National Regional State of Oromia
Oromia Irrigation Development Autority
Firi-Kebso Small Scale Irrigation Project
Draft Final Report

Section I: Sectoral studies

Volume I: Soil and Landevaluation

Oromia Water Works Design and Supervision Enterprise

(OWWDSE)

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Table of Contents

LIST OF TABLES

LIST OF FIGURES

LIST OF TABLES IN APPENDIX

LIST OF ABBREVIATIONS AND ACRONYMS

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

SUMMARY

The soil survey of the Firi kebso small scale irrigation Project (FKSSIP) 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 was made on 300m by 300m grid, profile description up to 2mt depth and soil sampling for laboratory analysis (Both Physical and Chemical Properties), field testing of infiltration rate and hydraulic conductivity were conducted on representative sites.

On the basis of soil depth, slope and soil texture and or soil type characteristics a total of 28 soil mapping units (SMU) were identified. On the basis of profile morphology and development, and nature of the soil material and profile depth, the soils of the study area are identified as Chromic, Eutric Cambisols (Aric), and Eutric Fluvisols (Aric)

The targeted project area is 136.44 ha and of which crop cultivation practiced widely. The proposed crops that can be cultivated by using irrigation are 5 Firi kebso small scale irrigation Project (FKSSIP) soil survey and land evaluation 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 (25augers and 3 Profile pits) were describes for the study area. The detail level soil survey study enabled the identification of 28. soil mapping units (SMU). It is hoped the information provided in this report helps in assembling and using data for the area of land suitability map.

To undertake the Landevaluation, land utilization types (LUT) for surface irrigation methods were identified first. Accordingly, a total of five LUTs for surface irrigation methods were therefore identified. These LUTs include Lowland maize, onion, tomato, pepper and sweet potato, and 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, OCand CEC of the soil.

1. INTRODUCTION

1.1 Back Ground

The Ethiopian economy is mainly dependant on agricultural production. The agricultural sector, however, is characterized by traditional practices and low productivity. One of main reasons for low productivity is the recurrent drought in the country. Thus, the government has decided to utilize all the available land and water resource of the country for the benefit of the community and to ensure sustainable development.

Due attention has been given for both small and large scale irrigation projects using surface and subsurface water potentials across the country. As part and parcel of these endeavours, various irrigation projects have been proposed in arid areas of the community. In this regard, the regional states of Oromia possessing high surface and subsurface water potential and vast plain land suitable for irrigation development.

The soil survey and land evaluation of the Firi-Kebso Irrigation based development Project was 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 selected crops.

Firi-Kebso Irrigation based dvelopment Project is located in east harerge Zone, melka bello district of the Oromia Regional State. The study area has surrounded by high mountanious relief hills and have a slope ranging from 0-2 up to 15-30% currentely cultivated land with banana, chat sweat potato, coffee, and onion. The present study area covers about 136.44ha of net irrigable area.

1.2. General Objective

The main objective of the soil survey is to provide detail information on land and soils of the study area (command area of the project) 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. 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 suitability for irrigation.

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:

- Summary of recommended criteria for soil chemical data interpretation
- Typical profile descriptions
- Location of geographical coordinate for soil profile description and auger observation
- Format for auger observation and profile description sheet
- Soil physical and chemical analytical data for representative soil profiles;
- Soil infiltration and hydraulic conductivity test

2. THE PHYSICAL ENVIRONMENT OF THE AREA

2.1. Location and Accessibility

The study area, Firi-Kebso small scale irrigation project, is located in the Oromia Regional State, east harerge Zone, melka bello district, The study area is close to the Weast of Jerjertu river. Irrigation to be used from Spring. More precisely it falls in between 991727 to 995008 UTM ^{N} and 750665 to 752768 UTM $^{E.}$ The targeted area of the project is 136.44ha. The altitude of the wereda ranges from 1250-1800masl while the altitude of the study area ranges from 1553 to 1658 m above sea level. There is accesses road (dry weather road) in the study area.

2.2. Climate

The study area has almost all year round precipitation with mean annual rainfall of 1047.73 mm and annual Potential Evapotranspiration of 1092.6mm. The major rainfall occurs from March to October months. The inter-tropical convergence zone (ITCZ) is the major rain causing mechanism in Ethiopia. The movement of ITCZ in the northward direction brings moisture from the South Atlantic Ocean, which results in the high rainfall in the project area. The mean monthly maximum and minimum temperature is between 19.29^0c to 21.12^0c and 9.29^0c to 11.60^0c, respectively.

2.3. Physiograpy and Geology

Residual land form with slope of 0-2 % rise up to 15-30%, developed on Mesozoic limestone and marl i.e hamale series, lower-upper Jurassic, limestone, oolitic limestone and lower bed of the uarandab series

2.4. Vegetation and Land Use

The vegetation cover is dominantly open wood land, Intensevely to peredominantely cultivation land on Cambisols and fluvisols, with traditional irrigation practice. Chat, sorgum, coffee, banana and sweet potato are cultivated in the command area, the vegetation cover is dominantly with wedessa and bekanisa tree

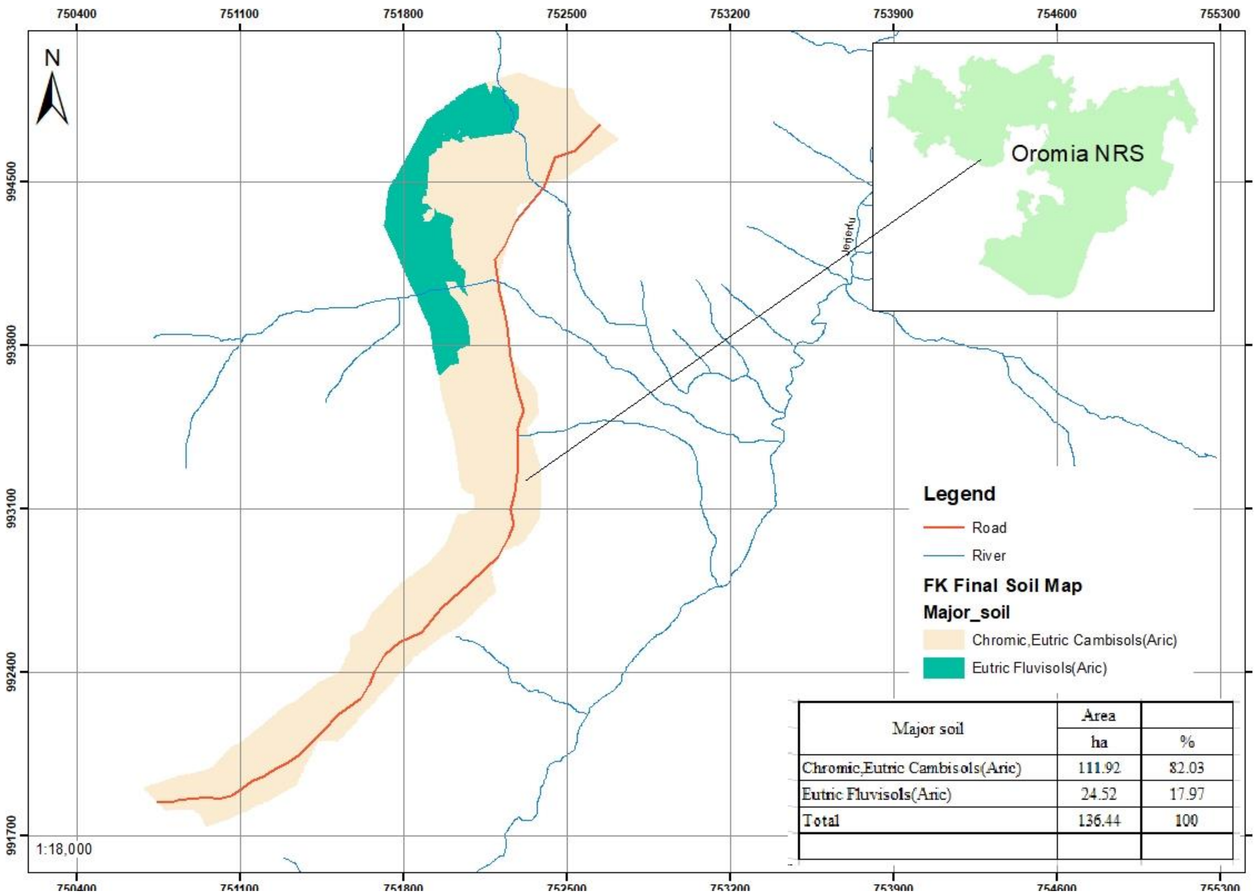


Figure 1: Location Map of Firi kebso small scale irrigation project

3. REVIEW OF PREVIOUS STUDIES

A number of previous soil and land evaluation studies on national level, basin wide and site-specific irrigation projects have been conducted in the sub basin in the past. Among these are:

- **Geomorphology and Soils Map of Ethiopia prepared by the then Land use planning and Regulatory Department LUPRD) of the Ministry of Agriculture.**

LUPRD, 1984h, i, j: Geomorphology and Soils Map of Ethiopia. The then land use planning and Regulatory Department of Ministry of Agriculture made a good effort in producing Geomorphology and Soil Map Ethiopia that provided mapping land forms and soils at 1:1000, 000 and soil association map at 1:2000, 000 scales respectively. This basic land form and soil mapping was carried out at national level covering the entire areas of Ethiopia as part of the assistance to land use planning Project. The mapping units were achieved by delineating geomorphic units (group of land system or individual land system) from interpretation panchromatic Land sat MSS imagery. However, compared to the current TM or SPOT imagery, the resolution is poor. The basic assumption in the preparation of the map is that geomorphic units delineated by manual interpretation of the land sat contain recurrent patterns of land forms, soils and vegetation.

- **The Wabi Shebele River basin integrated development master plan study project (2004) at the scale of 1:250,000.**

The Wabi Shebele River Basin Integrated Development Master Plan Study Project was conducted at the scale of 1:250,000 at reconnaissance level by the Ministry of Water Resource.

The major soil groups in the study area fall into 15 major soil groupings in the FAO – UNESCO – ISRIC (1988) system: *vis*, Andosols, Arenosols, Cambisols, Calcisols, Chernozems, Fluvisols, Gleysols, Gypsisols, Leptosols, Luvisols, Nitisols, Phaeozems, Regosols,and Solonchaks, Vertisols.and, 30 soil units in detail in the SOTER maps of the basin at the scale of 1:250,000. Likewise, a total of 61 soil-mapping units were distinguished for the basin. Location and distribution of soil survey observation points, major soil types and soil mapping units of the Wabi Shebele River basin were presented. In this report indicated that a total of 4028 soil observations were made (PS-130, PW-71, AS-12, AW-3752, CS-8 and O-55). The necessary data collected by this study has been carefully reviewed and considered for the included areas of the sub basin study. According to this study Leptosols fall in this new small-scale irrigation project (Firi kebso)

- **Ramis Sub basin landuse study project at the scale of 1:250,000. By OWWDSE,2010**

  - **Soil survey**

Ramis is one of the seven sub basins considered in the current land use planning study project found in Hararge administrative zone of Oromia regional state. The sub basin lay within latitude of 7.5° to 9.4° N and longitude of 40.6 to 42.02° E. It has a total land mass of approximately 1,509,500 hectares.

The purpose of soil survey in Ramis Sub Basin conducted at pre-feasibility level is to generate database of soil resources for designing integrated land use plan and natural resources management. The methodology of the study had adapted review of previous studies and conducting of soil survey at field condition to collect primary data of soil and land form requirements anticipated as essential for land suitability evaluations

During soil resource investigation total observation of 916 at different representative sites was conducted. Out of these 130 soil profile pits was dug and carefully studied, for detail observation of soil landscape units 786 auger whole without sampling was conducted (observed).

The soil survey of Ramis Sub Basin at a semi detailed scale of 1:50,000 levels have investigated 14 (fourteen) soil mapping units, 4 (four) major soils, and six associated soils. The major soils are Vertisols, Luvisols, Cambisols and Leptosols.

  - **Landevaluation**

The objectives of the evaluation were:

- Identification of the zone's resource potentials and constraints for rainfed agriculture, irrigated agriculture, and forestry ;
- Classification of land into suitability classes and subclasses according to limitations ;
- Suggesting alternative suitable uses and management interventions to design sustainable LUP.

✓ **Irrigation**

in the sub basin, evaluation result indicated that the provisional suitable area for surface irrigation, sprinkler irrigation and irrigated pasture are: 31.96 per cent, 70.8 per cent, and 21.28 per cent respectively

According to the assessment result 4.4 per cent of the land in the sub basin would be irrigated by surface irrigation method (0.24 per cent moderately suitable and 15.69 per cent marginally suitable). 84.07 per cent is unsuitable for surface irrigation, in which case 11.05 per cent is rock outcrops and 68.87 per cent permanently unsuitable due to heavy texture, shallow depth, steep slope and surface rocks and 4.16 per cent are currently not suitable due to low soil fertility (Available P). The currently not suitable land units can be improved to suitable class by fertility management (P application). The rest of the suitability classes remain unchanged as the limitations

According to the suitability assessment 65.48 per cent of the area is estimated to be suitable for sprinkler irrigation of which 61.37 per cent is moderately suitable, 3.9 per cent highly suitable and 0.21 per cent marginally suitable. Sever limitations of water holding capacity due to shallow depth, steep slope and rock outcrops totally preclude the use of sprinkler irrigation in 34.51 per cent of the sub basin area. The marginal limitation is from steep slope limitation and the moderate limitations are poor drainage, shallow depth as a consequence poor water holding capacity, steep slope and coarse texture soil that would result in poor water holding capacity. Some of the effects of the moderate limitations could be alleviated by appropriate management practices that include drainage and organic matter management to improve aeration and water holding capacity respectively.

4. METHODS 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 guide line for soil description FAO, 2006, and World reference base for soil resources, FAO, 1998 and FAO, 2006.

The methodology to be followed for the soil survey is designed to conform to the scope of the study. The overall survey procedure was consisting 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 was prepared from from ASTER Digital Elevation Model (DEM) of 30 m resolution created contour lines at 5m intervals. Auger hole observations sites were predetermined on 300 m by 300 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. Auger-hole observations made by fixed grid technique that transects laid at 300 m apart and auger observations made along every 300 m each grid transects. A total of 25 auger holes observation has been made, giving an overall density of one observation per 9 ha. 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, 3 representative 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 final classification was made in the office after chemical analyses completed. A total of 3 soil profil pits were dug and sampled. These samples (8 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 table2and 3.

4.3.2 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.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 table5.

Infiltration rate and Hydraulic conductivity test was determined in triplicates (8 to 10 m apart). A total of 1 representative sites by the double ring infiltrometer method and inverse Auger-hole Test method, respectively (FAO, 1979).

The soil survey data collected during field work is summarized in table 1 below.

Table 1: Soil survey data collected during the field work

S/N	Status	Number of observations
1	Total augers observation points	25
2	Soil profile description	3
3	Soil samples	8
4	Infiltration and hydraulic conductivity	1
5	Soil profile not sampled	3
6	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.

4.4. Post Fieldwork

After completion of the fieldwork, field data compilation and encoding, field and laboratory data interpretation and report writing was conducted. Legend was developed for the mapping units. Soil mapping units have been established based on slope, soil texture and soil depth and soil unit. A total of 28 SMU were identified on the basis of the above three criteria.

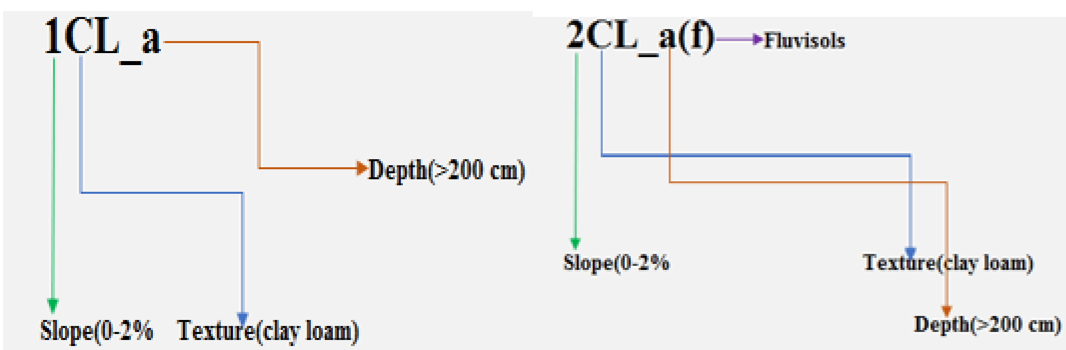
Table 2: Soil properties used for the definition of SMU

Slope		Texture		Depth		Soil units
Percent	Map Symbol	Class	Map Symbol	Cm	Map Symbol	
0-2	1	Clay loam	CL	>200	a	Chromic,Eutric Cambisols(Aric)
2-5	2	Loam	L	150-200	b	Eutric Fluvisols(Aric)
5-8	3	Clay	C	100-150	c	
8-15	4			50-100	d	
15-30	5			25-50	e	
				0-25	f	

Accordingly based on slope, top soil texture, soil depth and soil units of the study area 28 soil mapping units (SMU) were identified on the command area. Thus, SMU were represented by three symbols (e.g. 1CL_a = Flat/level land (0-2% slope) with Clay loam texture and having very deep soil profile (>200 cm)

Soil Mapping Units

Example :



4.4.1. 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 OWWDSE 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 WWDSE 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, etc…) and soil chemical characteristics (CEC, pH, 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 the Firi-Kebso small scale Irrigation project is classified in to the following two major soils, i.e. Cambisols, and Fluvisols. 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 , 2006 and (WRB ,2014) methods. Potential and limiting factors have been identified to make land suitability evaluation. The report and soil map of the Firi-Kebso small scale Irrigation project has been presented on 1:10,000 scale maps.

I- Cambisols

Cambisols mainly distributed in all part of the study area. dark brown (7.5YR 3/2 Dry); and very dark brown (7.5YR 2.5/2 moist) colored, Clay loam, clay and,loam textured, Shallow to very deep soil (25-50, 50-100,100-150,150-200 to >200 cm), The soil is well drained and developed on flat plain (0-2 per cent) to steep slope (>15-30 per cent) .The cambisols are with area coverage of **123.77** ha which constitutes **71.53%** of the total area. This soil has weak evidence of stratification in soil profile, which is indicated by soil color and texture change.

They 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 overlying subsoil which has a base saturation (by 1M NH4OAc) of >50 per cent for Cambisols. Cambisols are soils those lacks hydromorphic and permafrost within 100 cm and 200 cm of the surface respectively. In the study area identified **Chromic, Eutric Cambisols (Aric),** has no mottles; common fine and medium coarse fragments, moderate fine and Medium subangular blocky Structured, has no Crack, slightly hard (dry); friable (moist), sligtely sticky and sligtely plastic (wet); Representative profile FQP-3, See soil mapping unit description

II-Fluvisol

Fluvisol accommodate genetically young, azonal soils in alluvial deposits, these soils are not only confined to river sediments, they are also occurring in lacustrine and marine deposits. Mainly Fluvisol are correlated with alluvial soils. Eutric Fluvisol having a base saturation (by N H4OAC) of 50 percent or more at least between 20 and 50 cm from the surface but which are not calcareous at the same depth, lacking a sulfuric horizon and sulfidic material with in 125 cm of the surface, lacking salic property, The Fluvisol are with area coverage of **49.27 ha** which constitutes **28.47 %** of the total area.Well drained, moderately shallow to very deep (50-100,100-150,150-200 and >200cm), Very dark grayish brown (10YR3/2, Dry) and Very Dark brown 10YR3/1moist); mainely developed on Flat slope(0-2per sent) to stronly slopping (8-15 per sent), none mottling; dominantly Caly loam textured ,hard(dry) , friable (moist), sligtely sitcky and sligtely plastic (wet); moderate and medium subangular blocky; no coarse fragments; many fine and medium roots; many fine and medium pores; non-cemented and non-compacted; none mineral nodules; clear smooth boundary; strongly calcareous. Considering the above mentioned characteristics and other chemical properties they are identified as **Eutric Fluvisol (Aric)** Representative profile FQP-1 and FQP-2

Table 3: Description of soil physical and chemical properties by major soils

Soil physical and chemical characteristices	Unit	Horizone	Major soil			
			Fluvisols		Canbisols	
			Value	Remark	Value	Remark
PH	Water	T	7.4	Sligtely alkaline	7.1	Neutral
		S	7.55	Sligtely alkaline	7.2	Neutral
EC	ds/m(mmhos/cm)	T	0.224	salt free	0.191	salt free
		S	0.2615	salt free	0.189	salt free
Na	meq/100g of soil	T	0.15	Low	0.14	Low
		S	0.176	Low	0.14	Low
Ca	meq/100g of soil	T	37.26	Very high	21.33	Very high
		S	39.35	Very high	16.11	high
Mg	meq/100g of soil	T	10.58	Very high	4.62	high
		S	9.839	Very high	4.56	high
K	meq/100g of soil	T	0.72	high	0.60	high
		S	0.536	Medium	0.30	Medium
CEC	meq/100g of soil	T	55.9	Very high	30.9	high
		S	57	Very high	25.3	high
BS	%	T	87	high	86	high
		S	87.59	high	83	high
ESP	%	T	0.27	Low	0.46	Low
		S	0.31	Low	0.56	Low
TN	%	T	0.29	high	0.28	high
		S	0.255	high	0.20	Medium
OC	%	T	3.6	Low	3.6	Low
		S	3.34	Low	2.6	Low
OM	%	T	6.16	Very high	6.16	Very high
		S	5.76	Very high	4.43	high
AVP	PPM	T	0.98	Low	3.52	Low
		S	2.48	Low	1.20	Low
Texture	Class	T	Clay loam		Loam	
		S	CL		Loam	
Depth	cm		200		55	

6. DESCRIPTION OF SOIL PHYSICAL AND CHEMICAL PROPERTIES

6.1. Soil Physical Properties

The soil physical characteristics of Firi-Kebso Small scale irrigation project are discussed below.

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 >200 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 Firi-Kebso Small scale irrigation project are shallow to very deep (25-50cm to >200+ cm respectively), so have no limitation for normal rooting for most cultivated crops, grazing herbages, bushes and shrubs.

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

Depth (cm)	Area (ha)	%
>200	14.85	10.88
100-150	47.30	34.67
50-100	38.81	28.44
25-50	40.471	29.66
Total	136.44	100

6.1.3. 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 of every soil profile. Classification of structure follows the FAO *Guidelines for Soil Description* (2006). This is a subjective system of assessment. The surface and sub surface structure of Cambisols (Chromic, Eutric) is dominantly moderate, fine to medium to sub angular blocky type. and Fluvisols(Eutric) have dominantly moderate,medium sub angular blocky structure in their surface soils and moderate,fine to medium sub angular block structure in their sub soils.

6.1.4. Consistence

The consistence of soils varies with their textural composition both Chromic, Eutric Cambisols (Aric) and Eutric Fluvisols (Aric) of the study area have sligtely hard consistence when dry, friable when moist and slightly sticky and slightly plastic consistence when wet.

6.1.5. Texture

To determine the capacity of the soil to retain moisture and air, both of which are necessary for plant growth are depend on the proportions of sand, silt and clay are used to determine the textural class of the soil. Top and sub soils texture of the Firi-Kebso SSIP are dominantly **Clay loam** (for Eutric Fluvisols) and **Loam** both for top and sub soils of Chromic, Eutric Cambisols. Laboratory analysis of soil texture show that the percentage of its textural compostion is proportional /the same, through out thre profile horizon

6.1.6. 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 soils [(Eutric Fluvisol (Aric)] of the project area have vey dark grayish brown (10YR3/2) when dry and very dark brown (7.5YR2.5/1) when moist while for well drained Chromic, Eutric Cambisols very dark gray (7.5YR3/1) when dry and very dark brown (7.5YR2.5/1) when moist in color.

6.1.7. 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, poorly drained and very poorly drained

Soils of the Firi-Kebso SSIP study area have well drained in Cambisols and Fluvisols area . Soil condition which vary depending on their varying properties affecting drainage such as water transmission, soil depth, soil chemistry, slope gradient, etc.

6.1.8 Infiltration rate

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

Infiltration rate is mainly affected by texture of the soil and other properties of the soil such as organic matter content and structure of the soil. The infiltration tests were performed close to representative soil profiles. The result of the test indicates that soils of the study area have a basic/instantaneous/immediate average infiltration rate of **3.5 cm/hr**, which is **moderate** this implies the ranking result is suitable for surface irrigation and the mean average infiltration rate of **12.5 cm/hr,**is **moderately rapid** this implies the ranking result is marginaly suitable for surface irrigation ,as a result soils of the project area have a **moderate to moderately rapid** infiltration rate.

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

Soil unit	Texture	surface Textute	Immediate(instantanious) infiltration rate cm/hr		SUM	Range of IR	Immediate(instantanious) Average_IR	Ranking for surface irrigation development
			IR_Rep1	Rep2				
	class		cm/ha	cm/ha		cm/ha	cm/ha	
Chromic,Eutric Cambisols	Medium	CL	3	4	7	3-4	**3.5**	**Suitable**

Soil unit	Texture	surface Textute Class	Mean infiltration Rate cm/hr		SUM	Range of IR	Mean Average_IR	Ranking for surface irrigation development
			Rep1	Rep2				
	class		cm/ha	cm/ha		cm/ha	cm/ha	
Chromic,Eutric Cambisols	Medium	CL	12.2	12.8	25	12.2-12.8	**12.5**	**Marginally suitable(too rapid),small basin is needed**

6.1.9. 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 average hydraulic conductivity of **3.89 m/day** for soils of the study area [(Chromic, eutric cambisols (Aric)]. The result indicates that, the water movement is **very rapid**. this is because plant root penetration and some gravels found 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.

Study Area	Major soil	Textute	Texture	Hydraulic conductivity (Rep 1)	Hydraulic conductivity (Rep 2)	Hydraulic conductivity (Rep 1 and Rep2)_Range	Average Hydraulic conductivity	Hydraulic conductivity value
		Type	class	m/day	m/day	m/day	m/day	Rating
Firi Kebso	Chromic, Eutric Cambisols	CL	Medium	5.38	2.4	2.4-5.38	**3.89**	very Rapid

6.1.10. 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. The bulk density of the soils in the study area varies, in the top soil **1.37 g/cm^3** and sub soil **1.54 g/cm^3**. The result shows **moderate scale,** 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 except clay soil.

Table 7: Bulck density results versus soil textures of the study area

Soil units	Rep.Profile	Soil depth	Texture	Bulck density		Bulck density			Effect on soil condition
		cm	class	(gm/cm3)	Rating	Horizon	(gm/cm3)	Rating	
Eutric Fluvisols(Aric)	FQP_2	0-30	Clay loam	1.37	Moderate	Top	**1.37**	Moderate	
		30-55	Clay	1.60	Moderate	Sub	**1.54**	Moderate	Very compact
		55-120	Clay loam	1.47	Moderate				

6.1.11. 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 **38.40 %** in the top soil and **37.85%** in the sub soils. The following table shows the field capacity results of the study area versus texture.

Table 8: Field capacity results versus soil textures of the study area

Soil units	Rep.Profile	Soil depth	Texture	FC(0.33bar)	Horizon	FC(0.33bar)
Eutric Fluvisols(Aric)	FQP_2	0-30	Clay loam	38.40	Top	**38.40**
		30-55	Clay	37.40	Sub	**37.85**
		55-120	Clay loam	38.30		

6.1.12. Permanent wilting point (PWP)

Permanent wilting point is the soil moisture content at which plants can no longer obtain enough moisture to meet evapotranspiration requirements and remain wilted unless water is added to the soil. Permanent wilting pointis the moisture content level at which the plants are water stressed and irreversibly wilt. If water is continually taken-up by plants and no additional water is added to the soil in the form of precipitation or irrigation water, the medium and small soil pores will be emptied of water. With time, the plant will eventually wilt when it cannot extract more water.

The soil is said to be at the permanent wilting point when plants can no longer exert enough force to extract the remaining soil water. At the permanent wilting point, water is held in the soil at about 1.5 MPa (15 bars). The permanent wilting points of the soils of the study area fall in the range of **22.60%** in the top soil and **29.40%** in the sub soil.

Table 9: permanent wilting point results versus soil textures of the study area

Soil units	Rep.Profile	Soil depth	Texture	PWP(15bar)	Horizon	PWP(15bar)
Eutric Fluvisols(Aric)	FQP_2	0-30	Clay loam	22.60	Top	**22.60**
		30-55	Clay	28.20	Sub	**29.4**
		55-120	Clay loam	30.60		

6.1.13. 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 :

6.1.14. 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 10: 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.

Soil Units	Field Code	Horizon	Depth	Depth(Thickness)	Depth	Texture	Texture	FC	PWP	FC_PWP	BD	AWC	AWC	TAWC	TRAWC	AWC
			cm	cm	mm		class	0.33bar	(15bar)		gm_cmv3	cm	mm	mm/m	mm/m	
Eutric Fluvisols(Aric)	FQP_2	Top	0-30	30	300	CL	Medium	38.40	22.60	15.80	1.37	6.49	64.94	**131.74**	87.82	medium
		sub	30-60	30	300	C	fine	37.40	28.20	9.20	1.60	4.42	44.16			
		sub	60-90	30	300	CL	Medium	38.30	30.60	7.70	1.47	3.40	33.96			

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.

6.1.15. 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 Fluvisols and Cambisols become friable. 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 Fluvisols and Cambisols are all well-aerated at field capacity.

Table 11 **: Total porisity and Air-filled porosity**

Dominant_Soil Units	Field_Code	Texture class	Horizon	Bulk density g/cm3	Total porosity %	FC (0.33bar)	Air-filled porosity %	Effect on soil codittion
Eutric Fluvisols(Aric)	FQP_2	Clay loam	Top soil	1.37	48.30	38.4	9.90	
		Clay	0.3-0.6m	1.6	39.62	37.4	2.22	Very compact
		Clay loam	0.6-0.9m	1.47	44.53	38.3	6.23	

6.1.16. Soil Biological Features

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 according to profile description and surfce obsrvation.

6.1.17. Erosion Status

The erosion status of the command area is not observed both on site and in the surrounding for slope up to 5% (Eutric Fluvisols), where as for chromic, Eutric Cambisols (Aric), with slope ≥8% slight splas and sheet erosion observed, in addition in some elevated (15-30%) area of the site and the surrounding observed sheet, rill and guly erosion

6.1.18. 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 hazared, except for soils of some elevated part (15-30%) of the surrounding are affected by slight flooding during the rainy seasons for less than 15 days

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 **6.80 to 7.60** with an average of **7.29**. Which increase from top to sub soil. This range of soil pH is normally termed as Neutral to slightly alkaline soil, but the average value is neutral.

6.2.2. Electrical Conductivity (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. In general EC value of less than 2 mmhos/ cm is considered to be salt free. Excess salt in the soil hinders crop growth not only by toxicity effect but also by reducing water availability via the action of osmotic pressure moreover ; nutrient uptake may be unbalanced. The EC value for the study area was varying from **0.10-0.28 dS**/m with anaverage of **0.19** dS/m.A soil saturation extract was prepared, allowed to equilibrate and then the saline soil water removed by suction and analyzed for EC. The range of **ECe** measured for the soil of the study area was salt free to moderately saline i.e varying from **0.84 -2.40 dS**/m with anaverage of **1.68 dS/**m(which is salt free).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 growth 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 **2.57% to 3.57%** with average of **3.24 %** which it is rated as 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 area are in the range of **4.43% to 6.17 %** the average organic matter content of the soils of the study area is **5.58%** and is rated as high to very 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 **0.20 to 0.29** percent with an average of 0.27% which indicate that the total nitrogen content is medium to 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 10.27 to 13.67.

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 0.44 ppm to 12.20 ppm with average of 2.93ppm where the value is low to medium in top soil,with average range of low value.Generally the available phosphorus of the soils of the soil mapping units is rated as in adequate for crops.

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 25.34 meq/100g soil to 63.24 meq/100g. CEC values between this ranges is rated as high to very high, which in turn mean good agricultural soil in 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 66.67% to 100% 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 16.11 cmol (+)/kg soil to 44.30 cmol (+)/kg soil with average value of 33.34 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 4.56 to 32.90cmol (+)/kg soil with average value of 10.79 cmol (+)/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 0.30 to 1.21 cmol (+)/kg soil. Which indicates that the level of K is medium to high. The average value is 0.67 cmol (+)/kg The

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 0.14 to 0.0.83 cmol(+)/kg of soil, with mean value of 0.23 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)

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 0.25 % to 1.91% with avegage value of 0.53% it is below the allowable limit and there is no sodicity problem in the study area and no need of amendments.

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 per cent calcium carbonate equivalent. The calcium carbonate content of most of the soils in the study area **(Firi-Kebso SSIP) is trace to 50.21 per cent**, this value shows that the soils are free of Calcium Carbonate to very high and do not affect the soil conditions.

6.2.15. Potassium to Magnesium Ratio (K: Mg)

If the ratio of potassium to magnesium is more than 2:1, magnesium uptake may be inhibited. The ratio of K: Mg recorded for the project area is between 0.04 and 0.18(Average value is 0.07: 1, indicating an optimum situation for production of most field crops, vegetables and fruits.

6.2.16. Calcium to Magnesium Ratio (Ca: Mg)

The ratio of calcium to magnesium (Ca: Mg) in most soils of the project area is moderate 1.35 to 5.01. Which indicate that the level is less favorable(low) to moderately high favorable.

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

If the ratio of K: CEC is less than two per cent, it suggests a minimum level to avoid K deficiency and soils with more than 25% ratio is considered to be potassium rich soil. The minimum K: CEC ratio of the soil units in project area was 0.01 and maximum was 0.03 Hence, most of the soils in the project area have the ratio less than minimum level which indicates K deficiency.

6.2.18. Available Potassium (Avk)

Surface soils are generally around 0.2-0.5 cmol(+)/kg or 80-250 mg/kg (ppm). The levels can be significantly lower on sandier soils. Potassium is one of the most abundant elements in soil. The total K in soil will be dependent on soil parent material, the extent of weathering and leaching of soil minerals, the type of clay minerals, soil texture, organic matter content and K fertiliser history. Much of the potassium occurring in soils is not available to plants and crops, therefore soils containing high levels of K can still be responsive to K fertilisers. Because of the way K moves and is taken up, there are several things that cause problems when trying to predict K responsiveness using soil tests. These include :

1. Dry soil will mean K cannot be accessed, due to limited diffusion
2. In high yielding situations K diffusion can be slow and may not meet crop demands
3. Rooting patterns differ among crops, with fibrous rooted plants tend to exploit more K than that of tap rooted plants
4. Different species have different K demands
5. Other Cations can affect K demand through competition, substitution or physical disruption

Potassium interpretation is reliant on soil texture/soil type, as sandy soils have a lower potassium holding capacity than clay soils and K may leach before the plants can use it. A soil with higher clay content will have the ability to fix or provide more exchangeable K

In the study area the available K ranges from 89.70ppm(low) to 281.70 ppm(high), with average value of 208.36 ppm which is a medium value

6.2.19. Soil fertility index

Soil fertility index is the relative sufficiency expressed as a percentage of the amount of nutrients adequate for optimum yield. It is related with soil test values and crop response. The soil fertility index in the top soil ranges as 33.73 to 63.10(medium to high) this indicates crop response is possible to unlikely.

7. DESCRIPTION SOIL MAPPING UNITS

4.3.1. 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 28 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, texture,and soil depth, and other relevant soil drainage,and soil physical and chemical properties. Based on this, the following soil mapping units were identified

Table 12 : Area distribution of major soil groups in Firi Kebso small scale Irrigation Projectes

SN	Major soil group(FAO,1998,2006/WRB,2014)	Identified soil units(FAO,1998,2006/WRB,2014)	SMU	Area	
				ha	%
1	Cambisols	Chromic,Eutric Cambisols(Aric)	1CL_a	2.82	2.07
			1CL_c	2.17	1.59
			1CL_d	4.80	3.52
			2CL_a	1.39	1.02
			2CL_c	4.68	3.43
			2CL_d	16.90	12.39
			2CL_e	5.07	3.71
			2L_e	2.05	1.51
			3C_e	5.25	3.85
			3CL_a	2.49	1.82
			3CL_c	6.35	4.65
			3CL_d	5.21	3.82
			3CL_d	0.46	0.34
			3L_e	1.14	0.83
			4CL_a	3.51	2.57
			4CL_c	10.83	7.94
			4CL_d	5.40	3.96
			4CL_e	12.88	9.44
			4L_e	7.89	5.79
			5CL_a	0.32	0.24
			5CL_c	3.08	2.26
			5CL_d	1.03	0.76
			5CL_e	4.27	3.13
			5L_e	1.91	1.40
2	Fluvisols	Eutric Fluvisols(Aric)	2CL_a(f)	0.91	0.67
			2CL_c(f)	6.74	4.94
			3CL_a(f)	3.41	2.50
			3CL_c(f)	7.66	5.61
			4CL_c(f)	5.80	4.25
				136.44	100.00

Figure 2: Soil Maps of the study area by soil mapping units

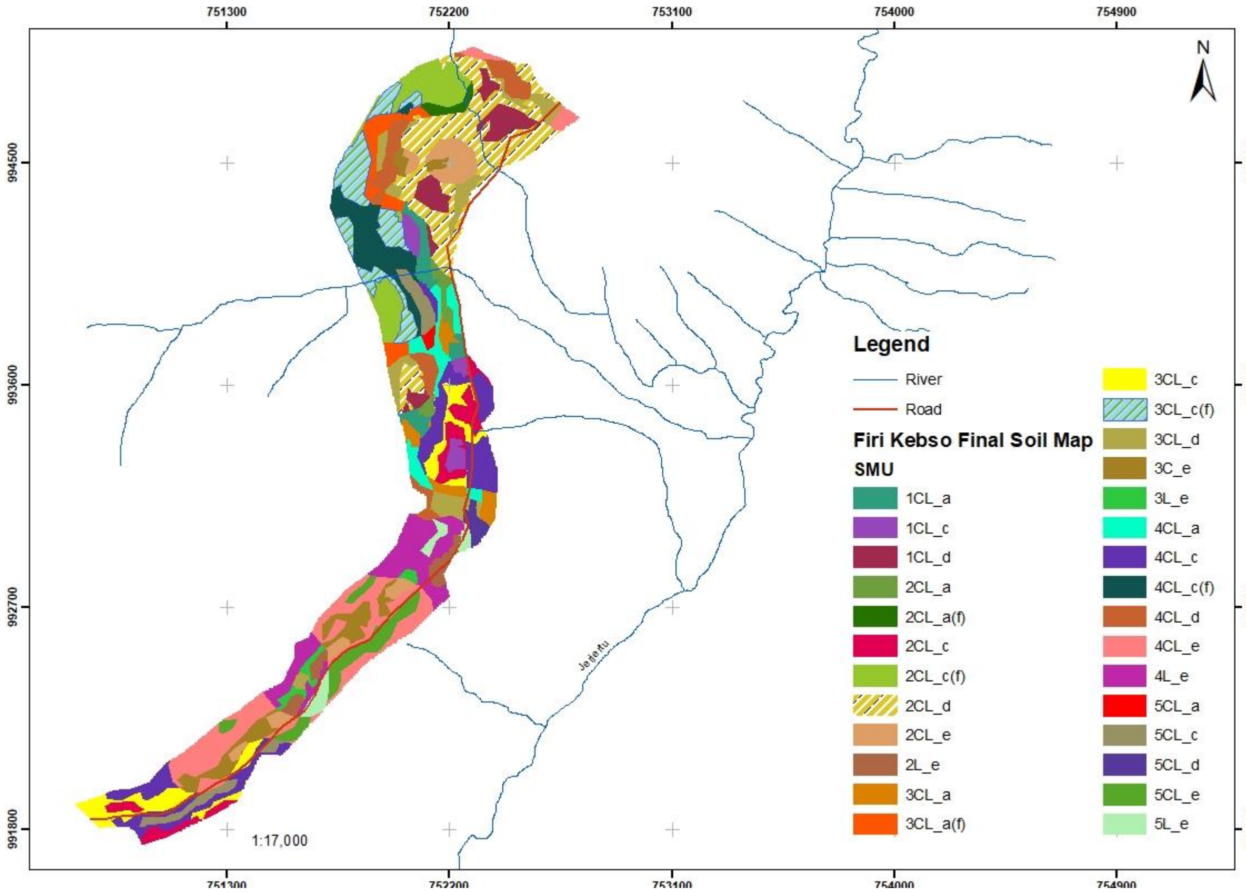
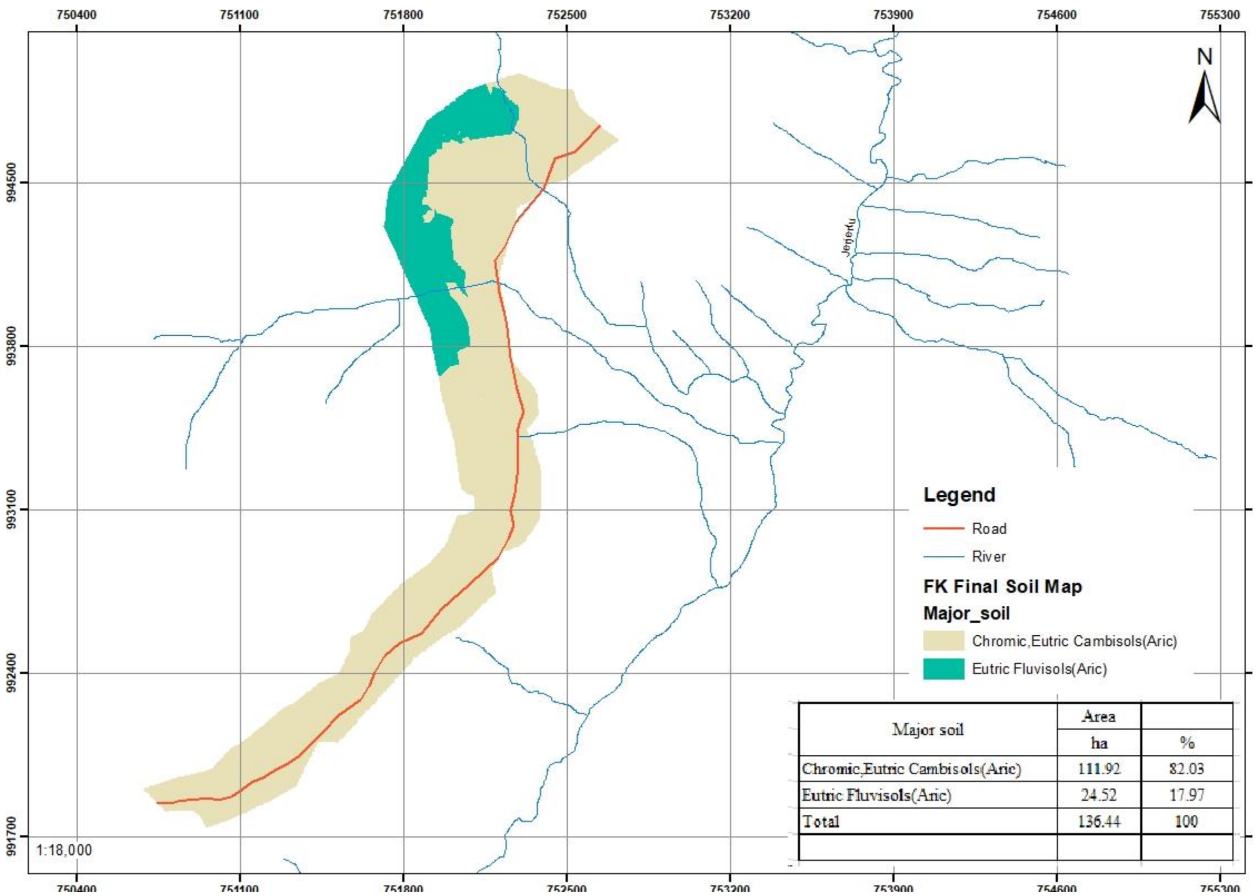


Figure 3: Soil Maps of the study area by Soil units



Soil Mapping units :

1CL-a

This mapping unit refers to soils developed on 0-2% slope with very deep profile (>200cm). The soils are well drained with moderate, fine to medium sub angular blocky structure and have Clayloam (CL) texture.

The average infiltration rate (IR) of this unit is categorized as optimum (3.5 cm/hr) and hydraulic conductivity (HC) ranges from 3.9 m/day.

The pH value is 7.4 in the top soil and 7.55 in the sub soil indicating that the soil is slightely alkaline. The overall organic carbon content of this soil unit is 3.57% in the top soil and 2.6 % in sub soil, which indicates very high to high level of organic matter content. Total nitrogen content ranges 0.29% in the top and 0.255 % in sub soil which shows high level status of the total nitrogen. This soil mapping unit has low available phosphorus (0.98ppm in the top soil &2.48ppm in the sub soil), very high CEC level (55.90 & 57 Meq/100g of soilin top and sub soil respectively) and very high base saturation percentage (87.14% in the top soil and 87.59% in the sub soil. The soils in this mapping unit have very high Ca2+ and are strongly calcareous. The soil units is Chromic, Eutric Cambisols (Aric). The total extent of this mapping unit is 2.82 ha or 2.07%.

1CL-c

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

The average infiltration rate (IR) of this unit is categorized as optimum (3.5 cm/hr) and hydraulic conductivity (HC) ranges from 3.9 m/day.

The pH value is 7.50 in the top and 7.6 in the sub soil indicating that the soil is slightely alkaline. The overall organic carbon content of this soil unit is 3.40% in the top soil and 3.3 % in sub soil, which indicates high top sub soil level of organic matter content. Total nitrogen content ranges 0.27% in the top and 0.24 % in sub soil which shows high level of the total nitrogen. This soil mapping unit has low available phosphorus (0.74 ppm in the top soil & 4.22ppm in the sub soil), very high CEC level (51.84 & 62 Meq/100g of soil in top and sub soil respectively) and very high base saturation percentage (88% in top and 86.99 sub soil. The soils in this mapping unit have high Ca2+ and are strongly calcareous. The soil units is Chromic, Eutric Cambisols (Aric)The total extent of this mapping unit is 2.17 ha or 1.59%.

1CL-d

This mapping unit refers to soils developed on 0-2% slope with moderately deep profile (50-100cm). The soils are well drained with fine to medium sub angular blocky structure and have clay loam (CL) texture.

The average infiltration rate (IR) of this unit is categorized as optimum (3.5 cm/hr) and hydraulic conductivity (HC) ranges from 3.9 m/day.

The pH value is 7.60 in the top and sub soil, which indicating that the soil is slightely alkaline. The overall organic carbon content of this soil unit is 3.28% in the top soil and 3.4 % in sub soil, which indicates very high level of organic matter content. Total nitrogen content ranges 0.24% in the top and 0.25 % in sub soil which shows high level status of the total nitrogen. This soil mapping unit has low available phosphorus (4.22ppm in the top soil & 1.20 ppm in the sub soil), very high to high CEC level (62.16 & 25.3 Meq/100g of soil in top and sub soil respectively) and high base saturation percentage (86.99% in the top and 83 % in the subsoil. The soils in this mapping unit have high Ca2+ and are highly calcareous. The soil units is Chromic, Eutric Cambisols (Aric). The total extent of this mapping unit is 4.799 ha or 3.51%.

2CL-a

This mapping unit refers to soils developed on 2-5 % slope with very deep profile (>200cm). The soils are well drained with fine & medium sub angular blocky structure and have clay loam (CL) texture.

The average infiltration rate (IR) of this unit is categorized as optimum (3.5 cm/hr) and hydraulic conductivity (HC) ranges from 3.9 m/day.

The pH value is 7.40 in the top and 7.55 in the sub soil, which indicating that the soil is slightely alkaline. The overall organic carbon content of this soil unit is 3.57% in the top soil and 3.34 % in sub soil, which indicates very high organic matter content. Total nitrogen content ranges 0.29% in the top and 0.255 % in sub soil which shows high level status of the total nitrogen. This soil mapping unit has low available phosphorus (0.98 ppm in the top soil & 2.47ppm in the sub soil), very high CEC level (55.90 & 57 Meq/100g of soil in top and sub soil respectively) and high base saturation percentage (87.14% in the top and 87.59 in the subsoil. The soils in this mapping unit have high Ca2+ and are highly calcareous. The soil units is The soil units is Chromic, Eutric Cambisols (Aric). The total extent of this mapping unit is 1.39 ha or 1.02%.

2CL-a(f)

This mapping unit refers to soils developed on 2-5 % slope with very deep profile (>200cm). The soils are well drained with fine & medium sub angular blocky structure and have clay loam (CL) texture.

The average infiltration rate (IR) of this unit is categorized as optimum (3.5 cm/hr) and hydraulic conductivity (HC) ranges from 3.9 m/day.

The pH value is 7.40 in the top and 7.55 in the sub soil, which indicating that the soil is slightely alkaline. The overall organic carbon content of this soil unit is 3.57% in the top soil and 3.34 % in sub soil, which indicates very high organic matter content. Total nitrogen content ranges 0.29% in the top and 0.255 % in sub soil which shows high level status of the total nitrogen. This soil mapping unit has low available phosphorus (0.98 ppm in the top soil & 2.47ppm in the sub soil), very high CEC level (55.90 & 57 Meq/100g of soil in top and sub soil respectively) and high base saturation percentage (87.14% in the top and 87.59 in the subsoil. The soils in this mapping unit have high Ca2+ and are highly calcareous. The soil units is The soil units is Eutric Fluvisols (Aric). The total extent of this mapping unit is 0.91 ha or 0.67%.

2CL-c

This mapping unit refers to soils developed on 2-5 % slope with very deep profile (100-150cm). The soils are well drained with fine & medium sub angular blocky structure and have clay loam (CL) texture.

The average infiltration rate (IR) of this unit is categorized as optimum (3.5 cm/hr) and hydraulic conductivity (HC) ranges from 3.9 m/day.

The pH value is 7.40 in the top and 7.55 in the sub soil, which indicating that the soil is slightely alkaline. The overall organic carbon content of this soil unit is 3.57% in the top soil and 3.34 % in sub soil, which indicates very high organic matter content. Total nitrogen content ranges 0.29% in the top and 0.255 % in sub soil which shows high level status of the total nitrogen. This soil mapping unit has low available phosphorus (0.98 ppm in the top soil & 2.47ppm in the sub soil), very high CEC level (55.90 & 57 Meq/100g of soil in top and sub soil respectively) and high base saturation percentage (87.14% in the top and 87.59 in the subsoil. The soils in this mapping unit have high Ca2+ and are highly calcareous. The soil units is The soil units is Chromic, Eutric Cambisols (Aric). The total extent of this mapping unit is 4.68 ha or 3.43%.

2CL-c(f)

This mapping unit refers to soils developed on 2-5 % slope with very deep profile (100-150cm). The soils are well drained with fine & medium sub angular blocky structure and have clay loam (CL) texture.

The average infiltration rate (IR) of this unit is categorized as optimum (3.5 cm/hr) and hydraulic conductivity (HC) ranges from 3.9 m/day.

The pH value is 7.40 in the top and 7.55 in the sub soil, which indicating that the soil is slightely alkaline. The overall organic carbon content of this soil unit is 3.57% in the top soil and 3.34 % in sub soil, which indicates very high organic matter content. Total nitrogen content ranges 0.29% in the top and 0.255 % in sub soil which shows high level status of the total nitrogen. This soil mapping unit has low available phosphorus (0.98 ppm in the top soil & 2.47ppm in the sub soil), very high CEC level (55.90 & 57 Meq/100g of soil in top and sub soil respectively) and high base saturation percentage (87.14% in the top and 87.59 in the subsoil. The soils in this mapping unit have high Ca2+ and are highly calcareous. The soil units is The soil units is Eutric Fluvisols (Aric). The total extent of this mapping unit is 6.74 ha or 4.94%.

2CL-d

This mapping unit refers to soils developed on 2-5 % slope with moderately deep profile (50-100cm). The soils are well drained with fine & medium sub angular blocky structure and have clay loam (CL) texture.

The average infiltration rate (IR) of this unit is categorized as optimum (3.5 cm/hr) and hydraulic conductivity (HC) ranges from 3.9 m/day.

The pH value is 7.50 in the top and 7.6 in the sub soil indicating that the soil is slightely alkaline. The overall organic carbon content of this soil unit is 3.40% in the top soil and 3.3 % in sub soil, which indicates high top sub soil level of organic matter content. Total nitrogen content ranges 0.27% in the top and 0.24 % in sub soil which shows high level of the total nitrogen. This soil mapping unit has low available phosphorus (0.74 ppm in the top soil & 4.22ppm in the sub soil), very high CEC level (51.84 & 62 Meq/100g of soil in top and sub soil respectively) and very high base saturation percentage (88% in top and 86.99 sub soil. The soils in this mapping unit have high Ca2+ and are strongly calcareous. The soils in this mapping unit have high Ca2+ and are highly calcareous. The soil units is The soil units is Chromic, Eutric Cambisols (Aric). The total extent of this mapping unit is 16.9 ha or 12.38%.

2CL-e

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

The average infiltration rate (IR) of this unit is categorized as optimum (3.5 cm/hr) and hydraulic conductivity (HC) ranges from 3.9 m/day.

The pH value is 7.60 in the top and sub soil, which indicating that the soil is slightely alkaline. The overall organic carbon content of this soil unit is 3.28% in the top soil and 3.4 % in sub soil, which indicates very high level of organic matter content. Total nitrogen content ranges 0.24% in the top and 0.25 % in sub soil which shows high level status of the total nitrogen. This soil mapping unit has low available phosphorus (4.22ppm in the top soil & 1.20 ppm in the sub soil), very high to high CEC level (62.16 & 25.3 Meq/100g of soil in top and sub soil respectively) and high base saturation percentage (86.99% in the top and 83 % in the subsoil. The soils in this mapping unit have high Ca2+ and are highly calcareous. The soil units is Chromic, Eutric Cambisols (Aric). The total extent of this mapping unit is 5.07 ha or 3.71%.

2L-e

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

The average infiltration rate (IR) of this unit is categorized as optimum (3.5 cm/hr) and hydraulic conductivity (HC) ranges from 3.9 m/day.

The pH value is 7.4 in the top soil and 7.55 in the sub soil indicating that the soil is slightely alkaline. The overall organic carbon content of this soil unit is 3.57% in the top soil and 2.6 % in sub soil, which indicates very high to high level of organic matter content. Total nitrogen content ranges 0.29% in the top and 0.255 % in sub soil which shows high level status of the total nitrogen. This soil mapping unit has low available phosphorus (0.98ppm in the top soil &2.48ppm in the sub soil), very high CEC level (55.90 & 57 Meq/100g of soilin top and sub soil respectively) and very high base saturation percentage (87.14% in the top soil and 87.59% in the sub soil. The soils in this mapping unit have very high Ca2+ and are strongly calcareous. The soil units is Chromic, Eutric Cambisols (Aric). The total extent of this mapping unit is 2.05 ha or 1.50%.

3C-e

This mapping unit refers to soils developed on 5-8 % slope with shallow profile (25-50cm). 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 (3.5 cm/hr) and hydraulic conductivity (HC) ranges from 3.9 m/day.

The pH value is 7.4 in the top soil and 7.55 in the sub soil indicating that the soil is slightely alkaline. The overall organic carbon content of this soil unit is 3.57% in the top soil and 2.6 % in sub soil, which indicates very high to high level of organic matter content. Total nitrogen content ranges 0.29% in the top and 0.255 % in sub soil which shows high level status of the total nitrogen. This soil mapping unit has low available phosphorus (0.98ppm in the top soil &2.48ppm in the sub soil), very high CEC level (55.90 & 57 Meq/100g of soilin top and sub soil respectively) and very high base saturation percentage (87.14% in the top soil and 87.59% in the sub soil. The soils in this mapping unit have very high Ca2+ and are strongly calcareous. The soil units is Chromic, Eutric Cambisols (Aric). The total extent of this mapping unit is 5.25 ha or 3.84%.

3CL-a

This mapping unit refers to soils developed on 5-8 % slope with shallow profile (>200cm). The soils are well drained with fine & medium sub angular blocky structure and have Clay loam (CL) texture The average infiltration rate (IR) of this unit is categorized as optimum (3.5 cm/hr) and hydraulic conductivity (HC) ranges from 3.9 m/day.

The pH value is 7.30 in the top and 7.25 in the sub soils, which indicating that the soil is Neutral. The overall organic carbon content of this soil unit is 3.40% in the top soil and 3.05 % in sub soil, which indicates very high level of organic matter content. Total nitrogen content ranges 0.29% in the top and 0.26 % in sub soil which shows high level of the total nitrogen. This soil mapping unit have low level of available phosphorus (0.44 ppm in the top soil & 1.27 ppm in the sub soil), very high CEC level (60.58 & 61.81 Meq/100g of soil in top and sub soil respectively) and high base saturation percentage (73.12% in the top and 69.9in the subsoil. The soils in this mapping unit have high Ca2+ and are sligtly to moderately calcareous. The soil units is Chromic, Eutric Cambisols (Aric). The total extent of this mapping unit is 2.49 ha or 1.82%.

3CL-a(f)

This mapping unit refers to soils developed on 5-8 % slope with shallow profile (>200cm). The soils are well drained with fine & medium sub angular blocky structure and have Clay loam (CL) texture The average infiltration rate (IR) of this unit is categorized as optimum (3.5 cm/hr) and hydraulic conductivity (HC) ranges from 3.9 m/day.

The pH value is 7.30 in the top and 7.25 in the sub soils, which indicating that the soil is Neutral. The overall organic carbon content of this soil unit is 3.40% in the top soil and 3.05 % in sub soil, which indicates very high level of organic matter content. Total nitrogen content ranges 0.29% in the top and 0.26 % in sub soil which shows high level of the total nitrogen. This soil mapping unit have low level of available phosphorus (0.44 ppm in the top soil & 1.27 ppm in the sub soil), very high CEC level (60.58 & 61.81 Meq/100g of soil in top and sub soil respectively) and high base saturation percentage (73.12% in the top and 69.9in the subsoil. The soils in this mapping unit have high Ca2+ and are sligtly to moderately calcareous. The soil units is Eutric Fluvisols (Aric). The total extent of this mapping unit is 3.41 ha or 2.50%.

3CL-c

This mapping unit refers to soils developed on 5-8 % slope with deep profile (100-150cm). The soils are well drained with fine & medium sub angular blocky structure and have Clay loam (CL) texture The average infiltration rate (IR) of this unit is categorized as optimum (3.5 cm/hr) and hydraulic conductivity (HC) ranges from 3.9 m/day.

The pH value is 7.30 in the top and 7.25 in the sub soils, which indicating that the soil is Neutral. The overall organic carbon content of this soil unit is 3.10% in the top soil and 3.4 % in sub soil, which indicates very high level of organic matter content. Total nitrogen content ranges 0.27% in the top and 0.26 % in sub soil which shows high level of the total nitrogen. This soil mapping unit have low level of available phosphorus (1.16 ppm in the top soil & 1.27 ppm in the sub soil), very high CEC level (60.38 & 61.81 Meq/100g of soil in top and sub soil respectively) and high base saturation percentage (66.67% in the top and 69.9in the subsoil. The soils in this mapping unit have high Ca2+ and are sligtly to moderately calcareous. The soil units is Chromic, Eutric Cambisols (Aric)The total extent of this mapping unit is 6.35 ha or 4.65%.

3CL-c(f)

This mapping unit refers to soils developed on 5-8 % slope with deep profile (100-150cm). The soils are well drained with fine & medium sub angular blocky structure and have Clay loam (CL) texture The average infiltration rate (IR) of this unit is categorized as optimum (3.5 cm/hr) and hydraulic conductivity (HC) ranges from 3.9 m/day.

The pH value is 7.30 in the top and 7.25 in the sub soils, which indicating that the soil is Neutral. The overall organic carbon content of this soil unit is 3.10% in the top soil and 3.4 % in sub soil, which indicates very high level of organic matter content. Total nitrogen content ranges 0.27% in the top and 0.26 % in sub soil which shows high level of the total nitrogen. This soil mapping unit have low level of available phosphorus (1.16 ppm in the top soil & 1.27 ppm in the sub soil), very high CEC level (60.38 & 61.81 Meq/100g of soil in top and sub soil respectively) and high base saturation percentage (66.67% in the top and 69.9in the subsoil. The soils in this mapping unit have high Ca2+ and are sligtly to moderately calcareous. The soil units is Eutric Fluvisols (Aric)The total extent of this mapping unit is 7.66 ha or 5.61%.

3CL-d

This mapping unit refers to soils developed on 5-8 % slope with moderately deep profile (50-100cm). The soils are well drained with fine & medium sub angular blocky structure and have Clay loam (CL) texture. The average infiltration rate (IR) of this unit is categorized as optimum (3.5 cm/hr) and hydraulic conductivity (HC) ranges from 3.9 m/day.

The pH value is 7.20 in the top and 7.25 in the sub soils, which indicating that the soil is Neutral. The overall organic carbon content of this soil unit is 3.0% in the top soil and 3.05% in sub soil, which indicates very high level of organic matter content. Total nitrogen content ranges 0.25% in the top and 0.26 % in sub soil which shows high level of the total nitrogen. This soil mapping unit have low level of available phosphorus (1.38 ppm in the top soil & 1.27 ppm in the sub soil), very high CEC level (63.24 & 61.81 Meq/100g of soil in top and sub soil respectively) and high base saturation percentage (73.23% in the top and 69.9in the subsoil. The soils in this mapping unit have high Ca2+ and are sligtly to moderately calcareous. The soil units is Chromic, Eutric Cambisols (Aric) The total extent of this mapping unit is 5.67 ha or 4.15%.

3L-e

This mapping unit refers to soils developed on 5-8 % slope with shallow profile (25-50cm). The soils are well drained with fine & medium sub angular blocky structure and have loam (L) texture. The average infiltration rate (IR) of this unit is categorized as optimum (3.5 cm/hr) and hydraulic conductivity (HC) ranges from 3.9 m/day.

The pH value is 7.10 in the top and 7.20 in the sub soils, which indicating that the soil is Neutral. The overall organic carbon content of this soil unit is 3.57% in the top soil and 2.6% in sub soil, which indicates very high to high level of organic matter content. Total nitrogen content ranges 0.28% in the top and 0.20 % in sub soil which shows high level of the total nitrogen. This soil mapping unit have low level of available phosphorus (3.52 ppm in the top soil & 1.20 ppm in the sub soil), high CEC level (30.38 & 25.3 Meq/100g of soil in top and sub soil respectively) and high base saturation percentage (86.43% in the top and 83 in the subsoil. The soils in this mapping unit have high Ca2+ and are sligtly to moderately calcareous. The soil units is Chromic, Eutric Cambisols (Aric) The total extent of this mapping unit is 1.19ha or 0.87%.

4CL-a

This mapping unit refers to soils developed on 8-15 % slope with very deep profile (>200cm). The soils are well drained with fine & medium sub angular blocky structure and have clay loam (CL) texture. The average infiltration rate (IR) of this unit is categorized as optimum (3.5 cm/hr) and hydraulic conductivity (HC) ranges from 3.9 m/day.

The pH value is 7.4 in the top soil and 7.55 in the sub soil indicating that the soil is slightely alkaline. The overall organic carbon content of this soil unit is 3.57% in the top soil and 2.6 % in sub soil, which indicates very high to high level of organic matter content. Total nitrogen content ranges 0.29% in the top and 0.255 % in sub soil which shows high level status of the total nitrogen. This soil mapping unit has low available phosphorus (0.98ppm in the top soil &2.48ppm in the sub soil), very high CEC level (55.90 & 57 Meq/100g of soilin top and sub soil respectively) and very high base saturation percentage (87.14% in the top soil and 87.59% in the sub soil. The soils in this mapping unit have very high Ca2+ and are strongly calcareous. The soil units is Chromic, Eutric Cambisols (Aric). The total extent of this mapping unit is 3.51 ha or 2.57%.

4CL-c

This mapping unit refers to soils developed on 8-15 % slope with very deep profile (100-150cm). The soils are well drained with fine & medium sub angular blocky structure and have clay loam (CL) texture. The average infiltration rate (IR) of this unit is categorized as optimum (3.5 cm/hr) and hydraulic conductivity (HC) ranges from 3.9 m/day.

The pH value is 7.20 in the top soil indicating that the soil is Neutral. The overall organic carbon content of this soil unit is 2.57% in the top soil, which indicates high level of organic matter content. Total nitrogen content ranges 0.20% in the top soil which shows high level status of the total nitrogen. This soil mapping unit has low available phosphorus (1.20ppm in the top soil), high CEC level (25.34 Meq/100g of soilin top) and very high base saturation percentage (83.29% in the top soil. The soils in this mapping unit have very high Ca2+ and are strongly calcareous. The soil units is Chromic, Eutric Cambisols (Aric). The total extent of this mapping unit is 10.83 ha or 7.93%.

4CL-c(f)

This mapping unit refers to soils developed on 8-15 % slope with very deep profile (100-150cm). The soils are well drained with fine & medium sub angular blocky structure and have clay loam (CL) texture. The average infiltration rate (IR) of this unit is categorized as optimum (3.5 cm/hr) and hydraulic conductivity (HC) ranges from 3.9 m/day.

The pH value is 7.20 in the top soil indicating that the soil is Neutral. The overall organic carbon content of this soil unit is 2.57% in the top soil, which indicates high level of organic matter content. Total nitrogen content ranges 0.20% in the top soil which shows high level status of the total nitrogen. This soil mapping unit has low available phosphorus (1.20ppm in the top soil), high CEC level (25.34 Meq/100g of soilin top) and very high base saturation percentage (83.29% in the top soil. The soils in this mapping unit have very high Ca2+ and are strongly calcareous. The soil units is Eutric Fluvisols (Aric). The total extent of this mapping unit is 5.799 ha or 4.25%.

4CL-d

This mapping unit refers to soils developed on 8-15 % slope with moderately deep profile (50-100cm). The soils are well drained with fine & medium sub angular blocky structure and have clay loam (CL) texture. The average infiltration rate (IR) of this unit is categorized as optimum (3.5 cm/hr) and hydraulic conductivity (HC) ranges from 3.9 m/day.

The pH value is 6.96 in the top soil indicating that the soil is Neutral. The overall organic carbon content of this soil unit is 3.18% in the top soil, which indicates high level of organic matter content. Total nitrogen content ranges 0.31% in the top soil which shows very high level status of the total nitrogen. This soil mapping unit has medium available phosphorus (12.20ppm in the top soil), very high CEC level (43.45 Meq/100g of soilin top) and very high base saturation percentage (100% in the top soil. The soils in this mapping unit have very high Ca2+ and are strongly calcareous. The soil units is Chromic, Eutric Cambisols (Aric). The total extent of this mapping unit is 5.40 ha or 3.95%.

4CL-e

This mapping unit refers to soils developed on 8-15 % slope with shallow profile (25-50cm). The soils are well drained with fine & medium sub angular blocky structure and have clay loam (CL) texture. The average infiltration rate (IR) of this unit is categorized as optimum (3.5 cm/hr) and hydraulic conductivity (HC) ranges from 3.9 m/day.

The pH value is 7.20 in the top soil indicating that the soil is Neutral. The overall organic carbon content of this soil unit is 2.57% in the top soil, which indicates high level of organic matter content. Total nitrogen content ranges 0.20% in the top soil which shows high level status of the total nitrogen. This soil mapping unit has low available phosphorus (1.20ppm in the top soil), high CEC level (25.34 Meq/100g of soilin top) and very high base saturation percentage (83.29% in the top soil. The soils in this mapping unit have very high Ca2+ and are strongly calcareous. The soil units is Chromic, Eutric Cambisols (Aric). The total extent of this mapping unit is 12.88 ha or 9.43%.

4L-e

This mapping unit refers to soils developed on 8-15 % slope with shallow profile (25-50cm). The soils are well drained with fine & medium sub angular blocky structure and have clay loam (CL) texture. The average infiltration rate (IR) of this unit is categorized as optimum (3.5 cm/hr) and hydraulic conductivity (HC) ranges from 3.9 m/day.

The pH value is 6.96 in the top soil indicating that the soil is Neutral. The overall organic carbon content of this soil unit is 3.18% in the top soil, which indicates high level of organic matter content. Total nitrogen content ranges 0.31% in the top soil which shows very high level status of the total nitrogen. This soil mapping unit has medium available phosphorus (12.20ppm in the top soil), very high CEC level (43.45 Meq/100g of soilin top) and very high base saturation percentage (100% in the top soil. The soils in this mapping unit have very high Ca2+ and are strongly calcareous. The soil units is Chromic, Eutric Cambisols (Aric). The total extent of this mapping unit is 7.89 ha or 5.84%.

5CL-a

This mapping unit refers to soils developed on 15-30 % slope with very deep profile (>200cm). The soils are well drained with fine & medium sub angular blocky structure and have clay loam (CL) texture. The average infiltration rate (IR) of this unit is categorized as optimum (3.5 cm/hr) and hydraulic conductivity (HC) ranges from 3.9 m/day.

The pH value is 7.4 in the top soil and 7.55 in the sub soil indicating that the soil is slightely alkaline. The overall organic carbon content of this soil unit is 3.57% in the top soil and 2.6 % in sub soil, which indicates very high to high level of organic matter content. Total nitrogen content ranges 0.29% in the top and 0.255 % in sub soil which shows high level status of the total nitrogen. This soil mapping unit has low available phosphorus (0.98ppm in the top soil &2.48ppm in the sub soil), very high CEC level (55.90 & 57 Meq/100g of soilin top and sub soil respectively) and very high base saturation percentage (87.14% in the top soil and 87.59% in the sub soil. The soils in this mapping unit have very high Ca2+ and are strongly calcareous. The soil units is Chromic, Eutric Cambisols (Aric). The total extent of this mapping unit is 0.32 ha or 0.23%.

5CL-c

This mapping unit refers to soils developed on 15-30 % slope with very deep profile (100-150cm). The soils are well drained with fine & medium sub angular blocky structure and have clay loam (CL) texture. The average infiltration rate (IR) of this unit is categorized as optimum (3.5 cm/hr) and hydraulic conductivity (HC) ranges from 3.9 m/day.

The pH value is 7.20 in the top soil indicating that the soil is Neutral. The overall organic carbon content of this soil unit is 2.57% in the top soil, which indicates high level of organic matter content. Total nitrogen content ranges 0.20% in the top soil which shows high level status of the total nitrogen. This soil mapping unit has low available phosphorus (1.20ppm in the top soil), high CEC level (25.34 Meq/100g of soilin top) and very high base saturation percentage (83.29% in the top soil. The soils in this mapping unit have very high Ca2+ and are strongly calcareous. The soil units is Chromic, Eutric Cambisols (Aric). The total extent of this mapping unit is 3.1 ha or 2.25%.

5CL-d

This mapping unit refers to soils developed on 15-30 % slope with shallow profile (25-50cm). The soils are well drained with fine & medium sub angular blocky structure and have clay loam (CL) texture. The average infiltration rate (IR) of this unit is categorized as optimum (3.5 cm/hr) and hydraulic conductivity (HC) ranges from 3.9 m/day.

The pH value is 7.15 in the top soil indicating that the soil is Neutral. The overall organic carbon content of this soil unit is 3.10% in the top soil, which indicates high level of organic matter content. Total nitrogen content ranges 0.26% in the top soil which shows high level status of the total nitrogen. This soil mapping unit has medium available phosphorus (8.35ppm in the top soil), high CEC level (38.47 Meq/100g of soilin top) and very high base saturation percentage (100% in the top soil. The soils in this mapping unit have very high Ca2+ and are strongly calcareous. The soil units is Chromic, Eutric Cambisols (Aric). The total extent of this mapping unit is 1.032 ha or 0.76%.

5CL-e

This mapping unit refers to soils developed on 15-30 % slope with shallow profile (25-50cm). The soils are well drained with fine & medium sub angular blocky structure and have clay loam (CL) texture. The average infiltration rate (IR) of this unit is categorized as optimum (3.5 cm/hr) and hydraulic conductivity (HC) ranges from 3.9 m/day.

The pH value is 7.15 in the top soil indicating that the soil is Neutral. The overall organic carbon content of this soil unit is 3.10% in the top soil, which indicates high level of organic matter content. Total nitrogen content ranges 0.26% in the top soil which shows high level status of the total nitrogen. This soil mapping unit has medium available phosphorus (8.35ppm in the top soil), high CEC level (38.47 Meq/100g of soilin top) and very high base saturation percentage (100% in the top soil. The soils in this mapping unit have very high Ca2+ and are strongly calcareous. The soil units is Chromic, Eutric Cambisols (Aric). The total extent of this mapping unit is 4.27 ha or3.13%.

5L-e

This mapping unit refers to soils developed on 15-30 % slope with shallow profile (25-50cm). The soils are well drained with fine & medium sub angular blocky structure and have loam (L) texture. The average infiltration rate (IR) of this unit is categorized as optimum (3.5 cm/hr) and hydraulic conductivity (HC) ranges from 3.9 m/day.

The pH value is 7.10 in the top soil indicating that the soil is Neutral. The overall organic carbon content of this soil unit is 3.57% in the top soil, which indicates high level of organic matter content. Total nitrogen content ranges 0.28% in the top soil which shows high level status of the total nitrogen. This soil mapping unit has low available phosphorus (3.52ppm in the top soil), high CEC level (30.88 Meq/100g of soilin top) and very high base saturation percentage (86.43% in the top soil. The soils in this mapping unit have very high Ca2+ and are strongly calcareous. The soil units is Chromic, Eutric Cambisols (Aric). The total extent of this mapping unit is 1.91 ha or 1.40%.

8. LAND EVALUATION

8.1. 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, Firi Kebso small scale irrigation project, is one of the selected area for the irrigation developements study. This project area is one of the most important potential areas for all developmental activities, especially for crop development.

8.2. 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.

8.3. 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.

8.4. 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

8.5. 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 13: *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

Class	Designation	Definition
		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.

8.6. 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 study area dominantely occurring on gentle slope to strongly sloping and the soils are clay, clayloam and Loam in texture and prone to water logging (for clay soil). Thus the land is Moderately to marginally suitable (65.99ha or 38.14%) for surface irrigation. See Table below

Table 14: Land use requirement and critical class limits for surface irrigation

S/N	*Limiting factors*	*Suitability Classes*				
		S1	*S2*	*S3*	*N1*	*N2*
1	*Slopes (%)*	*0 - 3*	*3-5*	*5-8*	*-*	*>8*
2	*Drainage*	*W*	*MW*	*I*	*P&E*	*VP*
3	*Depth (cm)*	*>200*	*120-200*	*60-120*	*30-60*	*<30*
4	*Soil texture*	*SL-CL*	*SL-C*	*LS & HC*	*S*	*VCS*
5	*Structure*	*SAB*	*SAB*	*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*	*1-3*	*<1*	*<1*	*-*
10	*Total N (%)*	*>0.5*	*0.2-0.5*	*0.1-0.2*	*-*	*<0.1*
11	*Av. P (ppm)*	*>15*	*5-15*	*<5*	*-*	*<2*
12	*C/N*	*10-12*	*6-10*	*<6*	*<6*	*-*
13	*PH*	*5.5-7*	*5-5.5 & 7-8*	*4.5-5 & 8-8.5*	*8.5-9*	*<4.5 &>9*
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*

8.7. 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, market availability, 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 landsand small scale Irrigation 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 vegetable cultivation (Sweet Potato, Tomato, Pepper and Onion)
2. Irrigated Low land maize 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 15: 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 &small-scale Irrigation 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 16 : Lowland Maize (*Zea Mays*)- Crop Environmental Requirements

Landuse Requirements for surface Irrigated Maize cultivation								
Land quality/diag.factors	Subclass	Land characteristices	unit	S1	S2	S3	S4	N
climate(cl)	c	Mean air temperature	oc	18-30	16-18/32-35	14-16/35-40		<14>40
Moisture availability(m)	m1	AWC	mm/m	>180	120-180	60-120		<60
	m2	Infiltration rate	cm/hr	0.7-3.5	0.3-0.7/3.5-6.5	0.1-0.3/6.5-12.5		<0.1>12.5
	m3	Hydraulic conductivity	m/day	1.4-3	0.5-1.4	0.2-0.5		<0.2>3
Oxygen availability(d)	d	drainage	class	wd/mwd	ID	Poor &aeric	poor &drainable	poor & not drainable
Nutrient retantion(n)	n1	Organic carbon	%	>0.8	0.5-0.8	<0.5		
	n2	CEC	meq/100g soil	>16	13-16	<13		
	n3	AVP	ppm	>15	8-15	4-8	<4	
Nutient Availability(z)	z	Soil reaction		6-7.6	5.6-6/7.6-8	5.5-5.6/8-8.2		<5.5>8.2
Rooting condition(rl)	r	Effective soil depth	cm	>75	50-75	20-50		<20
Workability(w)	w	Texture	class	c<60/cl/scl/sil/sicl/sic/sc/L	c>60v/sl/ls	fs/s/Lcs/cS		Cm/SiCm
Potential for mechanization(k)	k	slope	%	0-8	8-15	15-30		>30
Land preparation(t)	t	vegitation clearance	cover/ha	open	light	medium	dense	dense
		stone/Rocks		<15	15-35			>35
Flood hazard(f)	f	Flooding		FO		F1		F2+
Erosion Hazared(e)	e	sheet	class	no	slight	moderate		strong
		Gully	class	none	none	slight	moderate	strong

Table 17 : Onion (***Allium Cepa)***-Crop Environmental Requirements

Landuse Requirements for surface Irrigated Onion cultivation								
Land quality/diag.factors	Subclass	Land characteristices	unit	S1	S2	S3	S4	N
climate(cl)	c	Mean air temperature	oc	16-22	13-16/22-323	10-13/23-25		<10>25
Moisture availability(m)	m1	AWC	mm/m	>180	120-180	60-120		<60
	m2	Infiltration rate	cm/hr	0.7-3.5	0.3-0.7/3.5-6.5	0.1-0.3/6.5-12.5		<0.1>12.5
	m3	Hydraulic conductivity	m/day	1.4-3	0.5-1.4	0.2-0.5		<0.2>3
Oxygen availability(d)	d	drainage	class	wd/mwd	ID	Poor &aeric	poor &drainable	poor & not drainable
Nutrient retantion(n)	n1	Organic carbon	%	>1.2/1.2-2	0.8-1.2	<0.8		
	n2	CEC	meq/100g soil	>24/16-24	<16(-)	<16(+)		
	n3	AVP	ppm	>8	4-8	<4		
Nutient Availability(z)	z	Soil reaction		6-7.8	5.8-6/7.8-8	5.5-5.8/8-8.2	<5.5	>8.2
Rooting condition(r1)	r	Effective soil depth	cm	>75	50-75	20-50		<20
Workability(w)	w	Texture	class	c<60/cl/scl/sil/sicl/sic/sc/SL/L	c>60v/ls/C<60	C>60/fs/s/Lcs/cS		Cm/SiCm
Potential for mechanization(k)	k	slope	%	0-8	8-15	15-30		>30
Land preparation(t)	t	vegitation clearance	cover/ha	open	light	medium	dense	dense
		stone/Rocks		<15	15-35			>35
Flood hazard(f)	f	Flooding		FO		F1		F2+
Erosion Hazared(e)	e	sheet	class	no	slight	moderate		strong
		Gully	class	none	none	slight	moderate	strong
		Caco3	%	0-5	5-10	10-20		>20

Table 18 : Tomato (Lycopersicum esculentum)-Crop Environmental Requirements

Landuse Requirements for surface Irrigated Tomato cultivation								
Land quality/diag.factors	**Subclass**	**Land characteristices**	**unit**	**S1**	**S2**	**S3**	**S4**	**N**
climate(cl)	c	Mean air temperature	oc	18-26	16-18/26-30	13-16/30-35		<13>35
Moisture availability(m)	m1	AWC	mm/m	>180	120-180	60-120		<60
	m2	Infiltration rate	cm/hr	0.7-3.5	0.3-0.7/3.5-6.5	0.1-0.3/6.5-12.5		<0.1>12.5
	m3	Hydraulic conductivity	m/day	1.4-3	0.5-1.4	0.2-0.5		<0.2>3
Oxygen availability(d)	d	drainage	class	wd/mwd	ID	Poor &aeric	poor &drainable	poor & not drainable
Nutrient retantion(n)	n1	Organic carbon	%	>1.2/1.2-2	0.8-1.2	<0.8		
	n2	CEC	meq/100g soil	>16	<16(-)	<16(+)		
	n3	AVP	ppm	>15	10-15	4-10	<4	
Nutient Availability(z)	z	Soil reaction		6-6.2/7-7.5	5.5-6/7.5-8	5-5.5/8-8.2		<5>8.2
Rooting condition(r1)	r	Effective soil depth	cm	>100	75-100	50-75		<50
Workability(w)	w	Texture	class	c<60/cl/scl/sil/sicl/sic/sc/SL/L	c>60v/ls/C<60	C>60/fs/s/Lcs/cS		Cm/SiCm
Potential for mechanization(k)	k	slope	%	0-8	8-15	15-30		>30
Land preparation(t)	t	vegitation clearance	cover/ha	open	light	medium	dense	dense
		stone/Rocks		<15	15-35			>35
Flood hazard(f)	f	Flooding		FO		F1		F2+
Erosion Hazared(e)	e	sheet	class	no	slight	moderate		strong
		Gully	class	none	none	slight	moderate	strong

Table 19 : Sweet potato (Ipomoea batatas)-Crop Environmental Requirements

Landuse Requirements for surface Irrigated Sweet potato cultivation								
Land quality/diag.factors	Subclass	Land characteristices	unit	S1	S2	S3	S4	N
climate(cl)	c	Mean air temperature	oc	22-25/25-32	20-22/32-35	16-20/35-40		<16>40
Moisture availability(m)	m1	AWC	mm/m	>180	120-180	60-120		<60
	m2	Infiltration rate	cm/hr	0.7-3.5	0.3-0.7/3.5-6.5	0.1-0.3/6.5-12.5		<0.1>12.5
	m3	Hydraulic conductivity	m/day	1.4-3	0.5-1.4	0.2-0.5		<0.2>3
Oxygen availability(d)	d	drainage	class	wd/mwd	ID	Poor &aeric	poor &drainable	poor & not drainable
Nutrient retantion(n)	n1	Organic carbon	%	>3/2-3	1-2	<1		
	n2	CEC	meq/100g soil	>24/16-24	<16(-)	<16(+)		
Nutient Availability(z)	z	Soil reaction		5.2-6.6/6.6-8.2	4.8-5.2/8.2-8.4	4.5-4.8/8.4-8.5	<4.5	>8.5
Rooting condition(rl)	r	Effective soil depth	cm	>75	50-75	20-50		<20
Workability(w)	w	Texture	class	c<60/cl/scl/sil/sicl/sic/sc	c>60v/sl/ls	fs/s/Lcs/cS		Cm/SiCm
Potential for mechanization(k)	k	slope	%	0-8	8-15	15-30		>30
Land preparation(t)	t	vegitation clearance	cover/ha	open	light	medium	dense	dense
		stone/Rocks		<15	15-35			>35
Flood hazard(f)	f	Flooding		FO		F1		F2+
Erosion Hazared(e)	e	sheet	class	no	slight	moderate		strong
		Gully	class	none	none	slight	moderate	strong

Table 20 : Pepper (capsicum annuum)-Crop Environmental Requirements

Landuse Requirements for surface Irrigated Pepper cultivation								
Land quality/diag.factors	Subclass	Land characteristices	unit	S1	S2	S3	S4	N
climate(cl)	c	Mean air temperature	oc	18-22/22-26	16-18/26-27	14-16/27-28		<14>28
Moisture availability(m)	m1	AWC	mm/m	>180	120-180	60-120		<60
	m2	Infiltration rate	cm/hr	0.7-3.5	0.3-0.7/3.5-6.5	0.1-0.3/6.5-12.5		<0.1>12.5
	m3	Hydraulic conductivity	m/day	1.4-3	0.5-1.4	0.2-0.5		<0.2>3
Oxygen availability(d)	d	drainage	class	wd/mwd	ID	Poor &aeric	poor &drainable	poor & not drainable
Nutrient retantion(n)	n1	Organic carbon	%	>1.5/0.8-1.5	<0.8			
	n2	CEC	meq/100g soil	>24/16-24	<16(-)	<16(+)		
	n3	AVP	ppm	>8	4-8	<4		
Nutient Availability(z)	z	Soil reaction		6-7.6	5.5-6/7.6-8	5.2-5.5/8-8.2	<5.2	>8.2
Rooting condition(rl)	r	Effective soil depth	cm	>75	50-75	20-50		<20
Workability(w)	w	Texture	class	sicl/cl/sl/scl	c>60v/sl/ls/sc	c>60v		Cm/SiCm
Potential for mechanization(k)	k	slope	%	0-8	8-15	15-30		>30
Land preparation(t)	t	vegitation clearance	cover/ha	open	light	medium	dense	dense
		stone/Rocks		<15	15-35			>35
Flood hazard(f)	f	Flooding		FO		F1		F2+
Erosion Hazared(e)	e	sheet	class	no	slight	moderate		strong
		Gully	class	none	none	slight	moderate	strong

8.8. Land Characteristics (LCs) and Land 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 : 21 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 22. These survey data were used for matching of land qualities and land characteristic with land use requirements.

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 has 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.

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 flow 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.

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).

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.

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-t-on uniformity and/or rate of water application in the field.

Slope gradient is the dominant topographic factor that influences irrigation suitability in general. 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 slopes (FAO, 1979).

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 :

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).

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.

8.9. 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 21: 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 stone 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 22: LQ/LC and symbols assigned to evaluate suitability sub-class and unit.

Land quality	Symbol	Diagnostic factors
Temperature regime	c	Mean growing season temperature (°C)
Water availability	m1	AWC (mm/m)
	m2	IR (cm/hr
	m3	HC (m/day)
Nutrient retantion	n1	Organic carbon(%)
	n2	Cation exchange capacity (CEC) (Cmol+/kg of soil
	n3	Topsoil phosphorus (Olsen, ppm)
	n4	Total Nitrogen(%)
	n5	Organic matter(%)
Nutrient availability	z	soil reaction (pH)
Workability	w	Top soil Texture (class)
Oxygen availability	d	Land units having soil drainage deficiencies,
Rooting conditions and workability	r1	Effective soil depth (cm)
	r2	Top soil texture (class)
Mechanization Potential	k1	Slope angle (per cent)
	k2	stoniness (class)
Erosion hazard	e	Slope steepness (per cent)
Limitations /Toxicities	i1	salinity (mmhos/cm)
	i2	Alkalinity(ESP)

Table 23: Summarized Land Quality and Characteristics of the SMU

SMU	Major_soil	Area	Temprature	Drainage	Flooding	Erosion	Slope	Depth	Texture	IR_Rep1	IR_Rep2	Ave_IR	Rank_IR	MIR_R1	MIR_R2	Ave_MIR	Rank_M_IR	HC_Rep1	HC_Rep2	Ave_HC	Ranking_HC	Bd	FC	PWP
	Type		oc	class	class	class	%	cm	class	cm/hr	cm/hr	cm/hr	cm/hr	cm/hr	cm/hr	cm/hr	cm/hr	m/day	m/day	m/day	m/day	g/cm3	%	%
1CL_a	CM(aric)cr,eu	2.82	21.16	W	N	N	0_2	>200	Clay loam	3.00	4.00	3.50	Suitable	12.20	12.80	12.50	Marginally	2.75	2.40	2.58	Rapid	1.37	38.40	22.60
1CL_c	CM(aric)cr,eu	2.17	21.16	W	N	N	0_2	100_150	Clay loam	3.00	4.00	3.50	Suitable	12.20	12.80	12.50	Marginally	2.75	2.40	2.58	Rapid	1.37	38.40	22.60
1CL_d	CM(aric)cr,eu	4.80	21.16	W	N	N	0_2	50_100	Clay loam	3.00	4.00	3.50	Suitable	12.20	12.80	12.50	Marginally	2.75	2.40	2.58	Rapid	1.37	38.40	22.60
2CL_a	CM(aric)cr,eu	1.39	21.16	W	N	N	2_5	>200	Clay loam	3.00	4.00	3.50	Suitable	12.20	12.80	12.50	Marginally	2.75	2.40	2.58	Rapid	1.37	38.40	22.60
2CL_a(f)	FL(Aric),eu	0.91	21.16	W	N	N	2_5	>200	Clay loam	3.00	4.00	3.50	Suitable	12.20	12.80	12.50	Marginally	2.75	2.40	2.58	Rapid	1.37	38.40	22.60
2CL_c	CM(aric)cr,eu	4.68	21.16	W	N	N	2_5	100_150	Clay loam	3.00	4.00	3.50	Suitable	12.20	12.80	12.50	Marginally	2.75	2.40	2.58	Rapid	1.37	38.40	22.60
2CL_c(f)	FL(Aric),eu	6.74	21.16	W	N	N	2_5	100_150	Clay loam	3.00	4.00	3.50	Suitable	12.20	12.80	12.50	Marginally	2.75	2.40	2.58	Rapid	1.37	38.40	22.60
2CL_d	CM(aric)cr,eu	16.90	21.16	W	N	N	2_5	50_100	Clay loam	3.00	4.00	3.50	Suitable	12.20	12.80	12.50	Marginally	2.75	2.40	2.58	Rapid	1.37	38.40	22.60
2CL_e	CM(aric)cr,eu	5.07	21.16	W	N	N	2_5	25_50	Clay loam	3.00	4.00	3.50	Suitable	12.20	12.80	12.50	Marginally	2.75	2.40	2.58	Rapid	1.37	38.40	22.60
2L_e	CM(aric)cr,eu	2.05	21.16	W	N	N	2_5	25_50	Loam	3.00	4.00	3.50	Suitable	12.20	12.80	12.50	Marginally	2.75	2.40	2.58	Rapid	1.37	38.40	22.60
3C_e	CM(aric)cr,eu	5.25	21.16	W	N	N	5_8	25_50	Clay	3.00	4.00	3.50	Suitable	12.20	12.80	12.50	Marginally	2.75	2.40	2.58	Rapid	1.37	38.40	22.60
3CL_a	CM(aric)cr,eu	2.49	21.16	W	N	N	5_8	>200	Clay loam	3.00	4.00	3.50	Suitable	12.20	12.80	12.50	Marginally	2.75	2.40	2.58	Rapid	1.37	38.40	22.60
3CL_a(f)	FL(Aric),eu	3.41	21.16	W	N	N	5_8	>200	Clay loam	3.00	4.00	3.50	Suitable	12.20	12.80	12.50	Marginally	2.75	2.40	2.58	Rapid	1.37	38.40	22.60
3CL_c	CM(aric)cr,eu	6.35	21.16	W	N	N	5_8	100_150	Clay loam	3.00	4.00	3.50	Suitable	12.20	12.80	12.50	Marginally	2.75	2.40	2.58	Rapid	1.37	38.40	22.60
3CL_c(f)	FL(Aric),eu	7.66	21.16	W	N	N	5_8	100_150	Clay loam	3.00	4.00	3.50	Suitable	12.20	12.80	12.50	Marginally	2.75	2.40	2.58	Rapid	1.37	38.40	22.60

Cont'd

SMU	AWC	TAWC	RAWC	TAWC	PH	EC	ECe	PH	Na	K	Ca	Mg	SUM	CEC	BS	ESP	TN	OC	OM	C:N	AvK	AvP	P2O5	CaCO3	CaCO3	Ca:Mg	K:Mg	K:CEC	Ca+mg/k	T_porosity	Airf_porosity
	mm	mm/m	mm/m	Rating	H2O	ds/m	ds/m	Kcl	Cmol/kgm						%	%	%	%	%	ratio	ppm	ppm	%	%	gm/kg	ratio	ratio	ratio	ratio	%	%
1CL_a	64.94	131.74	87.82	Moderate	7.40	0.22	1.93	6.90	0.15	0.72	37.26	10.58	48.71	55.90	87.14	0.27	0.29	3.57	6.16	12.32	281.70	0.98	2.24	25.92	259.20	3.52	0.07	0.01	51.93	48.36	9.96
1CL_c	64.94	131.74	87.82	Moderate	7.50	0.24	2.10	7.00	0.16	0.54	37.14	7.89	45.72	51.84	88.20	0.30	0.27	3.40	5.86	12.59	211.80	0.74	1.69	32.64	326.40	4.71	0.07	0.01	51.84	48.36	9.96
1CL_d	64.94	131.74	87.82	Moderate	7.60	0.28	2.40	7.00	0.19	0.54	41.55	11.79	54.07	62.16	86.99	0.31	0.24	3.28	5.65	13.67	210.60	4.22	9.66	36.48	364.80	3.53	0.05	0.01	63.57	48.36	9.96
2CL_a	64.94	131.74	87.82	Moderate	7.40	0.22	1.93	6.90	0.15	0.72	37.26	10.58	48.71	55.90	87.14	0.27	0.29	3.57	6.16	12.32	281.70	0.98	2.24	25.92	259.20	3.52	0.07	0.01	51.93	48.36	9.96
2CL_a(f)	64.94	131.74	87.82	Moderate	7.40	0.22	1.93	6.90	0.15	0.72	37.26	10.58	48.71	55.90	87.14	0.27	0.29	3.57	6.16	12.32	281.70	0.98	2.24	25.92	259.20	3.52	0.07	0.01	51.93	48.36	9.96
2CL_c	64.94	131.74	87.82	Moderate	7.40	0.22	1.93	6.90	0.15	0.72	37.26	10.58	48.71	55.90	87.14	0.27	0.29	3.57	6.16	12.32	281.70	0.98	2.24	25.92	259.20	3.52	0.07	0.01	51.93	48.36	9.96
2CL_c(f)	64.94	131.74	87.82	Moderate	7.40	0.22	1.93	6.90	0.15	0.72	37.26	10.58	48.71	55.90	87.14	0.27	0.29	3.57	6.16	12.32	281.70	0.98	2.24	25.92	259.20	3.52	0.07	0.01	51.93	48.36	9.96
2CL_d	64.94	131.74	87.82	Moderate	7.50	0.24	2.10	7.00	0.16	0.54	37.14	7.89	45.72	51.84	88.20	0.30	0.27	3.40	5.86	12.59	211.80	0.74	1.69	32.64	326.40	4.71	0.07	0.01	51.84	48.36	9.96
2CL_e	64.94	131.74	87.82	Moderate	7.60	0.28	2.40	7.00	0.19	0.54	41.55	11.79	54.07	62.16	86.99	0.31	0.24	3.28	5.65	13.67	210.60	4.22	9.66	36.48	364.80	3.53	0.05	0.01	63.57	48.36	9.96
2L_e	64.94	131.74	87.82	Moderate	7.40	0.22	2.13	6.90	0.15	0.72	37.26	10.58	48.71	55.90	87.14	0.27	0.29	3.57	6.16	12.32	281.70	0.98	2.24	25.92	259.20	3.52	0.07	0.01	51.93	48.36	9.96
3C_e	64.94	131.74	87.82	Moderate	7.40	0.22	1.68	6.90	0.15	0.72	37.26	10.58	48.71	55.90	87.14	0.27	0.29	3.57	6.16	12.32	281.70	0.98	2.24	25.92	259.20	3.52	0.07	0.01	51.93	48.36	9.96
3CL_a	64.94	131.74	87.82	Moderate	7.30	0.13	1.13	6.80	0.15	0.82	34.98	8.35	44.30	60.58	73.12	0.25	0.29	3.40	5.86	11.72	318.70	0.44	1.01	0.19	1.92	4.19	0.10	0.01	45.17	48.36	9.96
3CL_a(f)	64.94	131.74	87.82	Moderate	7.30	0.13	1.13	6.80	0.15	0.82	34.98	8.35	44.30	60.58	73.12	0.25	0.29	3.40	5.86	11.72	318.70	0.44	1.01	0.19	1.92	4.19	0.10	0.01	45.17	48.36	9.96
3CL_c	64.94	131.74	87.82	Moderate	7.30	0.10	0.84	6.90	0.17	0.60	32.91	6.57	40.25	60.38	66.67	0.28	0.27	3.10	5.34	11.48	233.90	1.16	2.66	0.14	1.44	5.01	0.09	0.01	43.81	48.36	9.96
3CL_c(f)	64.94	131.74	87.82	Moderate	7.30	0.10	0.84	6.90	0.17	0.60	32.91	6.57	40.25	60.38	66.67	0.28	0.27	3.10	5.34	11.48	233.90	1.16	2.66	0.14	1.44	5.01	0.09	0.01	43.81	48.36	9.96

Cont'd

SMU	Major_soil	Area	Temprature	Drainage	Flooding	Erosion	Slope	Depth	Texture	IR_Rep1	IR_Rep2	Ave_IR	Rank_IR	MIR_R1	MIR_R2	Ave_MIR	Rank_M_IR	HC_Rep1	HC_Rep2	Ave_HC	Ranking_HC	Bd	FC	PWP
	Type		oc	class	class	class	%	cm	class	cm/hr	cm/hr	cm/hr	cm/hr	cm/hr	cm/hr	cm/hr	cm/hr	m/day	m/day	m/day	m/day	g/cm3	%	%
3CL_d	CM(aric)cr,eu	5.21	21.16	W	N	N	5_8	50_100	Clay loam	3.00	4.00	3.50	Suitable	12.20	12.80	12.50	Marginally	2.75	2.40	2.58	Rapid	1.37	38.40	22.60
3CL_d	CM(aric)cr,eu	0.46	21.16	W	N	N	5_8	50_100	Clay loam	3.00	4.00	3.50	Suitable	12.20	12.80	12.50	Marginally	2.75	2.40	2.58	Rapid	1.37	38.40	22.60
3L_e	CM(aric)cr,eu	1.14	21.16	W	N	N	5_8	25_50	Loam	3.00	4.00	3.50	Suitable	12.20	12.80	12.50	Marginally	2.75	2.40	2.58	Rapid	1.37	38.40	22.60
4CL_a	CM(aric)cr,eu	3.51	21.16	W	N	S/S	8_15	>200	Clay loam	3.00	4.00	3.50	Suitable	12.20	12.80	12.50	Marginally	2.75	2.40	2.58	Rapid	1.37	38.40	22.60
4CL_c	CM(aric)cr,eu	10.83	21.16	W	N	S/S	8_15	100_150	Clay loam	3.00	4.00	3.50	Suitable	12.20	12.80	12.50	Marginally	2.75	2.40	2.58	Rapid	1.37	38.40	22.60
4CL_c(f)	FL(Aric),eu	5.80	21.16	W	N	S/S	8_15	100_150	Clay loam	3.00	4.00	3.50	Suitable	12.20	12.80	12.50	Marginally	2.75	2.40	2.58	Rapid	1.37	38.40	22.60
4CL_d	CM(aric)cr,eu	5.40	21.16	W	N	S/S	8_15	50_100	Clay loam	3.00	4.00	3.50	Suitable	12.20	12.80	12.50	Marginally	2.75	2.40	2.58	Rapid	1.37	38.40	22.60
4CL_e	CM(aric)cr,eu	12.88	21.16	W	N	S/S	8_15	25_50	Clay loam	3.00	4.00	3.50	Suitable	12.20	12.80	12.50	Marginally	2.75	2.40	2.58	Rapid	1.37	38.40	22.60
4L_e	CM(aric)cr,eu	7.89	21.16	W	N	S/S	8_15	25_50	Loam	3.00	4.00	3.50	Suitable	12.20	12.80	12.50	Marginally	2.75	2.40	2.58	Rapid	1.37	38.40	22.60
5CL_a	CM(aric)cr,eu	0.32	21.16	W	N	S/S	15_30	>200	Clay loam	3.00	4.00	3.50	Suitable	12.20	12.80	12.50	Marginally	2.75	2.40	2.58	Rapid	1.37	38.40	22.60
5CL_c	CM(aric)cr,eu	3.08	21.16	W	N	S/S	15_30	100_150	Clay loam	3.00	4.00	3.50	Suitable	12.20	12.80	12.50	Marginally	2.75	2.40	2.58	Rapid	1.37	38.40	22.60
5CL_d	CM(aric)cr,eu	1.03	21.16	W	N	S/S	15_30	50_100	Clay loam	3.00	4.00	3.50	Suitable	12.20	12.80	12.50	Marginally	2.75	2.40	2.58	Rapid	1.37	38.40	22.60
5CL_e	CM(aric)cr,eu	4.27	21.16	W	N	S/S	15_30	25_50	Clay loam	3.00	4.00	3.50	Suitable	12.20	12.80	12.50	Marginally	2.75	2.40	2.58	Rapid	1.37	38.40	22.60
5L_e	CM(aric)cr,eu	1.91	21.16	W	N	S/S	15_30	25_50	Loam	3.00	4.00	3.50	Suitable	12.20	12.80	12.50	Marginally	2.75	2.40	2.58	Rapid	1.37	38.40	22.60

Cont'd

SMU	AWC	TAWC	RAWC	TAWC	PH	EC	ECe	PH	Na	K	Ca	Mg	SUM	CEC	BS	ESP	TN	OC	OM	C:N	AvK	AvP	P2O5	CaCO3	CaCO3	Ca:Mg	K:Mg	K:CEC	Ca+mg/k	T_porosity	Airf_porosity
	mm	mm/m	mm/m	Rating	H2O	ds/m	ds/m	Kcl	Cmol/kgm						%	%	%	%	%	ratio	ppm	ppm	%	%	gm/kg	ratio	ratio	ratio	ratio	%	%
3CL_d	64.94	131.74	87.82	Moderate	7.20	0.14	1.21	6.90	0.18	0.64	37.30	8.19	46.31	63.24	73.23	0.29	0.25	3.00	5.17	12.00	248.40	1.38	3.16	0.10	0.96	4.55	0.08	0.01	50.07	48.36	9.96
3CL_d	64.94	131.74	87.82	Moderate	7.20	0.14	1.21	6.90	0.18	0.64	37.30	8.19	46.31	63.24	73.23	0.29	0.25	3.00	5.17	12.00	248.40	1.38	3.16	0.10	0.96	4.55	0.08	0.01	50.07	48.36	9.96
3L_e	64.94	131.74	87.82	Moderate	6.80	0.13	1.24	6.00	0.29	1.17	32.14	6.49	40.09	43.08	87.40	0.67	0.23	2.74	4.73	11.93	0.00	9.30	21.30	0.00	0.00	4.95	0.18	0.03	37.69	48.36	9.96
4CL_a	64.94	131.74	87.82	Moderate	7.40	0.22	1.93	6.90	0.15	0.72	37.26	10.58	48.71	55.90	87.14	0.27	0.29	3.57	6.16	12.32	281.70	0.98	2.24	25.92	259.20	3.52	0.07	0.01	51.93	48.36	9.96
4CL_c	64.94	131.74	87.82	Moderate	7.20	0.19	1.63	6.80	0.14	0.30	16.11	4.56	21.11	25.34	83.29	0.56	0.20	2.57	4.43	12.85	89.70	1.20	2.75	0.48	4.80	3.53	0.07	0.01	31.30	48.36	9.96
4CL_c(f)	64.94	131.74	87.82	Moderate	7.20	0.19	1.63	6.80	0.14	0.30	16.11	4.56	21.11	25.34	83.29	0.56	0.20	2.57	4.43	12.85	89.70	1.20	2.75	0.48	4.80	3.53	0.07	0.01	31.30	48.36	9.96
4CL_d	64.94	131.74	87.82	Moderate	6.96	0.17	1.62	6.70	0.83	1.21	44.30	32.90	79.24	43.45	100.0	1.91	0.31	3.18	5.49	10.27	233.80	12.20	27.94	50.21	502.08	1.35	0.04	0.03	71.49	48.36	9.96
4CL_e	64.94	131.74	87.82	Moderate	7.20	0.19	1.63	6.80	0.14	0.30	16.11	4.56	21.11	25.34	83.29	0.56	0.20	2.57	4.43	12.85	89.70	1.20	2.75	0.48	4.80	3.53	0.07	0.01	31.30	48.36	9.96
4L_e	64.94	131.74	87.82	Moderate	6.96	0.17	1.62	6.70	0.83	1.21	44.30	32.90	79.24	43.45	100.0	1.91	0.31	3.18	5.49	10.27	233.80	12.20	27.94	50.21	502.08	1.35	0.04	0.03	71.49	48.36	9.96
5CL_a	64.94	131.74	87.82	Moderate	7.40	0.22	1.93	6.90	0.15	0.72	37.26	10.58	48.71	55.90	87.14	0.27	0.29	3.57	6.16	12.32	281.70	0.98	2.24	25.92	259.20	3.52	0.07	0.01	51.93	48.36	9.96
5CL_c	64.94	131.74	87.82	Moderate	7.20	0.19	1.63	6.80	0.14	0.30	16.11	4.56	21.11	25.34	83.29	0.56	0.20	2.57	4.43	12.85	89.70	1.20	2.75	0.48	4.80	3.53	0.07	0.01	31.30	48.36	9.96
5CL_d	64.94	131.74	87.82	Moderate	7.15	0.17	1.46	6.35	0.50	0.61	30.60	17.20	48.91	38.47	100.0	1.30	0.26	3.10	5.35	11.94	0.00	8.35	0.00	0.00	0.00	1.78	0.04	0.02	58.80	48.36	9.96
5CL_e	64.94	131.74	87.82	Moderate	7.15	0.17	1.46	6.35	0.50	0.61	30.60	17.20	48.91	38.47	100.0	1.30	0.26	3.10	5.35	11.94	0.00	8.35	0.00	0.00	0.00	1.78	0.04	0.02	58.80	48.36	9.96
5L_e	64.94	131.74	87.82	Moderate	7.10	0.19	1.81	6.70	0.14	0.60	21.33	4.62	26.69	30.88	86.43	0.46	0.28	3.57	6.16	12.75	233.80	3.52	8.06	50.21	502.08	4.61	0.13	0.02	29.02	48.36	9.96

8.10. Results of Land Suitability Evaluation for Surface Irrigation

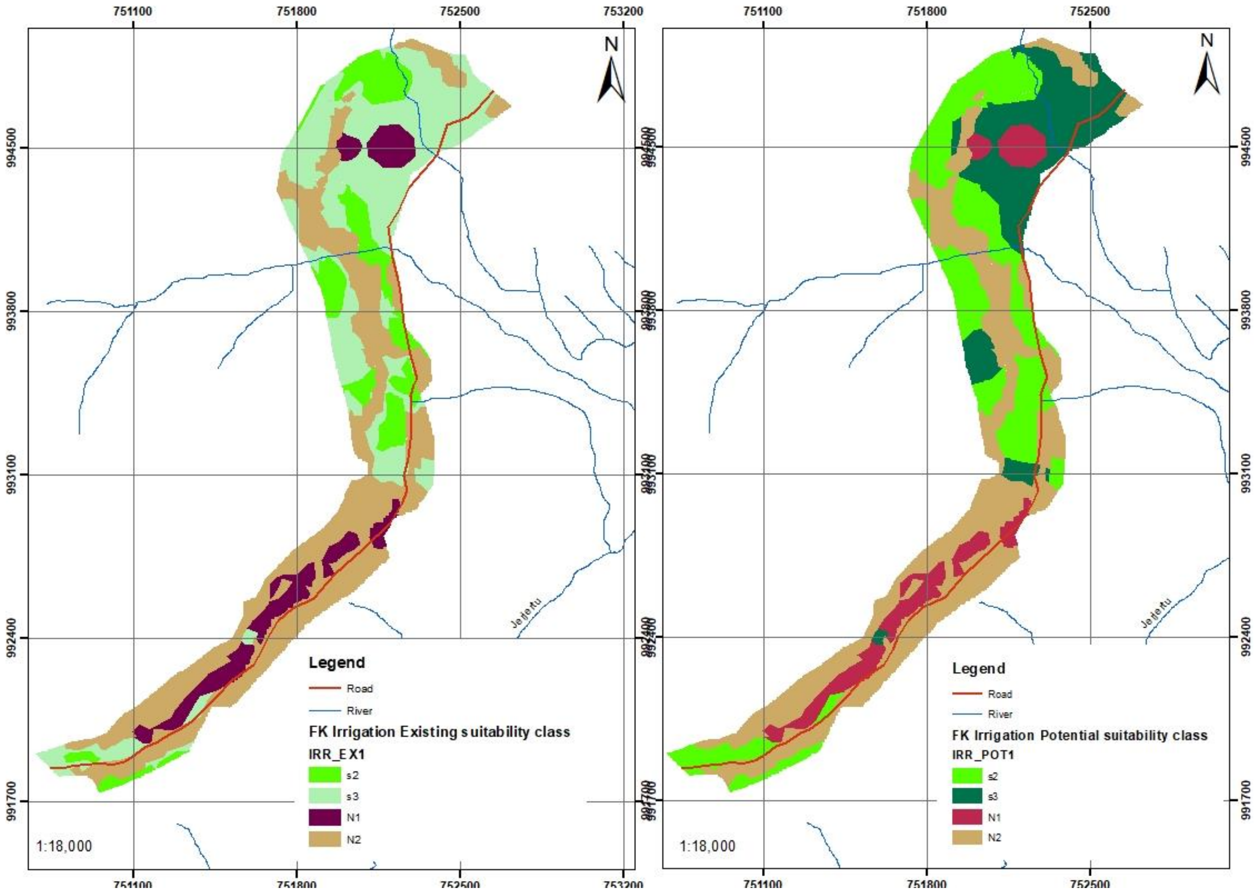
8.10.1. Existing Suitability for Surface Irrigation

The results of the suitability evaluation of the project area for surface irrigation are shown in Tables 24. The result indicates that a total of **18.71** ha of land is found to be moderately suitable for surface irrigation. An area amounting to **47.28** ha is found to be marginally suitable for surface irrigation development and some 13.51 ha of land currentely not suitable and 56.93 ha of land is permanentely not suitable for surface irrigation development. The areas identified as permanentely not suitable for surface irrigation are constrained by slope. The area identified as marginally suitable for surface irrigation is constrained by slope, and depth. The area identified as moderately suitable for surface irrigation is primarily constrained by TN, AWC, PH depth and slope, of the study area, As a result, the suitability level of the moderately suitable area can be improved by application of good quality of water, Integrated nutrent management, application of compost, manure and proper land preparation. The marginally suitable areas require careful land management, application of good quality of water and teracing like bunch terace, this improve the suitability level to moderately suitable.

Table 24: Existing Surface Irrigation Suitability by Area

Irrigation existing suitability				
S/N	Suitability class	Suitability	Area	%
1	S1	Highly suitable		
2	S2	Moderately suitable	18.7	10.8
3	S3	Marginally suitable	47.3	27.3
4	N1	Very marginally suitable	13.5	7.8
5	N2	Not suitable	56.9	32.9
			136.4	78.8

Figure 4: Existing and Potential Surface Irrigation Suitability Map



8.10.2. Potential Suitability for Surface Irrigation

The results of the potential suitability evaluation of the project area for surface irrigation are shown in Tables 25. The result indicates that a total of **38.6 ha** of land is found to be moderately suitable for surface irrigation development and some **27.4 ha** of land is marginally suitable for surface irrigation development. The areas identified as moderately and marginally suitable for surface irrigation are constrained by soil PH, soil depth an AWC. The total of 70.4 ha of land found to be currentely and permanentely not suitable and limited by slope ansd soil depth.

Table 25 : Potential Surface Irrigation Suitability by Area

Irrigation Potential suitability				
S/N	Suitability class	Suitability	Area	%
1	S1	Highly suitable		
2	S2	Moderately suitable	38.6	22.3
3	S3	Marginally suitable	27.4	15.8
4	N1	Very marginally suitable	13.5	7.8
5	N2	Not suitable	56.9	32.9
			136.4	78.8

Table 26: Results of Existing and Potential Land Suitability Evaluation for surface Irrigation by SMU

SMU	Area	Existing sub class	Existing suitability	Class	Limitation	Potential sub classsuitability	Potential suitability	class	Limitation
1CL_a	2.82	s2n4mlz	s2	Moderately suitable	TN.AWC,PH	s2mlz	s2	Moderately suitable	AWC,PH
1CL_c	2.17	s2n4mlrlz	s2	Moderately suitable	TN.AWC, depth,PH	s2mlrlz	s2	Moderately suitable	AWC,depth,PH
1CL_d	4.80	s3rl	s3	Marginaly suitable	depth	s3rl	s3	Moderately suitable	depth
2CL_a	1.39	s2n4mlkz	s2	Moderately suitable	TN.AWC, slope,PH	s2mlz	s2	Moderately suitable	AWC,depth
2CL_a(f)	0.91	s2n4mlkz	s2	Moderately suitable	TN.AWC, slope,PH	s2mlz	s2	Moderately suitable	AWC,depth,PH
2CL_c	4.68	s2n4mlkrlz	s2	Moderately suitable	TN.AWC, slope,depth,PH	s2mlrlz	s2	Moderately suitable	AWC,depth,PH
2CL_c(f)	6.74	s2n4mlkrlz	s2	Moderately suitable	TN.AWC, slope,depth,PH	s2mlrlz	s2	Moderately suitable	AWC,depth,PH
2CL_d	16.90	s3rl	s3	Marginaly suitable	depth	s3rl	s3	Marginaly suitable	depth
2CL_e	5.07	N1rl	N1	currentely not suitable	depth	N1rl	N1	currentely not suitable	depth
2L_e	2.05	N1rl	N1	currentely not suitable	depth	N1rl	N1	currentely not suitable	depth
3C_e	5.25	N1rl	N1	currentely not suitable	depth	N1rl	N1	currentely not suitable	depth
3CL_a	2.49	s3k	s3	Marginaly suitable	slope	s2mlz	s2	Moderately suitable	AWC,PH
3CL_a(f)	3.41	s3k	s3	Marginaly suitable	slope	s2mlz	s2	Moderately suitable	AWC,PH
3CL_c	6.35	s3k	s3	Marginaly suitable	slope	s2mlz	s2	Moderately suitable	AWC,PH
3CL_c(f)	7.66	s3k	s3	Marginaly suitable	slope	s2mlz	s2	Moderately suitable	AWC,PH
3CL_d	5.21	s3krl	s3	Marginaly suitable	slope,depth	s3rl	s3	Marginaly suitable	depth
3CL_d	0.46	s3krl	s3	Marginaly suitable	slope,depth	s3rl	s3	Marginaly suitable	depth
3L_e	1.14	N1rl	N1	currentely not suitable	depth	N1rl	N1	currentely not suitable	depth
4CL_a	3.51	N2k	N2	Permanentely not suitable	slope	N2k	N2	Permanentely not suitable	slope
4CL_c	10.83	N2k	N2	Permanentely not suitable	slope	N2k	N2	Permanentely not suitable	slope

Cont'd

SMU	Area	Existing sub class	Existing suitability	Class	Limitation	Potential sub classsuitability	Potential suitability	class	Limitation
4CL_c(f)	5.80	N2k	N2	Permanentely not suitable	slope	N2k	N2	Permanentely not suitable	slope
4CL_d	5.40	N2k	N2	Permanentely not suitable	slope	N2k	N2	Permanentely not suitable	slope
4CL_e	12.88	N2k	N2	Permanentely not suitable	slope	N2k	N2	Permanentely not suitable	slope
4L_e	7.89	N2k	N2	Permanentely not suitable	slope	N2k	N2	Permanentely not suitable	slope
5CL_a	0.32	N2k	N2	Permanentely not suitable	slope	N2k	N2	Permanentely not suitable	slope
5CL_c	3.08	N2k	N2	Permanentely not suitable	slope	N2k	N2	Permanentely not suitable	slope
5CL_d	1.03	N2k	N2	Permanentely not suitable	slope	N2k	N2	Permanentely not suitable	slope
5CL_e	4.27	N2k	N2	Permanentely not suitable	slope	N2k	N2	Permanentely not suitable	slope
5L_e	1.91	N2k	N2	Permanentely not suitable	slope	N2k	N2	Permanentely not suitable	slope

8.11. 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, Tomato, Onion, Pepper, and sweetpotato. The results of the crop suitability evaluation are shown in Table 27 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.

8.11.1. Existing Crop Suitabilty Evaluation

The result indicated that some 30.83 ha of land is found to be moderately siutable,26.11ha marginally suitable for low land maize cultivation by surface irrigation.For pepper 36.18 ha and 100.26 ha of land is moderately suitable and marginally suitable respectively.Some 44.02ha moderately suitable,26.11 ha marginally suitable and 66.31 ha of land very marginally suitable for Tomato.where as for onion and sweet potato 10.20 ha moderately suitable and 126.23 ha marginally suitable The dominant suitability subclass for onion, pepper and sweet potato is marginally suitable,while for lowland maize and tomato is very marginally suitable. The major limitations that downgraded the suitability level of the area to very marginally suitability subclass are low level of AVP, where as for marginally suitable subclass high slope (15-30%), low AVP and shallow soil depth. This indicates that with increasing the level of management practices to correct the limitations, the suitability and expected crop yield could be increased.

Table 27 : Existing Crop Suitability by Area for Surface Irrigation

Existing crop suitability by area for Surface Irrigation					
Crop	s1	s2	s3	s4	N
	Highly suitable	Moderately suitable	Marginally suitable	Very marginally suitable	Not suitable
	Area,ha	Area,ha	Area,ha	Area,ha	Area,ha
Lowland Maize		38.18	26.11	79.49	
Tomato		44.02	26.11	66.31	
Onion		10.2	126.23		
Pepper		36.18	100.26		
Sweet potato		10.2	126.23		

From the above table: 27 by existing condition the command area is primerly/ranking best/moderately suitable for Tomato (44.02ha of land), and following for pepper (36.18 ha), low land maize (30.83), and for onion and sweet potato is about (10.20ha)

Table 28: Existing Crop Suitability by subclass and Area for surface Irrigation

Crops	Existing suitabiity sub class comparing with crops for surface Irrigation									
Low land maize	Existing subclass	s2m1n3r1k	s3k	s3n3	s3n3r1	s3n3r1k	s3r1	s3r1k	s4n3	
	Area,ha	5.4	1.03	4.798	5.07	1.911	9.03	4.27	104.92	
Tomato	Existing subclass	s2m1n3	s3n3	s3n3k	s3n3r1	s3n3r1k	s3r1	s4n3		
	Area,ha	5.4	4.798	1.032	6.21	6.18	7.89	104.92		
Onion	Existing subclass	s2m1n3r1	s2m1r1k	s3k	s3n3	s3n3k	s3n3r1	s3r1	s3r1k	
	Area,ha	4.798	5.4	1.032	81.32	3.4	22.1	14.099	4.27	
Pepper	Existing subclass	s2m1k	s2m1n3	s3k	s3n3	s3n3k	s3n3r1	s3r1	s3r1k	
	Area,ha	5.4	4.798	1.032	81.33	3.4	20.19	14.099	6.18	
Sweet potato	Existing subclass	s2c1m1n3r1	s2c1m1r1k	s3k	s3n3	s3n3k	s3n3r1	s3n3r1k	s3r1	s3r1k
	Area,ha	4.798	5.4	1.032	81.33	3.4	20.19	1.911	14.099	4.27

8.11.2. Potential Crop Suitabilty Evaluation

The result indicated Table : 29 below with tha applicatin of good quality of irrigation water and integrated neutrient management the large part of the command area will be improved to a highly suitable land for intended crop production.

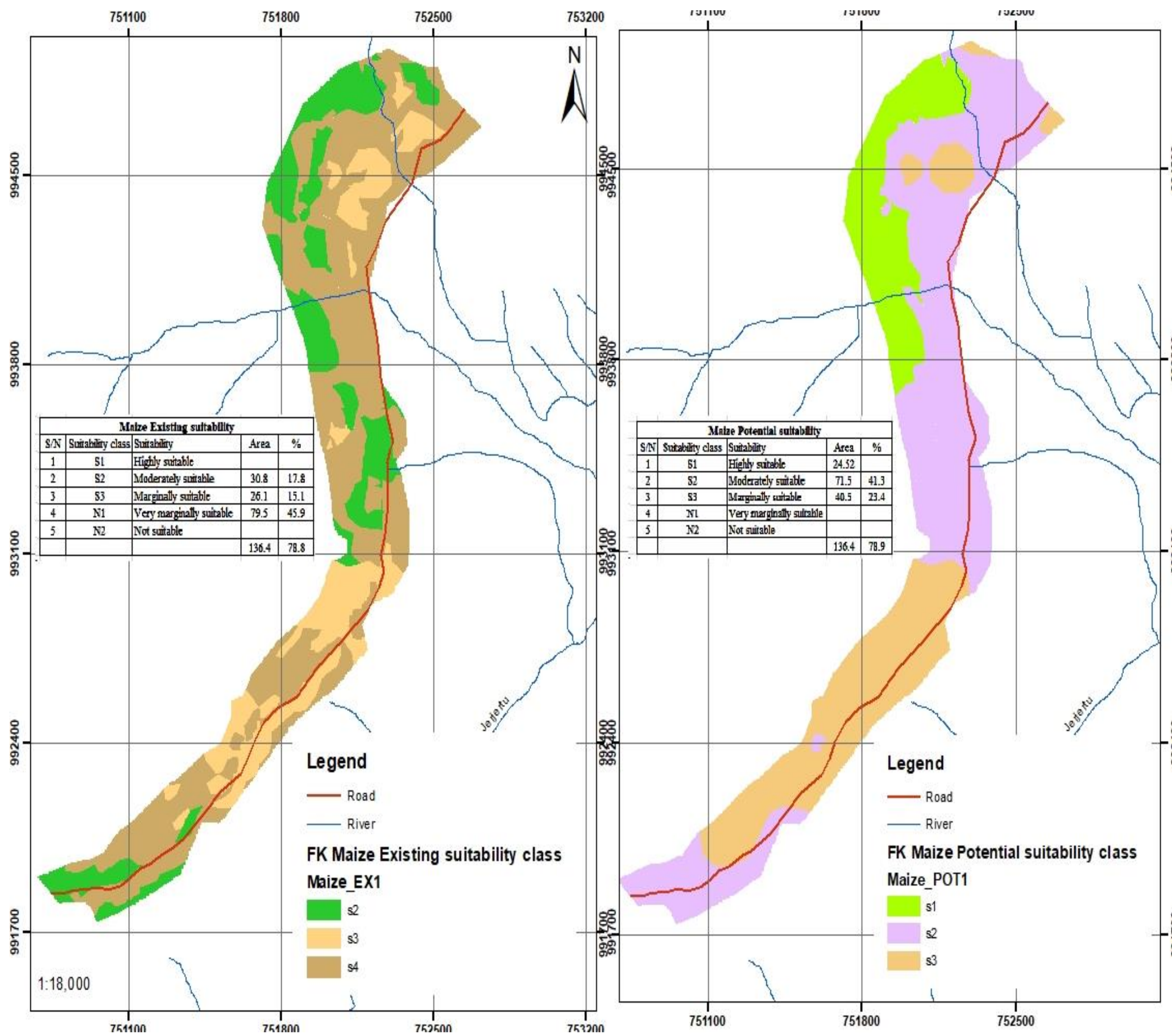
Cereal crop

- **Maize potential suitability**

Potential land suitability for the crop maize can be grouped into three classes. These include the marginally suitable lands, moderately suitable lands and highly suitable lands (Table 29 &30). Land units listed under the suitability sub class s3r1 (Table 29,30 and 32) are classified as the Marginally suitable land for maize crops production due to the soil depth the study area (Table 32). The area of these land units is also 40.47 ha. On the other hand, those land units listed under the suitability sub classes s2m1 and s2m1r1 are grouped under the moderately suitable lands. They are moderately limited by some chemical and physical properties of the soil like soil AWC and soil depth. The area coverage of these moderately suitable lands are 37.61 ha and 33.89 ha respectively. On the other hand, those land units listed under the suitability sub classes s1 is grouped under the Highly suitable lands. The area coverage of this highly suitable lands is 24.52ha

Maize Potential suitability				
S/N	Suitability class	Suitability	Area	%
1	S1	Highly suitable	24.52	
2	S2	Moderately suitable	71.5	41.3
3	S3	Marginally suitable	40.5	23.4
4	N1	Very marginally suitable		
5	N2	Not suitable		
			136.4	78.9

Figure 5: Maize Existing and Potential Suitability Map



Vegitable crops

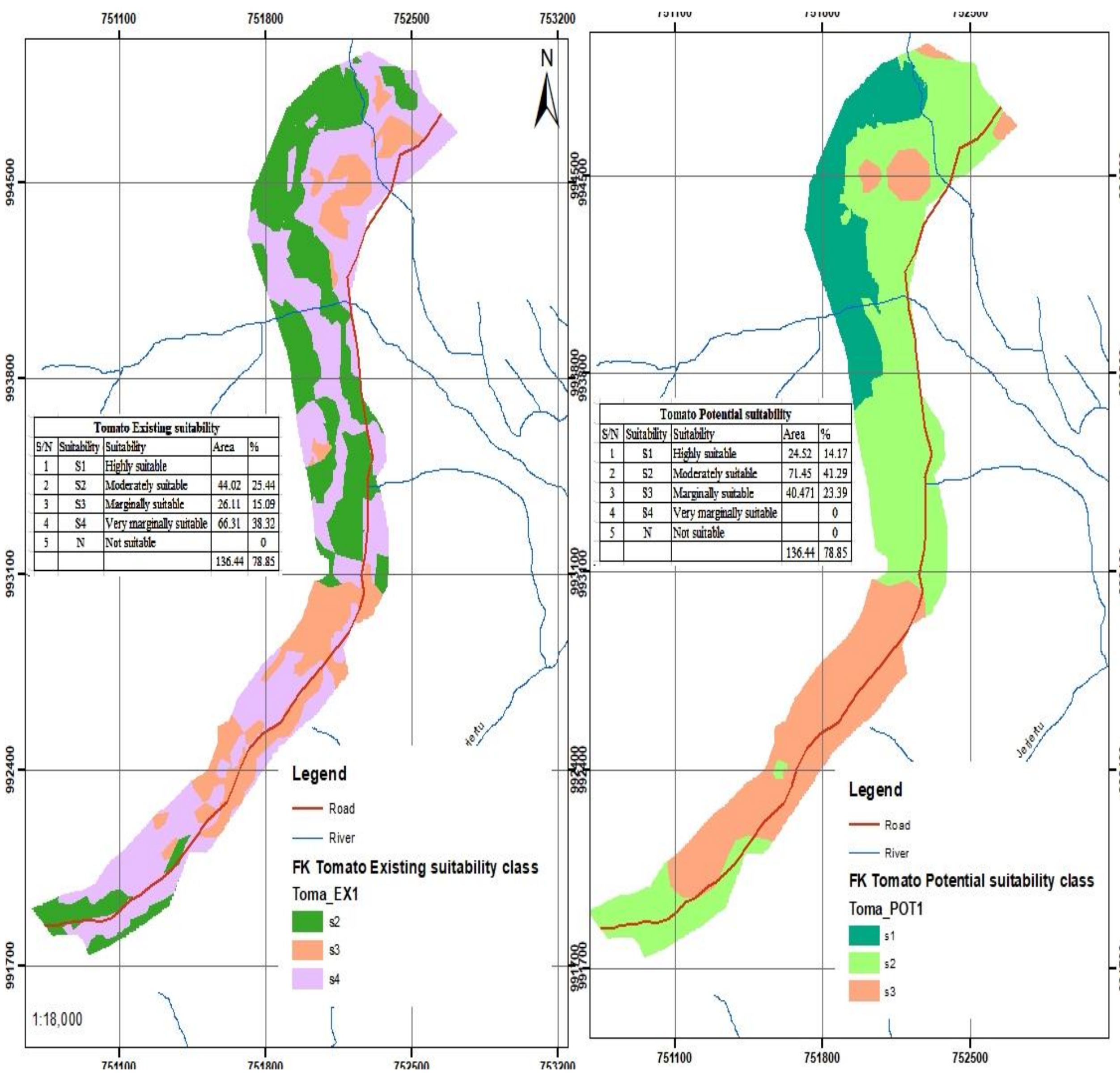
- **Tomato**

Potential land suitability for the crop tomato can be grouped into three classes. These include the marginally suitable lands, moderately suitable lands and highly suitable lands (Table 29 &30). Land units listed under the suitability sub class s3r1(Table 29,30 and 32) are classified as the

Marginally suitable land for tomato crops production due to the soil depth the study area (Table 32). The area of these land units is also 40.47 ha. On the other hand, those land units listed under the suitability sub classes s2m1 and s2m1r1 are grouped under the moderately suitable lands. They are moderately limited by some chemical and physical properties of the soil like soil AWC and soil depth. The area coverage of these moderately suitable lands are 37.61 ha and 33.89 ha respectively. On the other hand, those land units listed under the suitability sub classes s1 is grouped under the Highly suitable lands. The area coverage of this highly suitable lands is 24.52ha

Tomato Potential suitability				
S/N	Suitability	Suitability	Area	%
1	S1	Highly suitable	24.52	14.17
2	S2	Moderately suitable	71.45	41.29
3	S3	Marginally suitable	40.471	23.39
4	S4	Very marginally suitable		0
5	N	Not suitable		0
			136.44	78.85

Figure 6: Tomato Existing and Potential Suitability Map

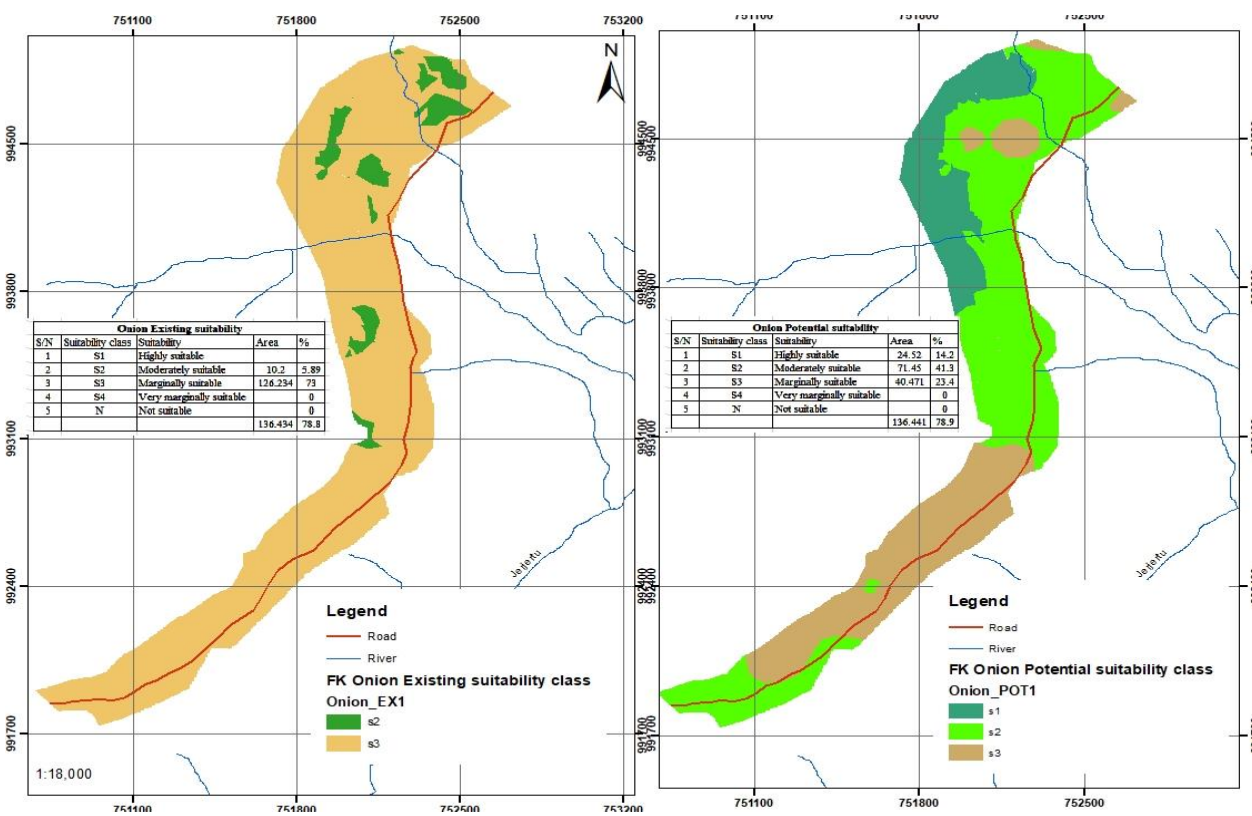


- **Onion**

Accordingly, Potential land suitability for the crop onion can be grouped into three classes. These include the marginally suitable lands, moderately suitable lands and highly suitable lands (Table 29 &30).. Land units listed under the suitability sub class s3r1 (Table 29,30 and 32) are classified as the Marginally suitable land for onion crops production due to the soil depth of the study area (Table 32). The area of these land units is also 40.47 ha. On the other hand, those land units listed under the suitability sub classes s2m1 and s2m1r1 are grouped under the moderately suitable lands. They are moderately limited by some chemical and physical properties of the soil like soil AWC and soil depth. The area coverage of these moderately suitable lands are 37.61 ha and 33.89 ha respectively. On the other hand, those land units listed under the suitability sub classes s1 is grouped under the Highly suitable lands. The area coverage of this highly suitable lands is 24.52ha

Onion Potential suitability				
S/N	Suitability class	Suitability	Area	%
1	S1	Highly suitable	24.52	14.2
2	S2	Moderately suitable	71.45	41.3
3	S3	Marginally suitable	40.471	23.4
4	S4	Very marginally suitable		0
5	N	Not suitable		0
			136.441	78.9

Figure 7: Onion Existing and Potential Suitability Map

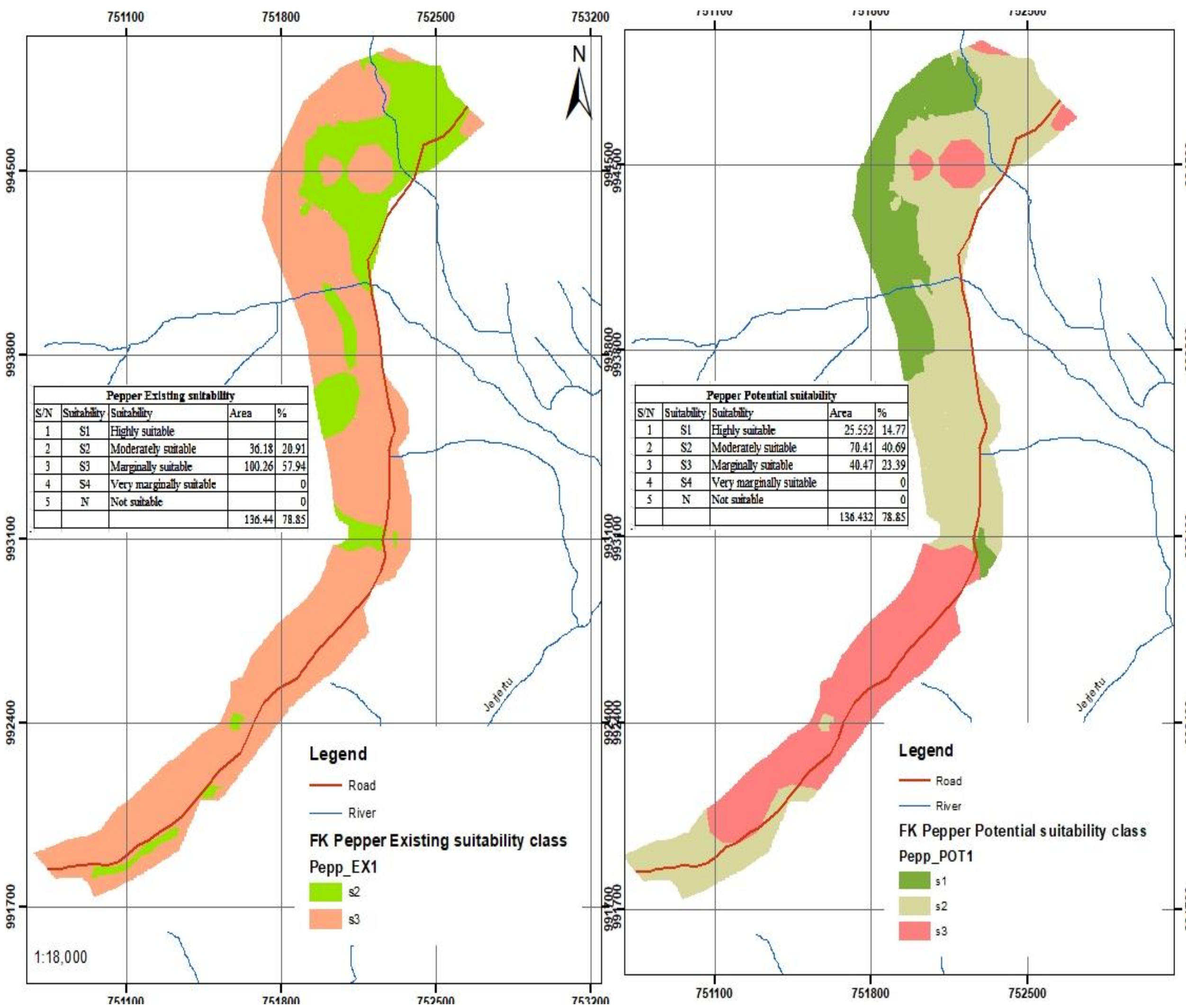


- **Pepper**

The Potential land suitability for the crop pepper can be grouped into three classes. These include the marginally suitable lands, moderately suitable lands and highly suitable lands (Table 29 &30). Land units listed under the suitability sub class s3r1 (Table 29,30 and 32) are classified as the Marginally suitable land for pepper crops production due to the soil depth of the study area (Table 32). The area of these land units is also 40.47 ha. On the other hand, those land units listed under the suitability sub classes s2m1 and s2m1r1 are grouped under the moderately suitable lands. They are moderately limited by some chemical and physical properties of the soil like soil AWC and soil depth. The area coverage of these moderately suitable lands are 42.44 ha and 22.57 ha respectively. Those land units listed under the suitability sub classes s1 is grouped under the Highly suitable lands. The area coverage of this highly suitable lands is 30.95ha

Pepper Potential suitability				
S/N	Suitability	Suitability	Area	%
1	S1	Highly suitable	25.552	14.77
2	S2	Moderately suitable	70.41	40.69
3	S3	Marginally suitable	40.47	23.39
4	S4	Very marginally suitable		0
5	N	Not suitable		0
			136.432	78.85

Figure 8: Pepper Existing and Potential Suitability Map



- **Sweet potato**

The same way, Potential land suitability for sweet potato can be grouped into two classes. These include the marginally suitable and moderately suitable lands (Table 29 &30). Land units listed under the suitability sub class s3r1 (Table 29,30 and 32) are classified as the marginally suitable land for sweet potato due to the soil depth of the study area (Table 32). The area of these land units is also 40.47 ha. On the other hand, those land units listed under the suitability sub classes s2c1m1 and s2c1m1r1 are grouped under moderately suitable lands due to soil temperatute, AWC and soil depth. Cover an area of 62.16 ha and33.82 ha of lan respectively

Sweet Potato Potential suitability				
S/N	Suitability class	Suitability	Area	%
1	S1	Highly suitable		
2	S2	Moderately suitable	95.96	55.46
3	S3	Marginally suitable	40.47	23.39
4	S4	Very marginally suitable		0
5	N	Not suitable		0
			136.4	78.84

Figure 9: Sweet potato Existing and Potential Suitability Map

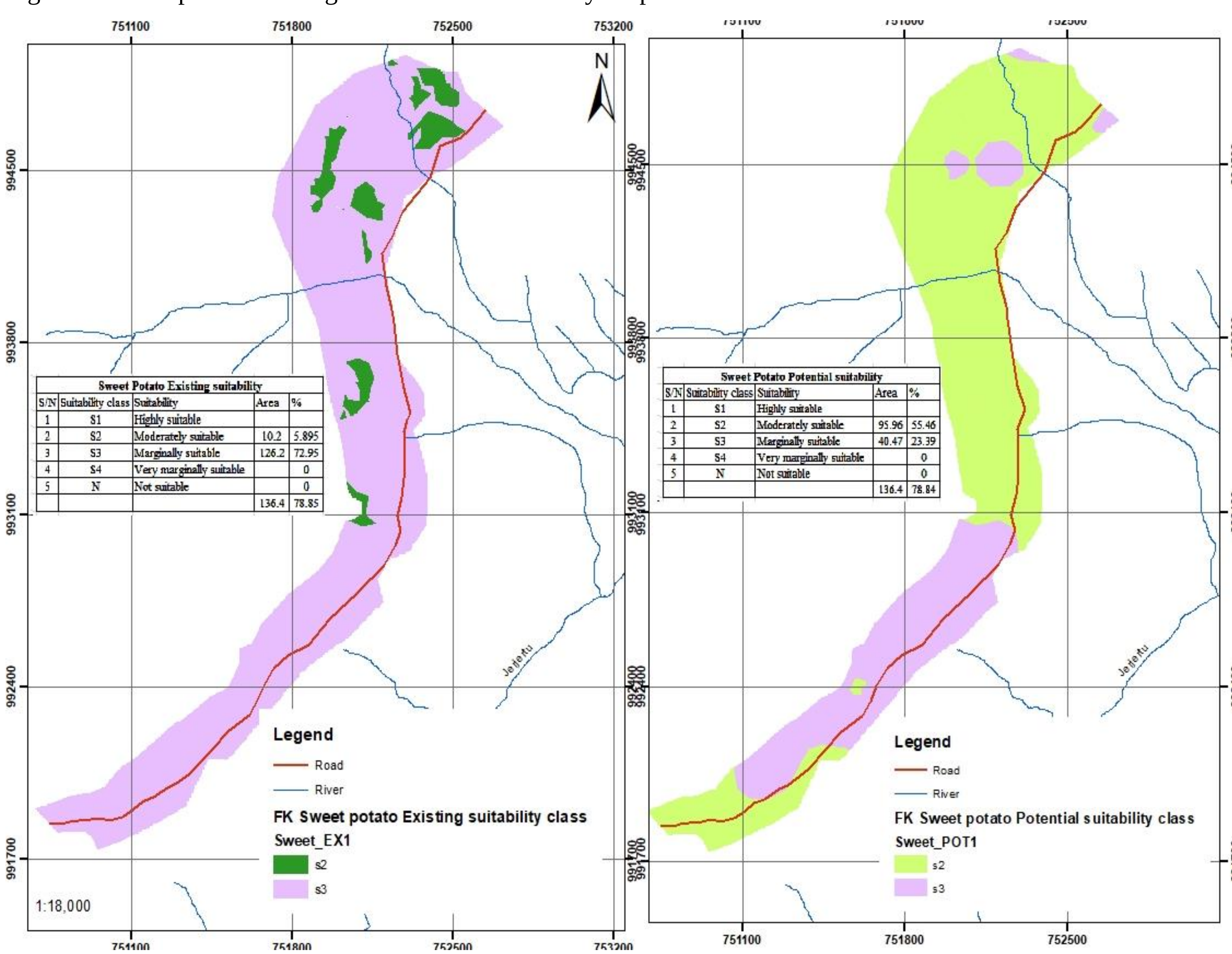


Table 29: Potential Crop Suitability by Area for surface Irrigation

Potential crop suitability by area for Surface Irrigation					
Crop	s1	s2	s3	s4	N
	Highly suitable	Moderately suitable	Marginally suitable	Very marginally suitable	Not suitable
	Area,ha	Area,ha	Area,ha	Area,ha	Area,ha
Lowland Maize	24.52	77.45	40.47	0	0
Tomato	24.52	71.45	40.47	0	0
Onion	25.52	71.45	40.47	0	0
Pepper	25.55	71.45	40.47	0	0
Sweet potato	0	95.96	40.47	0	0

Table 30: Potential Crop Suitability by subclass and Area for surface Irrigation

Crops	Potential suitabiity sub class comparing with crops for surface Irrigation				
Low land maize	Potential subclass	s1	s2m1	s2m1r1	s3r1
	Area,ha	24.52	37.64	33.81	40.47
Tomato	Potential subclass	s1	s2m1	s2m1r1	s3r1
	Area,ha	24.52	37.64	33.81	40.47
Onion	Potential subclass	s1	s2m1	s2m1r1	s3r1
	Area,ha	24.52	37.64	33.81	40.47
Pepper	Potential subclass	s1	s2m1	s2m1r1	s3r1
	Area,ha	30.95	42.44	22.57	40.47
Sweet potato	Potential subclass	s2c1m1	s2c1m1r1	s3r1	
	Area,ha	62.16	33.82	40.47	

Table 31: Results of Crop Existing and Potential Suitability Class Evaluation

SMU	Area	Tomato		Onion		Pepper		Sweet potato		Lowland maize	
		Existing	Potential	Existing	Potential	Existing	Potential	Existing	Potential	Existing	Potential
1CL_a	2.82	s2	s2	s3	s2	s3	s2	s3	s2	s4	s2
1CL_c	2.17	s2	s2	s3	s2	s3	s2	s3	s2	s4	s2
1CL_d	4.80	s3	s2	s2	s2	s2	s2	s2	s2	s3	s2
2CL_a	1.39	s2	s2	s3	s2	s3	s2	s3	s2	s4	s2
2CL_a(f)	0.91	s2	s1	s3	s1	s3	s1	s3	s2	s4	s1
2CL_c	4.68	s2	s2	s3	s2	s3	s2	s3	s2	s2	s2
2CL_c(f)	6.74	s2	s1	s3	s1	s3	s1	s3	s2	s2	s1
2CL_d	16.90	s4	s2	s3	s2	s2	s2	s3	s2	s4	s2
2CL_e	5.07	s3	s3	s3	s3	s3	s3	s3	s3	s3	s3
2L_e	2.05	s4	s3	s3	s3	s3	s3	s3	s3	s4	s3
3C_e	5.25	s4	s3	s3	s3	s3	s3	s3	s3	s4	s3
3CL_a	2.49	s2	s2	s3	s2	s3	s2	s3	s2	s4	s2
3CL_a(f)	3.41	s2	s1	s3	s1	s3	s1	s3	s2	s4	s1
3CL_c	6.35	s2	s2	s3	s2	s3	s2	s3	s2	s2	s2

Cont'd

SMU	Area	Tomato		Onion		Pepper		Sweet potato		Lowland maize	
		Existing	Potential	Existing	Potential	Existing	Potential	Existing	Potential	Existing	Potential
3CL_c(f)	7.66	s2	s1	s3	s1	s3	s1	s3	s2	s2	s1
3CL_d	5.21	s4	s2	s3	s2	s2	s2	s3	s2	s4	s2
3CL_d	0.46	s4	s2	s3	s2	s2	s2	s3	s2	s4	s2
3L_e	1.14	s3	s3	s3	s3	s3	s3	s3	s3	s3	s3
4CL_a	3.51	s4	s2	s3	s2	s3	s2	s3	s2	s4	s2
4CL_c	10.83	s4	s2	s3	s2	s3	s2	s3	s2	s4	s2
4CL_c(f)	5.80	s4	s1	s3	s1	s3	s1	s3	s2	s4	s1
4CL_d	5.40	s2	s2	s2	s2	s2	s2	s2	s2	s2	s2
4CL_e	12.88	s4	s3	s3	s3	s3	s3	s3	s3	s4	s3
4L_e	7.89	s3	s3	s3	s3	s3	s3	s3	s3	s3	s3
5CL_a	0.32	s4	s2	s3	s2	s2	s2	s3	s2	s4	s2
5CL_c	3.08	s4	s2	s3	s2	s2	s2	s3	s2	s4	s2
5CL_d	1.03	s3	s2	s3	s2	s3	s1	s3	s2	s3	s2
5CL_e	4.27	s3	s3	s3	s3	s3	s3	s3	s3	s3	s3
5L_e	1.91	s3	s3	s3	s3	s3	s3	s3	s3	s3	s3

Table 32: Results of Crop Existing and Potential SuitabilitySubclass Evaluation

SMU	Area	Tomato		Onion		Pepper		Sweet potato		Lowland maize	
		Existing	Potential	Existing	Potential	Existing	Potential	Existing	Potential	Existing	Potential
1CL_a	2.82	s4n3	s2m1	s3n3	s2m1	s3n3	s2m1	s3n3	s2c1m1	s4n3	s2m1
1CL_c	2.17	s4n3	s2m1	s3n3	s2m1	s3n3	s2m1	s3n3	s2c1m1	s4n3	s2m1
1CL_d	4.80	s3n3	s2m1r1	s2m1n3r1	s2m1r1	s2m1n3	s2m1	s2c1m1n3r1	s2c1m1r1	s3n3	s2m1r1
2CL_a	1.39	s4n3	s2m1	s3n3	s2m1	s3n3	s2m1	s3n3	s2c1m1	s4n3	s2m1
2CL_a(f)	0.91	s4n3	s1	s3n3	s1	s3n3	s1	s3n3	s2c1m1	s4n3	s1
2CL_c	4.68	s4n3	s2m1	s3n3	s2m1	s3n3	s2m1	s3n3	s2c1m1	s4n3	s2m1
2CL_c(f)	6.74	s4n3	s1	s3n3	s1	s3n3	s1	s3n3	s2c1m1	s4n3	s1
2CL_d	16.90	s4n3	s2m1r1	s3n3	s2m1r1	s3n3	s2m1r1	s3n3	s2c1m1r1	s4n3	s2m1r1
2CL_e	5.07	s3n3r1	s3r1	s3r1	s3r1	s3r1	s3r1	s3r1	s3r1	s3n3r1	s3r1
2L_e	2.05	s4n3	s3r1	s3n3r1	s3r1	s3n3r1	s3r1	s3n3r1	s3r1	s4n3	s3r1
3C_e	5.25	s4n3	s3r1	s3n3r1	s3r1	s3n3r1	s3r1	s3n3r1	s3r1	s4n3	s3r1
3CL_a	2.49	s4n3	s2m1	s3n3	s2m1	s3n3	s2m1	s3n3	s2c1m1	s4n3	s2m1
3CL_a(f)	3.41	s4n3	s1	s3n3	s1	s3n3	s1	s3n3	s2c1m1	s4n3	s1
3CL_c	6.35	s4n3	s2m1	s3n3	s2m1	s3n3	s2m1	s3n3	s2c1m1	s4n3	s2m1

Cont'd

SMU	Area	Tomato		Onion		Pepper		Sweet potato		Lowland maize	
		Existing	Potential	Existing	Potential	Existing	Potential	Existing	Potential	Existing	Potential
3CL_c(f)	7.66	s4n3	s1	s3n3	s1	s3n3	s1	s3n3	s2c1m1	s4n3	s1
3CL_d	5.21	s4n3	s2m1r1	s3n3	s2m1r1	s3n3	s2m1r1	s3n3	s2c1m1r1	s4n3	s2m1r1
3CL_d	0.46	s4n3	s2m1r1	s3n3	s2m1r1	s3n3	s2m1r1	s3n3	s2c1m1r1	s4n3	s2m1r1
3L_e	1.14	s3n3r1	s3r1	s3r1	s3r1	s3r1	s3r1	s3r1	s3r1	s3r1	s3r1
4CL_a	3.51	s4n3	s2m1	s3n3	s2m1	s3n3	s2m1	s3n3	s2c1m1	s4n3	s2m1
4CL_c	10.83	s4n3	s2m1	s3n3	s2m1	s3n3	s2m1	s3n3	s2c1m1	s4n3	s2m1
4CL_c(f)	5.80	s4n3	s1	s3n3	s1	s3n3	s1	s3n3	s2c1m1	s4n3	s1
4CL_d	5.40	s2m1n3r1k	s2m1r1	s2m1r1k	s2m1r1	s2m1k	s1	s2c1m1r1k	s2c1m1r1	s2m1n3r1k	s2m1r1
4CL_e	12.88	s4n3	s3r1	s3n3r1	s3r1	s3n3r1	s3r1	s3n3r1	s3r1	s4n3	s3r1
4L_e	7.89	s3r1	s3r1	s3r1	s3r1	s3r1	s3r1	s3r1	s3r1	s3r1	s3r1
5CL_a	0.32	s4n3	s2m1	s3n3k	s2m1	s3n3k	s2m1	s3n3k	s2c1m1	s4n3	s2m1
5CL_c	3.08	s4n3	s2m1	s3n3k	s2m1	s3n3k	s2m1	s3n3k	s2c1m1	s4n3	s2m1
5CL_d	1.03	s3n3k	s2m1r1	s3k	s2m1r1	s3k	s1	s3k	s2c1m1r1	s3k	s2m1r1
5CL_e	4.27	s3n3r1k	s3r1	s3r1k	s3r1	s3r1k	s3r1	s3r1k	s3r1	s3r1k	s3r1
5L_e	1.91	s3n3r1k	s3r1	s3n3r1	s3r1	s3r1k	s3r1	s3n3r1k	s3r1	s3n3r1k	s3r1

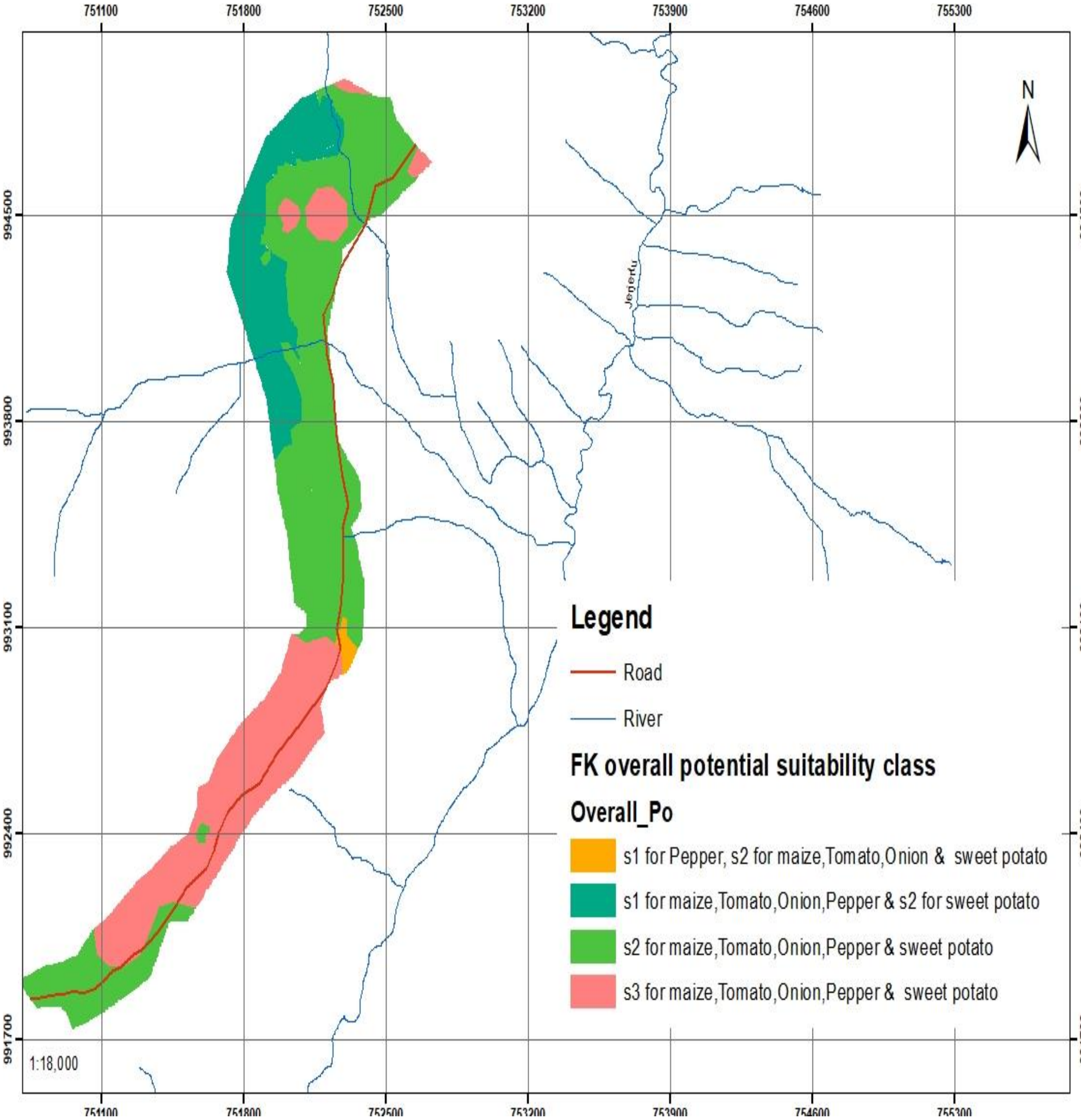
8.11.4. The Overall Crop Potential Suitability

The final Crop potential suitability is displayed briefly on Table : 33

Table 33: Final Crop Potential Suitability by SMU

SMU	Overall Crop Potential suitability	Area, ha	SMU	Overall Crop Potential suitability	Area, ha
1CL_a	s2 for maize, Tomato, Onion, Pepper & sweet potato	2.821	3CL_d	s2 for maize, Tomato, Onion, Pepper & sweet potato	0.464
1CL_c	s2 for maize, Tomato, Onion, Pepper & sweet potato	2.168	3CL_d	s2 for maize, Tomato, Onion, Pepper & sweet potato	5.207
1CL_d	s2 for maize, Tomato, Onion, Pepper & sweet potato	4.799	3L_e	s3 for maize, Tomato, Onion, Pepper & sweet potato	1.138
2CL_a	s2 for maize, Tomato, Onion, Pepper & sweet potato	1.387	4CL_a	s2 for maize, Tomato, Onion, Pepper & sweet potato	3.510
2CL_a(f)	s1 for maize, Tomato, Onion, Pepper & s2 for sweet potato	0.909	4CL_c	s2 for maize, Tomato, Onion, Pepper & sweet potato	10.829
2CL_c	s2 for maize, Tomato, Onion, Pepper & sweet potato	4.684	4CL_c(f)	s1 for maize, Tomato, Onion, Pepper & s2 for sweet potato	5.799
2CL_c(f)	s1 for maize, Tomato, Onion, Pepper & s2 for sweet potato	6.738	4CL_d	s2 for maize, Tomato, Onion, Pepper & sweet potato	5.403
2CL_d	s2 for maize, Tomato, Onion, Pepper & sweet potato	16.902	4CL_e	s3 for maize, Tomato, Onion, Pepper & sweet potato	12.882
2CL_e	s3 for maize, Tomato, Onion, Pepper & sweet potato	5.068	4L_e	s3 for maize, Tomato, Onion, Pepper & sweet potato	7.893
2L_e	s3 for maize, Tomato, Onion, Pepper & sweet potato	2.054	5CL_a	s2 for maize, Tomato, Onion, Pepper & sweet potato	0.323
3C_e	s3 for maize, Tomato, Onion, Pepper & sweet potato	5.254	5CL_c	s2 for maize, Tomato, Onion, Pepper & sweet potato	3.080
3CL_a	s2 for maize, Tomato, Onion, Pepper & sweet potato	2.490	5CL_d	s1 for Pepper, s2 for maize, Tomato, Onion & sweet potato	1.032
3CL_a(f)	s1 for maize, Tomato, Onion, Pepper & s2 for sweet potato	3.415	5CL_e	s3 for maize, Tomato, Onion, Pepper & sweet potato	4.270
3CL_c	s2 for maize, Tomato, Onion, Pepper & sweet potato	6.347	5L_e	s3 for maize, Tomato, Onion, Pepper & sweet potato	1.911
3CL_c(f)	s1 for maize, Tomato, Onion, Pepper & s2 for sweet potato	7.658			

Figure 10: Final Overall Crop Potential Suitability map of Fire Kebso SSIP



9. SOIL MANAGEMENT AND RECLAMATION

9.1. Soil Physical Soil factors

9.1.1. Workability

During soil survey observed no drainage proble as well as the soil texture is identified as clay loam, Loam and clay(red), so, there is no as such soil workability problem,

9.1.2. Surface coarse fragements

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

9.1.3. Soil Drainage

The study area is well drained and observed no flooding problem, as such, but in sloping area (slope 8-15 and 15-30%) only for few days might be observe flooding on Chromic, Eutric Cambisols (Aric) especially in SMU 5CL_a,5CL_c,5CL_d,5CL_and 5L_e

9.1.4. Flooding

In sloping area (slope 8-15 and 15-30%) only for few days might be observe flooding on Chromic, Eutric Cambisols (Aric) especially in SMU 5CL_a,5CL_c,5CL_d,5CL_and 5L_e

are affected by slight flooding during the rainy seasons for less than 10-15 days. In these lower lying soil mapping units in the study area, 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.

9.1.5. Erosion

The soils of the soil mapping units 4CL_a,4CL_c,4CL_c(f),4CL_d,4CL_e,4L_e, 5CL_a,5CL_c,5CL_d,5CL_and 5L_e are slightely affected by splash and sheet erosion, where as the rest of soils of the soil mapping units are not affecte by erosion.The main causes of this splash and sheet erosion are considerable slight run off (8-15 % and 15-30% slope land or SMU during the rainy session from the surrounding.The risk of erosion can be effectively controlled by terracing, and contour construction

9.2. Chemical Factores

9.2.1. Soil Fertility

The distributions of nutrients in the entire study are is uniform. The exchangeable Ca and Mg are high to very high in soils of the soil mapping units Chromic, Eutric Cambisols (Aric) and Eutric Fluvisols (Aric). The level of Potassum (K) is low to very high. All soils of the soil mapping units are high to very high level of CEC and high level of BSP. The PH value for most of the soils in the study area varies from 6.79 to 7.59, which is neutral to slightly alkaline. As indicated in Land evaluation result the major limitation (potential suitability) for most crop is Available water holding capacity,soil depth and temperatute(for sweet potato) .**Calcium to Magnesium ratio** for the dominant soil mapping units are 3.5:1 to 5.011:1, which is approximately optimum for most crops.The AVP content for soils of the soil mapping units are low (85.53%) to medium(14.47%) it needs application of organic fertilizer like compost is to considered. The total Nitrogen contents of the soils mapping unit’s uniform across the entire units (that is high to very high level of T.N). To be more efficient in crop production, site specific soil test-based fertilizer recommendations study has to be conducted.

10. CONCLUSION AND RECOMMENDATIONS

10.1. Conclusion

The present level of soil survey enabled the identification of 2 majors soils, 2 soil units and 29 soil mapping units in firi kebso SSIP. The soil map is prepared at 1:10,000 scale. Geomorphology and Soils Map of Ethiopian prepared by the then Land use planning and Regulatory Department LUPRD) of the Ministry of Agriculture, The Wabi Shebele River basin integrated development master plan study Project (2004) at the scale of 1 :250,000 and Ramis Sub basin land use study Project at the scale of 1 :250,000. By OWWDSE,2010, Study has been reviewed and compiled. Currently the field soil survey was carried out by Oromia Water Works Design and Supervision Enterprise. The soil survey was carried out over a gross area of some 136.44 ha at detailed level (1:10,000). Some 33 auger observation and 3 profiles were dug and described and 8 samples were collected from these moda 3 profiles for full chemical analysis. The major soil groups and soil units were classified based on the soil physical properties observed in the field i.e. texture, soil depth, drainage, slope, soil color and profile developments and Chemical characteristics from laboratory test results, CEC meq/100g soil, BS per cent, OM per cent, TN per cent, AV. P ppm, PH, EC meq/100g soil, ESP per cent etc. Were used for soil classification

10.2. Recommendations

In general the soil conditions of most identified soils by the present soil survey are suitable for irrigation agricultural development. The limitations of most soils in Firi kebso SSIP are Avalable water holding capacity,soil depth and temperature(for sweet potato) Limitted flooding problem in soils of the soil mapping units(5CL_a,5CL_c,5CL_d,5CL_and 5L_e with slope of 8-15% and 15-30%), are slightely affected by sheet, and splash erosion, where as soils of the soil mapping units 1CL_a, 1CL_c, 1CL_d, 2CL_a, 2CL_a(f), 2CL_c, 2CL_c(f), 2CL_d, 2CL_e, 2L_e, 3C_e, 3CL_a(f), 3CL_c, 3CL_c(f), 3CL_d, 3CL_d, 4CL_a, 4CL_c, 4CL_c(f), 4CL_e, 5CL_a, 5CL_c, and 5L_e are low in AVP

Therefore, the following recommendations are suggested :

- 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, and splash erosion. This can be controlled through careful planning and implementation Integrated Watershed Development. Technologies such as proper erosion control mechanism, such as, plantation of cover grasses, contouring and conservation structures can be incorporated specific to site condition.
- 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.

11. REFERENCES

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12. 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**

Soil profile Description	Profile code:FQP_1	Mapping code:	Status:PS
Date		UTM(X)	752262
Auter(s)	M &B	UTM(Y)	994762
Region	Oromia	Elivation	1610
Zone	E/Harerge	Parent material	LS
Wereda	Melka bello	Rock type	none
Soil classification	Fluvisols	Effective soil depth	200
Human influence	PL	Rockout crop	none
Landform	LT	Depth to bed rock	
Regional slope		Surface coarse fragement	none
Position	middle	Micro topography	AB/AT
Slopeclass	5-8%	Surfce sealing	none
slope aspect		Drainage class	WD
slope gradient		Internal drainage	
slope form	Undulating	slope length	
Drainage(external		Ground water	
erosion status	None	Surface crack	M
Fertilizer		Flooding	None
Existing crop	Chat,sorghum,coffee	Dissection	
Landcover	CL3,CP2	Moisture condition	
[illegible]	[illegible]	[illegible]	

0-30 cm	clear and smooth boundary,dry moisture status;10YR3/2(dry), 10YR3/2(moist) color;none mottling;clayloam texture ; none coarse fragment; moderate, medium ,angular structure; medium crack;hard(dry); friable (moist), slightly sticky and slightly plastic(wet) consistency; none cutanic features;none cemented and none compacted ;none mineral nodules;Many,common,fine to medium,fine to coarse root ;many,fine to medium pores;strong calcerous.
30-110cm	clear and smooth boundary,slightly moisture status; 10YR2/2(moist) color;none mottling;clay texture ; none coarse fragment; moderate, fine to medium ,sub-angular blocky structure; fine crack;slightly hard(dry); friable (moist), sticky and plastic(wet) consistency; none cutanic features;none cemented and none compacted ;none mineral nodules;common,medium to coarse root ;many,fine to medium pores;strong calcerous..
110-200cm	Slightly moisture status; 10YR2/1(moist) color;none mottling;clay texture ; none coarse fragment; moderate, fine ,sub-angular blocky structure; none crack;soft(dry); friable (moist), very sticky and very plastic(wet) consistency; none cutanic features;none cemented and none compacted ;none mineral nodules;few,fine to medium root ;common,fine to medium pores;strong calcerous..

Cont'd

Soil profile Descri	Profile code:FQP_2	Mapping code:	Status:PS
Date		UTM(X)	751869
Auter(s)	M &B	UTM(Y)	994447
Region	Oromia	Elivation	1640
Zone	E/Harerge	Parent material	LS
Wereda	Melka bello	Rock type	none
Soil classification	Fluvisols	Effective soil depth	120
Human influence	PL	Rockout crop	none
Landform	LT	Depth to bed rock	
Regional slope		Surface coarse fragement	F
Position	middle	Micro topography	AB/AT
Slopeclass	8-15%	Surfce sealing	none
slope aspect		Drainage class	P/S
slope gradient		Internal drainage	
slope form	Undulating	slope length	
Drainage(external		Ground water	
erosion status	None	Surface crack	M
Fertilizer		Flooding	None
Existing crop	Chat,sorghum,coffee	Dissection	
Landcover	CL3,CP2	Moisture condition	
Vegtaation type	WL2	Grazing land	

0-30cm	clear and smooth boundary,dry moisture status;7.5YR3/2(dry) ,7.5YR3/1(moist)color;none mottling;clayloam texture ; none coarse fragment; strong, fine to coarse ,angular blocky structure; medium crack;slightly hard(dry); friable (moist), slightly sticky and slightly plastic(wet) consistency; none cutanic features;none cemented and none compacted ;none mineral nodules;few,fine root ;many,fine to coarse pores;strong calcerous.
30-55cm	clear and smooth boundary,dry moisture status;7.5YR2.5/3(dry) ,7.5YR2.5/2(moist)color;none mottling;clay texture ; none coarse fragment; strong, fine to coarse ,angular blocky structure; medium crack;slightly hard(dry); friable (moist), sticky and plastic(wet) consistency; none cutanic features;none cemented and none compacted ;none mineral nodules;few,fine root ;many,fine to coarse pores;strong calcerous.
55-120cm	slightly moist moisture status;7.5YR2.5/1(moist)color;none mottling;clay texture ; many,fine to coarse coarse fragment; strong, fine to coarse ,angular blocky structure; medium crack;none(dry); friable (moist), sticky and plastic(wet) consistency; none cutanic features;none cemented and none compacted ;none mineral nodules;few,fine root ;few,fine to coarse pores;strong calcerous.

Cont'd

Soil profile Description	Profile code:FQP_3	Mapping code:	Status:PS
Date		UTM(X)	752113
Auter(s)	M &B	UTM(Y)	992971
Region	Oromia	Elivation	1576
Zone	E/Harerge	Parent material	LS
Wereda	Melka bello	Rock type	none
Soil classification	Fluvisols	Effective soil depth	55
Human influence	PL,VU	Rockout crop	none
Landform	LT	Depth to bed rock	
Regional slope		Surface coarse fragement	
Position	middle	Micro topography	AB/AT
Slopeclass	15-30%	Surfce sealing	none
slope aspect		Drainage class	WD
slope gradient		Internal drainage	
slope form	Rolling	slope length	
Drainage(external		Ground water	
erosion status	None	Surface crack	none
Fertilizer		Flooding	None
Existing crop	Chat,sorghum,coffee	Dissection	
Landcover	CL3,CP2	Moisture condition	
Vegtaation type	WL2	Grazing land	

0-30cm	clear and smooth boundary,dry moisture status;7.5YR3/1(dry),7.5YR2.5/1(moist) color;none mottling;clayloam texture ;common,fine to medium coarse fragment; moderate, fine to medium ,subangular blocky structure; none crack;slightly hard(dry); friable (moist), slightly sticky and slightly plastic(wet) consistency; none cutanic features;none cemented and none compacted ;none mineral nodules;common,fine to medium root ;many,fine to medium pores;strong calcerous.
30-55cm	slightly moist moisture status;7.5YR3/2(moist) color;none mottling;clay texture ;common,fine to medium coarse fragment; moderate, fine to medium ,subangular blocky structure; none crack;none(dry); friable (moist), sticky and plastic(wet) consistency; none cutanic features;none cemented and none compacted ;none mineral nodules;few,fine to medium root ;many,fine to medium pores;strong calcerous.

Appendix Table 3: **Location of geographical coordinate for soil profile description and Auger observation**

SN	Field_Code(Profile Description)	X	Y
1	FQP_1	752259	994746
2	FQP_2	751869	994447
3	FQP_3	752113	992971

SN	Field_No(Auger Observation)	X	Y	Elevation	
1	FQA_1	752000	993900	1634	
2	FQA_2	752099	993622	1623	
3	FQA_3	752200	994548	1618	
4	FQA_4	752200	994200	1559	
5	FQA_5	752200	993000	1605	
6	FQA_6	752200	993600	1612	
7	FQA_7	751200	992100	1592	
8	FQA_8	752200	994800	1603	
9	FQA_9	752600	994800	1601	
10	FQA_10	752400	994800	1604	
11	FQA_11	752000	994200	1640	
12	FQA_12	752200	993300	1605	
13	FQA_13	752400	993300	1608	
14	FQA_14	752200	994500	1658	
15	FQA_15	752000	993000	1553	
16	FQA_16	751800	994800	1651	
17	FQA_17	751800	994500	1644	
18	FQA_18	751800	994200	1648	
19	FQA_19	751800	992700	1553	
20	FQA_20	752000	994500	1612	
21	FQA_21	752000	994800	1624	
22	FQA_22	751600	992400	1578	
23	FQA_23	752000	992700	1554	
24	FQA_24	751800	992400	1607	
25	FQA_25	751200	992100	1578	

Appendix Table 4: **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 5**: Soil physical and chemical laboratory analysis results**

Name of Customer : OROMIA WATER WORKS DESIGN & SUPERVISION ENTERPRISE									
Project :Firi Kabso SS Irrigation					Location - East Hararge				
						Particle Size Distribution			TEXTURAL
LAB NO	Field Code	Depth	P^H -Water	E.C	P^H - KCl	Sand	SILT	CLAY	CLASS
		Cm	1:2.5	ds/m	1:2.5	%	%	%	
023 /19	FQP - 1	0-30	7.40	0.224	6.90	24	41	35	Clay loam
24 /19		30-110	7.50	0.244	7.00	34	33	33	Clay loam
25 /19		110-200	7.60	0.279	7.00	34	33	33	Clay loam
26 /19	FQP - 2	0-30	7.30	0.131	6.80	30	33	37	Clay loam
27 /19		30-55	7.30	0.098	6.90	20	31	49	clay
28 /19		55-120	7.20	0.141	6.90	34	35	31	Clay loam
29 /19	FQP - 3	0-30	7.10	0.191	6.70	38	41	21	Loam
30 /19		30-55	7.20	0.189	6.80	48	35	17	Loam
Core Sampler			BD (g/cm$^{3)}$		F.C (%)		P.W.P (%)		
31 /19	FQP - 2	0-30	1.37		38.4		22.6		
32 /19		30-60	1.60		37.4		28.2		
33 /19		60-90	1.47		38.3		30.6		

Cont'd

LAB NO	Na	K	Ca	Mg	SUM	CEC	BS	EX. Acidity	Ex. Al^{3+}
	Cmol(+)Kg^{-1}						%	Cmol(+)Kg-1	
023 /19	0.15	0.72	37.26	10.58	48.71	55.9	87	_	_
24 /19	0.16	0.54	37.14	7.89	45.72	51.8	88	_	_
25 /19	0.19	0.54	41.55	11.79	54.07	62.2	87	_	_
26 /19	0.15	0.82	34.98	8.35	44.30	60.6	73	_	_
27 /19	0.17	0.60	32.91	6.57	40.25	60.4	67	_	_
28 /19	0.18	0.64	37.30	8.19	46.31	63.2	73	_	_
29 /19	0.14	0.60	21.33	4.62	26.69	30.9	86	_	_
30 /19	0.14	0.30	16.11	4.56	21.11	25.3	83	_	_
LAB NO	T.N	O.C	O.M	C/N	Av.K	Av.P	P_2O_5	$CaCO_3$	
	%	%	%		PPM	PPM		%	gram kg^{-1}
023 /19	0.29	3.6	6.16	12	281.7	0.98	2.24	25.92	259.20
24 /19	0.27	3.4	5.86	13	211.8	0.74	1.69	32.64	326.40
25 /19	0.24	3.3	5.65	14	210.6	4.22	9.66	36.48	364.80
26 /19	0.29	3.4	5.86	12	318.7	0.44	1.01	0.19	1.92
27 /19	0.27	3.1	5.34	11	233.9	1.16	2.66	0.14	1.44
28 /19	0.25	3.0	5.17	12	248.4	1.38	3.16	0.10	0.96
29 /19	0.28	3.6	6.16	13	233.8	3.52	8.06	50.21	502.08
30 /19	0.20	2.6	4.43	13	89.7	1.20	2.75	0.48	4.80

Checked By Tadesse Bayissa Signature ________________ Date ______________

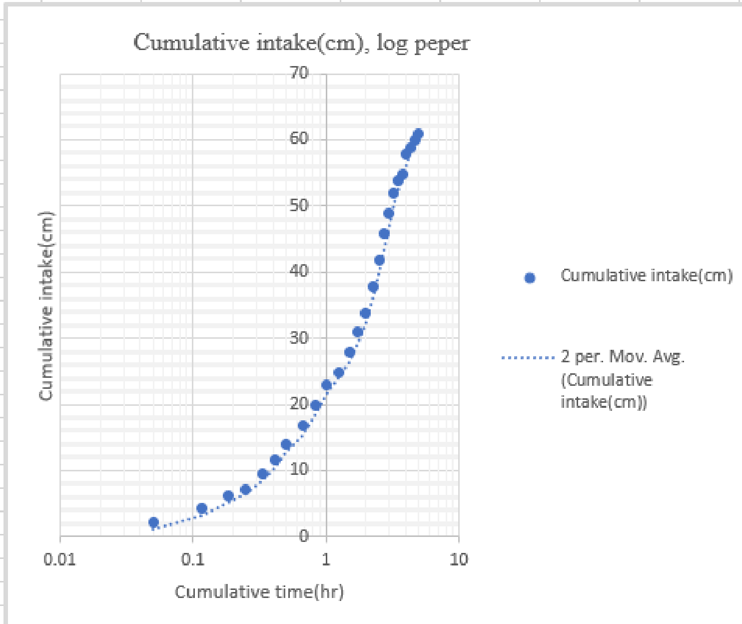
Appendix table 6**: Soil infiltration and permeability test**

I-Infiltration

Double Ring Infiltrometer Field Data						Project: ASSIP/Land Form:LP		Site:FQP-1	
Date:25/4/11/Author: M/B			GPS Reading/N:993762/E:752117			Soil Type: Chromic Eutric Fluvisols		Micro Topography:AT	
depth of insertion of ring=10/depth of insertion of ring=15			Elevation:1623/Slope Class:5-8			Rep.no=1		Infiltration rate(cm/hr)	
Local time(hr:mins)	Time Interval(mins)	Interval(hr)columon 2 ÷ 60mins	Cumulative time(mins)	Cumulative time(hr), columon 4 ÷ 60mins	Depth of water in infiltrometer(cm)	Intake(cm)	Cumulative intake(cm/hr)	immediate(instantanious)	mean
1	2	3	4	5	6	7	8	9=7/3	10=8/5
8.00	0	0.03	0	0	15.0				
	3	0.05	3	0.05	12.8	2.2	2.2	44.0	44.0
	4	0.067	7	0.117	10.8	2	4.2	30.0	36.0
	4	0.067	11	0.183	8.0	1.9	6.1	28.5	33.3
	4	0.067	15	0.250	7(15)Rif	1	7.1	15.0	28.4
	5	0.083	20	0.333	12.5	2.5	9.6	30.0	28.8
	5	0.083	25	0.417	10.5	2	11.6	24.0	27.8
	5	0.083	30	0.500	7.2(15)Rif	2.3	13.9	27.6	27.8
	10	0.167	40	0.667	12.0	3	16.9	18.0	25.4
	10	0.167	50	0.833	9(15)Rif	3	19.9	18.0	23.9
9.00	10	0.167	60	1	12.0	3	22.9	18.0	22.9
	15	0.25	75	1.25	10.0	2	24.9	8.0	19.9
	15	0.25	90	1.5	8(15)Rif	3	27.9	12.0	18.6
	15	0.25	105	1.75	12.0	3	30.9	12.0	17.7
10.00	15	0.25	120	2	8(15)Rif	3	33.9	12.0	17.0
	15	0.25	150	2.5	8.0	4	41.9	16.0	16.8
	15	0.25	165	2.75	2(15)Rif	4	45.9	16.0	16.7
11.00	15	0.25	180	3	12.0	3	48.9	12.0	16.3
	15	0.25	195	3.25	9.0	3	51.9	12.0	16.0
	15	0.25	210	3.5	7.0	2	53.9	8.0	15.4
	15	0.25	225	3.75	6(15)Rif	1.0	54.9	4.0	14.6
12.00	15	0.25	240	4	14.0	3.0	57.9	12.0	14.5
	20	0.33	260	4.33	13.0	1	58.9	3.0	13.6
	20	0.33	280	4.67	12.0	1	59.9	3.0	12.8
13.00	20	0.33	300	5	11.0	1	60.9	3.0	12.2

Worked Example of Basic Infiltration rate using Logarithimic paper

Cumulative time(hr)	Cumulative intake(cm)
0	0
0.05	2.2
0.117	4.2
0.183	6.1
0.250	7.1
0.333	9.6
0.417	11.6
0.500	13.9
0.667	16.9
0.833	19.9
1	22.9
1.25	24.9
1.5	27.9
1.75	30.9
2	33.9
2.25	37.9
2.5	41.9
2.75	45.9
3	48.9
3.25	51.9
3.5	53.9
3.75	54.9
4	57.9
4.33	58.9
4.67	59.9
5	60.9



To evaluate the infiltration function, select readings near the later part of the test are taken and the slope of the readings is taken as basic infiltration rate.

For the above example the reading are (5, 60.9) and (4.67, 57.99.9), and the slope is calculated as,

Slope= Y2-Y1/X2-X1

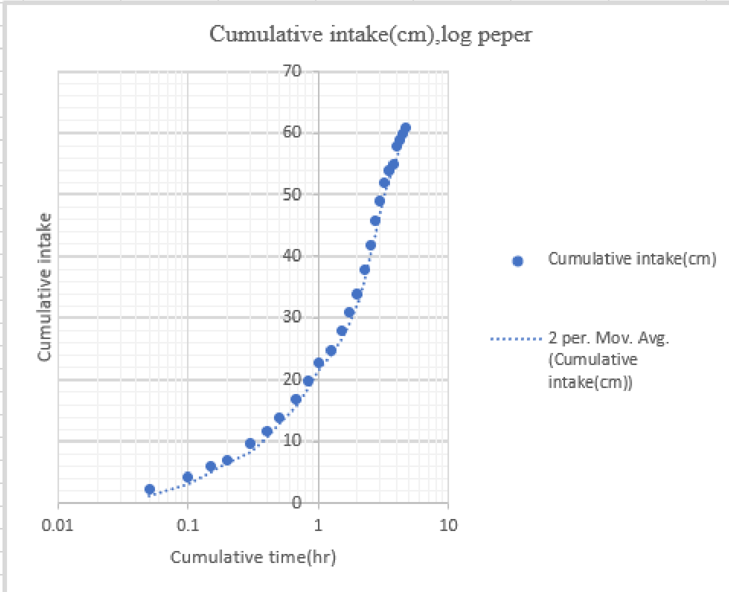
= 60.9-57.9/5.60-4.67

=3

Double Ring Inflitrometer Field Data/Date:25/4/11/Author: M/B			GPS Reading/N:993762/E:752117/Elevation:1623			Project: ASSIP/Land Form:LP		Site:FQP-1/Micro Topography:AT	
depth of insertion of ring=10/Rep.no=2			Soil Type: Chromic Eutric Fluvisols			Slope Class:5-8		Infiltration rate(cm/hr)	
Local time(hr:mins)	Time Interval(mins)	Interval(hr)columon 2 ÷ 60mins	Cumulative time(mins)	Cumulative time(hr), columon 4 ÷ 60mins	Depth of water in infiltrometer(cm)	Intake(cm)	Cumulative intake(cm/hr)	immediate(instantanious)	mean
1	2	3	4	5	6	7	8	9=7/3	10=8/5
8.00	0	0	0	0	15.0				
	3	0.05	3	0.05	12.8	2.2	2.2	44.0	44.0
	3	0.05	6	0.1	10.8	2	4.2	40.0	42.0
	3	0.05	9	0.15	8.0	1.9	6.1	38.0	40.7
	3	0.05	12	0.2	7(15)Rif	1	7.1	20.0	35.5
	6	0.1	18	0.3	12.5	2.5	9.6	25.0	32.0
	6	0.1	24	0.4	10.5	2	11.6	20.0	29.0
	6	0.1	30	0.5	7.2(15)Rif	2.3	13.9	23.0	27.8
	10	0.167	40	0.67	12.0	3	16.9	18.0	25.4
	10	0.167	50	0.83	9(15)Rif	3	19.9	18.0	23.9
9.00	10	0.167	60	1	12.0	3	22.9	18.0	22.9
	15	0.25	75	1.25	10.0	2	24.9	8.0	19.9
	15	0.25	90	1.5	8(15)Rif	3	27.9	12.0	18.6
	15	0.25	105	1.75	12.0	3	30.9	12.0	17.7
10.00	15	0.25	120	2	8(15)Rif	3	33.9	12.0	17.0
	15	0.25	135	2.25	11.0	4	37.9	16.0	16.8
	15	0.25	150	2.5	8.0	4	41.9	16.0	16.8
	15	0.25	165	2.75	2(15)Rif	4	45.9	16.0	16.7
11.00	15	0.25	180	3	12.0	3	48.9	12.0	16.3
	15	0.25	195	3.25	9.0	3	51.9	12.0	16.0
	15	0.25	210	3.5	7.0	2	53.9	8.0	15.4
	15	0.25	225	3.75	6(15)Rif	1.0	54.9	4.0	14.6
12.00	15	0.25	240	4	14.0	3.0	57.9	12.0	14.5
	15	0.25	255	4.25	13.0	1	58.9	4.0	13.9
13.00	15	0.25	270	4.5	12.0	1	59.9	4.0	13.3
13.15	15	0.25	285	4.75	11.0	1	60.9	4.0	12.8

Worked Example of Basic Infiltration rate using Logarithimic paper

Cumulative time(hr)	Cumulative intake(cm)
0	0
0.05	2.2
0.1	4.2
0.15	6.1
0.2	7.1
0.3	9.6
0.4	11.6
0.5	13.9
0.67	16.9
0.83	19.9
1	22.9
1.25	24.9
1.5	27.9
1.75	30.9
2	33.9
2.25	37.9
2.5	41.9
2.75	45.9
3	48.9
3.25	51.9
3.5	53.9
3.75	54.9
4	57.9
4.25	58.9
4.5	59.9
4.75	60.9



To evaluate the infiltration function, select readings near the later part of the test are taken and the slope of the readings is taken as basic infiltration rate.

For the above example the reading are (4.75, 60.9) and (4.5, 59.9), and the slope is calculated as,

Slope= Y2-Y1/X2-X1

= 60.9-59.9/4.75-4.5

=4

Hydraulic conductivity (permiability)

Saturated hydraulic conductivity			measurement form						
			Depth of insertion of auger (cm)				Date: 25/4/11 /Author:M/B		
Replication No. 1						Replication No. 2			
Depth(cm) :90						Depth(cm):90			
ti, sec	h'(t1),cm	h(ti),cm	h(t1+r/2),cm	Hydraulic Conductivity (m/day)	ti,sec	h'(t1),cm	h(ti),cm	h(t1+r/2),cm	Hydraulic Conductivity (m/day)
0	0	0			0	0			
10	14	76	78	2.75	60	11	79	81	2.4
30	15	75	77		150	15	75	77	
50	17	73	75		300	20	70	72	
70	19	71	73		600	35	55	57	
80	20	70	72		700	40	50	52	
100	25	50	52		800	48	42	44	
150	29	48	50		850	58	32	34	
250	30	32	34		900	69	21	23	
300	34	25	30						
400	36	18	30						
500	40	16	30						
600	42	10	30						