THE NATIONAL REGIONAL STATE OF OROMIA

WANGUR SMALL SCALE IRRIGATION PROJECT

SOIL SURVEY & LAND EVALUATION STUDY FINAL REPORT

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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

Meda Gura Erbe Small Scale irrigation Project is Located in West Hararghe Zone Oda Bultum Wereda,The Command area Soil survey 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 tests 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 15 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, vertisols, and, Leptosol. The dominant major soil is Cambisol. Maize,Sugar Cane, onion and Sorghum are cultivated crops in the project area with Livestock production (Cattle, Goats and Sheep)

The targeted project command *has* **79.48 ha** of Gross area, and Net Irrigable area is **23ha**. Saketa River Diversion is the source to irrigate the area by canal using gravity.

The proposed crops that can be cultivated by using surface irrigation are 4 (Low land Maize, Tomato, Onion, Pepper,) Crops. The results of the suitability evaluation of the project area for surface irrigation, indicates that Total area of **6.56.ha** of land is found to be (S2) Moderatly suitable for surface irrigation. An area amounting to **41.54ha** is found to be (S3) marginally suitable for surface irrigation development. The areas identified as moderately and marginally suitable for surface irrigation are constrained by Slope.depth, texture and nutrient availability (Avp and organic matter).

The result indicated that some, 6.01 moderatly Suitable(S2) ,41.74ha (S3) marginally suitable for Maize cultivation by surface irrigation. For Tomato Some 2.48 (S1) Highly suitable and 19.57 modaratly suitable (S2) some 25.69 ha marginaly suitable(S3)),For Pepper Some area of 2.48ha is(S1) Highly suitable Some 3.52 ha moderatly suitable(S2) and 41.74 ha marginaly Suitable (S3),for Onion,some 4.65 ha (S1) Highly suitable ,Some11.03ha moderatly suitable (S2), and some 32.06 ha marginaly suitable(S3), The major limitations that downgraded the suitability level of the area to marginally subclass are Slope, Texture, Depth and Soil low

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

Meda Gura Erbe 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 (24 augers and 3 Profile pits) were describes for the study area. The detail level soil survey study enabled the identification of 15 Soil mapping units (15 SMU). It is hoped the information provided in this report helps in assembling and using data for the area of landsuitability map.

To undertake the Land 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 Lowland maize, onion, tomato and pepper 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, pH, Caco3, OC and CEC of the soil.

1. INTRODUCTION

1.1 Back Ground

The soil survey and land evaluation of the Meda Gura Erbe 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,West Hararge zone Oda Bultum District. Residentes have food security Problem, maize and Sorghum are cultivated crops in the project area with Livestock production (Cattle, Goats and Sheep) 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 (Meda Gura Erbe 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, Meda Gura Erbe Small Scaleirrigation project, is Located in the Oromia Regional State, West Hararghe Zone Odaa Bultum wereda. Irrigation to be used from Saketa Rever Diversion. More precisely it falls in between 964762 to963645 UTM N and 695720 to 697653UTM E. The targeted area of the project is79.48 ha of Gross area and **23**ha net. The altitude of the area ranges from 1450-1462masl. The project area is acceceble via Finfine-chiro-asphalt road and Chiro To Bedessa allweather (Gravel) road 530Km, East from Finfine.

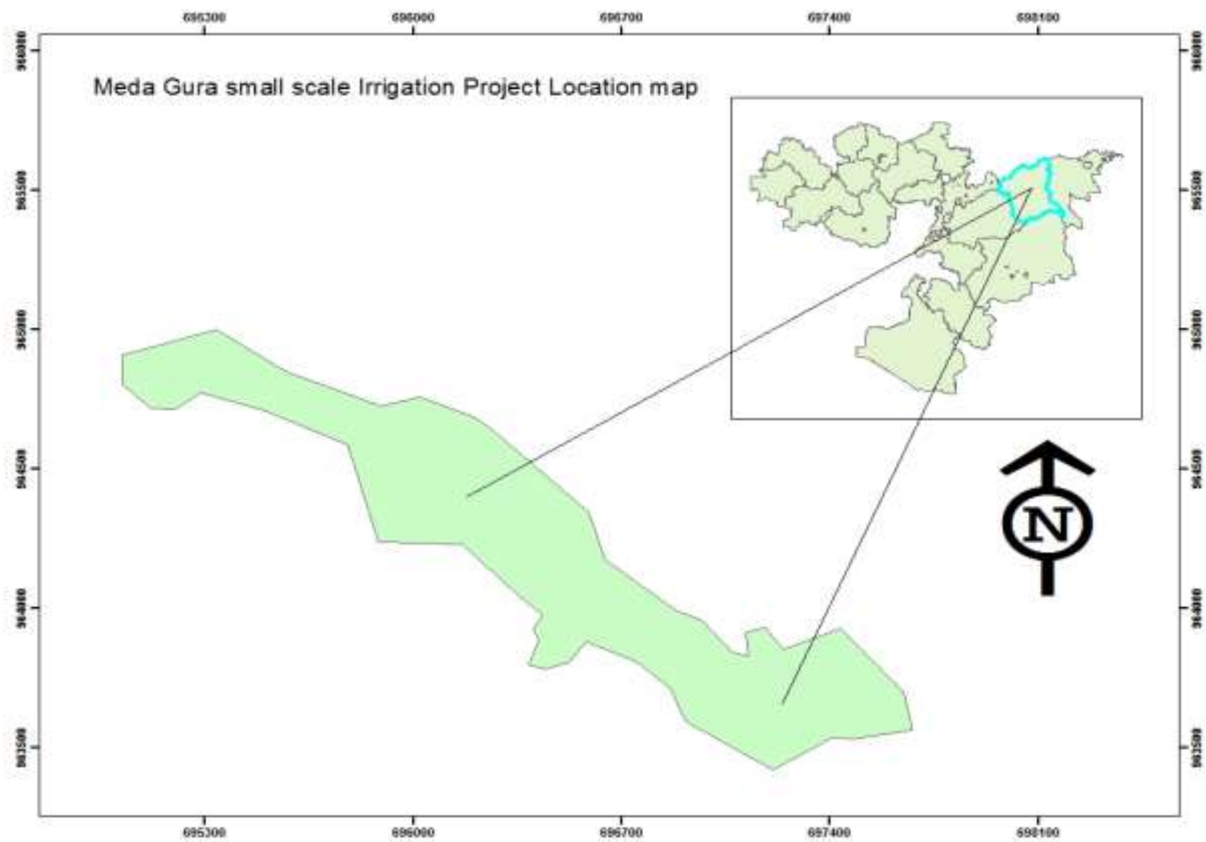


Figure 1 Location Map of Wangur Small scale irrigation project

2.2 Climate

Climate Is one of the components of an environment that determines formation and characteristics of natural vegetation, soil formation and farming systems of a particular area. Based on the climatic factors, the length of the growing period (LGP) for the crops produced in the study area will be described. Climate and soils gives information on the types of climate and soil that are best suited to the crop under consideration.minimum tempreture 14.4-17.6^{0}C, on average16.2^{0}C, and maximum tempreture of 26.4^{0}C-27.8^{0}C, on average of 26.4^{0}C,

The climate in the project area is characterized by a bimodal rainfall and the main rainy season is from mid March to mid May and the short rainy season is from mid September to early November. However the rainfall is highly erratic, late on the onset, less in amount and poor in distribution.

The nearest metreology station to the proposed command area is Bedessa for rain fall data. For minimum temperature, maximum temperature, relative humidity, wind speed and sunshine hour data, Bedessa metreology station is used for the computation of reference evapotranspiration and then crop water requirement was computed for all the proposed crops.

2.3 Rainfall

The rainfall pattern of the study area is bimodal. The total annual rainfall of the study area is about 1182 mm. The rainfall distribution and amounts vary from year to year. The moist months of the project area are mid September to end October, Mid March to beginning April and mid May to end May. The dry months are from end October to mid March and from end May to mid September. The rest months from mid April to mid May are humid period / growing seasons.

2.4 Physiograpy and Geology

2.5 Local Geology

The local geology of the project area is made up of Mesozoic sedimentary rocks, tertiary volcanic rock, and minor alluvial deposits of insignificant thickness found along stream courses.

2.2.2 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 Meda Gura Erbe River and its tributaries.Deep dark brown clay loam textured soils (*Vertisol, Cambisol* and Leptosol) are the most widespread soils developed on 0-8% slope mainly from limestone and Aluvium parent matterial, amounting to almost98% of the Study Area.

Table 1 Land form and Slope

Slope%	Area (ha)	Area (%)	Remark
0-2	10.10	12.70	
2-5	17.4	21.89	
5-8	20.24	25.46	
8-15	21.30	26.79	
>15	10.42	13.11	
Total	79.48	100	

2.2.3 Vegetation and Land Use

About 75% of the Study Area supports rainfed smallholder agriculture. the most common crops are Maize and sorghum. Tomato,Onion, sugar cane and pepper are also frequently grown and a wide range of other crops are grown in small amounts,

3. REVIEW OF PREVIOUS STUDIES

3.1 Wabe Shebele River Basin Master Plan project

Asoil survey of Wabeshebele river basen master plan project was carried out by Water works Desigen and Super vision Enterprice (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 Luvisol, and Eutric Nitisols

3.2 East and West Hararge Integrated Land Use Planning 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 is classified in to the following eight major soils i.e. Luvisols, Cambisols, Fluvisols,Vertisol and Leptosols.

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 the soil has been presented on 1:50,000 Scale map.in this study identifaid cambisol and Chromic vertisol in the project area.

3.3 Soil and Geomorphology map 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 representative 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 24 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, 3representative 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 3 (three) 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

4.3.3 Physical tests

For measurement of water content at various bars to determine soil available water capacity (AWC) 3 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 2 Soil survey data collected during the field work

S/N	Status	Number of observations
1	Total augers observation points	24
2	Soil profile description	3
3	Soil samples	7
4	Infiltration and hydraulic conductivity	1
5	Undisturbed core samples	3

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 16SMU were identified on the basis of the above three criteria.

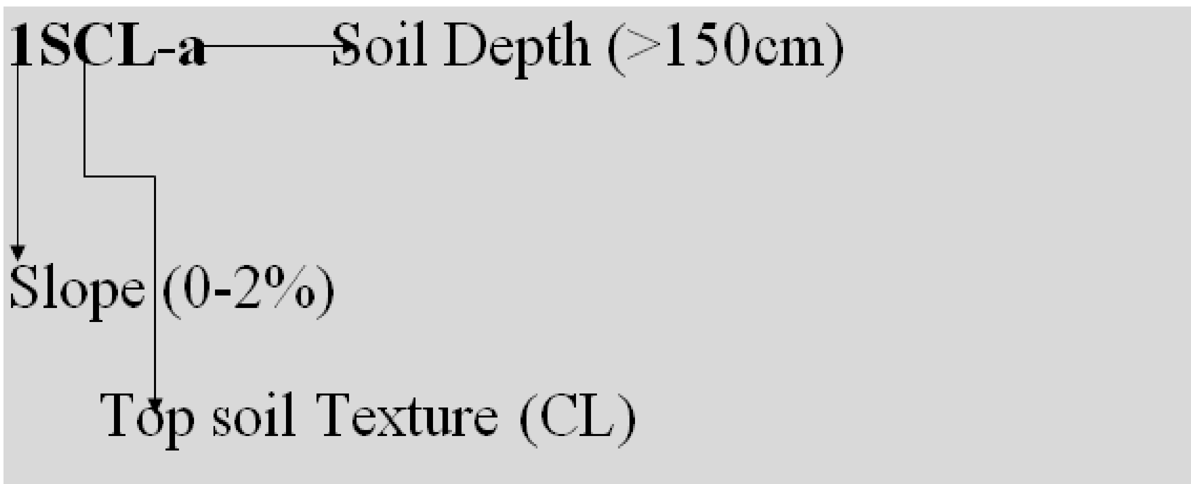
Table 3Soil properties used for the definition of SMU

Slope		**Texture**		**Depth**		**Soil type**
%	**Map Symbol**	**Class**	**Map Symbol**	**Cm**	**Map Symbol**	
0-1	1	Clay loam	CL	>150	a	Vr
1-2	2	Sandy Clay Loam	SCL	100-150	b	Cm
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 15 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 :



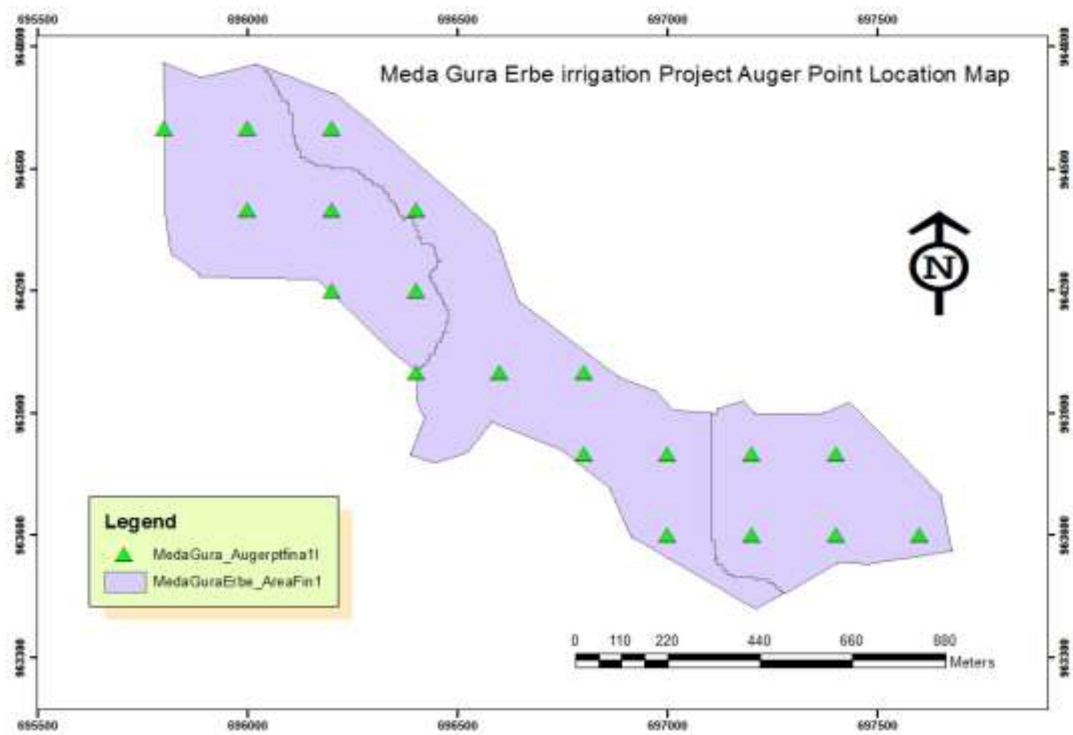


Figure 2 Location of Auger Observation Points

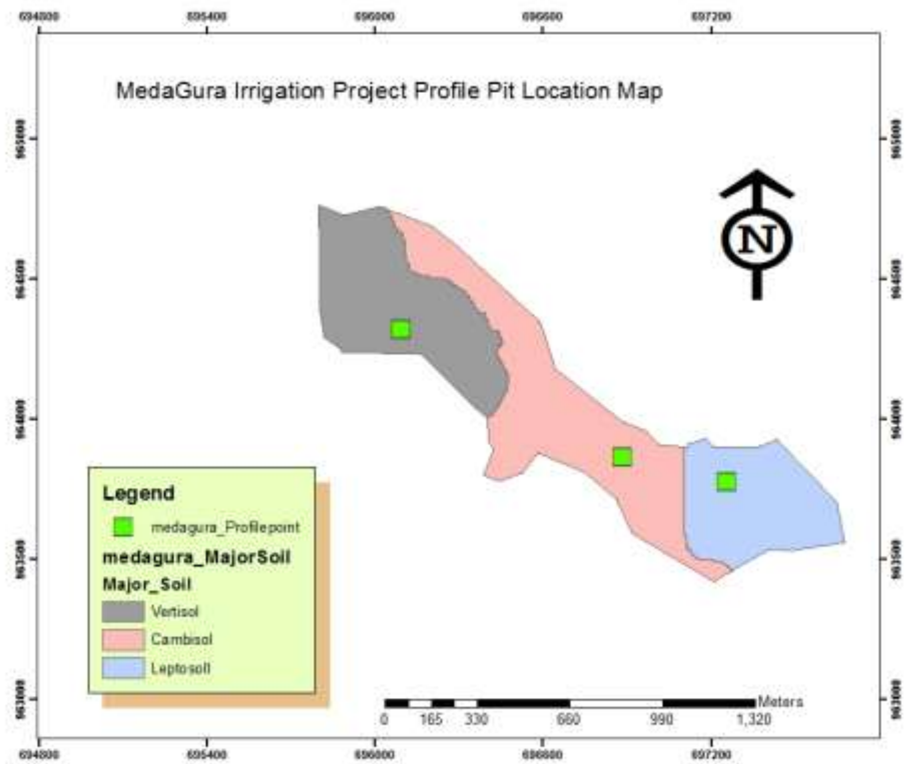


Figure 3 Location of Soil Profile Pits

4.3.5 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

$$PBS = \frac{(K + Na + Ca + Mg)}{CEC} * 100$$ (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 theMeda Gura Erbe Irrigation Project is classified in to the following three major soils, i.e.Vertisol, Cambisols, 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 Meda Gura Erbe Irrigation Project has been presented on 1:10,000 scale maps.

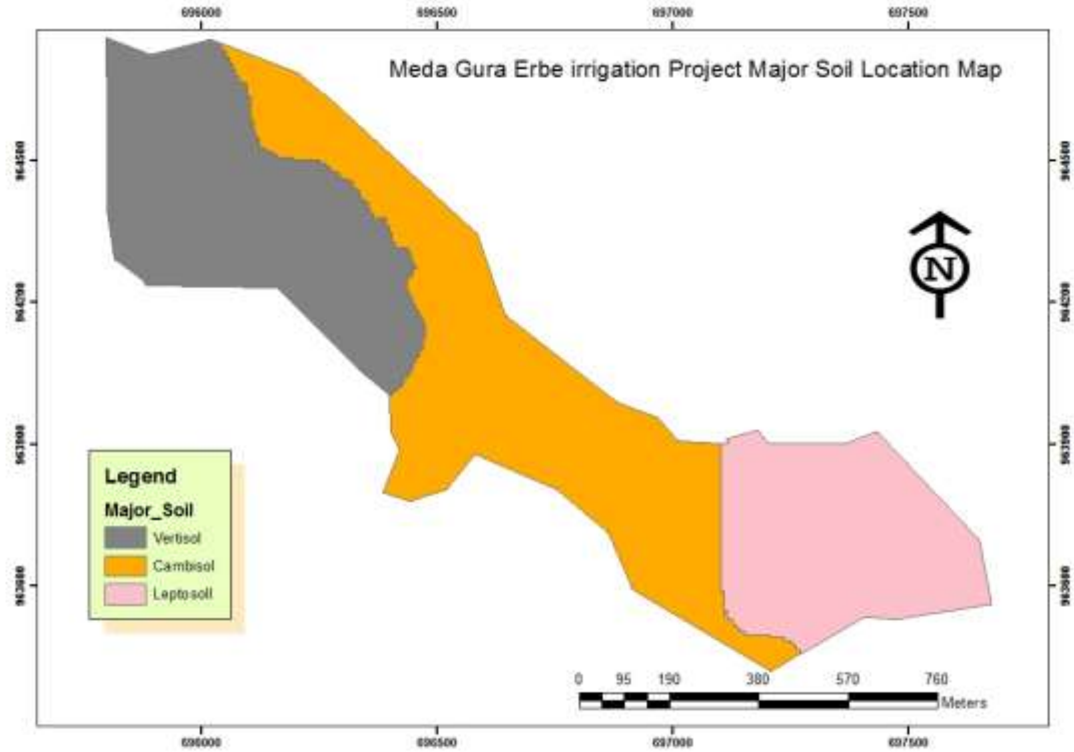


Figure 4 major soil map

5.3 Vertisols

Vertisols are churning, heavy clay soils with a high proportion of swelling clays. These soils form deep wide cracks from the surface downward when they dry out, which happens in most years. The name Vertisols (from Latin 'vertere', to turn) refers to the constant internal turnover of soil material. The parent material from which Vertisols are formed are those sediments that contain a high proportion of swelling clays, or products of rock weathering that have the characteristics of swelling clays. Vertisols occur in the environment of depressions and level to undulating areas, mainly in tropical, subtropical, and semi-arid to sub humid and humid climates with an alternation of distinct wet and dry seasons. The climax vegetation is savannah, natural grassland and/or woodland. In Vertisols, alternate swelling and shrinking of expanding clays results in deep cracks in the dry season, and formation of slickensides and wedge-shaped structural elements in the subsurface soil. Gilgai micro relief is peculiar to Vertisols although not commonly encountered (WRB, 2014).

Vertisols of the study area are dominantly distributed over the topography of slope below 5 % Slppes They have common to very common cracks with crack width up to 20 cm and crack depth up to 1.1 m. The land use and land cover of the Vertisols of the study area is mainly Cultivated and grasslands with some scattered trees. The total area coverage of Vertisols of the study area is 26.38 ha which constitutes 33.01 % of the total survey area. This major soil was further classified into soil phase as Mollic Vertisols (humic),

The Vertisols in the Study area are Neutral with pH 6.8 to 7.3in the topsoil and or pH of 6.8-7.2 in the sub soils.The CEC values of the soils are very high ranging from 56**C**mol (+) **k**g^{-1}in the topsoils and 52**C**mol (+) **k**g^{-1}in the subsoil. Base saturation percent is high 79%percent and 85 percent in the topsoils and the subsoil respectively.

The electrical conductivity is 0.4 ds/min in the top and 0.39 ds/m and salinity would not impose any limitations throughout the soil types. The calcium carbonate content of the Luvisols is <15 percent in the topsoil and the result is trecesub soil. The presence of free carbonate normally indicates that the clay complex is dominated by calcium, which usually implies favorable physical condition but high level affects chemical characteristics of the soils in sub soils.

Organic carbon percent is low (2.40) in the topsoils and very low to low in the subsoil 2.7%. The nitrogen percent is 0.24rated as highin the topsoils and 0.22% in the subsoil which is rated as low. Representative Vertisol Profile Narration

Soil profile Description. **Profile code:** *MGP-1* **Status:** *PS*

Date: *21//12/18*	**Long. In utm (E):***696095*
Author(s):*Abdulahi*	**Lat. in utm (N):***964330*
Region *Oromia*	**Elevation:***1425m*
Zone:*West Harerge*	**Parent material:** *AL*
Wereda:*Oddaa Bultum*	**Rock Types:**
Soil classification FAO Vertisoll	**Effective soil depth:***very deep*
Human influence:*PL*	**Rock out** None
	Crops:Maize
Land LP	**Depth to bed rock:***none*

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*

Surface coarse few
Micro topography:*Tressing*
Surface sealing: *None*
Drainage class: *M/W*

Drainage external:*well*

Drainage internal:

Ground water: *none*

Flooding: *none*

Moisture condition:0-30cm S/moist, 30- 200+cm moist

Land cover:
Land use: *CL4,*

Existing crops: *Maize* **Vegetation types:** *Mekenissa*

0-25cm clear and smooth boundary; moist moisture status; dark brown (10YR3/1) Moist color, no mottling, Clay , 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

25-100cm gradual and smooth boundary; moist moisture status; Black (10YR2/1) Moist, no Mottling, Clay , No coarse fragment, Modaret fine to medium Sub Angular structure; fine crack; Very friable when moist, sticky and 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.

100-200cm;Moist moisture status; VeryDark Grayish Brown (10YR2/2) when Moist, no mottling, Clay 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; slightly calcareous.

5.4 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 (Eutric), Haplic Cambisols (Eutric)

The Cambisols in the study area are with Neutral pH 6.9 in the top soils and 7.3 in the sub soils. The CEC values of the soils are high 52Cmol (+) Kg^{-1}in the top soils and high 48Cmol (+) Kg^{-1} in the sub soils. Base saturation percent is medium to high ranging from 88 and 89 percent in the top soils and the subsoil respectively.

The ESP of these soils is <15 and electrical conductivity is 0.25-0.41ds/m indicating no salinity limitation. Cambisols cover 33.73ha of the total area.

Soil profile Description **Profile code:**MG*P-2* **Mapping unit:** **Status:***PS*

Date:*22/12/18*	**Long. In utm (E):***696870*
Author(s):*Abdu*	**Lat. in utm (N):***963855*
Region*Oromia*	**Elevation:***1427m*
Zone:*West Harage*	**Parent material:***LI*
Wereda:*Oda Bultum*	**Rock Types:**
Soil classification FAO *Cambisol*	**Effective soil depth:***Moderatly Deep*
Human influence:*VU*	**Rock out** Few
	Crops:
Land LP	**Depth to bed rock:***55cm*
Regional slope:	**Surface coarse** N
Position:*MEDIUM*	**Micro topography:***, AB,*
Slope class: **5-***8%*	**Surface sealing:**
Slope aspect:	**Drainage class:***W/W*
Slope gradient:	
	Drainage external:*well*

Slope form:*U*

Slope length:

Surface cracks:*none*

Dissection:

Erosion sheet *and splash*

Fertilizers:*Unknown*
Existing crops:*Sorghum*

Drainage internal:

Ground water:*none*

Flooding: *none*

Moisture condition:0-50cm dry

Land cover:
Land use:*CL4*
Vegetation types:*Lafto*

0-20cm Clear smooth boundary; dry moisture status; (5YR4/6)dry colour;(5YR4/4)moist colour; none mottling; 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.

20-50cm dry moisture status; (2.5YR3/6) dry colour;red(2.5YR3/4) moist colour; none mottling; 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. >50cm Stones and gravels. Argic diagnostic horizon (surface), Cambic (sub-surface)

5.5 Leptosols (EskeletikLeptosol (eutric)

Leptosols are soils having 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 19.5 ha MGP-3 representative profiles.

6. SOIL PHYSICAL AND CHEMICAL 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 Meda Gura Erbe Irrigation Project are moderatly deep to very deep (50-100cm to >150 cm respectively), Some limitation for normal rooting for cultivated crops,on Leptosols (0-20cm) rooting Depth.

Table 4: Effective soil depth and area coverage of the area

Depth (cm)	Area (ha)	Ha (%)
>150cm	25.46	32.03
50-100	31.38	39.48
0-20	22.63	28.47

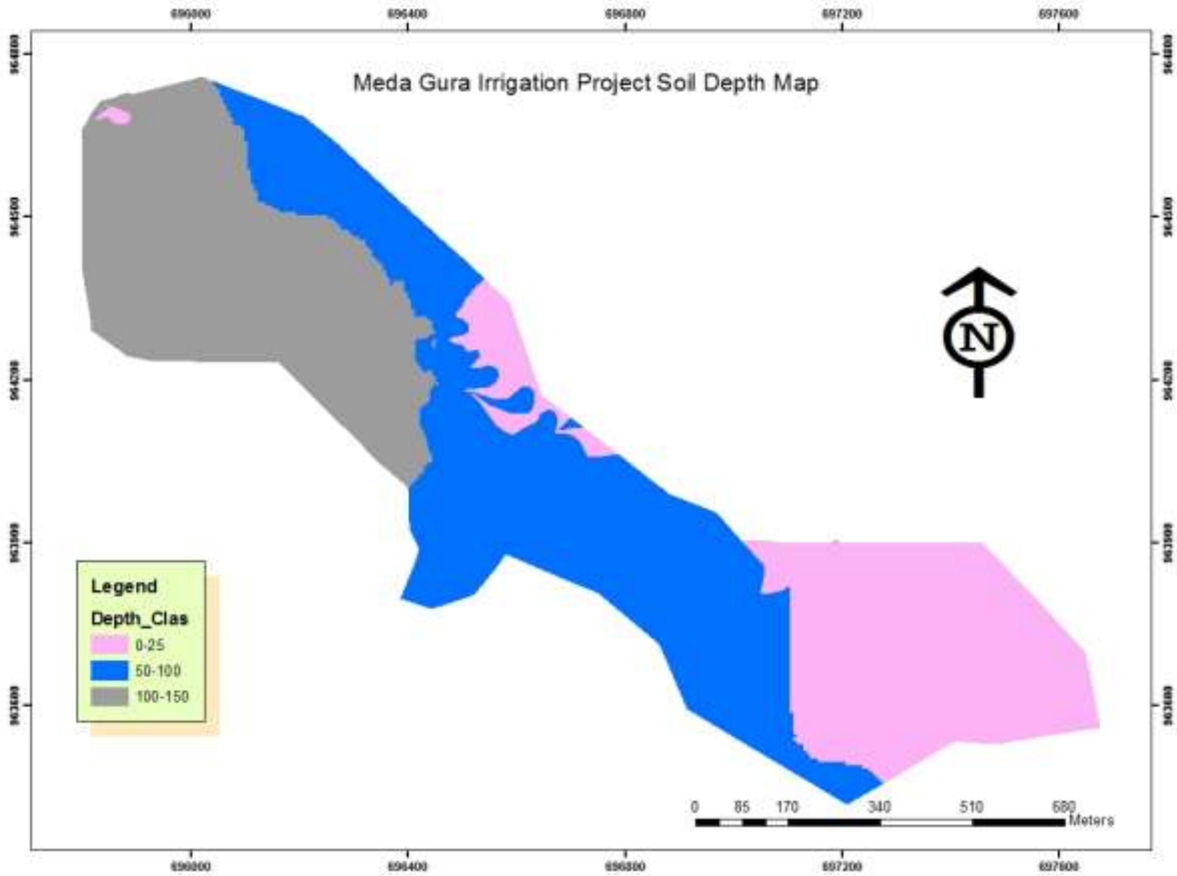


Figure 5 Depth map

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).

This is a subjective system of assessment. The surface structure of Vertisols is dominantly moderate to strong, medium angularblocky structure. for Cambisols (Eutric) weak to medium moderate sub angular blocky structure Soil structure of almost all soil types is moderately developed medium size and sub-angular blocky.

6.1.3 Consistence

The Vertisols with medium texture have hard consistence when dry, friable when moist and sticky and plastic consistence when wet. Cambisols have friable when moist, slighitly sticky and slightly plastic when wet, The consistence of other soils varies with their textural composition and accordingly the loam and 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 Clay for Vertisol and Loam for Cambisol and Leptosol respectively, Laboratory analysis of soil texture show that clay percentage increases down soil profile especially in Vertisols 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 areaVertisolsl to dark Gray to Black (10YR3/1and 2/1) while modaretly 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 moderately well drained in Vertisols area and moderately drained to well-drained in Cambisols Soil condition which vary depending on their varying properties affecting drainage such as water transmission, soil depth, soil chemistry colour, 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. Many challenges have been encountered during the test of infiltration on Vertisols and vertic soils because of the cracking nature of the soils that was not fully closed during pre-wetting time and consumed much more time and water. As a result of the unclosed hidden sub surface cracks, the effort of infiltration test on these soils frequently failed and finally achieved on the limited representative sits. All tests were performed close to representative soil profiles. The result of the test indicates that soils of the study area have a mean infiltration rate of **1.5cm/hr-2.2cm/hr** and this implies that soils of the project area have a **moderate** infiltration rate.

Table 5 The following table shows the results of infiltration tests of the soils.

No	Rep. Profile	Surface Texture	Rep1(cm/hr)	Rep2(cm/hr)	Rep3(cm/hr)	Infiltration rate (cm/hr)
1	MGP-1	ClayLoam	1.5	2.2	2.1	1.5-2.2

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

1.2 to 2.4 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.

Table 6: The hydraulic conductivity results of the soils are given below.

No	Rep. Profile	Surface Texture	Rep1 (m/day)	Rep2 (m/day)	Rep3 (m/day)	Hydraulic conductivity (m/day)
1	MGP-1	Clay Loam	1.2	2.4	1.8	1.2-2.4

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 of Silty loam is 1.54 g/cm3. The bulk density of the soils in the study area varies between **1.16and 1.34 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 7: Bulck density results versus soil textures of the study area

S/N	Rep.Profile	Surface Texture	Bulck density(gm/cm3)
1	MGP-1	Clay Loam	1.16

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 **42% in** the top soil and **44.8% to46.2%** 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 **25.4%** in the top soil and **26.3% to 27.0%** in the sub soil.

Table 8: permanent wilting point results versus soil textures of the study area

S/N	Rep.Profile	Surface Texture	Permanent wilting point (%) (15 bar)
1	MGP-1	Clay	25.4-27.0

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.

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

Table 9: 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.

Profile Code	Depth(cm)	Field Capacity (0.33bar)	Permanent Wilting Point(15bar)	Bulk Density (gm/cm3	FC-PWP	AWC	TAWC	Total Poresity
MGP-1	0-25	42.0	25.4	1.16	16.6	48.14		56.22
	25-60	44.8	26.3	1.20	18.5	55.5		54.71
	60-90	46.2	27.0	1.34	19.2	64.2	168	49.43

The above values were derived from the representative samples for the study area. The higher 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 Leptosol and Cambisols are all well-aerated at field capacity, but the Vertisols 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 10 **: 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	top soil	0.3–0.6m	0.6-1.0m	topsoil	0.3–0.6m	0.6-1.0m
MGP-1	Vr	1.16	1.20	1.34	56.22	54.71	49.43	14.22	10.1	3.23

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.

6.1.15 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 few rill and Gully erosion active in the comand area and not observed modern soil and water conservation practices. 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

6.1.16 Flooding

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

6.1.17 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 or sodicity 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 **6.6-7.3** on the top soil and **6.8-7.3 en Sub soil** with an average of **6.8** .which increase from top to sub soil. This range of soil pH is normally termed as Neutral soil. But nedded 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 **0.25 to 0.45** 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}. The range of **ECe** measured for the soil of the study area is very low varying from **1.32 -2.36 dS**/m with anaverage of **1.9 dS/**m.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 **2.70**% **to 3.36%** with average of **3.06**% 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 **4.66%to 5.80%**the average organic matter content of the soils of the study area is **5.28%** and is rated as High 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 **0.24 to 0.29%** percent with an average of 0.268% which indicate that the total nitrogen content is high in the study area**.**

6.2.5 Carbon 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 **11.2to 11.6**

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**0.68**ppm to **98.2ppm** with average of **41.98ppm** where the value is low to high 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 **45.54** meq/100g soil to **56.02** meq/100g. CEC on average **51.17**meq/100g medium value, this value between these ranges is rated as 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**79.06% to 89.43%** average **85.1%**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 **31.3**cmol (+)/kg soil to **35.96**cmol (+)/kg soil with average value of **33.35** 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 **6.8 to 11.0cmol (+)/kg** soil with average value of **8.76cmol(+)/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 **0.42 to 4.28 cmol (+)/kg** soil. Which indicates that the level of K is medium to high .the average value is **2.10 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 **0.15 to 0.22cmol(+)/**kg of soil, with mean value of **0.18 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 **0.32% to 0.38%** with avegage value of **0.35**% 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.

Calcium carbonate content of most of the soils in the study area ranges from **0.5-42.72%** is low to very high

MAJOR SOIL				
Soil Physical & chemical Properties	Horizon	VERTIISOL	CAMBISOL	LEPTOSOL
Ph	**top**	**6.6**	**6.9**	**7.3**
	sub	**6.9**	**7.3**	**-**

MAJOR SOIL				
Soil Physical & chemical Properties	Horizon	VERTIISOL	CAMBISOL	LEPTOSOL
Ec	**Top** **sub**	**0.41** **0.39**	**0.45** **0.39**	**0.25** **-**
Na	**top** **sub**	**0.22** **0.28**	**0.17** **0.16**	**0.15** **-**
K	**Top** **sub**	**0.79** **0.62**	**4.22** **8.20**	**0.85** **-**
Ca	**top** **sub**	**32.26** **33.85**	**35.96** **27.35**	**31.30** **-**
Mg	**top** **sub**	**11.00** **9.12**	**6.8** **5.21**	**8.20** **-**
CEC	**Top** **sub**	**56.02** **52.12**	**52.74** **45.8**	**45.54** **-**
BS%	**Top** **sub**	**79.06** **85.78**	**89.43** **89.39**	**88.95** **-**
ESP	**top** **sub**	**1.04** **1.1**	**1.23** **1.50**	**1.70** **-**

MAJOR SOIL				
Soil Physical & chemical Properties	Horizon	VERTIISOL	CAMBISOL	LEPTOSOL
TN	**top**	**0.24**	**0.25**	**0.26**
	sub	**0.22**	**0.26**	**-**
OC	**top**	**2.70**	**3.17**	**3.36**
	sub	**2.4**	**3.07**	**-**
OM	**top**	**4.66**	**5.46**	**5.80**
	sub	**4.14**	**5.30**	**-**
AvP	**top**	**0.68**	**98.2**	**11.88**
	sub	**0.94**	**22.08**	**-**
Caco3	**top**	**0.5**	**19.68**	**42.72**
	sub	**23.04**		
Texture	**top**	**C**	**L**	**L**
	sub	**C**	**CL**	**-**
Depth		**>150**	**50**	**20**

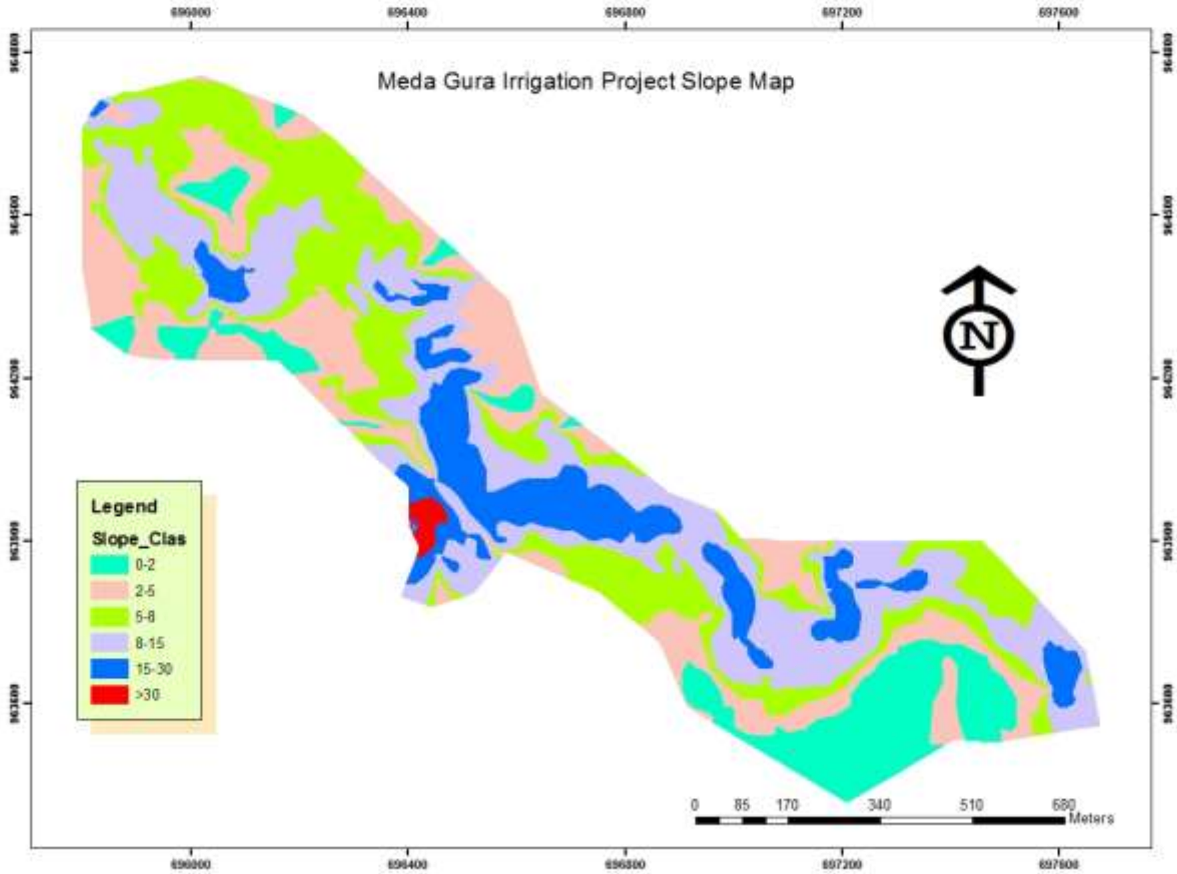


Figure 6: Slope Map

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 15 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.

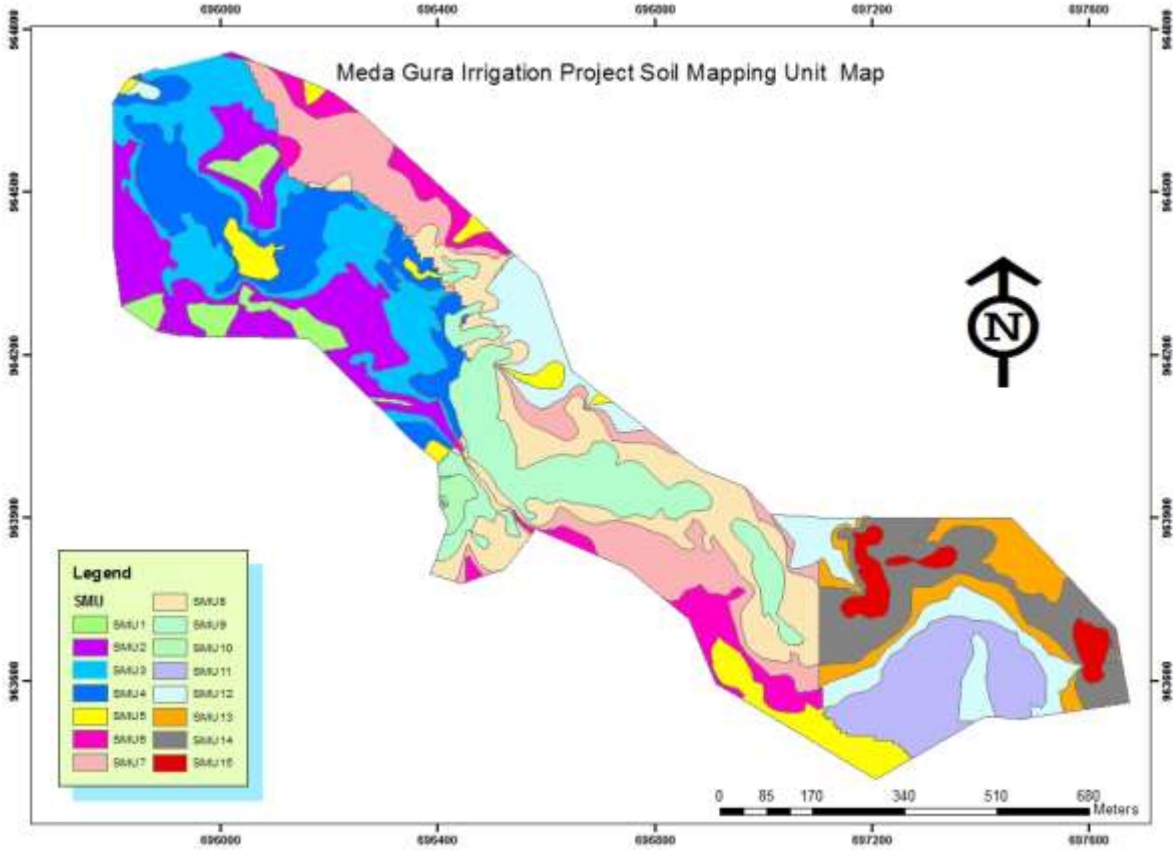


Figure 7 Soil mapping unit (SMU Map)

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

Major Soil Group(Fao,1988)	Identified soil	Area(ha)	Ha(%)
Vertisol	Eutric and chromic	26.38	32.03
Cambisol	Leptic,Mollic,eutric, Cambisol	33.73	39.48
Leptosol	Eskeletic Eutric	19.42	28.47
		79.48	100

7.2 Soil Mapping unitsDescription:

C (Vr, eu) -a(SMU1)

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

The average infiltration rate (IR) of this unit is categorized as optimum (1 to 3.0cm/hr) and hydraulic conductivity (HC) ranges from 1.18 to 2.1 m/day.

The pH value is 6.6 in the top soil and 6.9 in the sub soil indicating that the soil is Slightly acid The over all organic carbone content of this soil unit is 1.5% in the top soil and 0.45% 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), high CEC level (25.7&16.6Meq/100g of soilin top and sub soil respectively) and very high base saturation percentage (79% in the top soil and 89% in the sub soil. The soils in this mapping unit have high Ca2+ and are none calcareous. The soil unit is eutricVertisl.The total extent of this mapping unit is 2.17ha

1C (Lv, eu)-a(SMU2)

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

The pH value is 6.8 in the top and 7.3in the sub soil indicating that the soil is Neutral The overall organic carbon content of this soil unit is 2.40 % in the top soil and 2.65% 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 (56&52 Meq/100g of soil in top and sub soil respectively) and high base saturation percentage (79 in topand 85sub soil. The soil in this mapping unit have High Ca2+ and none calcareuse.The soil unit is eutric VertisolThe total extent of this mapping unit is 7.5 ha

1SC (Lv, eu)-a(SMU3)

This mapping unit refers to soils developed on 5-8% slope with very deep profile (>150cm). The soils are Moderatly wel drain with moderate, medium sub angular blocky structure and have Clay (C) texture.

The pH value is 6.8 in the top soil and7.3 in the sub soil, which indicating that the soil is Neutral. The over all organic carbone content of this soil unit is 2.40% in the top soil and 2.71% in sub soil, which indicates very Low level of organic matter content. Total nitrogen content ranges 0.24% in the top and 0.27% 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), high CEC level (56&52Meq/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 FluvisolThe total extent of this mapping unit is 8.16 ha

1SCL (-a(SMU4)

This mapping unit refers to soils developed on 8-15% slope with very deep profile (>150cm). The soils are well drained with fine & medium sub angular blocky structure and have Clay (C) texture.

The average infiltration rate (IR) of this unit is categorized as optimum (2.5to 3.5cm/hr) and hydraulic conductivity (HC) ranges from 1.14 to 2.17 m/day.

The pH value is 6.8in the top and 7.3in the sub soil, which indicating that the soil is Neutral. The overall organic carbone content of this soil unit is 2.7% in the top soil and 2.40% in sub soil, which indicates very low level of organic matter content. Total nitrogen content ranges 0.22% in the top and 0.40 % 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), high CEC level (54&52Meq/100g of soil in top and sub soil respectively) and high base saturation percentage (79 inthe topand88 subsoil. The soils in this mapping unit have high Ca2+ and are none calcareous. The soil units is Lixisol.The total extent of this mapping unit is 8.75ha

2SCL(Cm)-a(SMU5)

This mapping unit refers to soils developed on 2-5% slope with very deep profile (>150cm). The soils are imperfectely to moderately well drained with strong & medium sub angular blocky structure and have Sandy ClayLoam (SCL) texture.

The average infiltration rate (IR) of this unit is categorized as optimum (2.2to 3.5cm/hr) and hydraulic conductivity (HC) ranges from 1.36 to 2.5 m/day.

The pH value is 5.6 in the top soil and4.1in the sub soil, which indicating that the soil is Strongly 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 high available phosphorus in the top and medium in the sub soil (15.18 ppm in the top soil &7.02 ppm in the sub soil), Medium CEC level 15.7&13.8 Meq/100g of soil in top and sub soil respectively) and high base saturation percentage (47%and 45% both in the top and subsoil. The total extent of this mapping unit is 3.34ha.This soil mapping unit is Cambisol.

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

This mapping unit refers to soils developed on 5-8% slope with very deep profile (50-100cm). The soils are moderately well drained with moderate & medium sub angular blocky structure and have loam (L) texture.

The average infiltration rate (IR) of this unit is categorized as optimum (2.2 to 3.5cm/hr) and hydraulic conductivity (HC) ranges from 1.4 to 2.4 m/day.

The pH value is 6.9 in the top soil and7.3 in the sub soil, which indicating that the soil Neutral. The overall organic carbon content of this soil unit is 2.7% in the top soil and 2.49 % in sub soil, which indicates very high to high level of organic matter content. Total nitrogen content ranges 0.28% in the top and 0.26 % in sub soil which shows high level status of the total nitrogen. This soil mapping unit have high available phosphorus (11.082 ppm in the top soil &22. ppm in the sub soil),high CEC level (45&45.8 Meq/100g of soil in top and sub soil respectively) and high base saturation percentage (89% in the top and 79%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 3.52 ha

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

This mapping unit refers to soils developed on 5-8% slope with very deep profile (50-100cm). The soils are well drained with stronge& medium sub angular blocky structure and have Loam (L) texture.

The average infiltration rate (IR) of this unit is categorized as optimum (2.1 to 3.4cm/hr) and hydraulic conductivity (HC) ranges from 1.26 to 2.4 m/day.

The pH value is 6.8 in the top soil and 7.3 in the sub soil, which indicating that the soil is Neutral. The overall organic carbon content of this soil unit is 2.7% in the top soil and 2.4% 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), high CEC level 54&48 Meq/100g of soil in top and insub soil respectively) and high Level base saturation percentage (89% in the top and 89% 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 8.64 ha.

1SCL (Cm, eu)-a(SMU8)

This mapping unit refers to soils developed on 8-15 % slope with deep profile 50-100 cm). The soils are moderately well drained with mediumsubangular blocky structure and have Snndy Clay Loam (SCL) texture.

The average infiltration rate (IR) of this unit is categorized as optimum (2.2 to 4.6cm/hr) and hydraulic conductivity (HC) ranges from 1.26 to 2..4 m/day.

The pH value is 6.8in the top soil and 7.3 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), very high CEC level (31.3 &21.8 Meq/100g of soil in top and sub soil respectively) and high base saturation percentage (83% 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 8.86 ha

2SCL (Cm, eu)-a(SMU9)

This mapping unit refers to soils developed on 15 -30 % slope with moderatly deep profile (50-100 cm). The soils are well drained with moderate & medium sub angular blocky structure and have Loam (L) texture.

The pH value is 6.9 in the top soil and 7.3 in the sub soil, which indicating that the soil is Neutral. The overall organic carbon content of this soil unit is 2.4% in the top soil and 2.7 % 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 (11.2&15.3Meq/100g of soil in top and sub soil respectively) and high base saturation percentage (89% in the top and 88% subsoil and are None calcareous.The soil units is Cambisol.The total extent of this mapping unit is 7.37ha

5L (Cm, eu)-a(SMU10)

This mapping unit refers to soils developed on >30 % slope with moderatly deep profile (50-100 cm). The soils are well drained with moderate & medium sub angular blocky structure and have Loam (SL) texture.

The pH value is 6.8 in the top soil and 7.3 in the sub soil, which indicating that the soil is Neutral. The overall organic carbon content of this soil unit is 2.7% in the top soil and 2.45 % 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 (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 0.5 ha.

1L (Lp, eu)-d(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 Loam (L) texture.

The pH value is 7.3 in the top soil , which indicating that the soil is Neutral. The overall organic carbon content of this soil unit is 3.36% in the top soil and are Nonecalcareous.The soil units is Leptosol .The total extent of this mapping unit is 5.44 ha

2L (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 Loam (L) texture.

The pH value is 7.3 in the top soil , which indicating that the soil is Neutral. The overall organic carbon content of this soil unit is 3.36% in the top soil and are Nonecalcareous.The soil units is Leptosol .The total extent of this mapping unit is 6.36 ha

3L (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 Loam (L) texture.

The pH value is 7.3 in the top soil , which indicating that the soil is Neutral. The overall organic carbon content of this soil unit is 3.36% in the top soil and are Nonecalcareous.The soil units is Leptosol .The total extent of this mapping unit is 3.43 ha

4L (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 Loam (L) texture.

The pH value is 7.3 in the top soil , which indicating that the soil is Neutral. The overall organic carbon content of this soil unit is 3.36% in the top soil and are Nonecalcareous.The soil units is Leptosol .The total extent of this mapping unit is 5.68 ha

5L (Lp, eu)-a(SMU15)

This mapping unit refers to soils developed on 15-30 % slope with Shallow profile (0-25 cm). The soils are well drained with moderate & medium sub angular blocky structure and have Loam (L) texture.

The pH value is 7.3 in the top soil, which indicating that the soil is Neutral. The overall organic carbon content of this soil unit is 3.36% in the top soil and are Nonecalcareous.The soil units is Leptosol .The total extent of this mapping unit is 1.70 ha

8. CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

The detailed Soil survey of the study area Meda Gura Erbe 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 Clay and 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 depth

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 shallow to mderately deep effective depth of the soils and slope Greater than 8%.

8.2 Recommendations

Based the investigated potentials and limitations of the soils of the study area those crops that can be suitable should be selected through crop suitability evaluation. for this Problem Recommended Crop Rotation and Application of 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.

- 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, Meda Gura Erbe 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*

S/N	*Limiting factors*	*Suitability Classes*				
		S1	*S2*	*S3*	*S4*	*N*
						&>9
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: Chilie Pepper (L)-Crop Environmental Requirements

Land quality	Diagnostic Factor	Unit	Green Pepper(Capsicum annuum)-Crop Environmental Requirements				
			S_1		S_2	S_3	N
Climatic Chcs	Temperature	(ºC)	20-22	18-20	16-18	14-16	<14
			22-24	24-26	26-27	27-28	>28
	Altitude	masl	1400-1800		1200-1400	1000-1200	>2000
					1800-1850	1850-1900	
Topography	Slope	(%)	0-8		8-16	16-30	>30
Wetness	Flooding		F0		F1	F2	
	Drainage	Class	W,MW,SE,E			I	P,VP
Physical soil characteristics (s)	Texture	(class)	LS,SICL,SI,SIC,CL,L,SC,SCL,C<60		C>60s,LS,LfS	C>60v,Fs,LcS	Cm,SICm
	Soil Depth	(cm)	>75		50-75	30-50	<30
Salinity &Alkalinity	EC e	(mmhos/cm)	0-2	2-3	3-5	5-7	>7
	ESP	(%)	0-8	8-15	15-20	20-25	>25
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	>8		4-8	<4	
	PH H2O		6-6.2		5.5-6	5-5.5	<5
			6.8-7.6		7.6-8	8-8.2	>8.2
	Organic Carbon	%	0.8-1.5		<0.8		
			>1.5				
	$CaCO_3$	(%)	2-5		5-10	10-20	>20

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:

9.8.7 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).

9.8.8 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 19: 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 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 20: 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
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 21: 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	AWC	TAWC	BD	PH	Ece	EC
1C-a(SMU1)	**0_2**	**T**	**>150**	**C**	**Vertisol**	**MW**	**N**	**1.18**	**2**	**few fine**	**42.00**	**25.40**	**48.14**	**168**	**1.16**	**6.6**	**0.6**	**0.41**
2C-a(SMU2)	**2_5**	**T**	**>150**	**C**	**Vertisol**	**MW**	**N**	**1.18**	**2**	**few fine**	**44.00**	**26.30**	**48.14**	**168**	**1.16**	**6.8**	**0.5**	**0.41**
3C-a(SMU3)	**5_8**	**T**	**>150**	**C**	**Vertisol**	**MW**	**N**	**1.18**	**2**	**few fine**	**46.00**	**25.40**	**48.14**	**168**	**1.16**	**6.8**	**0.3**	**0.41**
4C-a(SMU4)	**8_15**	**T**	**>150**	**C**	**Vertisol**	**MW**	**N**	**1.18**	**2**	**few fine**	**42.00**	**25.40**	**48.14**	**168**	**1.2**	**6.8**	**0.6**	**0.41**
5C-a(SMU5)	**15_30**	**T**	**>150**	**C**	**Vertisol**	**MW**	**N**	**1.18**	**2**	**Few fine**	**44.00**	**25.40**	**48.14**	**168**	**1.16**	**6.8**	**0.7**	**0.41**
3L-b(SMU6)	**2_5**	**T**	**>150**	**L**	**Cambisol**	**WW**	**N**	**1.18**	**2**	**few fine & medium**	**42.00**	**25.40**	**48.14**	**168**	**1.16**	**6.9**	**0.4**	**0.45**
3L-b(SMU7)	**5_8**	**T**	**>150**	**L**	**Cambisol**	**WW**	**N**	**1.18**	**2**	**common medium& c**	**42.00**	**25.40**	**48.14**	**168**	**1.16**	**6.9**	**0.7**	**0.45**
4L-b(SMU8)	**8_15**	**T**	**50-100**	**L**	**Cambisol**	**WW**	**N**	**1.18**	**2**	**common medium& c**	**42.00**	**25.40**	**48.14**	**168**	**1.16**	**6.9**	**0.2**	**0.45**
5L-b(SMU9)	**15_30**	**T**	**50-100**	**L**	**Cambisol**	**WW**	**N**	**1.18**	**2**	**common medium& c**	**42.00**	**25.40**	**48.14**	**168**	**1.16**	**6.9**	**0.3**	**0.45**
6L-b(SMU10)	**>30**	**T**	**50-100**	**L**	**Cambisol**	**WW**	**N**	**1.18**	**2**	**common medium& c**	**42.00**	**25.40**	**48.14**	**168**	**1.16**	**6.9**	**0.6**	**0.45**
3SL-b(SMU11)	**0_2**	**T**	**0-25**	**L**	**Leptosol**	**WW**	**N**	**1.18**	**2**	**common medium& c**	**42.00**	**25.40**	**48.14**	**168**	**1.16**	**7.3**	**0.3**	**0.25**
4CL-b(SMU12)	**2_5**	**T**	**0-25**	**L**	**Leptosol**	**S/R**	**N**	**1.18**	**2**	**common medium& c**	**42.00**	**25.40**	**48.14**	**168**	**1.16**	**7.3**	**0**	**0.25**
1SL-c(SMU13)	**5_8**	**T**	**0-25**	**L**	**Leptosol**	**S/R**	**N**	**1.18**	**2**	**common medium& c**	**42.00**	**25.40**	**48.14**	**168**	**1.16**	**7.3**	**0**	**0.25**
2SL-c(SMU14)	**8_15**	**T**	**0-25**	**L**	**Leptosol**	**S/R**	**N**	**1.18**	**2**	**common medium& c**	**42.00**	**25.40**	**48.14**	**168**	**1.16**	**7.3**	**0**	**0.25**
3SL-c(SMU15)	**15_30**	**T**	**0-25**	**L**	**Leptosol**	**S/R**	**N**	**1.18**	**2**	**common medium& c**	**42.00**	**25.40**	**48.14**	**168**	**1.16**	**7.3**	**0**	**0.25**

Cont'd

SMU	Na	K	Ca	Mg	EX .Acidity	SUM	CEC	BS	ESP	T.N	C/N	OC	OM	A.V.P	Caco3	Soil units	Rep pit
1C-a(SMU1)	**0.22**	**0.8**	**32.27**	**11**	**0.00**	**44.29**	**56**	**79**	**0.375**	**0.24**	**11**	**2.71**	**4.66**	**0.68**	**0.5**	**Vertisol**	**MGP-1**
2C-a(SMU2)	**0.22**	**0.8**	**32.27**	**11**	**0.00**	**44.29**	**56**	**79**	**0.16**	**0.24**	**11.00**	**2.71**	**4.66**	**0.68**	**0.5**	**Vertisol**	**MGP-1**
3C-a(SMU3)	**0.22**	**0.8**	**32.27**	**11**	**0.00**	**44.29**	**56**	**79**	**0.99**	**0.24**	**11.00**	**2.71**	**4.66**	**0.68**	**0.5**	**Vertisol**	**MGP-1**
4C-a(SMU4)	**0.22**	**0.8**	**32.27**	**11**	**0.00**	**44.29**	**56**	**79**	**0.6**	**0.24**	**11.00**	**2.71**	**4.66**	**0.68**	**0.5**	**Vertisol**	**MGP-1**
5C-a(SMU5)	**0.22**	**0.8**	**32.27**	**11**	**0.00**	**44.29**	**56**	**79**	**0.42**	**0.24**	**11.00**	**2.71**	**4.66**	**0.68**	**0.5**	**Vertisol**	**MGP-1**
3L-b(SMU6)	**0.17**	**4.2**	**35.96**	**6.81**	**0.00**	**47.17**	**53**	**79**	**0.32**	**0.28**	**11**	**3.17**	**5.47**	**0.68**	**0.5**	**Cambisol**	**MGP-2**
3L-b(SMU7)	**0.17**	**4.23**	**35.96**	**6.81**	**0.00**	**47.17**	**52.7**	**79**	**0.42**	**0.28**	**11.00**	**3.17**	**5.47**	**98.20**	**19.68**	**Cm (cambisol)**	**MGP-2**
4L-b(SMU8)	**0.17**	**4.2**	**35.96**	**6.81**	**0.00**	**47.17**	**53**	**79**	**0.34**	**0.28**	**11.00**	**3.17**	**5.47**	**98.20**	**19.68**	**Cambisol**	**MGP-2**
5L-b(SMU9)	**0.17**	**4.23**	**35.96**	**6.81**	**0.00**	**47.17**	**52.7**	**79**	**0.13**	**0.28**	**11.00**	**3.17**	**5.47**	**98.20**	**19.68**	**Cambisol**	**MGP-2**
6L-b(SMU10)	**0.17**	**4.2**	**35.96**	**6.81**	**0.00**	**47.17**	**53**	**89.0**	**0.32**	**0.28**	**11.00**	**3.17**	**5.47**	**98.20**	**19.68**	**Cambisol**	**MGP-2**
3SL-b(SMU11)	**0.15**	**0.9**	**31.3**	**8.21**	**0.00**	**40.51**	**52.7**	**89.0**	**0.68**	**0.29**	**11.00**	**3.17**	**5.47**	**98.2**	**19.68**	**Cambisol**	**MGP-2**
4CL-b(SMU12)	**0.15**	**0.9**	**31.3**	**8.21**	**0.00**	**40.51**	**46**	**89.0**	**0.48**	**0.29**	**12**	**3.37**	**5.8**	**11.88**	**42.72**	**Cambisol**	**MGP-2**
1SL-c(SMU13)	**0.15**	**0.9**	**31.3**	**8.21**	**0.00**	**40.51**	**46**	**89.0**	**0.48**	**0.29**	**12**	**3.37**	**5.8**	**11.88**	**42.72**	**Cambisol**	**MGP-3**
2SL-c(SMU14)	**0.15**	**0.9**	**31.3**	**8.21**	**0.00**	**40.51**	**46**	**89.0**	**0.47**	**0.29**	**12**	**3.37**	**5.8**	**11.88**	**42.72**	**LP**	**MGP-3**
3SL-c(SMU15)	**0.15**	**0.9**	**31.3**	**8.21**	**0.00**	**40.51**	**46**	**89.0**	**0.47**	**0.29**	**12**	**3.37**	**5.8**	**11.88**	**42.72**	**LP**	**MGP-3**

9.10 Results of Land Suitability Evaluation for Surface Irrigation

9.10.1 Existing Suitability for Surface Irrigation

The results of the suitability evaluation of the project area for surface irrigation are shown in Tables 34. The result indicates that a totalarea amounting to **6.56**ha(S3) is found to be marginally suitable for surface irrigation, **41.51** ha of land is**(N1)** currently not Suitable suitable for Irrigation development, and some **31.37(N2)** ha of land is Permanently not suitable for surface irrigation development. The areas identified as not suitable for surface irrigation are constrained by slope. The area identified as marginally suitable for surface irrigation is constrained byslope, drainage, Available phosphorous, and texture problem. The marginally suitable areas require careful land management, application of good quality of water and application of organic fertilizer, this improve the suitability level to moderately suitable.

Table 22: Existing Surface Irrigation Suitability by Area

	S3	**(N1)**	**N2**
	Marginally Suitable	**Currently notSuitable**	**Not Suitable**
	Area,ha	**Area,ha**	**Area,ha**
	6.56	**41.51**	**31.37**

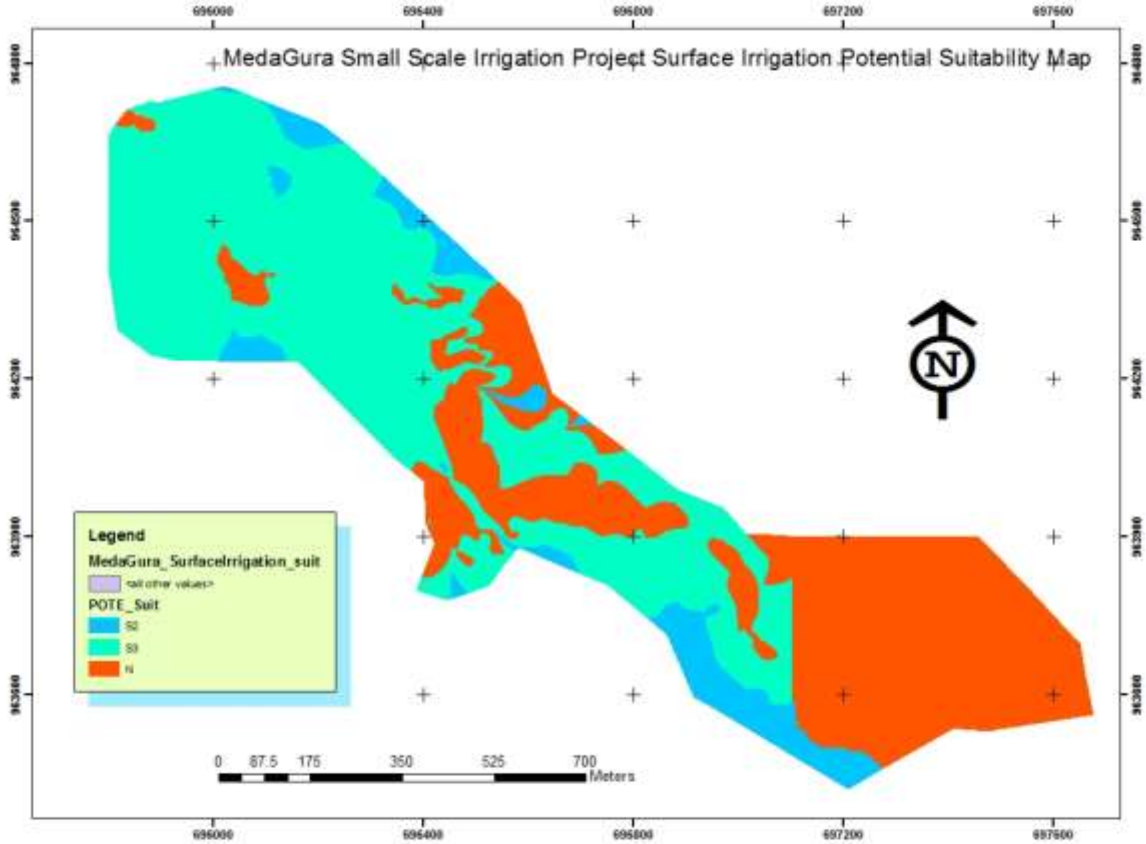


Figure 8Potential Surface Irrigation Suitability Map

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 6.56 ha of land Moderatly suitable(S2) for surface irrigation. An area amounting to 41.54 ha is found to be (S3) Marginally suitable for surface irrigation development and some 31.37ha of land is (N) Not suitable for surface irrigation development. The areas identified as Moderately and marginally suitable for surface irrigation are constrained by 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**
6.56	**41.54**	**31.37**

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, Pepper, Tomato and Onion 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 6.01ha moderatly (S2) ,41.74 ha (S3) marginally for **Low Land Maize** cultivation by surface irrigation. For **Tomato** Some 2.48 ha is Highly Suitable(S1), Some19.57ha (S2) moderatly suitable and 25.69 ha marginaly suitable (S3), For **Pepper** Some 2.48 ha is Highly Suitable (S1) ,3.52 ha moderatly suitable(S2) 41.74 ha marginaly Suitable (S3), for **Onion** Some 4.65 ha is Highly Suitable ,Some 11.03 ha moderatly suitable (S2), some 32.06 ha marginaly suitable(S3), The major limitations that downgraded the suitability level of the area are Slope, Texture, Depthin 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 24: Potential Crop Suitability by Area for surface Irrigation

Crops	S1 Highly Suitable(S1) Area,ha	S2 Moderatly Suitable(S2) Area,ha	S3 Marginally Suitable (S3) Area,ha	N2 Not Suitable (N) Area,ha
Low Land Maize		**6.01**	**41.74**	**31.73**
Tomato	**2.48**	**19.57**	**25.69**	**31.73**
Onion	**4.65**	**11.03**	**32.06**	**31.73**
Pepper	**2.48**	**3.52**	**41.74**	**31.73**

Table 25: Potential Crop Suitability by class and Area for surface Irrigation

SMU	Low L/Maize	Onion	Tomato	Pepper	Area/Ha
SMU1	S3	S1	S2	S3	2.17
SMU2	S3	S2	S2	S3	7.5
SMU3	S3	S3	S3	S3	8.16
SMU4	S3	N	N	N	6.75
SMU5	N	S1	S1	S1	3.34
SMU6	S2	S2	S2	S2	3.52
SMU7	S3	S3	S3	S3	8.64
SMU8	N	N	N	N	8.86
SMU9	N	N	N	N	7.38
SMU10	N	N	N	N	0.48
SMU11	S3	S3	S3	S3	5.44
SMU12	S3	S3	S2	S3	6.37
SMU13	S3	S3	S3	S3	3.43
SMU14	N	N	N	S3	5.68
SMU15	N	N	N	S3	1.69

Table 26 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)	6.01	41.74	31.73		
Tomato	Potential Subclass	S2,e,rd	S3,e,rd		Slope depth, texture	
	Area (ha)	*19.57*	25.69	31.73		
Pepper	Potential Subclass	*S2,e,rt,rd*	*S3,e,rt,rd*		Slope depth texture	
	Area (ha)	3.52	41.74	31.73		
Crops	Potential Crop Suitability by subclass	Sub Class	Sub Class		Sub Class	
Onion	Potential Subclass	S2,e,rd	S3,e,rd		Slope depth	
	Area (ha)					

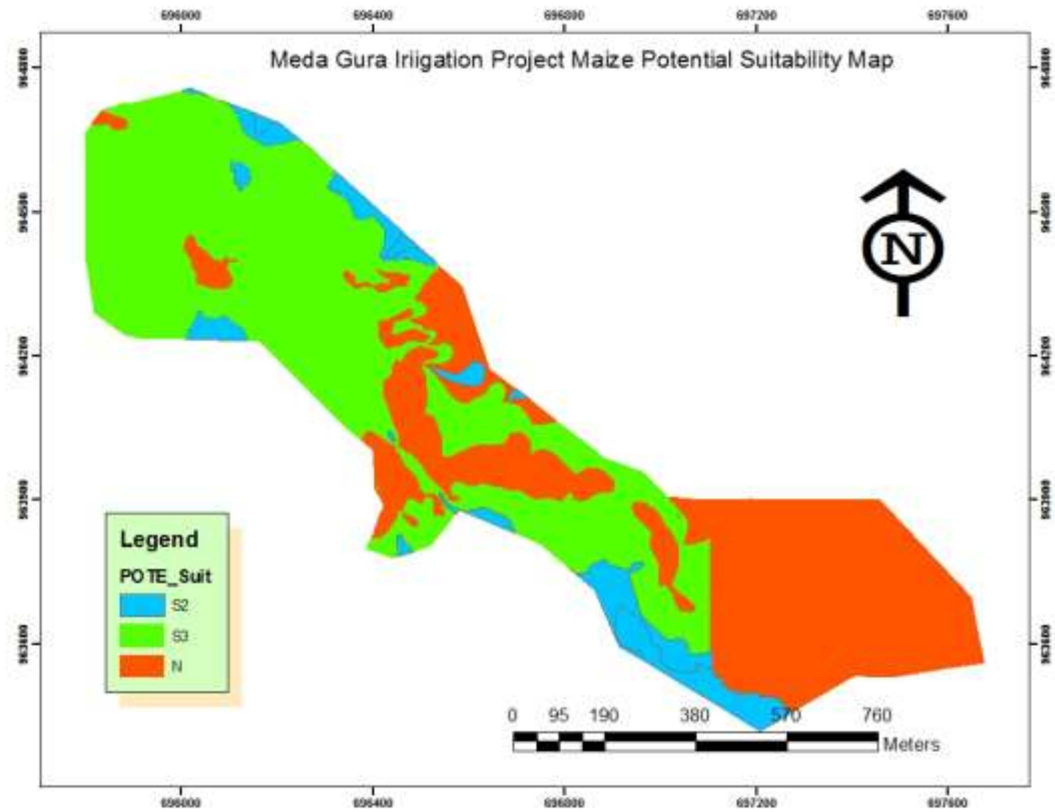


Figure 9 Maize Potential Suitability Map

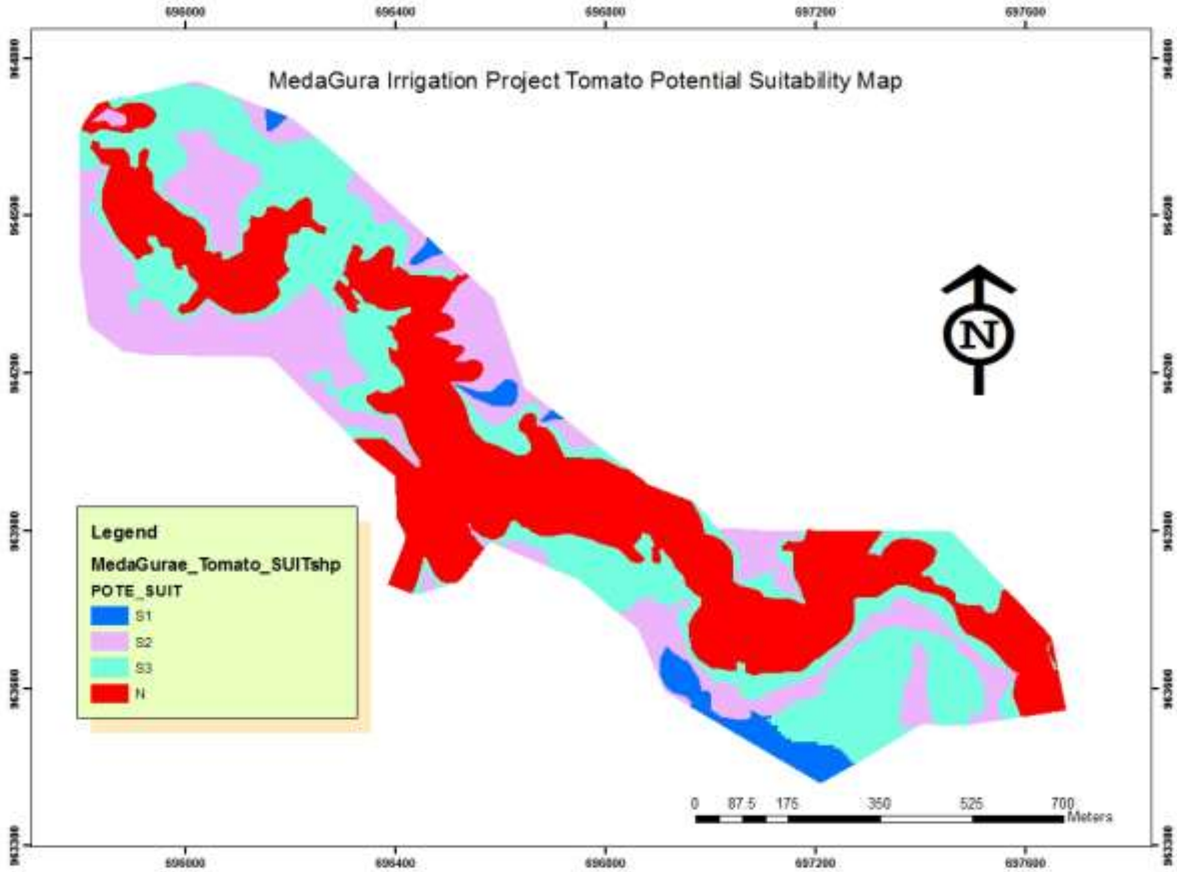


Figure 10 Tomato Potential Suitability Map

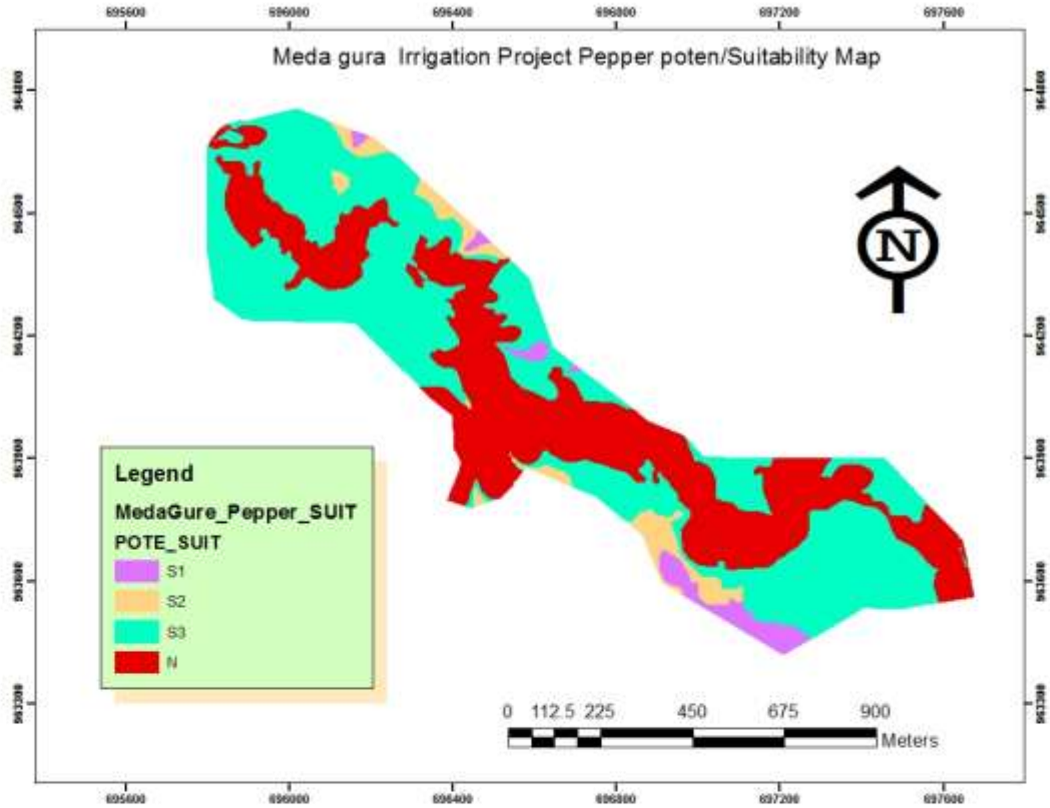


Figure 11 Pepper Potential Suitability Map

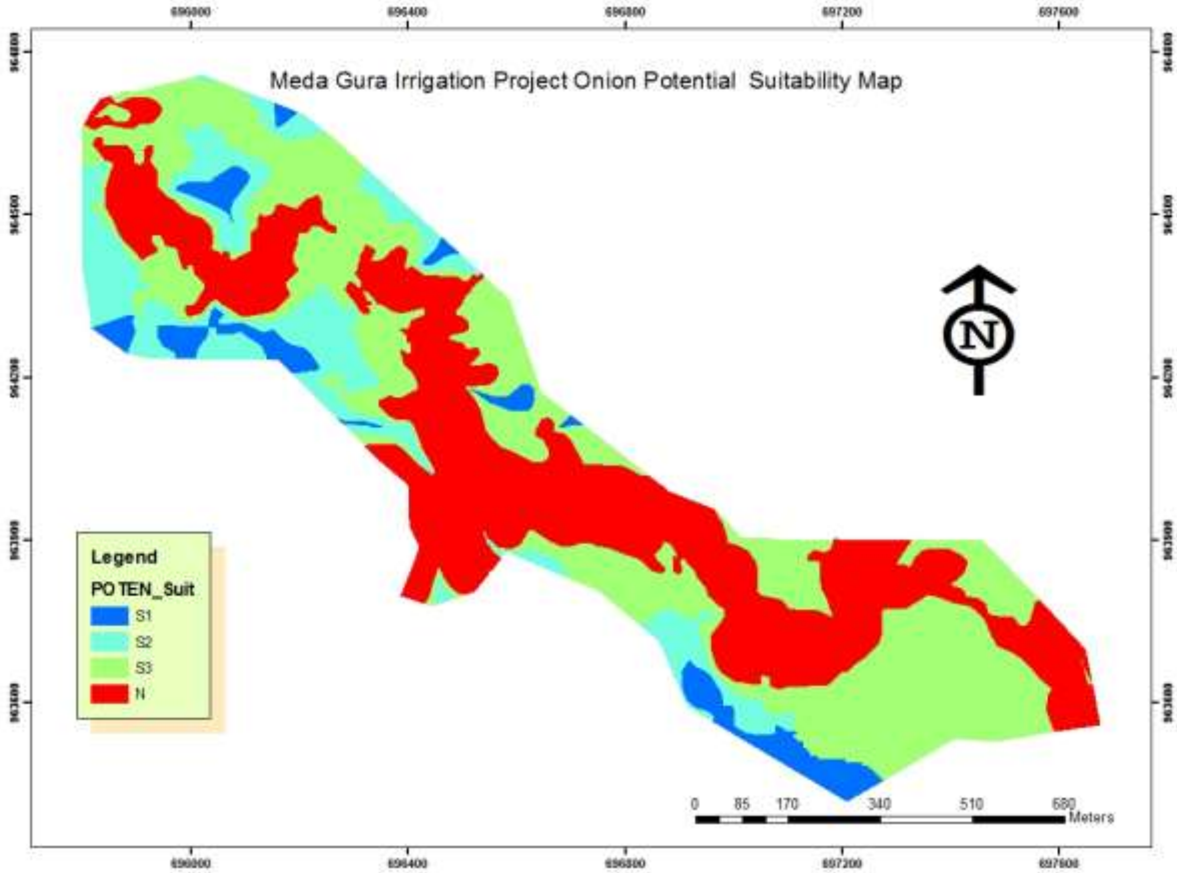


Figure 12 Onion potential suitability map

Table 27: The final proposed Crop Potential Suitability by SMU

SMU	Low L/Maize	Onion	Tomato	Pepper	Area/Ha
SMU1	S3	S1	S2	S3	2.17
SMU2	S3	S2	S2	S3	7.5
SMU3	S3	S3	S3	S3	8.16
SMU4	S3	N	N	N	6.75
SMU5	N	S1	S1	S1	3.34
SMU6	S2	S2	S2	S2	3.52
SMU7	S3	S3	S3	S3	8.64
SMU8	N	N	N	N	8.86
SMU9	N	N	N	N	7.38
SMU10	N	N	N	N	0.48
SMU11	S3	S3	S3	S3	5.44
SMU12	S3	S3	S2	S3	6.37
SMU13	S3	S3	S3	S3	3.43
SMU14	N	N	N	S3	5.68
SMU15	N	N	N	S3	1.69

Crops	S1	S2	S3	N2
	Highly Suitable	Moderatly Suitable	Marginally Suitable	Not Suitable
	Area,ha	Area,ha	Area,ha	Area,ha
Low Land Maize		6.01	41.74	31.73
Tomato	2.48	19.57	25.69	31.73
Onion	4.65	11.03	32.06	31.73
Pepper	2.48	3.52	41.74	31.73

10. SOIL MANAGEMENT AND RECLAMATION

10.1 Soil Physical Soil factors

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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.

10.1.2 Flooding

The flooding problem in the study area is not Significant except in the Meda Gura Erbe river buffer zone or river side and vertisols 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.

10.1.3 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**smu9smu14, smu15** 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, Cambisols . 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 area6.6up to7.3 with average of 7.1on the top soil, which is Slightly acid at this PH level there is a possibility of 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 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 6.56 ha of land is found to be (S2) Moderatly suitable for surface irrigation. An area amounting to 41.54ha 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 Depth and slope.

Crop Suitability : The result indicated that a total of 6.00 moderatly (S2) ,41.74ha (S3) marginally for Maize cultivation by surface irrigation.For Tomato Some 2.48haHighly Suitable(S1) Some 19.57ha (S2) moderatly suitable and 25.69 ha marginaly suitable (S3}, For Pepper 2.48ha Highly Suitable(S1).3.52 ha moderatly suitable(S2) 41.74 ha marginaly Suitable (S3),for Onion,Some 4.65 ha Highly Suitable some 11.03 ha moderatly suitable (S2), some 32.06 ha marginaly suitable(S3)

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 Depth, in the study area. This indicates that with high level of management practices Application (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 Meda Gura Erbe Irrigation Project are Nutrient deficency (Low Level of availabile phosphorus, organicmatter), Depth and slope

The most limiting land characteristic in soils of Meda Gura Erbe Surface Irrigation Project development is Soil Depth and slope 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 . 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) , and to improve physical and chemical properity of soils.
- Application of organic fertilizers 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

Meda Gura ErbeSmall Scale Irrigation Project Soil Profile Description

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

Date: *20/12/18*	**Long. In utm (E):** *696221*
Author(s): *Abdu*	**Lat. in utm (N):** *964270*
Region *Oromia*	**Elevation:** *1415m*
Zone: *West Hararge*	**Parent material:** *LI*
Wereda: *Odaa Bultum*	**Rock Types:**
Soil classification FAO Vertisol	**Effective soil depth:** *very deep*
Human influence: *SC,PL*	**Rock out** C **Crops:**
Land LP	**Depth to bed rock:** *none*
Regional slope:	**Surface coarse** few
Position: *lower*	**Micro topography:** *Trecing*
Slope class: *0-2*	**Surface sealing:** *None*
Slope aspect: *North-Southu east*	**Drainage class:** *M/W*
Slope gradien	**Drainage external:** *well*
Slope form: *U*	**Drainage internal:**
Slope length:	**Ground water:** *none*
Surface cracks: *fine cracks*	**Flooding:** *none*
Dissection:	**Moisture condition:** 0-25Dry
Erosion *sheet and splash*	**Land cover:**
Fertilizers: *Unknown*	**Land use:** *CL4,*
Existing crops: *Maize*	**Vegetation types: Wedessas**

0-25cm clear and smooth boundary; moist moisture status; dark brown 7.5YR4/2)when dry and7.5YR3/2 When moist 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; Slightly calcareous

25-100cm gradual and smooth boundary; slightly moist moisture status; dark red (7.5YR3/3)

Moist, no Mottling, Clay Texture ,few fine coarse fragment, weak fine to medium sub angular structure; fine crack; Very friable when moist, sticky and plastic when wet; no cutans; no cementation; no mineral Nodules; few fine medium, few medium to coarse roots; common fine medium fine coarse pores; slightly Calcareous.

110-200cm;Moist moisture status; dark red (7.5YR2.5/3) when Moist, no mottling, sandy clay 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 Description. **Profile code:***MGP-2* **Mapping unit:Status:** *PS*

Date: *21/12/18*
Author(s):*Abdu*
Region *Oromia*
Zone:*West Harerge*
Wereda:*Oddaa Bultum*

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

Land *plain*
Regional slope:
Position: *MEDIUM*
Slope class:*2-5*
Slope aspect: *WEST TO EAST*
Slope gradient:

Slope form: *U*

Slope length:

Surface cracks: *none*

Dissection:

Erosion *sheet and splash*

Fertilizers: *Unknown*
Existing crops:sor

Long. In utm (E):*696567*
Lat. in utm (N): *964042*
Elevation:*1437m*
Parent material: *LI*
Rock Types:
Effective soil depth: *shallow*
Rock out *F*
Crops:
Depth to bed rock: *50cm*
Surface coarse *few*
Micro topography: *TM, AB*
Surface sealing:
Drainage class: W/*W*

Drainage external: *well*

Drainage internal:

Ground water: *none*

Flooding: *none*

Moisture condition: Dry

Land cover:
Land use: *HE2*
Vegetation types: *doditi*

0-25cm clear and smooth boundary; moist moisture status; dark Reddish brown (5YR4/2) Moist, no Mottling, sandy clay loam, few fine, coarse fragments, weak, fine to medium sub angular blocky structure; no crack; very Friable when moist, slightly sticky and slightly plastic when wet; no cutans; no cementation; no mineral Nodules; many fine to medium, few medium to coarse, roots; many fine medium, few medium to coarse pores; Non calcareous.

25-50cm diffuse and smooth boundary; dry moisture status; Red (5YR3/3) when dry; dark Red (5YR3/2) When Moist, no mottling, sandy clay loam texture, no coarse fragment, moderate, medium sub angular blocky structure; No crack; slightly hard when dry, 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, few Medium to coarse pores; slightly calcareous.

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

Date: *20/12/18*
Author(s):*Abdulahi*
Region *Oromia*
Zone:*West Guji*
Wereda:*Oddaa Bultum*

Soil classification FAO *Leptosol*
Human influence:*SC, BR, VU*

Land *LT*
Regional slope:
Position:*M*
Slope class: *8%*
Slope aspect:*WEAST TO EAST*
Slope gradient:

Slope form:*U*

Slope length:

Surface cracks:*N*

Dissection:

Long. In utm (E):*697320*
Lat. in utm (N):*963765*
Elevation:*1420m*
Parent material: *LI*
Rock Types:
Effective soil depth: *Very Shallow*
Rock out Crops: Common
Depth to bed rock: *20cm*
Surface coarse *many*
Micro topography: *TM, AB*
Surface sealing:
Drainage class: *M/W*

Drainage external :S/R

Drainage internal:

Ground water: *none*

Flooding: *none*

Erosion *sheet and Rill*

Fertilizers:*none*
Existing crops:*N*

Moisture condition: 0-20cm dry.

Land cover:
Land use: *HE1*, *EV2*
Vegetation types: *HERER*

0-20cm Clear smooth boundary;dry moisture status;Brown(5YR4/3)dry colour;Dark brown(5YR3/2), moist colour; none mottling;sandyclayloam texture; none mottling;common,fine to medium coarse fragement; strong, medium, sub-angular blocky structure; fine crack; hard(dry); friable (moist), slightly sticky and slighty plastic(wet) consistency; none cutanic features; none cemented; none mineral nodules; ,many,fine to medium, root;common fine to medium pores, none calcareous

For soil profile description and Auger observation

Profile No	X	Y
MGP_1	696221	964270
MGP_2	696567	964042
MGP_3	697300	963765

AugerNo	X	Y
MGA1	695800	964600
MGA2	696000	964600
MGA3	696200	964600
MGA4	696400	964600
MGA5	696600	964400
MGA6	696400	964400
MGA7	696200	964400
MGA8	696000	964400
MGA9	696200	964200
MGA10	696400	964200
MGA11	696400	964000
MGA12	696600	964000
MGA13	696800	964000
MGA14	697000	964000
MGA15	697200	963800
MGA16	697000	963800
MGA17	696800	963800

MGA18	696600	963800
MGA19	697000	963600
MGA20	697200	963600
MGA21	697400	963600
MGA22	697400	963400
MGA23	697200	963400
MGA24	697600	963200
MGA25	695800	964800
MGA26	696000	964800
MGA27	696200	964800
MGA28	695800	964400
MGA29	696000	964200
MGA30	697600	963600
MGA31	695800	964200
MGA32	697400	963800
MGA33	697200	964000

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 4. 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**

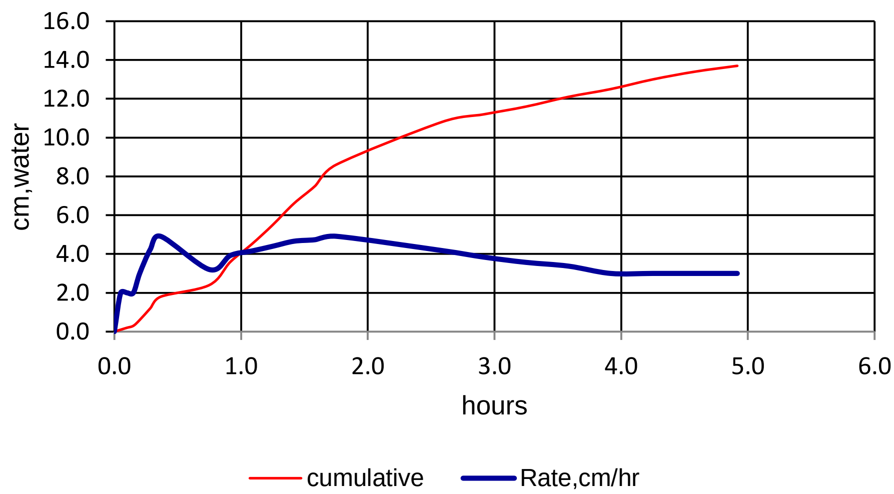
See the excel Meda Gura ErbeLab result on sheet-1

Appendix table 5**: Soil infiltration and permeability test**

I-Infiltration

Profile number: **MGP-1** **Replicate:**

	Time		*Depth to water*		*Water intake, cm*		*Infiltration*
interval	*min.*	*hr.*	*cm*		*Immediate*	*cumulative*	*Rate,cm/hr*
0	0	0.0	14.0	14.0	0.0	0.0	0.0
3	3	0.1	13.9	13.9	0.1	0.1	2.0
3	6	0.1	13.8	13.8	0.1	0.2	2.0
3	9	0.2	13.7	13.7	0.1	0.3	2.0
3	12	0.2	13.4	13.4	0.3	0.6	3.0
5	17	0.3	12.8	12.8	0.6	1.2	4.2
5	22	0.4	12.2	12.2	0.6	1.8	4.9
5	45	0.8	11.6	11.6	0.6	2.4	3.2
10	55	0.9	10.4	10.4	1.2	3.6	3.9
10	65	1.1	9.5	9.5	0.9	4.5	4.2
10	75	1.3	8.5	8.5	1.0	5.5	4.4
10	85	1.4	7.4	7.4	1.1	6.6	4.7
10	95	1.6	6.5	6.5	0.9	7.5	4.7
10	105	1.8	5.4	5.4	1.1	8.6	4.9
15	155	2.6	14.0	14.0	0.0	10.8	4.2
15	175	2.9	13.9	13.6	0.4	11.2	3.8
15	195	3.3	13.2	13.0	0.4	11.6	3.6
15	215	3.6	12.4	12.5	0.5	12.1	3.4
15	235	3.9	11.9	11.9	0.4	12.5	3.0
20	255	4.3	11.4	11.4	0.5	13.0	3.0
20	275	4.6	11.0	11.0	0.4	13.4	3.0
20	295	4.9	10.5	10.5	0.3	13.7	3.0



Appendix table 6: **Soil physical test**

Name of Customer : OROMIA WATER WORKS DESIGN & SUPERVISION ENTERPRISE

Project : Meda Gura SS Irrigation **Location - West Hararge, Oda Bultum**

LAB NO	Field Code	Depth	PH - Water	E.C	PH - KCl	Particle Size Distribution Sand	Silt	Clay	TEXTURAL CLASS
		Cm	1:2.5	ds/m	1:2.5	%	%	%	
001 /19	MGP - 1	0-25	6.6	0.414	6.0	22	35	43	clay
2 /19		25-100	6.8	0.392	6.2	18	31	51	clay
3 /19		100-200	7.0	0.396	6.6	18	31	51	clay
4 /19		200-300	7.1	0.345	6.6	28	31	41	clay
5 /19	MGP - 2	0-20	6.9	0.456	6.4	34	41	25	Loam
6 /19		20-50	7.3	0.417	6.8	32	35	33	Clay loam
7 /19	MGP - 3	0-20	7.3	0.256	6.8	34	45	21	Loam

LAB NO	Na	K	Ca	Mg	SUM	CEC	BS	EX. Acidity	Ex. Al^{3+}
	Cmol(+)Kg^{-1}						%	Cmol(+)Kg-1	
001 /19	0.22	0.80	32.27	11.00	44.29	56.0	79	_	_
2 /19	0.29	0.62	33.85	9.95	44.71	52.1	86	_	_
3 /19	0.27	0.62	37.78	9.13	47.80	53.4	89	_	_
4 /19	0.27	0.70	33.87	8.15	42.99	49.4	87	_	_
5 /19	0.17	4.23	35.96	6.81	47.17	52.7	89	_	_
6 /19	0.17	8.21	27.35	5.22	40.94	45.8	89	_	_

7 /19	0.15	0.85	31.30	8.21	40.51	45.5	89	_	_
LAB NO	T.N	O.C	O.M	C/N	Av. K	Av. P	P_2O_5	$CaCO_3$	
	%	%	%		PPM	PPM		%	gram kg^{-1}
001 /19	0.24	2.71	4.66	11	306.9	0.68	1.56	0.50	5.00
2 /19	0.22	2.41	4.15	11	232.8	0.94	2.15	0.70	7.00
3 /19	0.17	2.29	3.95	13	239.5	1.18	2.70	23.04	230.40
4 /19	0.14	2.00	3.45	14	269.8	2.32	5.31	30.24	302.40
5 /19	0.28	3.17	5.47	11	989.6	98.20	224.88	19.68	196.80
6 /19	0.26	3.08	5.30	12	1578.9	22.08	50.56	25.44	254.40
7 /19	0.29	3.37	5.80	12	356.5	11.88	27.21	42.72	427.20

Remarks

Checked By Tadesse Bayissa Signature _________________ Date ______________

Approved By ____________________ Signature __________________

Date _______________

Name of Customer:OROMIA WATER WORKS DESIGN & SUPERVISION ENTERPRISE

Project : Meda Gura SS Irrigation

Location - West Hararge, Oda Bultum

LAB NO	Field Code	Depth	BD	F.C	P.W.P				
		Cm	g/cm^3	%	%				
17 /19	MGP - 1	0-25	1.16	42.0	25.4				
18 /19		25-60	1.20	44.8	26.3				
19 /19		60-90	1.34	46.2	27.0				

Company Name: OROMIA WATER WORKS DESIGN AND SUPERVISION ENTERPRISE

Doc. Title: Soil Analysis Laboratory Result

Doc. No: ILR /11

Page No.: 1 of 1

Name of Customer: OROMIA WATER WORKS DESIGN & SUPERVISION ENTERPRISE

Project : Wangur SS Irrigation

Location - West Hararge, Doba District

LAB NO	Field Code	Depth Cm	P^H-Water 1:2.5	E.C ds/m	P^H-KCl 1:2.5	Particle Size Distribution Sand %	SILT %	CLAY %	TEXTURAL CLASS
008/19	WGP-1	0-25	7.1	0.288	6.7	38	33	37	Clay loam
9/19		25-80	7.1	0.348	6.9	28	31	41	clay
10/19		80-150	7.3	0.351	7.0	22	29	49	clay
11/19	WGP-2	0-25	7.4	0.267	7.0	24	45	31	Clay loam
12/19		25-120	7.6	0.367	7.2	28	33	41	clay
13/19	WGP-3	0-25	7.1	0.390	6.6	30	43	27	Loam
14/19		25-85	7.1	0.374	6.8	34	35	31	Clay loam
15/19		85-120	7.2	0.239	6.8	20	39	41	clay
16/19	WGP-4	0-25	7.3	0.243	7.0	22	47	31	Clay loam

Core Sampler			BD (g/cm³)	F.C (%)	P.W.P (%)	
020/19	WGP-1	0-25	1.23	47.1	25.2	
21/19		25-60	1.21	51.7	23.9	
22/19		60-90	1.20	50.8	30.2	

LAB NO	Na (Cmol(+)Kg⁻¹)	K	Ca	Mg	SUM	CEC	BS %	EX. Acidity (Cmol(+)Kg-1)	Ex. Al^{3+}
008/19	0.22	0.82	54.18	10.58	65.72	79.5	83	-	-
9/19	0.24	0.67	57.67	11.68	70.18	79.8	88	-	-
10/19	0.45	0.62	53.43	12.04	66.55	76.0	88	-	-
11/19	0.19	0.74	42.50	8.84	52.27	60.3	87	-	-
12/19	1.38	0.43	36.59	8.83	46.37	53.7	86	-	-
13/19	0.22	0.81	38.53	11.37	50.93	59.8	85	-	-
14/19	0.20	0.56	40.93	11.55	53.23	60.8	88	-	-
15/19	0.24	0.62	37.76	10.14	48.76	64.7	75	-	-
16/19	0.41	0.85	38.71	9.44	49.41	58.8	84	-	-

LAB NO	T.N %	O.C %	O.M %	C/N	Av.K PPM	Av.P PPM	P_2O_5	$CaCO_3$ %	$CaCO_3$ gram kg⁻¹
008/19	0.23	2.71	4.68	12	316.8	1.42	3.25	0.29	2.88
9/19	0.22	2.54	4.38	12	258.9	0.22	0.50	0.29	2.88
10/19	0.17	1.96	3.38	12	243.5	0.88	1.83	1.92	19.20
11/19	0.13	1.50	2.58	12	288.7	0.14	0.32	14.21	142.08
12/19	0.10	1.17	2.01	12	566.9	12.36	28.30	18.72	187.20
13/19	0.21	2.39	4.12	12	315.4	2.38	5.45	0.29	2.88
14/19	0.21	2.41	4.15	12	217.8	7.64	17.50	0.20	2.00
15/19	0.24	2.83	4.87	12	239.8	6.70	15.34	0.24	2.40
16/19	0.22	2.58	4.46	12	328.7	3.14	7.19	4.42	44.16

Remarks

Checked By Tadesse Bayissa Signature Date 25/01/19

Approved By Hassen Ahmed Mume Laboratory Service Process ... Signature Date

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