	Low traditional subsistence management	Improved Intermediate level of management	High level of management
Production systems	Rain-fed cultivation of presently grown cultivars	Rain-fed cultivation of presently grown and improved cultivars	Rainfed as well as irrigated cultivation of improved cultivars
Market orientation	Subsistence with little or no market	Subsistence production with some marketable or surplus crops	Commercial production
Power source	Draught animal and manual labor	Draught animal and manual labor	Complete mechanization
Labor intensity	High, including family labor	High, including family labor	Low, family labour costed if used
Capital intensity	Very low or no use of credit services	Intermediate access to credit services	High
Land holdings	Small and fragmented	Small and fragmented	Large, consolidated
Technology employed and input required	Local cultivars, no fertilizers or chemical pests weed killers, only traditional soil conservation schemes, no agricultural and extension advice	Improved cultivars, early land preparation and timely planting. Moderate use of fertilizers, pesticides. Correct plant densities and adequate manual weeding. Cultivation on correctly spaced and contour aligned ridges. Integration of traditional and modern soil and water conservation measures. Extension advice is followed	High-yielding cultivars including hybrids. Optimum fertilizer application. Chemical pest, disease and weed control. Full conservation measures. Use of modern management interventions
Income level	Low and subsistence and deficit	Intermediate, self dependent subsistence and some extra production(Moderate)	High
Infrastructure requirements	Limited access to markets and agricultural services	Organized markets for sale of cash and surplus products and to obtain agricultural inputs (fertilizers, pesticides, improved varieties)	Market accessibility essential, High level of advisory services and Application of research finding

Source: Modified after UNEP and FAO (1999)

Table 15 : Lowland Maize (*Zea Mays*)- Crop Environmental Requirements

Land quality	Diagnostic Factor	Unit	LowLand Maize(Zea mays)Crop Environmental Requirements			
			S_1	S_2	S_3	N
Climatic Chcs	Temperature	(ºC)	22.5-27.5	18-30	17.5-32.5	>32.5
	Altitude	masl	400-1400	1400-1600	1600-1700	>1800
Topography	Slope	(%)	0-8	8-16	16-30	>30
Wetness	Flooding					
	Drainage	Class	MW,W,SE<E		I	P,VP
Physical soil characteristics (s)	Texture	(class)	L,SIC,SI	SC,SICL,CL,SIL,SCL	LS,SL/SiCC(rd)	S
	Soil Depth	(cm)	>80	65-75	45-65	0-45
Salinity &Alkalinity	EC e	(mmhos/cm)	0-3.5	3.5-7.5	7.5-8	>8.5
	ESP	(%)	0-15	15-35	35-45	>45
Soil Fertility characteristics (s)	Apparent (CEC)	(cmol(+)/kg clay	>40	25-40	15-40	<5
					5-15	
	Sum of Basic Cations	(cmol(+)/kg soil)				
	AVP	PPM	>15	8-15	4-8	
	PH H2O		5.5-6.5	5.2-6.7	5.0-8.0	<5.0>8
	Organic Carbon	%	>2.5	1.5-2.5	1.0-7.5	<1.0
	$CaCO_3$	(%)	0-12	12.0-25	25-35	>35

Table 16: Onion (***Allium Cepa)***-Crop Environmental Requirements

Land quality	Diagnostic Factor	Unit	Onion(Allium Cepa)-Crop Environmental Requirements			
			S_1	S_2	S_3	N
Climatic Chcs	Temperature	(ºC)	0-19	22-23	23-25	>25
				25-30	30-35	>35
	Altitude	masl	1800-2200	1500-1800	1250-1500	>2500
				2200-2300	2300-2400	
Topography	Slope	(%)	0-2.0	2.-4	4.-6.	>6
Wetness	Flooding		F0			F1+
Physical soil characteristics (s)	Texture	(class)	L-SC	LS/SiCs	SL	S
					SiC	C(rd)-C(bl)
	Soil Depth	(cm)	>75	50-75	50-30	<20
Salinity &Alkalinity	EC e	(mmhos/cm)	0-1.2	1.2-2.8	2.8-4.3	>6
	ESP	(%)	0-20	20.0-35.0	35.0-50	>50
Soil Fertility characteristics (s)	Apparent (CEC)	(cmol(+)/kg clay	>24	<16(-)	<16(+)	
			24-16			
	Sum of Basic Cations	(cmol(+)/kg soil)	2.-1.2	1.2-0.8	<0.8	
	PH H2O		6.7-7.2	7.2-7.8	7.8-8.2	<5.5
						>8.2
	Organic Carbon	%	2.1-2	1.2-0.8	<0.8	
	$CaCO_3$	(%)	0-5	5.0-10	10.0-20	>20

Table 17: Tomato (Lycopersicum esculentum)-Crop Environmental Requirements

Land quality	Diagnostic Factor	Unit	Tomato(Capsicum annuum)-Crop Environmental Requirements				
			S_1		S_2	S_3	N
Climatic Chcs	Temperature	(ºC)	22-24	24-26	26-30	30-35	>35
			20-22	18-20	16-18	13-16	<13
	Altitude	masl	200-2100		2100-2400	2400-2800	>3200
Topography	Slope	(%)	0-2		2-4	4-6	>6
Wetness	Flooding		F0			F1	F+2
	Drainage	Class	MW,W,SE,E			I	P,VP
Physical soil characteristics (s)	Texture	(class)	CL,L,SICL,SI,SIC,Co,C<60s,SC,SCL		C>60s,C<60v,LS,LfS	Fs,LcS	Cm,SICm
	Soil Depth	(cm)	>150	100-150	75-100	50-75	<50
Salinity &Alkalinity	EC e	(mmhos/cm)	0-3.5		3.5-7.5	7.5-8	>8.5
	ESP	(%)	0-15		15-25	25-35	>35
Soil Fertility characteristics (s)	Apparent (CEC)	(cmol(+)/kg clay	>24		<16(-)		
			16-24				
	AVP	PPM	>15		10-15	4-10	
	PH H2O		6-6.2		5.5-6	5-5.5	<5
			7-7.5		7.5-8	8-8.2	>8.2
	Organic Carbon	%	1.2-2		0.8-1.2	<0.8	
	$CaCO_3$	(%)	0-5		5-10	10-25	>25

Table 18 : Haricot Bean (Spp)-Crop Environmental Requirements

Land quality	Diagnostic Factor	Unit	Soyabean(glycine maximum)Crop Environmental Requirements					
			S1		S2	S3	N1	N2
Climatic Chcs	Temperature	(ºC)	20-22		18-20	15-18		<15
			25-30		26-27.5	28-38		>38
Topography	Slope	(%)	0-8		8-16	16-30		>30
Wetness	Flooding		FO		F1	F2		F+3
	Drainage	(class)	E,SE,WMW			I	P	VP
Physical soil characteristics (s)	Texture	(class)	SIC,SIL,CL,SI,SICL,SC,L,SCL		LS,SL,C>60	LcS,FS		Cm,SICm
						SIC		
	Soil Depth	(cm)	>75	50-75	50-75	20-50		<20
Salinity &Alkalinity	EC e	(mmhos/cm)	5-6		6-7	7-8		>10
			0-5					
	ESP	(%)	8-15		15-20	20-25		>25
			0-8					
Soil Fertility characteristics (s)	Apparent (CEC)	(cmol(+)/kg clay	>24		<16(-)	<16(+)		
			16-24					
	Sum of Basic Cations	(cmol(+)/kg soil)	3.5-5		2-3.5	<2		
	AVP	ppm	>15	8-15	4-8	<4		
	PH H2O		5.5-6		5.4-5.5	5.2-5.4		
			7-7.5		7.5-7.8	7.5-8.2		
	Organic Carbon	%	1.2-2		0.8-1.2	<0.8		
	$CaCO_3$	(%)	6-15		15-20	20-25		>25
			0-6					

Table 19: Cabbage (Brassica oleracea) - Crop Environmental Requirements

Land quality	Diagnostic Factor	Unit	Cabbage(Brassica oleracea)-Crop Environmental Requirements				
			S_1		S_2	S_3	N
Climatic Chcs	Temperature	(ºC)	18-20	20-24	24-30	30-35	>35
			15-18	13-15	10-13	5-10	<5
	Altitude	masl	1800-2400		2400-2900	2900-3400	>3800
					1400-1800	1000-1400	<700
Topography	Slope	(%)	0-40		40-50	50-55	>55
Wetness	Flooding		F0				
	Drainage	Class	MW,W,SE,E			I	P,VP
Physical soil characteristics (s)	Texture	(class)	L,Sil,SCL,SI,CL,SICL		CL,SiC, C	SL,SC	LS,S
	Soil Depth	(cm)	>75		50-75	20-50	<20
Salinity &Alkalinity	EC e	(mmhos/cm)	0-3	3-4.5	4.5-7	7-10	>10
	ESP	(%)	0-8	8-15	15-20	20-25	>25
Soil Fertility characteristics (s)	Apparent (CEC)	(cmol(+)/kg clay	>24	16-24	<16(-)	<16(+)	
	AVP	PPM					
	PH H2O		6.2-6.8	6-6.2	5.8-6	5.5-5.8	<5.5
			6.8-7.5	7.5-7.8	7.8-8	8-8.2	>8.2
	Organic Carbon	%	>1.5	0.8-1.5	<0.8		
	$CaCO_3$	(%)	0-6	6-15	15-25	25-35	>35

9.8. Land Characteristics (LCs) andLand Qualities (LQs)

These are measurable properties of the physical and socioeconomic and environmental conditions directly related to land use. Land characteristics are made available through soil and land use surveys, socioeconomic and farming system surveys and environmental assessment. Some of the land characteristics and qualities are climate, topography, soil physical and chemical properties, soil fertility, salinity and alkalinity, etc.

Land quality is an attribute of land which acts in a distinct manner in its influence on the suitability of the land for specific kind of land use. Examples of land qualities that are widely applicable to Rainfed cropping are temperature regime, moisture availability, drainage, and nutrient supply, rooting condition, potential for mechanization and erosion hazard (FAO, 1983). See more table : 27 below

Land qualities and land characteristics selected for influencing irrigated agriculture are listed below. The field survey data comprising each land qualities and land characteristics of the study area are however displayed in detail on Table 29. These survey data were used for matching of land qualities and land characteristic with land use requirements.

9.8.1. Temperature regime

There are three main effects of temperature on plant growth

I) Growth ceases below critical temperature, varying with the plant, but typically6.5^{0}C

II) The rate of growth varies with temperature

III) Very high temperature have adverse effect

Crops are divided into five adaptability groups on the basis of their photosynthetic carbon assimilation and response of photosynthesis to radiation and temperature. Between the minimum temperature for growth and the optimum temperature for photosynthesis, the rate of growth rises more or less linearly with temperature; growth rate then reaches a plateau within the optimum temperature range before falling off at higher temperature. This relationship interacts with radiation; that is the highest potential for growth is achieved with temperature in the optimal range and high amounts of radiation.

Adverse effects of high temperatures only occur for most crops above 30^0C. In temperate and subtropical latitude, soil temperature can be substantially affected by slope aspects: this in turn affects rate of growth.

9.8.2. Topography

Topography is often a major factor in irrigation evaluation as it influences the choice of irrigation method, drainage, erosion, irrigation efficiency, costs of land development, etc. Of all the most important parameter of topography that has special bearing on irrigation suitability is slope.

Slope may affect the following factors: intended methods of irrigation, erosion, mechanization, etc. The acceptable degree of slope depends on factors such as: intended method of irrigation, risk of erosion and planned cropping pattern. Gravity irrigation is rarely suited to slopes exceeding 15 per cent. Sprinkler irrigation of arable crops is acceptable on slopes not exceeding 20 per cent, but tree crops are commonly grown on slopes of 45 per cent and occasionally greater than 45 per cent (FAO, 1979).

Irrigation of extremely gentle slopes (0-0.5 per cent), where the soil is slowly permeable and heavy rain is frequent, may lead to scalding by ponded water and water logging, particularly in a hot climate. However, if infiltration rates are moderately good and large flows of water are available to push the water across the field; such slopes are conducive to high irrigation efficiency. Smooth slopes of 0.1 to 2 per cent are usually regarded as ideal for gravity irrigation under average topographic conditions.

9.8.3. Rooting conditions and workability

Rooting conditions signifies root room and mechanical impedance. Soil temperature, soil aeration, soil nutrients and the chemical environment including salinity, Sodicity, pH and toxicities, mechanical impedance to root penetration and pest and disease all these factors affect root growth and root system development or function. However, because of their separate importance in land evaluation and for convenience some of these factors were assessed under different headings. Example, soil aeration was discussed under LQ oxygen availability. Rooting conditions is assessed by critical limits of effective soil depth and soil strength defined by consistence class, sub soil texture and sub soil structure.

The depth of soil that can be effectively exploited by the plant roots is an important criterion in selecting land for irrigation. A depth of 150 cm is ideal in a well drained friable soil; however, experience has shown that many irrigated annual and perennial crops produce excellent yields with a well drained effective root zone depth of 90 cm. When close attention is given to irrigation and crop management, most crops give well to excellent yields with effective soil depth of only 45 cm, while well managed grass give good response with depths of 30 cm. A soil depth of 90 cm is often chosen as the minimum for class 1 (highest level) production under average management. Lesser depths are commonly assigned a lower rating because of a smaller range of suitable crops (FAO, 1979; 1985).

9.8.4. Nutrient availability and nutrient retention capacity

The land quality nutrient availability and retention capacity is used as a measure of the ability of soils to supply the amounts needed for maximum crop yield under the system of agriculture being practiced. In dry land areas soil fertility is usually the second most limiting production factor after moisture stress. The improvement in the supply of water available to plants under any form of irrigation can lead to depletion of soil nutrients.

Most of the time areas in semi-arid and arid areas were limited by low soil fertility as much as by lack of moisture. Nitrogen and phosphorus are usually the elements most deficient in these area soils. Nitrogen is second only to water in importance as a factor affecting the yield of most irrigated crops. Nitrogen deficiency is especially common on sandy and well-weathered soils in areas of high rainfall and on soils low in organic matter. Total nitrogen content of soils gives some indication of nutrient N availability. Total soil nitrogen is low if it is less than 0.1 per cent and high if it is more than 0.3 per cent. Phosphorus deficiency most commonly occurs on highly weathered tropical soils, calcareous soils and peat and muck soils. Level of available phosphorus in the soil indicates the fertility status of the soil with regard to phosphorus. Nutrient availability and retention capacity is assessed in relation to pH of the soil.

9.8.5. Conservation and water application management

Several land characteristics affect the water application management of the different irrigation methods. Amongst those characteristics, slope gradient, soil texture, and structure are found to be relevant and class-determining factors for water application management. The suitability of these land characteristics is determined by considering their effect or influence on uniformity and/or rate of water application in the field.

- Slope gradient is the dominant topographic factor that influences irrigation suitability in The study area. It affects occurrence of erosion due to faulty irrigation water alignment in surface irrigation. As slope gradient increases, surface water irrigation may induce erosion. Furrow irrigation method requires a slight slope gradient. A slope gradient up to 2 per cent can be levelled for furrow irrigation and is optimal under low input management level. Slopes gradient of 6 per cent are considered as marginal for furrow irrigation. Levelling and grading are considered as ordinary management practices up to 6 per cent slopesIn farming areas improved agronomic practices specific to the site condition is recommended, because it is essential for controlling soil productivity, increases its water holing capacity, provide take full advantage of fertilizer, prevent the unbalanced depletion of plant nutrients improving soil condition, cover, soil and water conservation, plant protection, yields and counter acts developments of the toxic substance, if any. (FAO, 1979).

9.8.6. Salinity/Sodicity

Sodic soils, which have a high exchangeable sodium percentage and saline soil which have excess soluble salts, should be avoided for irrigated agriculture. These soils can reduce moisture availability directly, or indirectly, as well as exerting direct harmful influence on plant growth. Sodicity is determined as the exchangeable sodium percentage (ESP). It is a good indicator of the structural stability of a soil and of the physical response that may be anticipated when water is applied. Most soils exhibit unfavourable physical properties at levels of ESP greater than 15 per cent. In general, physical properties become increasingly adverse with increasing levels of exchangeable sodium. In addition to the possible deleterious effects that high ESP levels may have on the physical properties of soil, some crops have a low tolerance for exchangeable sodium.

As a general guidance the ratings s1, s2, s3 and n reflect non-sodic, slightly sodic, moderately sodic and strongly sodic soils with respective values of < 10, 10 - 20, 20 - 35 and > 35 ESP per cent (FAO, 1985; 1996).

Salinity - an excess of soluble salts - is probably the most widespread soil quality adverse to crop growth in arid areas. The primary deleterious effect of excessive salinity is to raise the concentration of the soil solution. In consequence, the flow of water into the plant by osmosis is reduced or reversed and the plant is starved of water even though the soil is moist. Electrical conductivity (EC) measurements are used as indicators of total soluble salts in soil. General interpretation of EC values in soil mapping and land evaluation is as follows:

9.8.8. Water retention capacity

The capacity of a soil to retain water available to plants is important in judging the suitability of a soil for irrigation as this soil property determines the availability of soil water for crop requirements. Soil depth and texture are some of the major soil physical characteristics determining the capacity of a soil to retain available water to plants (FAO, 1979).

Soil texture is evaluated to 1m depth with regard to its capacity to retain water as most crops draw their major water requirements within this depth. Coarse textured soils such as sandy soils typically have high infiltration rates and very low soil moisture storage capacities; medium textured soils show medium storage capacities while those of fine textured soils with low infiltration or permeability rates show high water holding capacity, particularly the expandable type of clay (FAO, 1979).

9.8.9. Mechanization

This assessment concerns conditions of the land that specifically affect mechanized agricultural operations. The conditions which act as limitations to mechanization are slope angle, rock hindrances, stoniness or extreme shallowness of the soil, and the presence of heavy clays.

9.9. Matching of land use requirement with land qualities.

The term matching has both a broader and a more specific meaning. In its broader sense it refers to the process in which land utilization types and land units are progressively and mutually adapted as the evaluation proceeds. The more specific meaning of matching refers to the comparison of the requirements of land utilization types with the qualities of specified land use. It is in this specific sense that the term matching employed in this report.

Matching answers the question "How well the qualities of the land satisfy the requirement of land use?"

A land utilization types have requirements related to the crop or crops produced, the system of management, and conservation. Factor ratings are sets of values which indicate how well each land use requirement is satisfied by particular conditions of the corresponding land quality. In other words it is the suitability of the land quality for the specific land use. Because the land-use requirements are different, factor ratings vary from one crop to another and from one land utilization type to another. Therefore, factor ratings were made in terms of five classes (s1, s2, s3, n1, n2) where s1 stands for highly suitable, s2 for moderately suitable, s3 for marginally suitable n1 currently non-suitable and n2 permanently not-suitable.

The procedure used for suitability assessment here is that assessments were first made for the individual crop, assessments which are necessarily confined to the ecological and technological aspects of the crop; these are then combined with considerations deriving from the farming system itself. In general, the stages used in suitability assessments were:

1. First suitability assessments for the individual crops were made.
2. Then suitability assessments related to managements were taken in to consideration
3. Thirdly, suitability assessments related to erosion and suitability hazards were considered (Intermediate and high management levels were considered)
4. Finally, the above steps were combined for the overall suitability classes for each specific land utilization types.

Table 20: Land suitability Limitations (sub-classes)

Sub-class/suffixes	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 lower in pH <6.0 and >7.5 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

Sub-class/suffixes	Description
	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**.**

Table 21: LQ/LC and symbols assigned to evaluate suitability sub-class and unit.

Land quality	**Symbol**	**Diagnostic factors**
Temperature regime	t1	Mean growing season temperature (^{o}C)
Water availability	m1	Length of growing season (days)
	m2	Growing season rainfall (mm)
	m3	IR
	m4	HC
	m5	AWC
Nutrient availability	n1	Topsoil organic matter content (per cent)
	n2	Topsoil phosphorus (Olsen, ppm)
	n3	soil reaction (pH)
	n4	Top soil Texture (class)
	n5	Cation exchange capacity (CEC) (Cmol+/kg of soil

Land quality	**Symbol**	**Diagnostic factors**
Oxygen availability	d	Land units having soil drainage deficiencies,
Rooting conditions and workability	r1	Effective soil depth (mm)
	r2	Top soil texture (class)
	r3	Calcium carbonate (%)
	r4	Soil structure
Mechanization Potential	p1	Slope angle (per cent)
	p2	stoniness (class)
Erosion hazard	e	Slope steepness (per cent)
Limitations /Toxicities	i1	salinity (mmhos/cm)
	i2	Alkalinity(ESP)

Table 22: Summarized Land Quality and Characteristics of the SMU

SMU	Slope %	Horizone	Depth	Texture	Major Soil	Dranage	Flooding	Hydrouli con	Infiltration	Surface.C.F	FC	PWP	TAWC	BD	PH	Ece	EC
1SCL-a(SMU1)	0-2	T	100-150	SCL	Lixisol	MW	N	2.5	3.5	few fine	13.20	6.90	97.42	1.71	6.1	0.61	0.11
2SL-a(SMU2)	2_5	T	100-150	SL	Lixisol	WW	N	2.5	3.5	few fine	13.20	6.90	97.42	1.71	5.8	0.5	0.04
3SL-b(SMU3)	5_8	T	50-100	SL	Cambisol	WW	N	2.5	3.5	few fine	13.20	6.90	97.42	1.71	5.8	0.3	0.07
4SL-b(SMU4)	8_15	T	50-100	SL	Cambisol	WW	N	2.5	3.5	few fine	13.20	6.90	97.42	1.71	5.8	0.3	0.07
1SL-c(SMU5)	0_2	T	25-50	SL	L/ Cambisol	WW	N	3.5	6.5	Few fine	13.20	6.90	97.42	1.71	5.8	0.4	0.05
2SL-c(SMU6)	2_5	T	25-50	SL	L/ Cambisol	WW	N	3.5	6.5	few fine & medium	13.20	6.90	97.42	1.71	5.8	0.4	0.05
3SL-c(SMU7)	5_8	T	25-50	SL	L/ Cambisol	WW	N	3.5	6.5	common medium & c	13.20	6.90	97.42	1.71	5.8	0.4	0.05
4SL-c(SMU8)	8_15	T	25-50	SL	L/ Cambisol	WW	N	3.5	6.5	few fine & medium	13.20	6.90	97.42	1.71	5.8	0.4	0.05
5SL-c(SMU9)	15_30	T	25-50	SL	L/ Cambisol	WW	N	3.5	6.5	few fine	13.20	6.90	97.42	1.71	5.8	0.4	0.05
6SL-c(SMU10)	>30	T	25-50	SL	L/ Cambisol	WW	N	3.5	6.5	few fine & medium	13.20	6.90	97.42	1.71	5.8	0.4	0.05
1SL-d(SMU11)	0_2	T	0-25	SL	Leptosol	WW	N	3.5	6.5	few fine & medium	13.20	6.90	97.42	1.71	5.8	0.4	0.05
4CL-d(SMU12)	2_5	T	0-25	SL	Leptosol	WW	N	3.5	6.5	few fine	13.20	6.90	97.42	1.71	5.8	0.4	0.05
1SL-d(SMU13)	5_8	T	0-25	SL	Leptosol	WW	N	3.5	6.5	few fine & medium	13.20	6.90	97.42	1.71	5.8	0.4	0.05
2SL-d(SMU14)	8_15	T	0-25	SL	Leptosol	WW	N	3.5	6.5	few fine & medium &c	13.20	6.90	97.42	1.71	5.8	0.4	0.05

Na	K	Ca	Mg	EX .Acidity	SUM	CEC	BS	ESP	T.N	C/N	OC	OM	A.V.P	Caco3	Soil units	Rep pit
0.15	0.9	7.79	4.1	0.00	12.16	17.5	69	0.38	0.1	12	1.17	2.02	2.4	0	Lix	ORP-3
0.15	0.5	6.31	2.03	0.00	8.96	15.8	57	0.16	0.09	10.00	0.87	1.49	2.4	0.00	Lix	ORP-1
0.13	0.57	5.31	5.29	0.00	26.28	47.2	56.0	0.99	0.09	12.00	1.09	1.88	2.72	0	Cambi	ORP-4
0.13	0.57	5.31	5.29	0.00	26.28	47.2	56.0	0.99	0.09	12.00	1.09	1.88	2.72	0	Cambi	ORP-4
0.17	0.58	5.31	2.57	0.00	8.63	12.0	72.0	0.42	0.06	12.00	0.74	1.28	6.64	0	Cambi	ORP-4
0.17	0.58	5.31	2.57	0.00	8.63	12.0	72.0	0.42	0.06	12.00	0.74	1.28	6.64	0	Cambi	ORP-4
0.17	0.58	5.31	2.57	0.00	8.63	12.0	72.0	0.42	0.06	12.00	0.74	1.28	6.64	0	Cambi	ORP-4
0.17	0.58	5.31	2.57	0.00	8.63	12.0	72.0	0.42	0.06	12.00	0.74	1.28	6.64	0	Cambi	ORP-4
0.17	0.58	5.31	2.57	0.00	8.63	12.0	72.0	0.42	0.06	12.00	0.74	1.28	6.64	0	Cambi	ORP-4
0.17	0.58	5.31	2.57	0.00	8.63	12.0	72.0	0.42	0.06	12.00	0.74	1.28	6.64	0	Leptosol	ORP-2
0.17	0.58	5.31	2.57	0.00	8.63	12.0	72.0	0.42	0.06	12.00	0.74	1.28	6.64	0	Leptosol	ORP-2
0.17	0.58	5.31	2.57	0.00	8.63	12.0	72.0	0.42	0.06	12.00	0.74	1.28	6.64	0	Leptosol	ORP-2
0.17	0.58	5.31	2.57	0.00	8.63	12.0	72.0	0.42	0.06	12.00	0.74	1.28	6.64	0	Leptosol	ORP-2
0.17	0.58	5.31	2.57	0.00	8.63	12.0	72.0	0.42	0.06	12.00	0.74	1.28	6.64	0	Leptosol	ORP-2

9.10 Results of Land Suitability Evaluation for Surface Irrigation

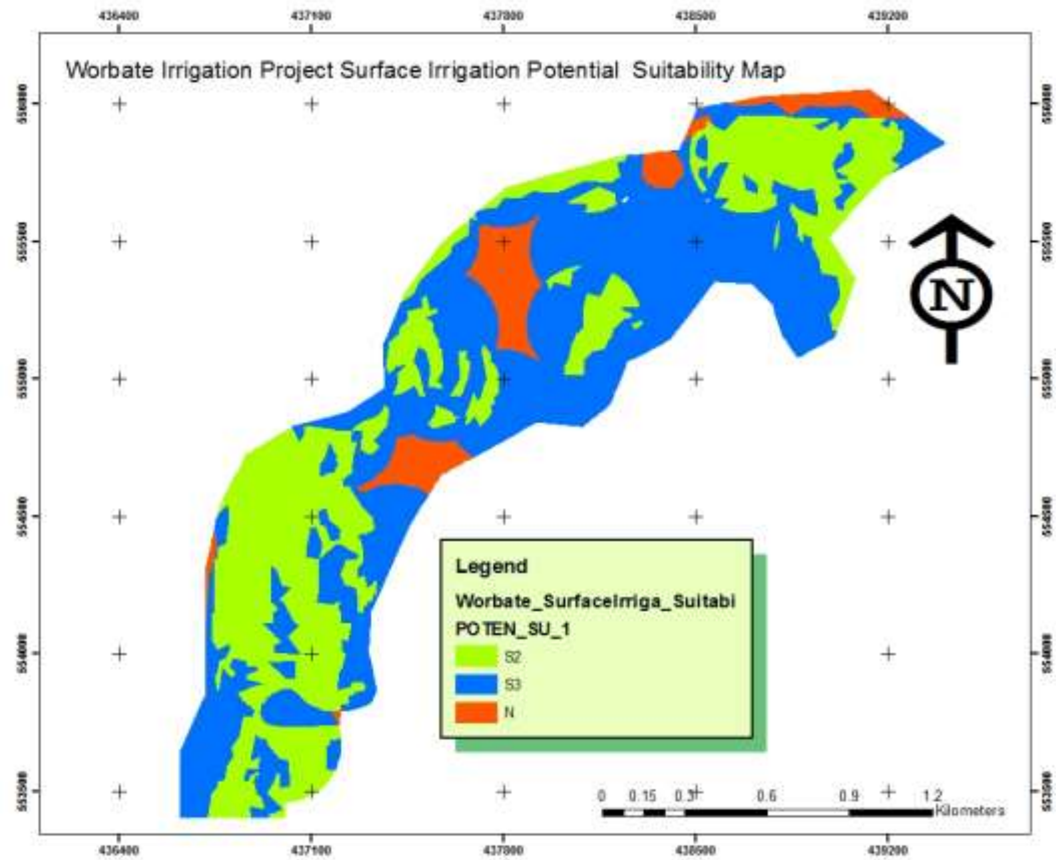


Figure 7: Potential Surface Irrigation Suitability Map

9.10.2. Potential Suitability for Surface Irrigation

The results of the suitability evaluation of the project area for surface irrigation are shown in Tables 33. The result indicates that a total of 89.73 ha of land Moderatly suitable(S2) for surface irrigation. An area amounting to 123.12 ha is found to be (S3) Marginally suitable for surface irrigation development and some 18.13ha of land is (N) Not suitable for surface irrigation development. The areas identified as Moderately and marginally suitable for surface irrigation are constrained by Low Ph (Stronly acid),Slope(>8%,)and depth.The total area not included, Cannal Area and town.

Table 23 : Potential Surface Irrigation Suitability by Area

S2	S3	N
Moderatly Suitable	**Marginally Suitable**	**Permanently Not Suitable**
Area,ha	**Area,ha**	**Area,ha**
89.73	**123.12**	**18.13**

Table 24: Results of Existing and Potential Land Suitability Evaluation for surface Irrigation by SMU

SMU	Area-ha	Existing suit Class	Existing Subclass	Class	Limitation	Potential Class	Potential Sub Class	Not Correctable Limitation
SMU 1	11.55	S3	S3, , n	Marginaly Suitable	A.v.p, Organic matter	S2	S2,	, Soil Ph
SMU 2	78.18	S3	S3,n,	Marginally Suitable	Avp, OC, Om	S2	S2, rt,n	Soil,Ph, Texture
SMU 3	58.08	N	N,n	Not Suitable	Nutrient availability	S2	S2	Soil Ph,
SMU 4	9.23	N	N,n	Not Suitable	Nutrient availablity	S2	S2	Slope ,soil Ph
SMU 5	2.87	S3	S3n,	Marginally Suitable	Nutrient Availablity	S2	S2,e,nr	Slope,Soil Ph, Texture
SMU 6	26.19	N	N,n	Not Suitable	Nutrient availability	S3	S3,e	Slope
SMU 7	23.69	S3	S3n,	Marginal Suitable	Availa-Phosphor	S3	S3,e	slope
SMU 8	3.03	N	N,n	Not Suitable	Nutrient availabilty	S3	S3,nr	Soil Reaction (Ph)

SMU	Area-ha	Existing suit Class	Existing Subclass	Class	Limitation	Poten tial Class	Potential Sub Class	Permanenet Limitation
SMU9	0.82	N	N,n	Not Suitable	Nutrient availability	N	S2,e	slope
SMU10	1.71	N	N,n	Not Suitable	Nutrient availability	S2	S2,r,e	Slope,depth
SMU11	1.033	N	N,n	Not Suitable	Nutrient availability		S3,e,r	Depth, slope
SMU12	3.85	N	N	Not Suitable	Nutrient availability	N	N,e,r	Slope,
SMU13	9.14	N	N,n	Not Suitable	Nutrient availability	S2	S3,,rd	, depth
SMU14	1.56	N	N,,n	Not Suitable	Nutrient availability	S3	S3,rd	Depth

9.11. Results of Crop Suitability Evaluation

The crops were selected based on existing condition, climate and requirement of individual crop to the daily diet and the cash value of the crop to generate for the community. The major proposed crops are: Lowland Maize, Sorghum, Tomato, Onion, Haricot bean. The results of the crop suitability evaluation are shown in Table 37 and maps.

The suitability evaluation under irrigated condition was considered for the current land and soil condition and for future (potential) suitability after improvement of some correctable soil limitations.

9.11.1. Potential Crop Suitabilty Evaluation.

The result indicated that a total of 11.55 moderatly (S2) ,201.30 ha (S3) marginally for **Low Land Maize** cultivation by surface irrigation.For **Sorghum** Some, 11.55 ha highly suitable (S1) 78.18 ha Moderatly Suitable (S2) and 138.71 ha Marginally suitable(S3),. Olso for **Haricot bean** some 12.30 ha of land is moderately suitable (S2), 216.14 ha marginally suitable(S3). For **Tomato** Some 11.55 (S1) Highly suitable and 216.9 marginaly suitable (S3), For **Onion** Some 11.55 ha Highly Suitable(S1) Some 122.17 ha moderatly suitable (S2), some 94.72ha marginaly suitable(S3), The major limitations that downgraded the suitability level of the area are Soil Ph (Low PH) Slope, Texture, Depth in the study area.

The result indicated Table : 39 below with tha applicatin of fertilizers and good quality of irrigation water and integrated neutrient management some part of the command area will be improved to moderatly suitable land for intended crop production.

Table 25:Potential Crop Suitability by Area for surface Irrigation

Crops	**S1**	**S2**	**S3**	**N2**
	Highly Suitable	**Moderatly Suitable**	**Marginally Suitable**	**Not Suitable**
	Area,ha	**Area,ha**	**Area,ha**	**Area,ha**
Low Land Maize	**-**	**11.55**	**201.30**	**18.13**
Sorghum	**11.55**	**78.18**	**138.71**	**2.54**
Haricot bean		**12.30**	**216.14**	**2.54**
Tomato	**11.55**	**-**	**216.9**	**2.54**
Onion	**11.55**	**122.17**	**94.72**	**2.54**

Table 26: Potential Crop Suitability by class and Area for surface Irrigation

SMU	Low L/Maize	L/Sorghum	Haricot Bean	Onion	Tomato	Area/Ha
SMU1	S3	S1	S2	S1	S1	11.55
SMU2	S3	S2	S3	S2	S3	78.18
SMU3	S3	S3	S3	S3	S3	58.08
SMU4	S3	S3	S3	S3	S3	9.23
SMU5	S3	S3	S3	S2	S3	2.87
SMU6	S3	S3	S3	S2	S3	26.19
SMU7	S3	S3	S3	S3	S3	23.69
SMU8	S3	S3	S3	S3	S3	3.03
SMU9	N	N	N	N	N	0.82
SMU10	N	N	N	N	N	1.71
SMU11	N	S3	S3	S3	S3	1.03
SMU12	N	S3	S3	S3	S3	3.85
SMU13	N	S3	S3	S3	S3	9.14
SMU14	N	S3	S3	S3	S3	1.56

Table 27 Potential Crop Suitability by Sub Class

Crops	Potential Crop Suitability by subclass	Sub Class S2	Sub Class S3	Sub Class Not correctable	
Low Land Maize	Potential Subclass	S2, e, rd, rt	S3, e, rd, rt	Slope, depth, Texture	
	Area(ha)	11.55	201.3	18.13	
Sorghum	Potential Subclass	S2,e,rt.rd	S3,e,rt,rd	Slope,depth,texture	
	Area (ha)	78.18	138.71	2.54	
Haricot bean	Potential Subclass	S2,e,rt,rd	S3,e,rt,rd	Slope depth texture	
	Area (ha)	12.3	216.14	2.54	
Tomato	Potential Subclass	S1	S3,e,rt,rd	Slope depth,texture	
	Area (ha)	*11.55*	216.9	2.54	
Crops	Potential Crop Suitability by subclass	Sub Class	Sub Class	Sub Class N	
Onion	Potential Subclass	S2, e,n,rt,rd	S3,e,rt,rd	Slope depth texture	
	Area (ha)	122.17	94.72	2.54	

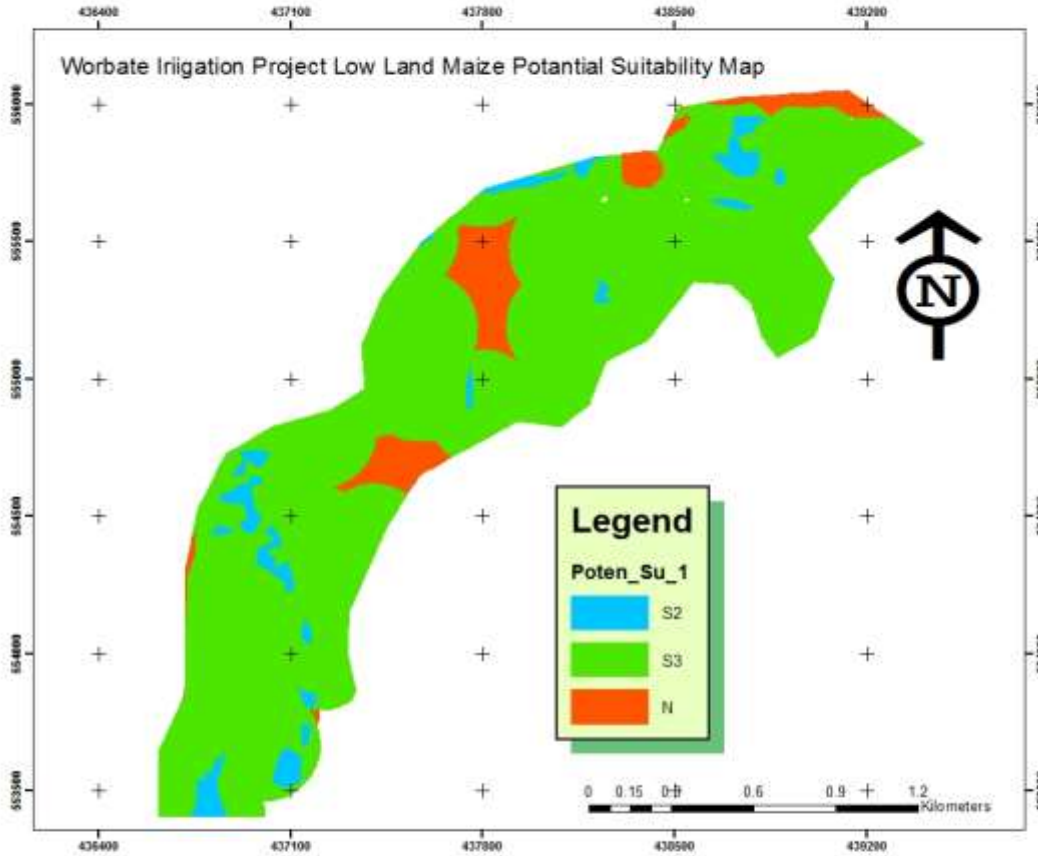


Figure 8: Maize Potential Suitability Map

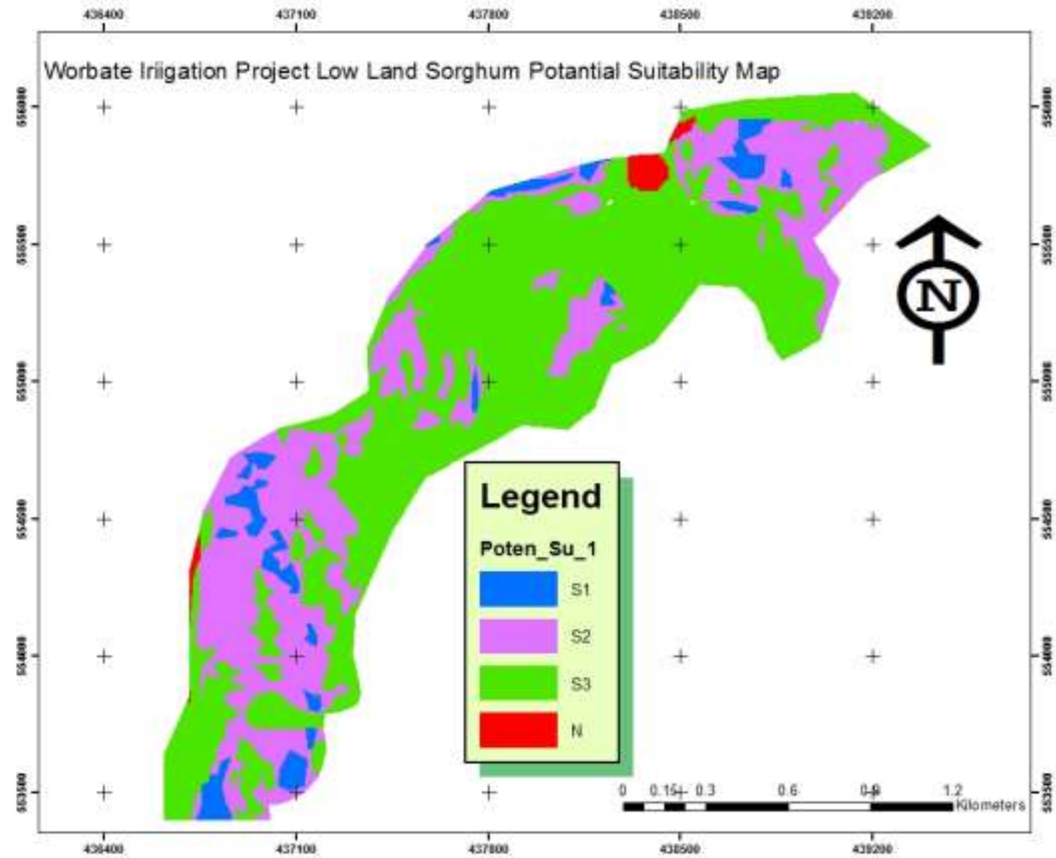


Figure 9 Sorghum Potential Suitability Map

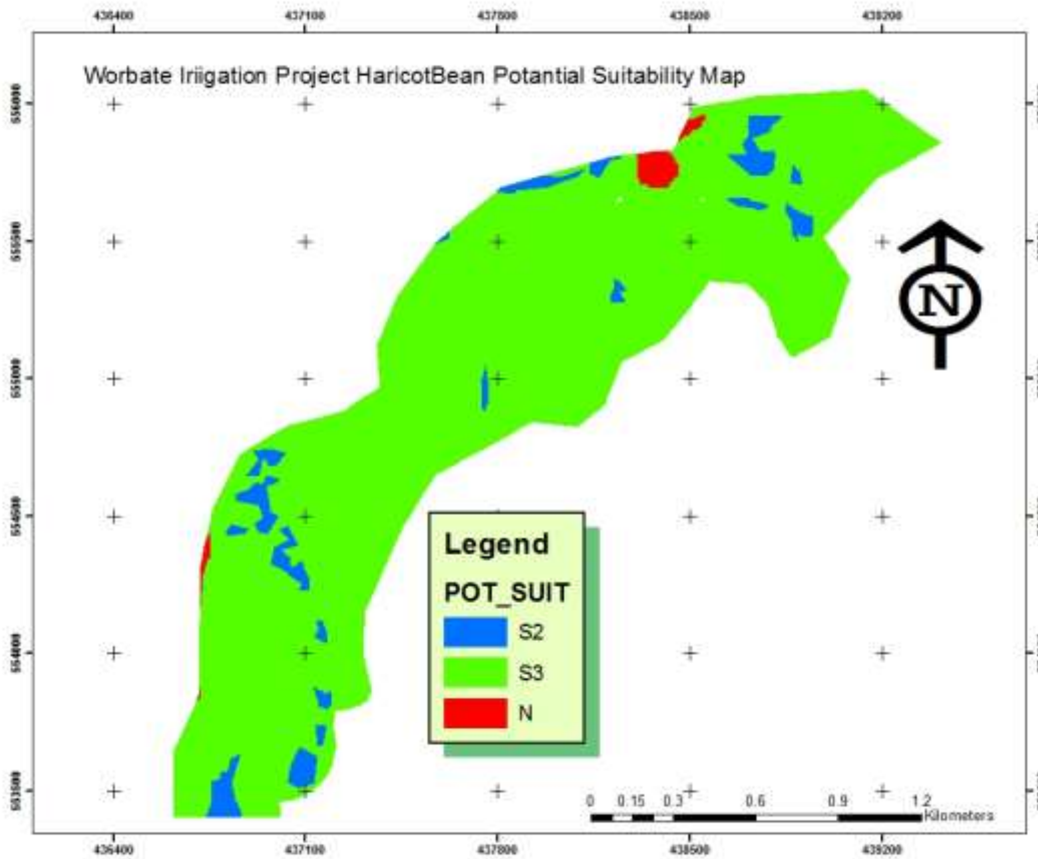


Figure 10: Haricot bean Potential Suitability Map

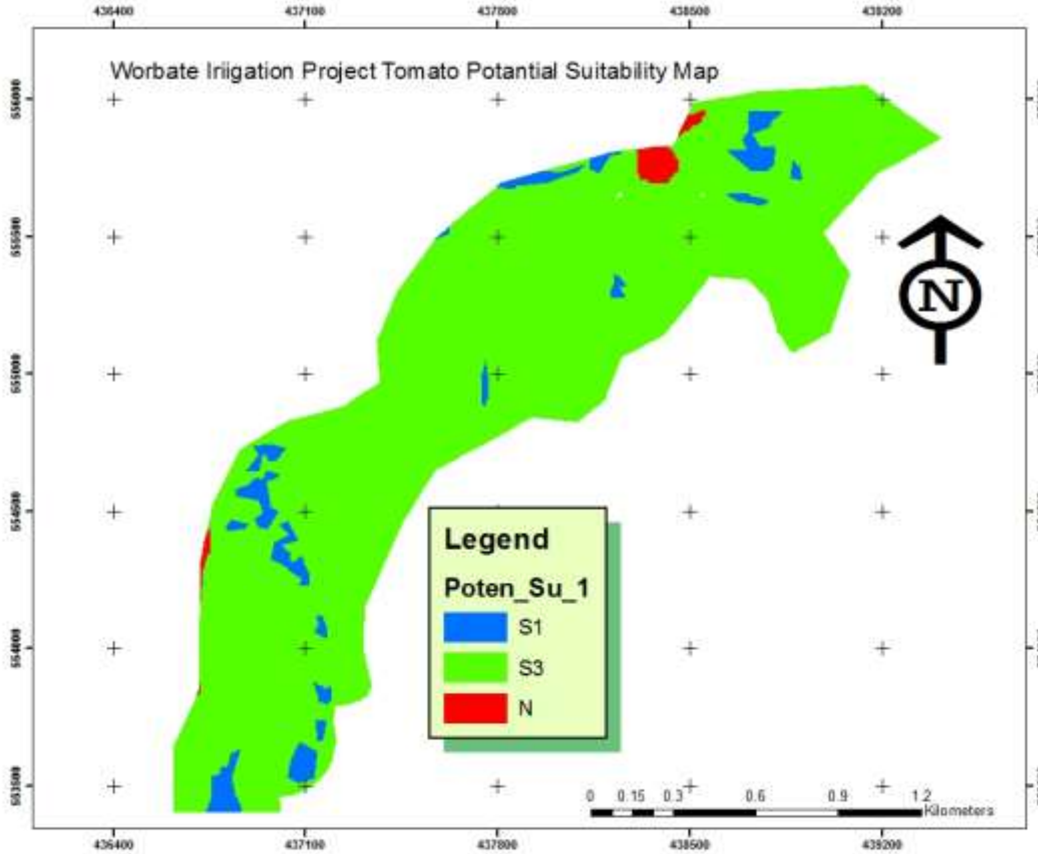


Figure 11:Tomato Potential Suitability Map

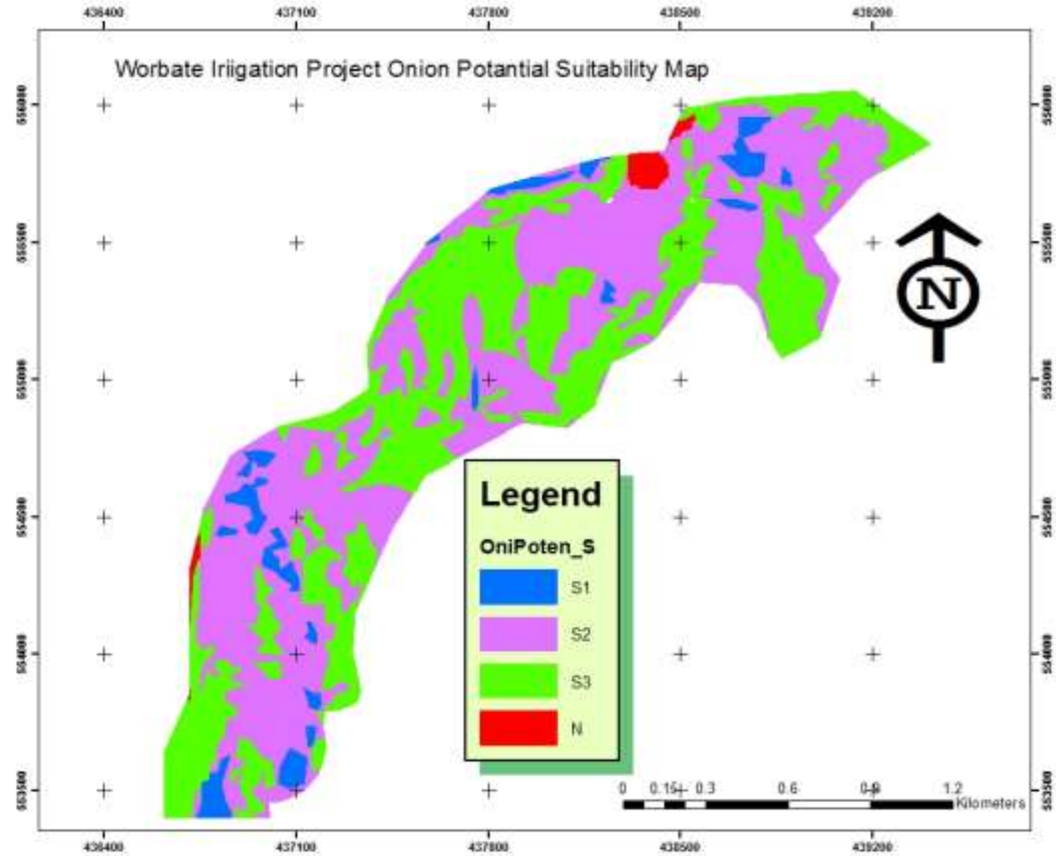


Figure 12: Onion potential suitability map

Table 28: The final proposed Crop Potential Suitability by SMU

SMU	Low L/Maize	L/Sorghum	Haricot Bean	Onion	Tomato	Area/Ha
SMU1	S3	S1	S2	S1	S1	11.55
SMU2	S3	S2	S3	S2	S3	78.18
SMU3	S3	S3	S3	S3	S3	58.08
SMU4	S3	S3	S3	S3	S3	9.23
SMU5	S3	S3	S3	S2	S3	2.87
SMU6	S3	S3	S3	S2	S3	26.19
SMU7	S3	S3	S3	S3	S3	23.69
SMU8	S3	S3	S3	S3	S3	3.03
SMU9	N	N	N	N	N	0.82
SMU10	N	N	N	N	N	1.71
SMU11	N	S3	S3	S3	S3	1.03
SMU12	N	S3	S3	S3	S3	3.85
SMU13	N	S3	S3	S3	S3	9.14
SMU14	N	S3	S3	S3	S3	1.56

Table 29: Final Proposed Overall Potential suitability map

SMU	Low L/Maize	L/Sorghum	Haricot Bean	Onion	Tomato	Area/Ha
SMU1	S3	S1	S2	S1	S1	11.55
SMU2	S3	S2	S3	S2	S3	78.18
SMU3	S3	S3	S3	S3	S3	58.08
SMU4	S3	S3	S3	S3	S3	9.23
SMU5	S3	S3	S3	S2	S3	2.87
SMU6	S3	S3	S3	S2	S3	26.19
SMU7	S3	S3	S3	S3	S3	23.69
SMU8	S3	S3	S3	S3	S3	3.03
SMU9	N	N	N	N	N	0.82
SMU10	N	N	N	N	N	1.71
SMU11	N	S3	S3	S3	S3	1.03
SMU12	N	S3	S3	S3	S3	3.85
SMU13	N	S3	S3	S3	S3	9.14
SMU14	N	S3	S3	S3	S3	1.56

Crops	**S1**	**S2**	**S3**	**N2**
	Highly Suitable	**Moderatly Suitable**	**Marginally Suitable**	**Not Suitable**
	Area,ha	**Area,ha**	**Area,ha**	**Area,ha**
Low Land Maize	**-**	**11.55**	**201.30**	**18.13**
Sorghum	**11.55**	**78.18**	**138.71**	**2.54**
Haricot bean		**12.30**	**216.14**	**2.54**
Tomato	**11.55**	**-**	**216.9**	**2.54**
Onion	**11.55**	**122.17**	**94.72**	**2.54**

10. SOIL MANAGEMENT AND RECLAMATION

101 Soil Physical Soil factors

. 10.1.1. Surface coarse fragements

Surface **coarse fragements** is one of the limiting factors observed during the field survey. During soil survey observed from few fine to common fine and medium fragements ,but this fragements cause no limitation for irrigation development in the study area .Surface coarse fragements less than 2 per cent in abundance considered as very low.

10.1.4. Flooding

The flooding problem in the study area is not Significant except in the Worbate river buffer zone or river side and Fluvisols with flat or palain land; flooding will not be as such difficult and expensive to control. To prevent the flooding problem and subsequent water movement across the areas Watershed Development Measurements should be applied. The technology should be site specific. Among the measures to be applied construction of structures along the major water courses is required. Ridging, field leveling and furrows will also effectively prevent the wide spread movement of water over the surrounding area.

10.1.5 Erosion

The project area is on plain land dominanatly 0-8% of slope but there is some rill and sheet erosion evidences.soils of the soil mapping units **smu8smu9, smu10**are affected by sheet and rill erosion ,the rest of the soil mapping units are none to silgtely sheet and splash erosion The main types of erosion in the study area are sheet ,splash and rill erosion

The risk of erosion can be effectively controlled by applying site specific technologies of Integrated Watershed Development practices. Constructing of cut of drains along the perimeter in order to intercept the runoff water from the surrounding to reservoirs (water harvesting), if any for feature use is very important, besides terracing, contour construction and plantation of tress and cover grasses are important measures to be considered.

10.2. Chemical Factores

10.2.1 Soil Fertility

The distributions of nutrients in the entire study area are uniform. The exchangeable Ca, K and Mg are midium to high in soils of the soil mapping units Vertisols, Luvisols, Cambisols and Lexisol. Dominantly the available phosphorous content is low. All soils of the soil mapping units are medium to high level of CEC and high level of BSP%.

The PH value for most of the soils in the study area5.6 up to6.1 with average of 5.9on the top soil, which is modaretly acid at this PH level there is a possibility of Lime application (Limming) organic fertilizer application for plants up take, low level of organic carbone content description has been observed by the laboratory result .As indicated in Land evaluation result the major limitation for most crop is (acidity problem or low Ph level) Phosphorous availability may reduced, where as.The AVP content for soils of the majority soil mapping units are low it needs application of organic and inorganic(phosphorus fertilizer) fertilizer like compost is to considered. The total Nitrogen contents of the soil mapping unit is uniform across the entire units (medium to high level of T.N). To be more efficient in crop production, site specific soil test based fertilizer recommendations study has to be conducted.. The over all Integrated Nutrient Management (INM) activities should be adopted for the study area for optimum and sustainable crop production .

11. CONCLUSION AND RECOMMENDATIONS

11.1. Conclusion

Surface Irrigatin Suitability : The result indicates that a total of 89.73 of land is found to be (S2) Moderatly suitable for surface irrigation. An area amounting to 123.12 ha is found to be (S3) Marginally suitable for surface irrigation development. The areas identified as Moderately and marginally suitable for surface irrigation are constrained bysoil reaction (Low Ph), Depth and slope.

Crop Suitability : The result indicated that some, 11.55 moderatly Suitable(S2) ,201.30 ha (S3) marginally suitable for Maize cultivation by surface irrigation.For Sorghum Some 11.55ha is Highly suitabile Some 78.18 ha Moderatly Suitable(S2) and 138.71 ha Marginally suitable (S3) Olso for Haricot bean some 12.30 ha of land is moderately suitable(S2), 216.14 ha marginally suitable (S3) respectively. For Tomato Some 11.55ha Higly suitable and 216.9 marginaly suitable (S3), for Onion,some 11.55 ha is Highly Suitable,Some 122.17 moderatly suitable (S2), and some 94.72 ha marginaly suitable.

The dominant suitability subclass for all the considered crops is marginally suitable. The major limitations that downgraded the suitability level of the area to marginally subclass are Slope, Soil reaction(Low Ph) and shallow Soil Depth, in the study area. This indicates that with high level of management practices Application of lime for low ph problems to correct the limitations, the suitability and expected crop yield be increased except uncorrecteble Limitations (slope). Special attention should be given on land management practicies, specifically ; applications of locally available sourcess of organic fertilizers and watershed level integrated soil fertility management options for susteinable productivity of soils.

11.2 Recommendations

In general the soil conditions of most identified soils by the present soil surve are suitable for irrigation agricultural development. The limitations of most soils in Worbate Irrigation Project are Low PH level or soil Reaction,Nutrient deficency (Low Level of availabile phosphorus, organicmatter), Depth and slope

The most limiting land characteristic in soils of Worbate Surface Irrigation Project development is Soil Reaction (Low Ph Level) Sligtly to modaretely acidity. Concerning topography, although lands having slope gradient greater than 8% is not suitable theoretically under surface irrigation, the farmers experience in different areas show that this lands are developed under irrigation using different irrigation techniques like adequate conservation practice. Considering those indigenous knowledge of the farmers and by integrating conservation measures with the agricultural irrigation practice, the suitability evaluation was done for lands have slope up to 8%. However, there is a need to apply more and efficient conservation measures to use those sloping land for surface irrigation.water conservation in crop production, seepage control, water management and irrigation scheduling for water availability to crop and fertilizer need are important facters to apply in the project area.

Possible soil and water conservation interventions such as bench terracing need to be applied in lands with slope >8% which helps to converts a steep slope into a series of steps, with nearly horizontal benches to reduce velocity of runoff, reduce soil erosion and the decline in crop yields. Moreover, level soil bund as an alternative conservation measure can also be applied for those cultivated lands with a slope of 3-15% which further helps to reduce and stops the velocity of runoff and consequently reduces soil erosion. As a result, those soil mapping units that are not suitable for surface irrigation due to slope gradient will be amended accordingly.

Based on the investigated potentials and limitations of the soils of the study area, the soils and agronomic management and other activities should be carried out to maintain the already exisiting good conditions of the soils and to ammend or correct the correctable limitations. This can be application of organic fertilizers and liming to raise the pH of the soils to near neutrality where most of the plant nutrients are available for plant up take. The over all Integrated Nutrient Management (INM) activities should be adopted for the study area for optimum and sustainable crop production .

The following recommendations are suggested:

- Application of organic fertilizer and ISFM (integrated soil fertility management) to maintain/increase pH to neutral level, and to improve physical and chemical properity of soils.
- Application of organic fertilizers and liming to raise the pH of the soils to near neutrality where most of the plant nutrients are available for plant up take. The over all Integrated Nutrient Management (INM) activities should be adopted for the study area for optimum and sustainable crop production .

- some of the soil mapping units can be affected by sheet, rill and gully erosion. This can be controlled through careful planning and implementation Integrated Watershed Development. Technologies such as proper erosion control mechanism, such as afforestation, plantation of cover grasses, contouring and conservation structures can be incorporated specific to site condition and irrigation water quality management.
- In farming areas improved agronomic practices specific to the site condition is recommended, because it is essential for controlling soil productivity, increases its water holing capacity, provide take full advantage of fertilizer, prevent the unbalanced depletion of plant nutrients improving soil condition, cover, soil and water conservation, plant protection, yields and counter acts developments of the toxic substance, if any.
- Careful planning and implementation Integrated Watershed Management Development,Crop rotation,Application of organic fertilzer like compost,good quality of irrigation water for irrigation can improves the suitability of the land for crop production and the quality of the land can improve from not suitable to marginally suitable,marginally suitable land to moderately suitable, andmoderately suitable land to highly suitable
- Biological and chemical Control of Termite: - care full biological (traditional) and chemical control of termite is needed there is many termite mundes in the project area

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13. LIST OF APPENDIXES

Appendix Table 1: Summary of recommended criteria for soil chemical data interpretation

DESCRIPTION	UNIT	RANGE	RATING
PH	Water	<4.5	Extremely acid
		4.5-5.0	Very Strongly acid
		5.1-5.5	Strongly acid
		5.6-6.0	Moderately acid
		6.1-6.5	Slightly acid
		6.6-7.3	Neutral
		7.4-8.0	Slightly alkaline
		8.1-9.0	Strongly alkaline
		> 9.0	Very strangely alkaline
Electrical conductivity (EC)	mmhos/ cm	<2	Salt free
		2-4	Slightly saline
		4-8	Moderately saline
		8-15	Strongly saline
CEC	meq/100gm	>40	Very high
		25-40	High
		15-25	Medium
		5-15	Low
		<5	Very low
Base saturation (BS)	per cent	<20	Low
		20-60	Medium
		>60	High

Appendix Table 1. Continued.

Exchangeable Cations			
Ca	meq/100g of soil	>20	High
		10-20	High
		1-10	Medium
		2-5	Low
		<2	Very Low
Mg	meq/100g of soil	>8	Very High
		3-8	High
		1.5-3	Medium
		0.5-1.5	Low
		<0.5	Very Low
K	meq/100g of soil	>1.2	Very High
		0.6-1.2	High
		0.3-0.6	Medium
		0.1-0.3	Low
		<0.1	Very Low
Na	meq/100g of soil	>2	Very High
		0.7-2	High
		0.3-0.7	Medium
		0.1-0.3	Low
		<0.1	Very low
Organic matter (OM)	per cent	>5	Very high
		3-5	High
		1-3	Medium
		<1	Low

Appendix Table 1.Continued.

Total nitrogen (T.N)	per cent	<0.03	Low
		0.03-0.06	Medium
		>0.06	High
Available phosphorous (A.V.P)	ppm	>15	High
		5-15	Medium
		<5	Low
Caco3	meq/100gm	<1	Low
		1-4	Medium
		4-10	High
		>10	Very high
Organic carbon (OC)	per cent	>20	Very high
		10-20	High
		4-10	Medium
		2-4	Low
		<2	Very low
Exchangeable Sodium Percentage (ESP)	per cent	<2	Low
		2-8	Medium
		8-15	High
		15-27	Very high
		>27	Extremely high
Ca: Mg Ratio	Ratio	>40	Extremely high
		12-40	Very high
		6-12	High
		3.5-6	Moderately high
		2.5-3.5	Moderately low
		1.5-2.5	Low
		<1.5	Very low

Source: 1- Booker Tropical soil manual (1991).

Appendix Table 2: Typical profile descriptions

Worbate Small Scale Irrigation Project Soil Profile Description

Soil profile Profile code: ***WobP-1*** **Mapping unit:** **Status:** *PS*
Description.

Date: *24/01/19*
Author(s):*Leta/Ararsa*
Region *Oromia*
Zone:*Borena*
Wereda:*Gomole*

Soil classification FAO Lixi
Human influence:*SC, VU*

Land LP

Regional slope:
Position:*lower*
Slope class:*0-2*
Slope aspect:*North-Southu east*
Slope gradient:

Slope form:*U*

Slope length:

Surface cracks: *none*

Dissection:

Erosion *sheet and splash*

Fertilizers:*Unknown*
Existing crops:*N*

Long. In utm (E):*436940*
Lat. in utm (N):*554063*
Elevation:*1459m*
Parent material: *AL*
Rock
Types:
Effective soil depth: *deep*
Rock out N
Crops:
Depth to bed rock:*none*
Surface coarse few
Micro topography:*termite mound*
Surface sealing: *None*
Drainage class: *W/W*

Drainage external:*well*

Drainage internal:

Ground water: *none*

Flooding: *none*

Moisture condition:dray

Land cover:
Land use: *CL5, HE1*
Vegetation types: *hamaressa*

0-30cm clear and smooth boundary; moist moisture status;Dray dark redish brown (5YR4/4)dark brown (5YR3/3)Moist color, no mottling, sandy loam Texture, few fine coarse fragment, strong fine to medium Sub angular structure; No crack; very friable When moist, sticky and plastic when wet; no cutans; no cementation; no mineral nodules; common Fine medium, few medium to coarse roots; common fine medium fine coarse pores; non calcareous

30-100cm gradual and smooth boundary; Dray moisture status; dark red (2.5YR3/6) red

(2.5YR3/3) Moist, no Mottling, sandy clay , common fine coarse fragment, weak fine to medium granular structure; fine crack; Very friable when moist, slightly sticky and slightly plastic when wet; no cutans; no cementation; no mineral Nodules; few fine medium, few medium to coarse roots; common fine medium fine coarse pores; non Calcareous.

100-130cm;Dray moisture status; dark red (2.5YR3/4) and (2.5YR2.5/2 when Moist, no mottling, sandy Loam texture, few fine to medium coarse fragment, Strong medium Sub angular blocky structure; no crack; slightly hard when dry, friable to firm when moist, sticky and plastic When wet; no cutans; no cementation; few, white, both, concretion, calcium, mineral nodules; few fine roots; Common fine to medium pores; strongly calcareous.

Worbate Small Scale Irrigation Project Soil Profile Description

Soil profile Description. **Profile code:** ***WobP-3*** **Mapping unit:** **Status:** *PS*

Date: *26/01/19*

Author(s):*Leta/Ararsa*

Region *Oromia*

Zone:*Borena*

Wereda:*Gomole*

Soil classification FAO Lixi

Human influence:*SC, VU*

Land LP

Regional slope:

Position:*lower*

Slope class:*0-2*

Slope aspect:*North-Southu east*

Slope gradient:

Slope form:*U*

Slope length:

Surface cracks: *none*

Dissection:

Erosion *sheet and splash*

Long. In utm (E):*438100*

Lat. in utm (N):*555821*

Elevation:*1429m*

Parent material: *AL*

Rock Types:

Effective soil depth: *M/deep*

Rock out N

Crops:

Depth to bed rock:*none*

Surface coarse few

Micro topography:*termite mound*

Surface sealing: *None*

Drainage class: *W/W*

Drainage external:*well*

Drainage internal:

Ground water: *none*

Flooding: *none*

Moisture condition:dray

Land cover:

Fertilizers:*Unknown* **Land use:** *CL5, HE1*
Existing crops:*N* **Vegetation types:** *hamaressa*

0-30cm clear and smooth boundary; moist moisture status;Dray dark redish brown (5YR4/4)dark brown (5YR3/3)Moist color, no mottling, sandy loam Texture, few fine coarse fragment, strong fine to medium Sub angular structure; No crack; very friable When moist, sticky and plastic when wet; no cutans; no cementation; no mineral nodules; common Fine medium, few medium to coarse roots; common fine medium fine coarse pores; non calcareous

30-100cm gradual and smooth boundary; Dray moisture status; dark red (2.5YR3/6) red (2.5YR3/3) Moist, no Mottling, sandy clay , common fine coarse fragment, weak fine to medium granular structure; fine crack; Very friable when moist, slightly sticky and slightly plastic when wet; no cutans; no cementation; no mineral Nodules; few fine medium, few medium to coarse roots; common fine medium fine coarse pores; non Calcareous.

100-130cm;Dray moisture status; dark red (2.5YR3/4) and (2.5YR2.5/2 when Moist, no mottling, sandy Loam texture, few fine to medium coarse fragment, Strong medium Sub angular blocky structure; no crack; slightly hard when dry, friable to firm when moist, sticky and plastic When wet; no cutans; no cementation; few, white, both, concretion, calcium, mineral nodules; few fine roots; Common fine to medium pores; strongly calcareous.

Soil profile Profile code: *ORP-4* **Mapping unit:Status:***PS*
Description

Date:*26/01/19*
Author(s):*Leta/Ararsa*
Region*Oromia*
Zone:*Borena*
Wereda:*Gommole*
Soil classification FAO *Cambisol*
Human influence:*VU*
Land LP
Regional slope:
Position:*Medium*
Slope class:*2-5%*
Slope aspect:
Slope gradient:

Long. In utm (E):*438903*
Lat. in utm (N):*555385*
Elevation: *1432m*
Parent material:*BT*
Rock Types:
Effective soil depth:*Moderatly Deep*
Rock out N
Crops:
Depth to bed rock:*80cm*
Surface coarse N
Micro topography:*TM, AB, AT*
Surface sealing:
Drainage class:*M/W*
Drainage external:*well*

Slope form:*U*

Slope length:

Surface cracks:*none*

Dissection:

Erosion sheet *and splash*

Fertilizers:*Unknown*
Existing crops:*N*

Drainage internal:

Ground water:*none*

Flooding: *none*

Moisture condition:0-80cm dry

Land cover:
Land use:*GL2*
Vegetation types:*HERER*

0-20cm Clear smooth boundary; dry moisture status; (5YR4/3)dry colour;(5YR3/3)moist colour; none mottling; clay loam texture; none coarse fragement; weak,fine &,medium ,sub- angular blocky structure; none crack;slightly hard,friable (moist), sticky and plastic(wet) consistency; none cutanic features; non-cemented & non-compacted; none mineral nodules;many, fine to medium root;:many, fine to medium pores;none calcareous.

20-80cm dry moisture status; (2.5YR4/6) dry colour;red(2.5YR3/4) moist colour; none mottling; sand clay loam texture;common, fine to medium coarse fragement; moderate,fine & medium , sub- angular blocky structure; nonecrack;hard(dry)' friable (moist), sticky to sticky and plastic to plastic (wet) consistency; none cutanic features; non-cemented & non-compacted; none mineral nodules;common,fine & medium, root;many,fine to medium pores; nonecalcareous. >80cm coarse and gravels. Argic diagnostic horizon (surface), Cambic (sub-surface

.

For soil profile description and Auger observation

Auger No	X	Y	Z
Ora1	436796	553402	1470
ora2	436801	553603	1467
Ora3	436794	553805	1457
Ora4	436808	553995	1450
Ora5	436815	554197	1438
Ora6	436842	554407	1435
Ora7	436849	554603	1431
Ora8	436861	554813	1431
Ora9	436997	554799	1432
Ora10	437004	554603	1439
Ora11	437004	554400	1434
Ora12	437004	554197	1439
Ora13	436983	553986	1453
Ora14	436995	553798	1458
Ora15	436997	553670	1460
Ora16	437196	554002	1454
Ora17	437192	554209	1447
Ora18	437188	554404	1440
Ora19	437201	554001	1440
Ora20	437201	554810	1447
Ora21	437205	555005	1432
Ora22	437401	555001	1430
Ora23	437387	554594	1435
Ora24	437406	554407	1453

Auger No	X	Y	Z
Ora51	439000	554600	1431
Ora52	439000	554300	1437
Ora53	439300	554299	1452
Ora54	439300	554599	1440
Ora55	439299	554904	1432
Ora56	439292	555200	1421
Ora57	439297	555503	1413
Ora58	439593	555497	1414
Ora59	439598	555201	1429
Ora60	439601	554898	1445
Ora61	439602	554595	1457
Ora62	439597	554301	1452
Ora63	436620	555199	1428
Ora64	436900	555200	1429
Ora65	437200	555200	1427
Ora66	437203	555471	1426
Ora67	437500	555518	1419
Ora68	437800	555525	1426
Ora69	437801	555766	1419
Ora70	438098	555816	1423
Ora71	438400	555814	1429
Ora72	438690	555817	1419
Ora73	438991	555800	1425
Ora74	439301	555803	1413

Appendix Table 3: Format for auger observation and profile description sheet

Oromia Water Works Design and Supervision Enterprise

Soil Survey Format for Soil auger observation

Field No. ________________ Author__________________Status__________

Project site________________ Date________________

Observation site location __________ **GPS N:**_____________**E:** _____________

Surface crust_______________Erosion

Cracking____________________A) At site__________________Land use ____________

Elevation____________________B) At surrounding___________Crop grown________

Drainage Class/Ext________ Micro topography___________Crop grown since when__

Land Form________________Seepage____________________-Range Land

Flooding F/D_______________SMU_________________________Over grazing___________

Position____________________Slope Class________________Bush encroachment____

GWTD (cm) _______________Slope aspect/direction____ -Vegetation type__________

Permeability_______________Rock out crop________________Dominant species______

Parent material____________Surface Stone/gravel______ Invasive species________

Human Influence___________

Depth(cm)						
Moisture Status	D/T					
Color	Dry					
	Moist					
Mottles	Abundance					
	Size					
	Contrast					
Texture						
Coarse Fragment	Abundance					
	Size					
Topsoil Structure	Grade					
	Size					
	Type					

Consistency	Dry					
	Moist					
	Wet					
Cementation	Grade					
Mineral nodules	Abundance					
	Color					
	Hardiness					
	Nature					
	Kind					
Carbonate						
Field PH						
Field EC						
Diagram and/or comment of the site			Diagram and/or comments between sites			

Appendix Table 3 Continued

Oromia Water Works Design and Supervision Enterprise

Soil Survey Format for Soil Profile Observation

Field No. ________________ Author__________________Status__________

Project site________________ Date________________

Observation site location __________ **GPS N**:_____________**E:** _____________

Surface crust________________Erosion

Cracking ___________________ A) At site________________Land use ____________

Elevation___________________ B) At surrounding________ Crop grown_______

Drainage Class/Ext__________Micro topography__________Crop grown since when__

Land Form______________ Seepage___________________-Range Land

Flooding F/D______________SMU_______________________Over grazing__________

Position____________________Slope Class________________Bush encroachment____

GWTD (cm) _______________Slope aspect/direction_____ -Vegetation type_________

Permeability_______________Rock out crop________________Dominant species______

Parent material____________ Surface Stone/gravel___________Invasive species_______

Human Influence___________

Horizon symbol						
Depth(cm)						
Boundary						
Moisture Status	D/T					
Color	Dry					
	Moist					
Mottles	Abundance					
	Size					
	Contrast					
Texture						
Coarse Fragment	Abundance					
	Size					
Structure	Grade					
	Size					
	Type					
Crack						
Consistency	Dry					
	Moist					
	Wet					
Cutans	Abundance					
	Size					
	Nature					
Cementation	Grade					
Mineral nodules	Abundance					
	Color					
	Hardiness					
	Nature					
	Kind					
Root	Abundance					
	Size					

Pores	Abundance					
	Size					
Carbonate						
Sample						

Diagnostic horizon (surface) _______________ Sub surface __________________

Diagnostic property ______________________ Depth to paralitic contact_____

FAO field classification____________________Final Classification______

Remark/Comment, Diagram_________________

Appendix Table 4: Soil physical and chemical laboratory analysis results

See the excel WorbateLab result on sheet-1

Name of Customer : OROMIA WATER WORKS DESIGN AND SUPERVISION ENTERPRISE

Project : Worbate SSI **Location -**

LAB No	Field Code	Depth	P^H - Water	E.C	P^H - KCl	Particle Size Distribution			TEXTURAL CLASS
						Sand	SILT	CLAY	
		Cm	1:2.5	ds/m	1:2.5	%	%	%	
173 /19	OrbP - 1	0-30	6.0	0.044	5.6	76	8	16	Sandy Loam
174 /19		30-100	5.9	0.031	5.6	52	8	40	Sandy clay
175 /19	OrbP - 2	0-30	5.8	0.054	5.5	72	10	18	Sandy Loam
176 /19		30-45	5.9	0.157	5.5	56	18	26	Sandy clay loam
177 /19	OrbP - 3	0-30	6.1	0.110	5.8	60	16	24	Sandy clay loam
178 /19		30-100	6.4	0.057	5.9	60	18	22	Sandy clay loam
179 /19	OrbP - 4	0-20	5.8	0.073	5.5	80	6	14	Sandy Loam
180 /19		20-80	5.6	0.049	5.4	52	12	36	Sandy clay
			Core Samples						

			Bulk Density			F. Capacity		P.Wilting Point	
			g/ Cm^3			%			
195 /19	OrbP - 1	0-30	1.71			13.2	6.9		
196 /19		30-100	1.51			18.1	11.9		
LAB NO	Na	K	Ca	Mg	SUM	CEC	BS	EX. Acidity	Ex. Al^{3+}
	Cmol(+)Kg^{-1}						%	Cmol(+)Kg-1	
173 /19	0.15	0.47	6.31	2.03	8.96	15.8	57	_	_
174 /19	0.20	0.79	7.37	2.70	11.05	20.4	54	_	_
175 /19	0.17	0.58	5.31	2.57	8.63	12.0	72	_	_
176 /19	0.18	0.12	9.51	3.22	13.03	18.8	69	_	_
177 /19	0.15	0.90	7.79	3.31	12.16	17.5	69	_	_
178 /19	0.18	0.21	18.61	5.50	24.50	47.7	51	_	_
179 /19	0.13	0.57	20.29	5.29	26.28	47.2	56	_	_
180 /19	0.19	0.45	13.11	4.58	18.32	27.9	66	_	_
LAB NO	T.N	O.C	O.M	C/N	Av.K	Av.P	P_2O_5	$CaCO_3$	
	%	%	%		PPM	PPM		%	gram kg^{-1}
173 /19	0.09	0.87	1.49	10	179.80	2.14	4.90	_	_
174 /19	0.04	0.50	0.85	11	306.80	0.74	1.69	_	_
175 /19	0.06	0.74	1.28	12	225.60	2.90	6.64	_	_
176 /19	0.05	0.60	1.03	11	74.60	0.80	1.83	_	_
177 /19	0.10	1.17	2.02	12	347.90	2.36	5.40	_	_
178 /19	0.05	0.55	0.95	11	89.70	1.92	4.40	_	_
179 /19	0.09	1.09	1.88	12	221.30	2.72	6.23	_	_
180 /19	0.04	0.49	0.84	11	174.30	1.38	3.16	_	_