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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

Oromia region in general and western Oromia in particular is endowed with highly diversified and multi potential natural resources. These natural resources are making the area potentially ideal for both commercial and small-scale farming. Despite the availability of huge natural resource potentials and opportunities, it is not efficiently and sustainably utilized.

The soil survey of the Hirba Giristu small scale irrigation Project (KSSIP) 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 23 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 Eutric Cambisols, and Vertic, chromic Luvisols

The targeted project area is 478.98 ha and of which crop cultivation practiced widely. The proposed crops that can be cultivated by using irrigation are four Hirba Giristu small scale irrigation Project (KSSIP) 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 (81augers and 3 Profile pits) were describes for the study area. The detail level soil survey study enabled the identification of 23 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 seven LUTs for surface irrigation methods were therefore identified. These LUTs include maize, sorghum, onion, tomato, pepper, head

cabbage and haricot bean 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 Hirba Giristu 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.

Hirba Giristu Irrigation based dvelopment Project is located in east west Bale Zone Zone, delomena district, of the Oromia Regional State. The study area has surrounded by strongely sloping to moderately steep slope ranging from 8-15 up to 15-30% currentely cultivated land with tomato, maize, sorghum, teff, enset, masho, onion, chat and mango. The present study area covers about 478.98ha 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, Hirba Giristu small scale irrigation project, is located in the Oromia Regional State, Bale zone, Delo mena district, hirba kebele, west to dawa river. More precisely it falls in between 709490 to 713456 UTM ^{N} and 595166 to 597947 UTM $^{E.}$ The targeted area of the project is 478.98ha. The altitude of the the study area ranges from 1236-1302 masl. 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 1207.5mm and annual Potential Evapotranspiration of 1351.2mm. The catchment area of the project has obtained bimodal rainfall type from April to June high rainfall and from July to November medium rainfall observed. The major rainfall occurs from March to November 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 18.94 ^{0}c to 26.1^{0}c and 9.79^{0}c to 12.6^{0}c, respectively.

2.3. Physiograpy and Geology

Residual land form with surruonding undulating side slopes and piedmont zones strongly influenced by coluvial processes but retaining distinct residual characteristices. The major land form of the command arean is plain and undulating side slope slope of 0-2 % rise up to 15-30%, developed on shallow colluvium over tertiary basalt and tuffs

2.4. Vegetation and Land Use

The vegetation cover is dominantly open wood and bush land spercely to moderately cultivation land on Cambisols and Luvisols, with traditional irrigation practice.

maize, sorghum, chat, mango, enset, teff and onion are cultivated in the command area, the vegetation cover is dominantly with Bekanisa and oda tree

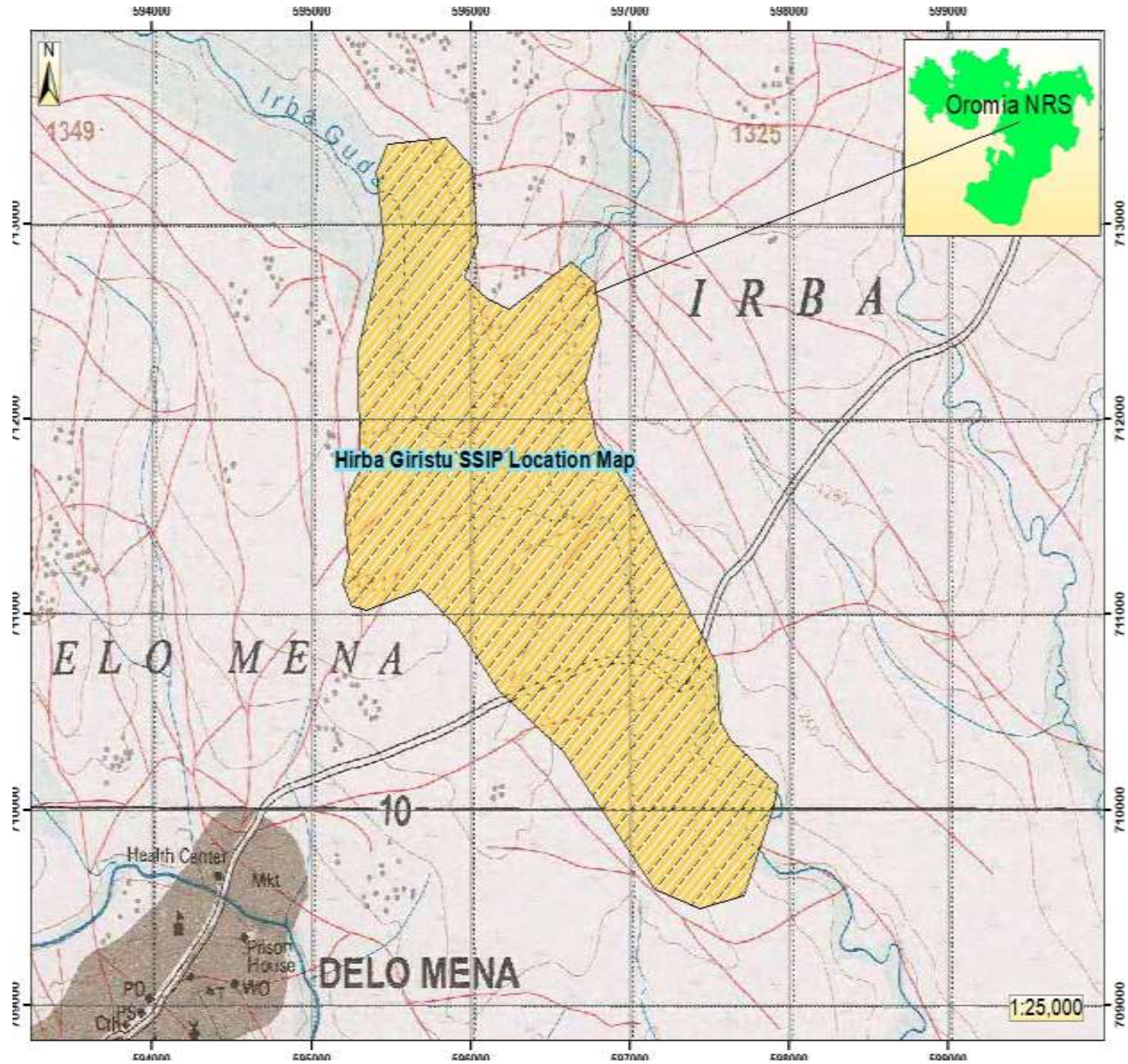


Figure 1: Location Map of Hirba Giristu small scale irrigation project

3. REVIEW OF PREVIOUS STUDIES

A number of previous soil and land evaluation studies on national level, basin wide and site specific such as different small scale and medium scale 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.

- **Guji- Bale Integrated Land Use Planning Study Genale Sub-Basin Final Soil survey report. The study was conducted by OWWDSE, The Client of the project is Oromia Rural Land Administration and Use Bureau,2016**

I-Soil survey

Genale sub basin is one of the largest sub basins in guji bale integrated land use planning covering an area of 6,417,029.5 hectares (45.55%) of the total area of Guji and Bale zones. This sub basin covers partially and fully included districts of Liben, Bore, Harenfamma, Adola, Wadera, Mada Walabu, Mena, Gura Dhamole, Dawa Sarar, Dawa Kachan, Goro, Barbare, Harena Buluk, Sinana, and Goba Districts of Guji and Bale Zones. This study area is extending from Geographical coordinate 04°37’28’’ to 07°08’38’’N and 38°33’09’’ to 41°35’34’’E and with an elevation range of 448m to 4368 m.a.s.l.

The overall objective of soil survey is to provide detailed information of the soil resources and related land forms of the Genale Sub basin which could be used as main data sources while evaluating, planning and setting the management option for integrated and sustainable land use planning in the study area. The vector study of the boundary of the sub basin was carried out by GIS software.

The main and general objective of the study is to investigate the necessary land qualities and characteristics for the purpose of land evaluation.

The specific objectives of the study are

- To carry out the soil survey at the scale of 1:50,000.
- To identify land quality and land characteristics of the soil for the purpose of land evaluation.
- To characterize the identified soil mapping units and the dominant soils with respect soil physical, morphological and chemical properties of the soil.
- To identify the limitation of the soil mapping units and give necessary recommendation and management option for those identified constraints.

Based on this Auger observation points, profile description and laboratory analysis, there are seven major soil types were identified in the study area having varying areal extent and distribution. These are Luvisols, Nitisols, Fluvisols, Calcisols, Vertisols, Cambisols and Leptosols having. Soil of the study area was mapped in to ninety-five soil mapping units. Cambisols and Luvisols of major soils were the dominant soil in the study area and bellow table shows the area extent and percentage of the major soil in the study area.

II-landevaluation for Irrigation

The objective of this part of the study is to assess the provisional suitability and delineate potentially suitable from non-suitable land for irrigated agriculture and to identify major limitations to cultivate agricultural crops under irrigation condition.

The FAO suitability evaluation methodology (FAO, 1985) with its detail procedures has been used at a scale of 1 : 50,000. Towards this end, the following main steps were followed :

1. Land utilization types (LUTs) eight (8) crops under irrigated condition selected.

2. Selection of the relevant class determining factor and establishment of the appropriate land use requirement or limitation in the form of factor rating table were made.
3. . Matching of critical limits of each land use requirement or limitation with the conditions found in the land unit to obtain a factor rating of s1, s2, s3, s4, n for each combination of LUT and land unit were made.
4. Combining individual class determining factor ratings to obtain a tentative land suitability classification for each LUT on each land unity following through the maximum limitation method was executed.
5. Mapping of provisionally irrigable area for each individual crops and development potentials were made as a final outcome.

Land utilization types such as Tomato, sesame, low land maize, Chili pepper, Citrus, onion and Banana. For irrigation agriculture were selected as a result the overall irrigated crop suitability evaluation under intermediate input level indicated that out the total 4,430,357.05 ha of the study area highly suitable 1.38%, and moderately suitable 1.33%, which is suitable for commercial and small holding farmers. In additions to this marginally suitable 62.23% of the total area may suitable for small holding farmers, and very marginally suitable 21.26% may suitable for non-crop uses and not suitable 13.8 % of the study area.

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 (2014), 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 1m 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 33 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" (2014) 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 (7 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 table 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	81
2	Soil profile description	3
3	Soil samples	11
4	Infiltration and hydraulic conductivity	3
5	Soil profile not sampled	0
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 23 SMU were identified on the basis of the above three criteria.

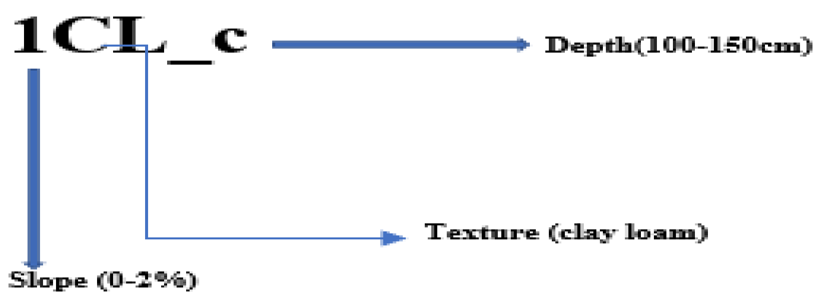
Table 2: Soil properties used for the definition of SMU

Slope		Texture		Depth		soil units
Percent	Map symbol	class	Map symbol	cm	Map symbol	
0-2	1	Clay loam	CL	>200	a	Chromic Luvisols
2-5	2	Sandy clay loam	SCL	150-200	b	cambisols
5-8	3			100-150	c	
8-15	4			50-100	d	
15-30	5					

- Accordingly based on slope, top soil texture, soil depth and soil units of the study area 23 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 deep soil profile (100-150 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 Hirba Giristu small scale Irrigation project is classified in to the following two major soils, i.e. Cambisols and Luvisols. 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 Hirba Giristu small scale Irrigation project has been presented on 1:10,000 scale maps.

I- Cambisols

Cambisols mainly distributed in North and north west part of the study area. dark reddish brown (5YR 3/3 Dry); and dark reddish brown (5YR 3/2 moist) colored, Clay loam textured, moderately deep to deep soil (50-100 cm and 100-150 cm), The soil is well drained and developed on undulating,rolling and moderately steep land (%,5-8%,8-15% and 15-30%) .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 **Cambisols** 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); The Cambisols of the study area with area coverage of 34.34 ha which constitutes 7.17% of the total area.Representative profile HGP-3. See soil mapping unit description

II-Luvisols

Luvisols are soils that have a higher clay content in the subsoil than in the topsoil as a result of pedogenetic processes (especially clay migration) leading to an argic subsoil horizon. Luvisols have high-activity clays throughout the argic horizon and a high base saturation at certain depths. Luvisols are Soils having an argichorizon with a cation exchange capacity (in 1 M NH4OAc at pH 7.0) equal to or greater than 24 cmol (+) kg-1 clay, either starting within 100 cm from the soil surface *or* within 200 cm from the soil surface if the argic horizon is overlain by material that is loamy sand or coarser throughout (FAO, 2001, WRB, 2014). The Luvisols soils of the study area with area coverage of 444.64 ha which constitutes 92.83% of the total area.

The Luvisols of the study area are classified as chromic Luvisols, with representative profile HGDBP-1 and HGP-2. The surface textures of the Luvisols are clay loam (the dominant) and the effective depth range is from 350 cm and >200cm respectively.

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

Soil physical and chemical characteristices	Units	Horizon	cambisols		Chromic Luvisols	
			value	Remark	Value	Remark
PH	water	Top	5.8	moderately acid	5-6	very strongly acid to moderately acid
	water	Sub	6.3	sligtely acid	5.40-6.30	strongly acid to sligtely acid
EC	ds/m	Top	0.18	salt free	0.05-0.08	salt free
	ds/m	Sub	0.047	salt free	0.02-0.05	salt free
Na	meq/100g soil	Top	0.22	low	0.13-0.16	low
	meq/100g soil	Sub	0.16	low	0.14-0.16	low
Ca	meq/100g soil	Top	16.31	High	7.28-14.37	medium to High
	meq/100g soil	Sub	13.1	High	7.74-13.01	medium to High
Mg	meq/100g soil	Top	9.47	very high	3-5.88	low to medium
	meq/100g soil	Sub	5.88	High	3.95-5.88	High
K	meq/100g soil	Top	0.87	High	0.03-0.35	very low to medium
	meq/100g soil	Sub	0.34	midium	0.03-0.33	very low to medium
CEC	meq/100g soil	Top	42.82	very high	20.96-41.82	medium to very High
	meq/100g soil	Sub	39.92	High	19.50-39.93	medium to High
BS	%	Top	64.27	High	47.48-64.27	medium to High
	%	Sub	48.72	medium	48.72-62	medium to High
ESP	%	Top	0.54	low	0.37-0.73	low
	%	Sub	0.4	low	0.40-0.80	low
AVP	ppm	Top	8.12	medium	0.04-5.40	low to medium
	ppm	Sub	0.1	low	0.06-0.10	low
OM	%	Top	5.76	very high	0.91-4.80	low to high
	%	Sub	1.6	medium	0.52-1.60	low to medium
TN	%	Top	0.32	very high	0.05-0.24	low to medium
	%	Sub	0.08	low	0.03-0.08	very low to low
Texture	class	Top	CL		CL-SCL	
	class	Sub	C		CL-SCL	
Depth	class	Top	30		30	
	class	Sub	80		>200	

6. DESCRIPTION OF SOIL PHYSICAL AND CHEMICAL PROPERTIES

6.1. Soil Physical Properties

The soil physical characteristics of Hirba Giristu 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 Hirba Giristu Small scale irrigation project are moderate to very deep (50-100 cm 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	Area	
cm	ha	%
>200	4.355	0.91
150-200	1.933	5.42
100-150	357.47	74.49
50-100	115.23	19.18
Total	478.988	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 is dominantly moderate,fine to medium sub angular blocky type,and weak, fine sub-angular blocky respectively and Chromic Luvisols have dominantly moderate, fine to medium sub angular blocky structure in their surface soils and weak,fine to medium, angular blocky structure in their sub soils.

6.1.4. Consistence

The consistence of soils varies with their textural composition Cambisols have sligtely hard(dry), friable(moist), slightely stick and slightely plastic and in the top soil and slightly sticky and slightly plastic when wet in the sub soil, for chromic Luvisols of the study area have slightly hard when dry friable when moist, sticky and plastic 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 soils texture of the Hirba Giristu SSIP are dominantly **Clay loam** and **clay** both for cambisols and Luvisols in the top and sub soil respectively

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 cambisols of the project area have dark redish brown (5YR3/3) when dry and dark redish brown (5YR3/2) when moist while for well drained chromic Luvisols is redish brown 5YR 4/4(when dry) and dark redish brown

5 YR3/3(when moist) in the top soil and 2.5YR3/4 dark redish brown when moist in color in the sub soil.

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 Hirba Giristu SSIP study area have well drained in Cambisols and Chromic Luvisols 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 surveys 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 5.68 cm/hr, this implies the ranking result is suitable for surface irrigation and the mean average infiltration rate of 6.47 cm/hr is also this implies the ranking result is suitable for surface irrigation ,as a result soils of the project area have a **suitable** infiltration rate.which implies small basins needed

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

Study area	Soil unit	Texture	Surface Textute	Immediate(instantanious)			SUM	Range of IR	Immediate(instantanious) Average_IR	Ranking for surface irrigation development
				IR_Rep1	IR_Rep2	IR_Rep3				
		class		cm/ha	cm/ha			cm/ha	cm/ha	
Hirba Giristu	chromic Luvisols and Cambisols	Medium	CL	6	5	6.5	17.5	5-6.5	**5.68**	**Suitable**

Study area	Soil unit	Texture	Surface Textute	Mean infiltration Rate cm/hr			SUM	Range of IR	Mean Average_IR	Ranking for surface irrigation development
				Rep1_M	Rep2_M	Rep3_M				
		class		cm/ha	cm/ha			cm/ha	cm/ha	
Hirba Giristu	chromic Luvisols and Cambisols	Medium	CL	6.57	5.87	6.98	19.42	5.87-6.98	**6.47**	**Suitable**

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 **2.06 m/day** for soils of the study area. The result indicates that, the water movement is 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 3)	Hydraulic conductivity (Rep 1 Rep2 and Rep3) Range	Average Hydraulic conductivity	Hydraulic conductivity value
		Type	class	m/day	m/day	m/day	m/day	m/day	Rating
Hirba Giristu	chromic Luvisols and Cambisols	CL	Medium	2.13	2.14	1.91	1.91-2.14	**2.06**	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 **1.27 g/cm^3**. The result shows moderate in the top to low in the sub 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)	Average	Rating	
Luvisols	**DBHGPcs - 1**	**0-30**	**CL**	**1.40**	Moderate	Top	**1.40**	**Top soil =1.37**	Moderate	
		30-100	**C**	**1.20**	Moderate	Sub	1.28			
		100-200	**C**	**1.36**	Low	Sub				
Luvisols	**HGPcs - 2**	**0-30**	**CL**	**1.34**	Moderate	Top	**1.34**	**Sub soil =1.27**	Low	
		30-80	**C**	**1.25**	Moderate	Sub	1.26			some too compact
		80-150	**C**	**1.28**	Low	Sub				

6.1.11. Field capacity

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 34.8 **%** in the top soil and 37.44**%** in the sub soils.

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)	Average
		cm	class				
Luvisols	DBHGPcs - 1	0-30	CL	36.8	Top	36.8	Top soil= 34.8
		30-100	C	37.2	sub	36.49	
		100-200	C	35.8			
Luvisols	HGPcs - 2	0-30	CL	32.8	Top	32.8	Sub soil= 37.44
		30-80	C	38.7	sub	38.38	
		80-150	C	38.1			

6.1.12. Permanent wilting point

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 (Rhodic, Eutric Nitisols andChromic Luvisols) of the study area fall in the range of 22.9**%** in the top soil and25.21**%** 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)	Average
		cm	class				
Luvisols	DBHGPcs - 1	0-30	CL	23.7	Top	23.7	Top soil=22.9
		30-100	C	24.1	sub	24.51	
		100-200	C	24.9			
Luvisols	HGPcs - 2	0-30	CL	22.1	Top	22.1	Sub soil=25.21
		30-80	C	25.6	sub	25.91	
		80-150	C	26.2			

6.1.13. Available water capacity

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), Total available water capacity (TAWC) and readily available water capacity (RAWC) value for the Representative profile of the soils of the study area.

Major Soil	Field_Code	Horizon	Depth	Depth	Depth	Texture	Texture	FC	PWP	FC_PWP	BD	AWC	AWC	TAWC	TRAWC	AWC
		cm	cm	cm(Thickness)	mm	class	class	(0.33bar)	(15bar)		(gm_cm^3)	cm	mm	mm/m	mm/m	Rating
Luvisols	DBHGPcs - 1	Top	0-30	30	300	CL	medium	36.8	23.7	13.12	1.40	5.52	55.16	**263.09**	175.39	high
		sub	30-100	70	700	C	fine	37.2	24.1	13.08	1.20	10.94	109.41			
		sub	100-200	100	1000	C	fine	35.8	24.9	10.88	1.36	14.78	147.78			
Luvisols	HGPcs - 2	Top	0-30	30	300	CL	medium	32.8	22.1	10.65	1.34	4.30	42.97	**265.33**	176.89	high
		sub	30-80	50	500	C	fine	38.7	25.6	13.08	1.25	8.14	81.44			
		sub	80-150	70	700	C	fine	38.1	26.2	11.87	1.28	10.64	106.43			

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

6.1.15. 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 Cambisols and Chromic Luvisols are all well-aerated at field capacity.

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

Major Soil	Field_Code	Texture class	Horizon	Bulk density g/cm3	Total porosity %	FC (0.33bar)	**Air-filled porosity %**	Effect on soil codition
Luvisols	DBHGPcs - 1	CL	Top soil	1.40	47.13	36.8	**10.29**	adequate aeration, for plant growth and for biological activity
		C	0.3-1m	1.20	54.90	37.2	**17.73**	adequate aeration, for plant growth and for biological activity
		C	1-2m	1.36	48.73	35.8	**12.93**	adequate aeration, for plant growth and for biological activity
Luvisols	HGPcs - 2	CL	Top soil	1.34	49.26	32.8	**16.48**	adequate aeration, for plant growth and for biological activity
		C	0.3-0.8m	1.25	52.99	38.7	**14.31**	adequate aeration, for plant growth and for biological activity
		C	0.8-1.5m	1.28	51.67	38.1	**13.60**	adequate aeration, for plant growth and for biological activity

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 sheet and splash erosion observed both on site and in the surrounding for slope up to 5% (Chromic Luvisols), where as for, with slope ≥8%(cambisols) slight splash, sheet and rill observed

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 10 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 pH(h2o) value of the project area in soil-water suspension varies from **5.0 to 6.30** with an average of **5.5,** Which increase from top to sub soil (DBHGP-1, HGP-2 and HGP-3), This range of soil pH is normally termed as very Strongly acid to sligtely acid soil, but the average value is Strongly acid acid.

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 **0.05-0.18 dS**/m with an average of **0.095** 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 i.e varying from **0.34 -1.55 dS**/m with anaverage of **0.81 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 0.53**% to 3.34%** with average of 2.34 **%** which it is rated as very low to low level of organic carbon content. The determination of organic matter (OM) is conducted to evaluate availability of plant nutrients and physical condition of the soil. Soil organic matter consists of plant, animal and microbial residues in various stage of decay. Organic matter contains about five present (5 per cent) of total nitrogen, so it serves as a storehouse for reserve nitrogen. But the nitrogen in organic matter is in inorganic form and not immediately available for plant use, since decomposition usually occurs slowly. Organic matter results to dark color of many soils, holds water 20 times of its weight, provides aggregation and has high CEC.

The organic matter content of the study area area are in the range of 0.91**% to 5.76 %** the average organic matter content of the soils of the study area is 4.04**%** and is rated as low 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 **0.05 to 0.32** percent with an average of 0.22% which indicate that the total nitrogen content is low 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 10.44 to 12.02. The average value is 10.85

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 (AvP) 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 0.04 ppm to 8.12 ppm with average of 3.99ppm where the value is low, 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 values of CEC lie in the range of 20.90 meq/100g soil to 42.82

meq/100g. CEC values between this ranges are rated as medium to very high, which in turn mean moderate to 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 47.48% to 64.82% indicating very medium to 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 7.28 cmol (+)/kg soil to 16.31 cmol (+)/kg soil with average value of 12.41 cmol (+)/kg soil, which indicate that medium to 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 3.0 to 9.47cmol (+)/kg soil with average value of 5.89 cmol (+)/kg soil. The result shows that the level of Mg is high to very high

6.2.11. Exchangeable Potassium (K)

Plant requirements for potassium (K) are supplied from two soil sources : exchangeable K that is immediately available, and non-exchangeable available potassium (NEAP), which is more slowly available.

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 0.03 to 0.87 cmol (+)/kg soil. Which indicates that the level of K is very low to high. The average value is 0.42 cmol (+)/kg

6.2.12. Exchangeable Sodium (Na)

Sodium is not an essential plant nutrient; but some plants for potassium substitute can utilize it. On the other hand, when sodium is present in the soil in significant quantities, particularly in proportion to the other cations present it can have an adverse effect to both plant nutrition and physical conditions of the soils; however, no structural degradation was observed during the present filed work.The value of the measured exchangeable Na falls in the range of 0.13 to 0.22 cmol(+)/kg of soil, which is low level,with mean value of 0.0.172 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 0.37 % to 0.70% with avegage value of 0.52% 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 carbonate

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 **Hirba Giristu SSIP is trace**, this value shows that the soils are free of Calcium Carbonate 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 0.01 and 0.09(Average value is 0.065: 1, indicating an optimum situation for production of most field crops, vegetables, fruit and suger beet.

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 very low to moderately high 1.63 to 4.78. 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 0.00 and maximum was 0.02 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 23.70ppm(low) to 288.70 ppm(high), with average value of 152.39 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 20.38 to 46.33(low to medium) this indicates crop response is probable to possible.

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 19 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 Hirba Giristu small scale Irrigation Projectes

Major soil group(FAO,1998,2006,WRB,2014	Major soil uinits(FAO,1998,2006,WRB,2014	SMU	Area,ha	%
		1C_c	0.433	0.090
		1CL_c	63.993	13.360
		1CL_d	6.889	1.438
		2C_c	7.297	1.523
Luvisols	Chromic Luvisols	2CL_a	0.449	0.094
		2CL_b	1.266	0.264
		2CL_c	126.550	26.421
		2CL_d	26.078	5.445
		3CL_a	3.054	0.638
		3CL_b	0.666	0.139
		3CL_c	95.458	19.929
		3CL_d	25.470	5.318
		4CL_a	0.851	0.178
		4CL_c	59.255	12.371
		4CL_d1	17.150	3.581
		5CL_c	0.765	0.160
		5CL_d	9.018	1.883
Cambisols	Haplic Cambisols	3CL_c1	1.337	0.279
		4CL_c1	3.927	0.820
		4CL_d	27.710	5.785
		5CL_d1	1.370	0.286
	Total area,ha		478.987	100

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

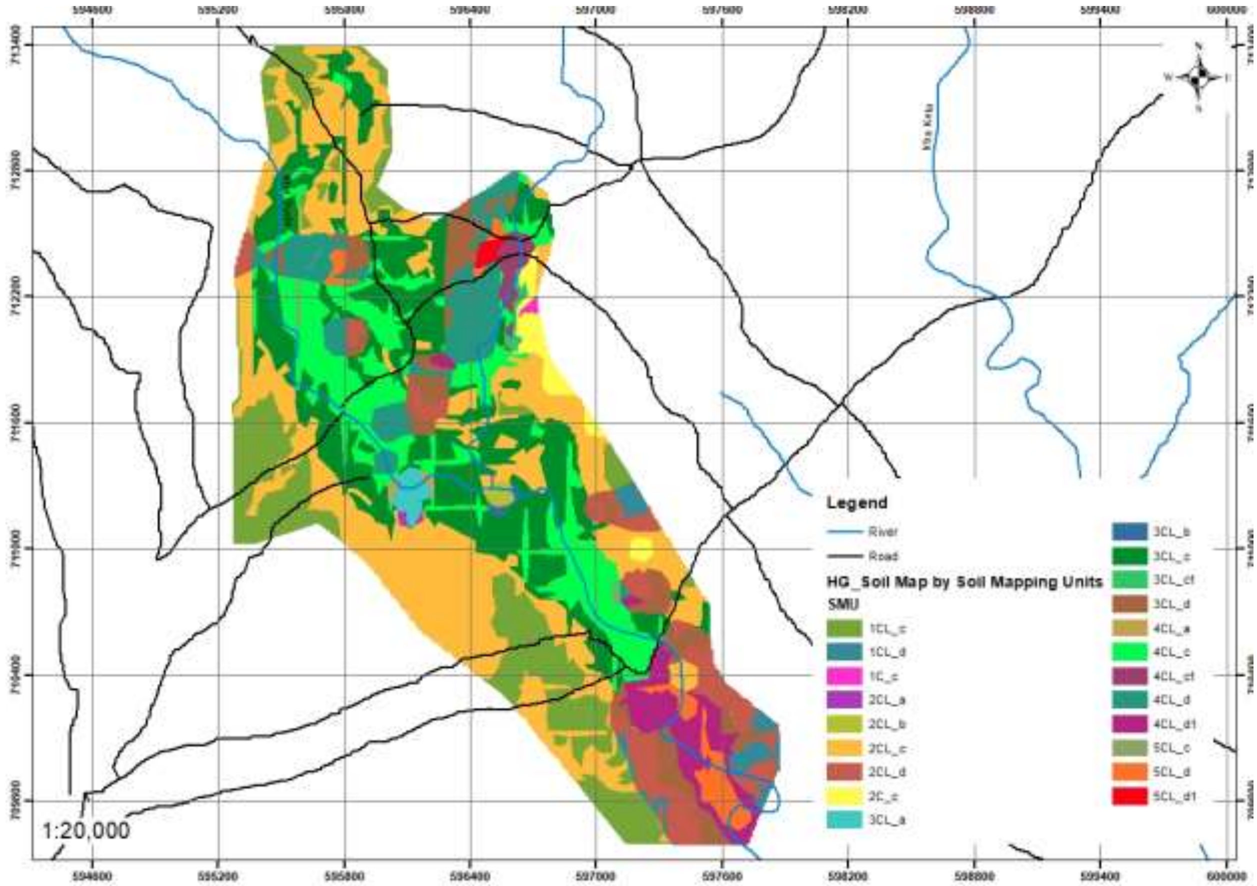
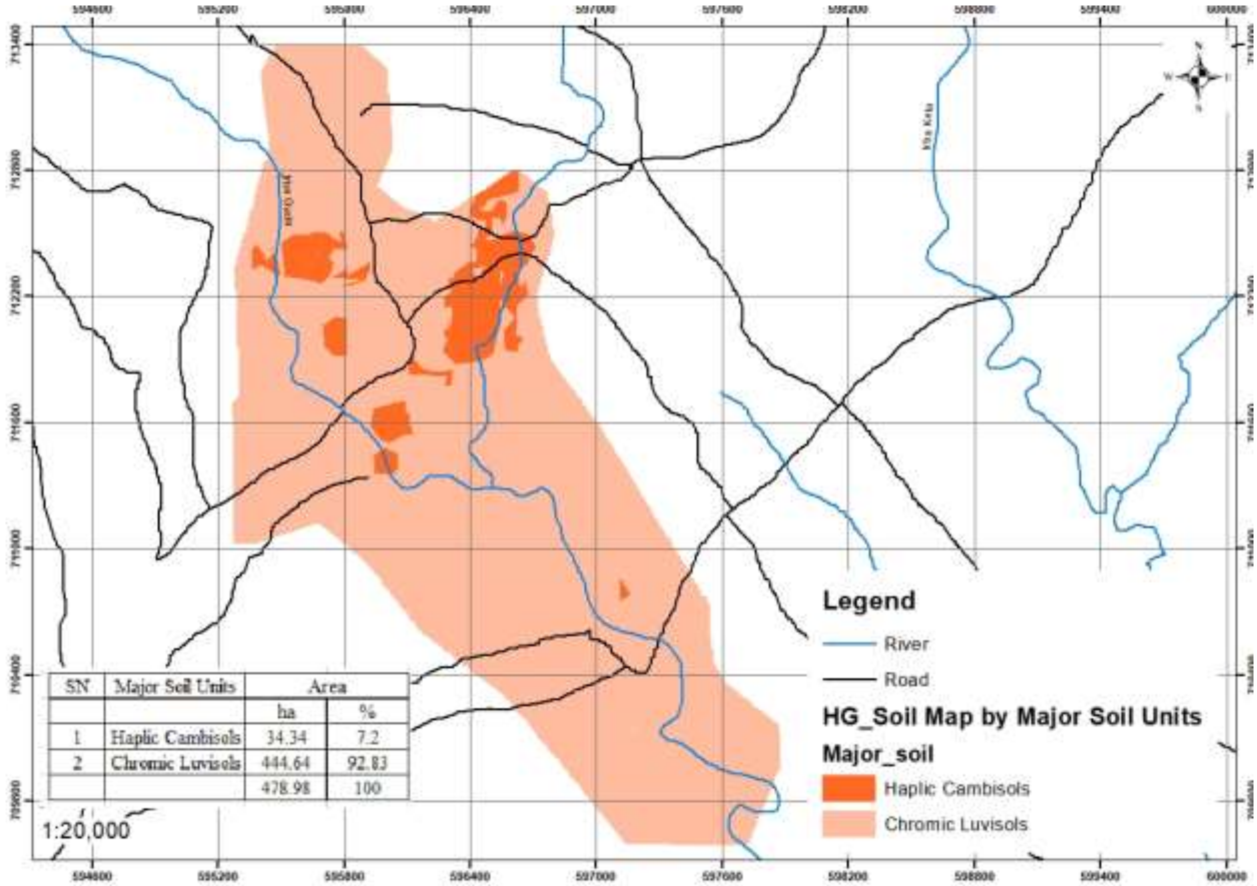


Figure 3: Soil Maps of the study area by Soil units



Soil Mapping units :

1C-c

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

The average infiltration rate (IR) of this unit is categorized as suitable (5.68 cm/hr) and the average hydraulic conductivity (HC) is 2.06 m/day, which is rapid.

The pH_h2o value is 6.30 in the top soil and 5.8 in the sub soil indicating that the soil is sligtely acid to moderatly acid. The overall organic carbon content of this soil unit is 0.94% in the top soil and 0.05 % in sub soil, which indicates very low level of organic matter content. Total nitrogen content ranges 0.08% in the top and 0.06 % in sub soil which shows low status of the total nitrogen. This soil mapping unit has low available phosphorus (0.10 ppm in the top soil & 0.06ppm in the sub soil), high CEC level (39.92 & 25.5Meq/100g of soilin top and sub soil respectively) and medium base saturation percentage (48.72% in the top soil and 56% in the sub soil). The soil units is Chromic Luvisols. The total extent of this mapping unit is 0.433 ha or 0.090 %.

1CL-c

This mapping unit refers to soils developed on 0-2% slope with moderate 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 suitable (5.68 cm/hr) and the average hydraulic conductivity (HC) is 2.06 m/day, which is rapid.

The pH_h2o value is 6.30 in the top soil and 5.8 in the sub soil indicating that the soil is sligtely acid to moderatly acid. The overall organic carbon content of this soil unit is 0.94% in the top soil and 0.05 % in sub soil, which indicates very low level of organic matter content. Total nitrogen content ranges 0.08% in the top and 0.06 % in sub soil which shows low status of the total nitrogen. This soil mapping unit has low available phosphorus (0.10 ppm in the top soil & 0.06ppm in the sub soil), high CEC level (39.92 & 25.5Meq/100g of soilin top and sub soil respectively) and medium base saturation percentage (48.72% in the top soil and 56% in the sub soil). The soil units is Chromic Luvisols. The total extent of this mapping unit is 63.99 ha or 13.4 %.

1CL-d

This mapping unit refers to soils developed on 0-2% slope with moderate profile (50-100cm). 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 suitable (5.68 cm/hr) and the average hydraulic conductivity (HC) is 2.06 m/day, which is rapid.

The pH_h2o value is 5.10 in the top soil and 5.4 in the sub soil indicating that the soil is strongly acid. The overall organic carbon content of this soil unit is 2.34% in the top soil and 0.30 % in sub soil, which indicates very low to very low level of organic matter content. Total nitrogen content ranges 0.22% in the top and 0.03 % in sub soil which shows medium to low status of the total nitrogen. This soil mapping unit has low available phosphorus (0.58 ppm in the top soil & 0.07ppm in the sub soil), medium CEC level (23.68 & 19.5Meq/100g of soil in top and sub soil respectively) and medium to high base saturation percentage (50.64% in the top soil and 62% in the sub soil). The soil units is Chromic Luvisols. The total extent of this mapping unit is 6.89 ha or 1.44 %.

2C-c

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

The average infiltration rate (IR) of this unit is categorized as suitable (5.68 cm/hr) and the average hydraulic conductivity (HC) is 2.06 m/day, which is rapid.

The pH_h2o value is 6.30 in the top soil and 5.8 in the sub soil indicating that the soil is sligtely acid to moderatly acid. The overall organic carbon content of this soil unit is 0.94% in the top soil and 0.05 % in sub soil, which indicates very low level of organic matter content. Total nitrogen content ranges 0.08% in the top and 0.06 % in sub soil which shows low status of the total nitrogen. This soil mapping unit has low available phosphorus (0.10 ppm in the top soil & 0.06ppm in the sub soil), high CEC level (39.92 & 25.5Meq/100g of soilin top and sub soil respectively) and medium base saturation percentage (48.72% in the top soil and 56% in the sub soil). The soil units is Chromic Luvisols. The total extent of this mapping unit is 0.433 ha or 0.090 %.

2CL_a

This mapping unit refers to soils developed on 2-5% slope with very deep profile (>200cm). 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 suitable (5.68 cm/hr) and the average hydraulic conductivity (HC) is 2.06 m/day, which is rapid.

The pH_h2o value is 5.10 in the top soil and 5.4 in the sub soil indicating that the soil is strongly acid. The overall organic carbon content of this soil unit is 2.34% in the top soil and 0.30 % in sub soil, which indicates very low to very low level of organic matter content. Total nitrogen content ranges 0.22% in the top and 0.03 % in sub soil which shows medium to low status of the total nitrogen. This soil mapping unit has low available phosphorus (0.58 ppm in the top soil & 0.07ppm in the sub soil), medium CEC level (23.68 & 19.5Meq/100g of soil in top and sub soil respectively) and medium to high base saturation percentage (50.64% in the top soil and 62% in the sub soil). The soil units is Chromic Luvisols. The total extent of this mapping unit is 0.45 ha or 0.094 %.

2CL_b

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

The average infiltration rate (IR) of this unit is categorized as suitable (5.68 cm/hr) and the average hydraulic conductivity (HC) is 2.06 m/day, which is rapid.

The pH_h2o value is 6.30 in the top soil and 5.8 in the sub soil indicating that the soil is sligtely acid to moderatly acid. The overall organic carbon content of this soil unit is 0.94% in the top soil and 0.05 % in sub soil, which indicates very low level of organic matter content. Total nitrogen content ranges 0.08% in the top and 0.06 % in sub soil which shows low status of the total nitrogen. This soil mapping unit has low available phosphorus (0.10 ppm in the top soil & 0.06ppm in the sub soil), high CEC level (39.92 & 25.5Meq/100g of soilin top and sub soil respectively) and medium base saturation percentage (48.72% in the top soil and 56% in the sub soil). The soil units is Chromic Luvisols. The total extent of this mapping unit is 1.27 ha or 0.264 %.

2CL_c

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

The average infiltration rate (IR) of this unit is categorized as suitable (5.68 cm/hr) and the average hydraulic conductivity (HC) is 2.06 m/day, which is rapid.

The pH_h2o value is 6.30 in the top soil and 5.8 in the sub soil indicating that the soil is sligtely acid to moderatly acid. The overall organic carbon content of this soil unit is 0.94% in the top soil and 0.05 % in sub soil, which indicates very low level of organic matter content. Total nitrogen content ranges 0.08% in the top and 0.06 % in sub soil which shows low status of the total nitrogen. This soil mapping unit has low available phosphorus (0.10 ppm in the top soil & 0.06ppm in the sub soil), high CEC level (39.92 & 25.5Meq/100g of soilin top and sub soil respectively) and medium base saturation percentage (48.72% in the top soil and 56% in the sub soil). The soil units is Chromic Luvisols. The total extent of this mapping unit is 126.6 ha or 26.42 %.

2CL_d

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

The average infiltration rate (IR) of this unit is categorized as suitable (5.68 cm/hr) and the average hydraulic conductivity (HC) is 2.06 m/day, which is rapid.

The pH_h2o value is 6.30 in the top soil and 5.8 in the sub soil indicating that the soil is sligtely acid to moderatly acid. The overall organic carbon content of this soil unit is 0.94% in the top soil and 0.05 % in sub soil, which indicates very low level of organic matter content. Total nitrogen content ranges 0.08% in the top and 0.06 % in sub soil which shows low status of the total nitrogen. This soil mapping unit has low available phosphorus (0.10 ppm in the top soil & 0.06ppm in the sub soil), high CEC level (39.92 & 25.5Meq/100g of soilin top and sub soil respectively) and medium base saturation percentage (48.72% in the top soil and 56% in the sub soil). The soil units is Chromic Luvisols. The total extent of this mapping unit is 26.1 ha or 5.45 %.

3CL_a

This mapping unit refers to soils developed on 5-8% slope with very deep profile (>200cm). 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 suitable (5.68 cm/hr) and the average hydraulic conductivity (HC) is 2.06 m/day, which is rapid.

The pH_h2o value is 5.10 in the top soil and 5.4 in the sub soil indicating that the soil is strongly acid. The overall organic carbon content of this soil unit is 2.34% in the top soil and 0.30 % in sub soil, which indicates very low to very low level of organic matter content. Total nitrogen content ranges 0.22% in the top and 0.03 % in sub soil which shows medium to low status of the total nitrogen. This soil mapping unit has low available phosphorus (0.58 ppm in the top soil & 0.07ppm in the sub soil), medium CEC level (23.68 & 19.5Meq/100g of soil in top and sub soil respectively) and medium to high base saturation percentage (50.64% in the top soil and 62% in the sub soil). The soil units is Chromic Luvisols. The total extent of this mapping unit is 3.1 ha or 0.64 %.

3CL_b

This mapping unit refers to soils developed on 5-8% slope with moderately deep profile (100-150cm). The soils are well drained with moderate, fine to medium sub angular blocky structure and have Clay (C) texture.

The average infiltration rate (IR) of this unit is categorized as suitable (5.68 cm/hr) and the average hydraulic conductivity (HC) is 2.06 m/day, which is rapid.

The pH_h2o value is 6.30 in the top soil and 5.8 in the sub soil indicating that the soil is sligtely acid to moderatly acid. The overall organic carbon content of this soil unit is 0.94% in the top soil and 0.05 % in sub soil, which indicates very low level of organic matter content. Total nitrogen content ranges 0.08% in the top and 0.06 % in sub soil which shows low status of the total nitrogen. This soil mapping unit has low available phosphorus (0.10 ppm in the top soil & 0.06ppm in the sub soil), high CEC level (39.92 & 25.5Meq/100g of soilin top and sub soil respectively) and medium base saturation percentage (48.72% in the top soil and 56% in the sub soil). The soil units is Chromic Luvisols. The total extent of this mapping unit is 0.67 ha or 0.14 %.

3CL_c

This mapping unit refers to soils developed on 5-8% slope with moderately deep profile (100-150cm). The soils are well drained with moderate, fine to medium sub angular blocky structure and have Clay (C) texture.

The average infiltration rate (IR) of this unit is categorized as suitable (5.68 cm/hr) and the average hydraulic conductivity (HC) is 2.06 m/day, which is rapid.

The pH_h2o value is 6.30 in the top soil and 5.8 in the sub soil indicating that the soil is sligtely acid to moderatly acid. The overall organic carbon content of this soil unit is 0.94% in the top soil and 0.05 % in sub soil, which indicates very low level of organic matter content. Total nitrogen content ranges 0.08% in the top and 0.06 % in sub soil which shows low status of the total nitrogen. This soil mapping unit has low available phosphorus (0.10 ppm in the top soil & 0.06ppm in the sub soil), high CEC level (39.92 & 25.5Meq/100g of soilin top and sub soil respectively) and medium base saturation percentage (48.72% in the top soil and 56% in the sub soil). The soil units is Chromic Luvisols. The total extent of this mapping unit is 95.46 ha or 19.93 %.

3CL_c1

This mapping unit refers to soils developed on 5-8% slope with moderately 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 suitable (5.68 cm/hr) and the average hydraulic conductivity (HC) is 2.06 m/day, which is rapid.

The pH_h2o value is 5.8 in the top soil and 6.3 in the sub soil indicating that the soil is moderately acid to sligtely acid. The overall organic carbon content of this soil unit is 3.34% in the top soil and 0.94 % in sub soil, which indicates low to very low level of organic matter content. Total nitrogen content ranges 0.32% in the top and 0.084 % in sub soil which shows very high to low status of the total nitrogen. This soil mapping unit has medium to low available phosphorus (8.12 ppm in the top soil & 0.10ppm in the sub soil), very high to high CEC level (41.82 & 39.32Meq/100g of soil in top and sub soil respectively) and high to medium base saturation percentage (64.27% in the top soil and 48.7% in the sub soil). The soil units is Haplic Cambisols. The total extent of this mapping unit is 1.34 ha or 0.279 %.

3CL_d

This mapping unit refers to soils developed on 5-8% slope with moderate profile (50-100cm). 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 suitable (5.68 cm/hr) and the average hydraulic conductivity (HC) is 2.06 m/day, which is rapid.

The pH_h2o value is 5.8 in the top soil and 6.3 in the sub soil indicating that the soil is moderately acid to sligtely acid. The overall organic carbon content of this soil unit is 3.34% in the top soil and 0.94 % in sub soil, which indicates low to very low level of organic matter content. Total nitrogen content ranges 0.32% in the top and 0.084 % in sub soil which shows very high to low status of the total nitrogen. This soil mapping unit has medium to low available phosphorus (8.12 ppm in the top soil & 0.10ppm in the sub soil), very high to high CEC level (41.82 & 39.32Meq/100g of soil in top and sub soil respectively) and high to medium base saturation percentage (64.27% in the top soil and 48.7% in the sub soil). The soil units is Haplic Cambisols. The total extent of this mapping unit is 25.47 ha or 5.32 %.

4CL_a

This mapping unit refers to soils developed on 8-15% slope with very deep profile (>200cm). 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 suitable (5.68 cm/hr) and the average hydraulic conductivity (HC) is 2.06 m/day, which is rapid.

The pH_h2o value is 5.10 in the top soil and 5.4 in the sub soil indicating that the soil is strongly acid. The overall organic carbon content of this soil unit is 2.34% in the top soil and 0.30 % in sub soil, which indicates very low to very low level of organic matter content. Total nitrogen content ranges 0.22% in the top and 0.03 % in sub soil which shows medium to low status of the total nitrogen. This soil mapping unit has low available phosphorus (0.58 ppm in the top soil &

0.07ppm in the sub soil), medium CEC level (23.68 & 19.5Meq/100g of soil in top and sub soil respectively) and medium to high base saturation percentage (50.64% in the top soil and 62% in the sub soil). The soil units is Chromic Luvisols. The total extent of this mapping unit is 0.85 ha or 0.18 %.

4CL_c

This mapping unit refers to soils developed on 8-15% slope with moderately deep profile (100-150cm). The soils are well drained with moderate, fine to medium sub angular blocky structure and have Clay (C) texture.

The average infiltration rate (IR) of this unit is categorized as suitable (5.68 cm/hr) and the average hydraulic conductivity (HC) is 2.06 m/day, which is rapid.

The pH_h2o value is 6.30 in the top soil and 5.8 in the sub soil indicating that the soil is sligtely acid to moderatly acid. The overall organic carbon content of this soil unit is 0.94% in the top soil and 0.05 % in sub soil, which indicates very low level of organic matter content. Total nitrogen content ranges 0.08% in the top and 0.06 % in sub soil which shows low status of the total nitrogen. This soil mapping unit has low available phosphorus (0.10 ppm in the top soil & 0.06ppm in the sub soil), high CEC level (39.92 & 25.5Meq/100g of soilin top and sub soil respectively) and medium base saturation percentage (48.72% in the top soil and 56% in the sub soil). The soil units is Chromic Luvisols. The total extent of this mapping unit is 59.26 ha or 12.37 %.

4CL_c1

This mapping unit refers to soils developed on 8-15% slope with moderately 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 suitable (5.68 cm/hr) and the average hydraulic conductivity (HC) is 2.06 m/day, which is rapid.

The pH_h2o value is 5.8 in the top soil and 6.3 in the sub soil indicating that the soil is moderately acid to sligtely acid. The overall organic carbon content of this soil unit is 3.34% in the top soil and 0.94 % in sub soil, which indicates low to very low level of organic matter content. Total nitrogen content ranges 0.32% in the top and 0.084 % in sub soil which shows very high to low status of the total nitrogen. This soil mapping unit has medium to low available phosphorus (8.12 ppm in the top soil & 0.10ppm in the sub soil), very high to high CEC level (41.82 & 39.32Meq/100g of soil in top and sub soil respectively) and high to medium base saturation percentage (64.27% in the top soil and 48.7% in the sub soil). The soil units is Haplic Cambisols. The total extent of this mapping unit is 3.93 ha or 0.82 %.

4CL_d

This mapping unit refers to soils developed on 8-15% slope with moderate deep profile (50-100cm). 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 suitable (5.68 cm/hr) and the average hydraulic conductivity (HC) is 2.06 m/day, which is rapid.

The pH_h2o value is 5.8 in the top soil and 6.3 in the sub soil indicating that the soil is moderately acid to sligtely acid. The overall organic carbon content of this soil unit is 3.34% in the top soil and 0.94 % in sub soil, which indicates low to very low level of organic matter content. Total nitrogen content ranges 0.32% in the top and 0.084 % in sub soil which shows very high to low status of the total nitrogen. This soil mapping unit has medium to low available phosphorus (8.12 ppm in the top soil & 0.10ppm in the sub soil), very high to high CEC level (41.82 & 39.32Meq/100g of soil in top and sub soil respectively) and high to medium base saturation percentage (64.27% in the top soil and 48.7% in the sub soil). The soil units is Haplic Cambisols. The total extent of this mapping unit is 27.71 ha or 5.79 %.

4CL_d1

This mapping unit refers to soils developed on 8-15% slope with moderate deep profile (50-100cm). 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 suitable (5.68 cm/hr) and the average hydraulic conductivity (HC) is 2.06 m/day, which is rapid.

The pH_h2o value is 5.8 in the top soil and 6.3 in the sub soil indicating that the soil is moderately acid to sligtely acid. The overall organic carbon content of this soil unit is 3.34% in the top soil and 0.94 % in sub soil, which indicates low to very low level of organic matter content. Total nitrogen content ranges 0.32% in the top and 0.084 % in sub soil which shows very high to low status of the total nitrogen. This soil mapping unit has medium to low available phosphorus (8.12 ppm in the top soil & 0.10ppm in the sub soil), very high to high CEC level (41.82 & 39.32Meq/100g of soil in top and sub soil respectively) and high to medium base saturation percentage (64.27% in the top soil and 48.7% in the sub soil). The soil units is Haplic Cambisols. The total extent of this mapping unit is 17.15 ha or 3.58 %.

5CL_c

This mapping unit refers to soils developed on 15-30% slope with moderately deep profile (100-150cm). The soils are well drained with moderate, fine to medium sub angular blocky structure and have Clay (C) texture.

The average infiltration rate (IR) of this unit is categorized as suitable (5.68 cm/hr) and the average hydraulic conductivity (HC) is 2.06 m/day, which is rapid.

The pH_h2o value is 6.30 in the top soil and 5.8 in the sub soil indicating that the soil is sligtely acid to moderatly acid. The overall organic carbon content of this soil unit is 0.94% in the top soil and 0.05 % in sub soil, which indicates very low level of organic matter content. Total nitrogen content ranges 0.08% in the top and 0.06 % in sub soil which shows low status of the total nitrogen. This soil mapping unit has low available phosphorus (0.10 ppm in the top soil & 0.06ppm in the sub soil), high CEC level (39.92 & 25.5Meq/100g of soilin top and sub soil respectively) and medium base saturation percentage (48.72% in the top soil and 56% in the sub soil). The soil units is Chromic Luvisols. The total extent of this mapping unit is 0.77 ha or 0.16 %.

5CL_d

This mapping unit refers to soils developed on 15-30% slope with moderately deep profile (100-150cm). The soils are well drained with moderate, fine to medium sub angular blocky structure and have Clay (C) texture.

The average infiltration rate (IR) of this unit is categorized as suitable (5.68 cm/hr) and the average hydraulic conductivity (HC) is 2.06 m/day, which is rapid.

The pH_h2o value is 6.30 in the top soil and 5.8 in the sub soil indicating that the soil is sligtely acid to moderatly acid. The overall organic carbon content of this soil unit is 0.94% in the top soil and 0.05 % in sub soil, which indicates very low level of organic matter content. Total nitrogen content ranges 0.08% in the top and 0.06 % in sub soil which shows low status of the total nitrogen. This soil mapping unit has low available phosphorus (0.10 ppm in the top soil & 0.06ppm in the sub soil), high CEC level (39.92 & 25.5Meq/100g of soilin top and sub soil respectively) and medium base saturation percentage (48.72% in the top soil and 56% in the sub soil). The soil units is Chromic Luvisols. The total extent of this mapping unit is 9.02 ha or 1.88 %.

5CL_d1

This mapping unit refers to soils developed on 15-30% slope with moderate deep profile (50-100cm). 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 suitable (5.68 cm/hr) and the average hydraulic conductivity (HC) is 2.06 m/day, which is rapid.

The pH_h2o value is 5.8 in the top soil and 6.3 in the sub soil indicating that the soil is moderately acid to sligtely acid. The overall organic carbon content of this soil unit is 3.34% in the top soil and 0.94 % in sub soil, which indicates low to very low level of organic matter content. Total nitrogen content ranges 0.32% in the top and 0.084 % in sub soil which shows very high to low status of the total nitrogen. This soil mapping unit has medium to low available phosphorus (8.12 ppm in the top soil & 0.10ppm in the sub soil), very high to high CEC level (41.82 & 39.32Meq/100g of soil in top and sub soil respectively) and high to medium base saturation percentage (64.27% in the top soil and 48.7% in the sub soil). The soil units is Haplic Cambisols. The total extent of this mapping unit is 1.370 ha or 0.286 %.

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, Hirba Giristu 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 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 clayloam, Sandy clay loam and Sandy Loam in texture.

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 (Head cabbage, Haricot bean, Tomato, Pepper and Onion)
2. Irrigated Cereal crop cultivation (Low land maize, sorgum)

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 : 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 17 : 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 18 : 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(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/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 19 : Cabbage (brassica oleracea)-Crop Environmental Requirements

Landuse Requirements for surface Irrigated Cabbage cultivation								
Land quality/diag.factors	Subclass	Land characteristices	unit	S1	S2	S3	S4	N
climate(cl)	c	Mean air temperature	oc	13-18/18-24	10-13/24-30	5-10/30-35		<5>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	%	>1.5/0.8-1.5	<0.8			
	n2	CEC	meq/100g soil	>24/16-24	<16(-)	<16(+)		
	n3	AVP	ppm	>15	8-15	4-8	<4	
	n4	TN	%					
	n5	OM	%					
Nutient Availability(z)	z	Soil reaction		6-6.8/6.8-7.8	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	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: Sorghum (sorghum bicolor)-Crop Environmental Requirements

Landuse Requirements for surface Irrigated Sorghum cultivation								
Land quality/diag.factors	Subclass	Land characteristices	unit	S1	S2	S3	S4	N
climate(cl)	c	Mean air temperature	oc	17-30	16-17/30-35	15-16/35-38	14-15/38-40	<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/SE/E	I		P	VP
Nutrient retantion(n)	n1	Organic carbon	%	>2.5	1.7-2.5	1.5-1.7	1-1.5	<0.1
	n2	CEC	meq/100g soil	>24/16-24	<16(-)	>16(+)		
	n3	AVP	ppm	>15	8-15	4-8	<4	
Nutient Availability(z)	z	Soil reaction		5.5-6.5/6.5-8.5	5.3-5.5/8.2-8.5	5.2-5.3/8.3-8.5	<5.2	>8.5
Rooting condition(rl)	r	Effective soil depth	cm	>100	70-100	25-70	15-25	<15
Workability(w)	w	Texture	class	c<60/cl/scl/sil/sicl/sic/sc/L	c>60v/sl	fs/s/Lcs/LS		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		0-3	3-15	15-35	35-55	>55
Flood hazard(f)	f	Flooding		FO		F1		F2+
Erosion Hazared(e)	e	sheet	class	no	slight	moderate	sever	very sever
		Gully	class	none	none	slight	moderate	strong

Table 21:Haricot bean (Phaseolus vulgaris)-Crop Environmental Requirements

Landuse Requirements for surface Irrigated Haricot bean cultivation								
Land quality/diag.factors	Subclass	Land characteristices	unit	S1	S2	S3	S4	N
climate(cl)	c	Mean air temperature	oc	20-22.5	17.5-20/22.5-25	14-16/35-40		<17>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	%	>2/1.2-2	0.8-1.2	<0.8		
	n2	CEC	meq/100g soil	>24/16-24	<16(-)	>16(+)		
	n3	AVP	ppm	>15	8-15	4-8	<4	
	n4	TN	%					
	n5	OM	%					
Nutient Availability(z)	z	Soil reaction		5.5-7.5	5.4-5.5/7.5-7.8	5.2-5.4/7.8-8.2		<5.2>8.2
Rooting condition(rl)	r	Effective soil depth	cm	>100/75-100	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 clearance		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
cao3			%	0-6/6-15	15-20	20-25		>25

Table 22:Pepper(capsicum)-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 : 23 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 24. 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 23: 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 24: 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 25: Summarized Land Quality and Characteristics of the SMU

SMU	Area		Slope	Depth	Texture	Major_soil	Drainage	Flooding	Erosion	IR_Rep1	IR_Rep2	IR_Rep3	Av_Ins_IR	R_Av_IR	M_IR_1	M_IR_2	M_IR_3	M_Ave_IR	R_Ave_M
	ha	%	class	class	class	type	class	class	class	cm/hr	cm/hr	cm/hr	cm/hr		cm/hr	cm/hr	cm/hr	cm/hr	cm/hr
1C_c	0.433	0.090	0-2	100-150	C	Chromic Luvisols	w/w	N	S/R	6.00	5.00	6.05	5.68	suitable	6.57	5.87	6.98	6.47	suitable
1CL_c	63.993	13.360	0-2	100-150	CL	Chromic Luvisols	w/w	N	S/S	6.00	5.00	6.05	5.68	suitable	6.57	5.87	6.98	6.47	suitable
1CL_d	6.889	1.438	0-2	50-100	CL	Chromic Luvisols	w/w	N	S/S	6.00	5.00	6.05	5.68	suitable	6.57	5.87	6.98	6.47	suitable
2C_c	7.297	1.523	2-5	100-150	C	Chromic Luvisols	w/w	N	S/S	6.00	5.00	6.05	5.68	suitable	6.57	5.87	6.98	6.47	suitable
2CL_a	0.449	0.094	2-5	>200	CL	Chromic Luvisols	w/w	N	S/S	6.00	5.00	6.05	5.68	suitable	6.57	5.87	6.98	6.47	suitable
2CL_b	1.266	0.264	2-5	150-200	CL	Chromic Luvisols	w/w	N	S/S	6.00	5.00	6.05	5.68	suitable	6.57	5.87	6.98	6.47	suitable
2CL_c	126.550	26.421	2-5	50-100	CL	Chromic Luvisols	w/w	N	S/S	6.00	5.00	6.05	5.68	suitable	6.57	5.87	6.98	6.47	suitable
2CL_d	26.078	5.445	2-5	50-100	CL	Chromic Luvisols	w/w	N	S/S	6.00	5.00	6.05	5.68	suitable	6.57	5.87	6.98	6.47	suitable
3CL_a	3.054	0.638	5-8	>200	CL	Chromic Luvisols	w/w	N	S/S	6.00	5.00	6.05	5.68	suitable	6.57	5.87	6.98	6.47	suitable
3CL_b	0.666	0.139	5-8	150-200	CL	Chromic Luvisols	w/w	N	S/S	6.00	5.00	6.05	5.68	suitable	6.57	5.87	6.98	6.47	suitable
3CL_c	95.458	19.929	5-8	100-150	CL	Chromic Luvisols	w/w	N	S/S	6.00	5.00	6.05	5.68	suitable	6.57	5.87	6.98	6.47	suitable
3CL_c1	1.337	0.279	5-8	100-150	CL	Cambisols	w/w	N	S/R	6.00	5.00	6.05	5.68	suitable	6.57	5.87	6.98	6.47	suitable
3CL_d	25.470	5.318	5-8	50-100	CL	Chromic Luvisols	w/w	N	S/R	6.00	5.00	6.05	5.68	suitable	6.57	5.87	6.98	6.47	suitable
4CL_a	0.851	0.178	8-15	>200	CL	Chromic Luvisols	w/w	N	S/S	6.00	5.00	6.05	5.68	suitable	6.57	5.87	6.98	6.47	suitable
4CL_c	59.255	12.371	8-15	100-150	CL	Chromic Luvisols	w/w	N	S/S	6.00	5.00	6.05	5.68	suitable	6.57	5.87	6.98	6.47	suitable
4CL_c1	3.927	0.820	8-15	100-150	CL	Cambisols	w/w	N	S/R	6.00	5.00	6.05	5.68	suitable	6.57	5.87	6.98	6.47	suitable
4CL_d	27.710	5.785	8-15	50-100	CL	Cambisols	w/w	N	S/R	6.00	5.00	6.05	5.68	suitable	6.57	5.87	6.98	6.47	suitable
4CL_d1	17.150	3.581	8-15	50-100	CL	Chromic Luvisols	w/w	N	S/R	6.00	5.00	6.05	5.68	suitable	6.57	5.87	6.98	6.47	suitable
5CL_c	0.765	0.160	15-30	100-150	CL	Chromic Luvisols	w/w	N	S/S	6.00	5.00	6.05	5.68	suitable	6.57	5.87	6.98	6.47	suitable
5CL_d	9.018	1.883	15-30	50-100	CL	Chromic Luvisols	w/w	N	S/S	6.00	5.00	6.05	5.68	suitable	6.57	5.87	6.98	6.47	suitable
5CL_d1	1.370	0.286	15-30	50-100	CL	Cambisols	w/w	N	S/R	6.00	5.00	6.05	5.68	suitable	6.57	5.87	6.98	6.47	suitable

Cont'd

SMU	Area		HC_Rep1	HC_Rep2	HC_Rep3	Ave_HC	Ranking_HC	Bd	FC	PWP	AWC	TAWC	RAWC	R_TAWC	T_porosity	AF_Porosit	PH	EC	ECe
	ha	%	m/day	m/day	m/day	m/day	m/day	gm/cm3	%	%	mm	mm/m	mm/m		%	%	water	ds/m	ds/m
1C_e	0.433	0.090	2.13	2.14	1.91	2.06	Rapid	1.34	32.80	22.10	42.97	265.33	176.89	high	49.26	16.48	6.30	0.05	0.35
1CL_e	63.993	13.360	2.13	2.14	1.91	2.06	Rapid	1.40	36.80	23.70	55.16	263.09	175.39	high	47.13	10.29	5.00	0.08	0.66
1CL_d	6.889	1.438	2.13	2.14	1.91	2.06	Rapid	1.40	36.80	23.70	55.16	263.09	175.39	high	47.13	10.29	5.10	0.06	0.49
2C_e	7.297	1.523	2.13	2.14	1.91	2.06	Rapid	1.34	32.80	22.10	42.97	265.33	176.89	high	49.26	16.48	5.60	0.05	0.41
2CL_a	0.449	0.094	2.13	2.14	1.91	2.06	Rapid	1.40	36.80	23.70	55.16	263.09	175.39	high	47.13	10.29	5.10	0.06	0.49
2CL_b	1.266	0.264	2.13	2.14	1.91	2.06	Rapid	1.40	36.80	23.70	55.16	263.09	175.39	high	47.13	10.29	5.00	0.08	0.66
2CL_e	126.550	26.421	2.13	2.14	1.91	2.06	Rapid	1.40	36.80	23.70	55.16	263.09	175.39	high	47.13	10.29	5.00	0.08	0.66
2CL_d	26.078	5.446	2.13	2.14	1.91	2.06	Rapid	1.40	36.80	23.70	55.16	263.09	175.39	high	47.13	10.29	5.00	0.08	0.66
3CL_a	3.054	0.638	2.13	2.14	1.91	2.06	Rapid	1.40	36.80	23.70	55.16	263.09	175.39	high	47.13	10.29	5.10	0.06	0.49
3CL_b	0.666	0.139	2.13	2.14	1.91	2.06	Rapid	1.40	36.80	23.70	55.16	263.09	175.39	high	47.13	10.29	5.00	0.08	0.66
3CL_e	95.468	19.929	2.13	2.14	1.91	2.06	Rapid	1.40	36.80	23.70	55.16	263.09	175.39	high	47.13	10.29	5.00	0.08	0.66
3CL_e1	1.337	0.279	2.13	2.14	1.91	2.06	Rapid	1.34	32.80	22.10	42.97	265.33	176.89	high	49.26	16.48	5.80	0.18	1.55
3CL_d	25.470	5.318	2.13	2.14	1.91	2.06	Rapid	1.34	32.80	22.10	42.97	265.33	176.89	high	49.26	16.48	5.80	0.18	1.55
4CL_a	0.851	0.178	2.13	2.14	1.91	2.06	Rapid	1.40	36.80	23.70	55.16	263.09	175.39	high	47.13	10.29	5.10	0.06	0.49
4CL_e	59.255	12.371	2.13	2.14	1.91	2.06	Rapid	1.34	32.80	22.10	42.97	265.33	176.89	high	49.26	16.48	5.60	0.05	0.41
4CL_e1	3.927	0.820	2.13	2.14	1.91	2.06	Rapid	1.34	32.80	22.10	42.97	265.33	176.89	high	49.26	16.48	5.80	0.18	1.55
4CL_d	27.710	5.785	2.13	2.14	1.91	2.06	Rapid	1.34	32.80	22.10	42.97	265.33	176.89	high	49.26	16.48	5.80	0.18	1.55
4CL_d1	17.150	3.581	2.13	2.14	1.91	2.06	Rapid	1.34	32.80	22.10	42.97	265.33	176.89	high	49.26	16.48	5.80	0.18	1.55
5CL_e	0.765	0.160	2.13	2.14	1.91	2.06	Rapid	1.34	32.80	22.10	42.97	265.33	176.89	high	49.26	16.48	6.00	0.05	0.34
5CL_d	9.018	1.883	2.13	2.14	1.91	2.06	Rapid	1.34	32.80	22.10	42.97	265.33	176.89	high	49.26	16.48	6.00	0.05	0.34
5CL_d1	1.370	0.286	2.13	2.14	1.91	2.06	Rapid	1.34	32.80	22.10	42.97	265.33	176.89	high	49.26	16.48	5.80	0.18	1.55

Cont'd

SMU	Area		PH	Na	K	Ca	Mg	SUM	CEC	BS	ESP	EX_Acidity	Ex_Al	TN	OC	OM	C:N	AvK	AvP	P2O5	CaCO3	CaCO3	Ca:Mg	K:Mg	K_CEC	Ca+Mg/k
	ha	%	kcl	meq/100g soil						%	%	%		%	%	%	%	ppm	ppm	ppm	%	gram	ratio	ratio	ratio	ratio
1C_e	0.433	0.090	5.70	0.16	0.34	13.07	5.88	19.45	39.92	48.72	0.41	_	_	0.08	0.94	1.62	11.21	142.70	0.10	0.23	_	_	2.22	0.06	0.01	30.43
1CL_e	63.993	13.360	4.70	0.16	0.35	12.54	4.63	17.68	37.24	47.48	0.43	0.32	0	0.24	2.66	4.58	11.07	137.90	5.40	12.37	_	_	2.71	0.08	0.01	25.62
1CL_d	6.889	1.438	4.70	0.15	0.27	7.28	4.30	11.99	23.68	50.64	0.62	0.08	0	0.22	2.34	4.03	10.63	98.70	0.58	1.33	_	_	1.69	0.06	0.01	23.24
2C_e	7.297	1.523	5.20	0.13	0.05	14.37	3.00	17.55	34.58	50.76	0.37	_	_	0.08	0.96	1.66	12.02	27.80	0.08	0.18	_	_	4.78	0.02	0.00	79.58
2CL_a	0.449	0.094	4.70	0.15	0.27	7.28	4.30	11.99	23.68	50.64	0.62	0.08	0	0.22	2.34	4.03	10.63	98.70	0.58	1.33	_	_	1.69	0.06	0.01	23.24
2CL_b	1.266	0.264	4.70	0.16	0.35	12.54	4.63	17.68	37.24	47.48	0.43	0.32	0	0.24	2.66	4.58	11.07	137.90	5.40	12.37	_	_	2.71	0.08	0.01	25.62
2CL_e	126.550	26.421	4.70	0.16	0.35	12.54	4.63	17.68	37.24	47.48	0.43	0.32	0	0.24	2.66	4.58	11.07	137.90	5.40	12.37	_	_	2.71	0.08	0.01	25.62
2CL_d	26.078	5.445	4.70	0.16	0.35	12.54	4.63	17.68	37.24	47.48	0.43	0.32	0	0.24	2.66	4.58	11.07	137.90	5.40	12.37	_	_	2.71	0.08	0.01	25.62
3CL_a	3.054	0.638	4.70	0.15	0.27	7.28	4.30	11.99	23.68	50.64	0.62	0.08	0	0.22	2.34	4.03	10.63	98.70	0.58	1.33	_	_	1.69	0.06	0.01	23.24
3CL_b	0.666	0.139	4.70	0.16	0.35	12.54	4.63	17.68	37.24	47.48	0.43	0.32	0	0.24	2.66	4.58	11.07	137.90	5.40	12.37	_	_	2.71	0.08	0.01	25.62
3CL_e	95.458	19.929	4.70	0.16	0.35	12.54	4.63	17.68	37.24	47.48	0.43	0.32	0	0.24	2.66	4.58	11.07	137.90	5.40	12.37	_	_	2.71	0.08	0.01	25.62
3CL_el	1.337	0.279	5.50	0.22	0.87	16.31	9.47	26.88	41.82	64.27	0.54	_	_	0.32	3.34	5.76	10.44	288.70	8.12	18.59	_	_	1.72	0.09	0.02	27.24
3CL_d	25.470	5.318	5.50	0.22	0.87	16.31	9.47	26.88	41.82	64.27	0.54	_	_	0.32	3.34	5.76	10.44	288.70	8.12	18.59	_	_	1.72	0.09	0.02	27.24
4CL_a	0.851	0.178	4.70	0.15	0.27	7.28	4.30	11.99	23.68	50.64	0.62	0.08	0	0.22	2.34	4.03	10.63	98.70	0.58	1.33	_	_	1.69	0.06	0.01	23.24
4CL_e	59.255	12.371	5.20	0.13	0.05	14.37	3.00	17.55	34.58	50.76	0.37	_	_	0.08	0.96	1.66	12.02	27.80	0.08	0.18	_	_	4.78	0.02	0.00	79.58
4CL_el	3.927	0.820	5.50	0.22	0.87	16.31	9.47	26.88	41.82	64.27	0.54	_	_	0.32	3.34	5.76	10.44	288.70	8.12	18.59	_	_	1.72	0.09	0.02	27.24
4CL_d	27.710	5.785	5.50	0.22	0.87	16.31	9.47	26.88	41.82	64.27	0.54	_	_	0.32	3.34	5.76	10.44	288.70	8.12	18.59	_	_	1.72	0.09	0.02	27.24
4CL_dl	17.150	3.581	5.50	0.22	0.87	16.31	9.47	26.88	42.82	62.77	0.53	_	_	0.32	3.34	5.76	10.44	288.70	8.12	18.59	_	_	1.72	0.09	0.02	27.24
5CL_e	0.766	0.160	5.50	0.15	0.03	8.31	5.10	13.59	20.96	64.82	0.73	_	_	0.05	0.53	0.91	10.53	23.70	0.04	0.09	_	_	1.63	0.01	0.00	185.55
5CL_d	9.018	1.883	5.50	0.15	0.03	8.31	5.10	13.59	20.96	64.82	0.73	_	_	0.05	0.53	0.91	10.53	23.70	0.04	0.09	_	_	1.63	0.01	0.00	185.55
5CL_dl	1.370	0.286	5.50	0.22	0.87	16.31	9.47	26.88	41.82	64.27	0.54	_	_	0.32	3.34	5.76	10.44	288.70	8.12	18.59	_	_	1.72	0.09	0.02	27.24

8.10. Results of Land Suitability Evaluation for Surface Irrigation

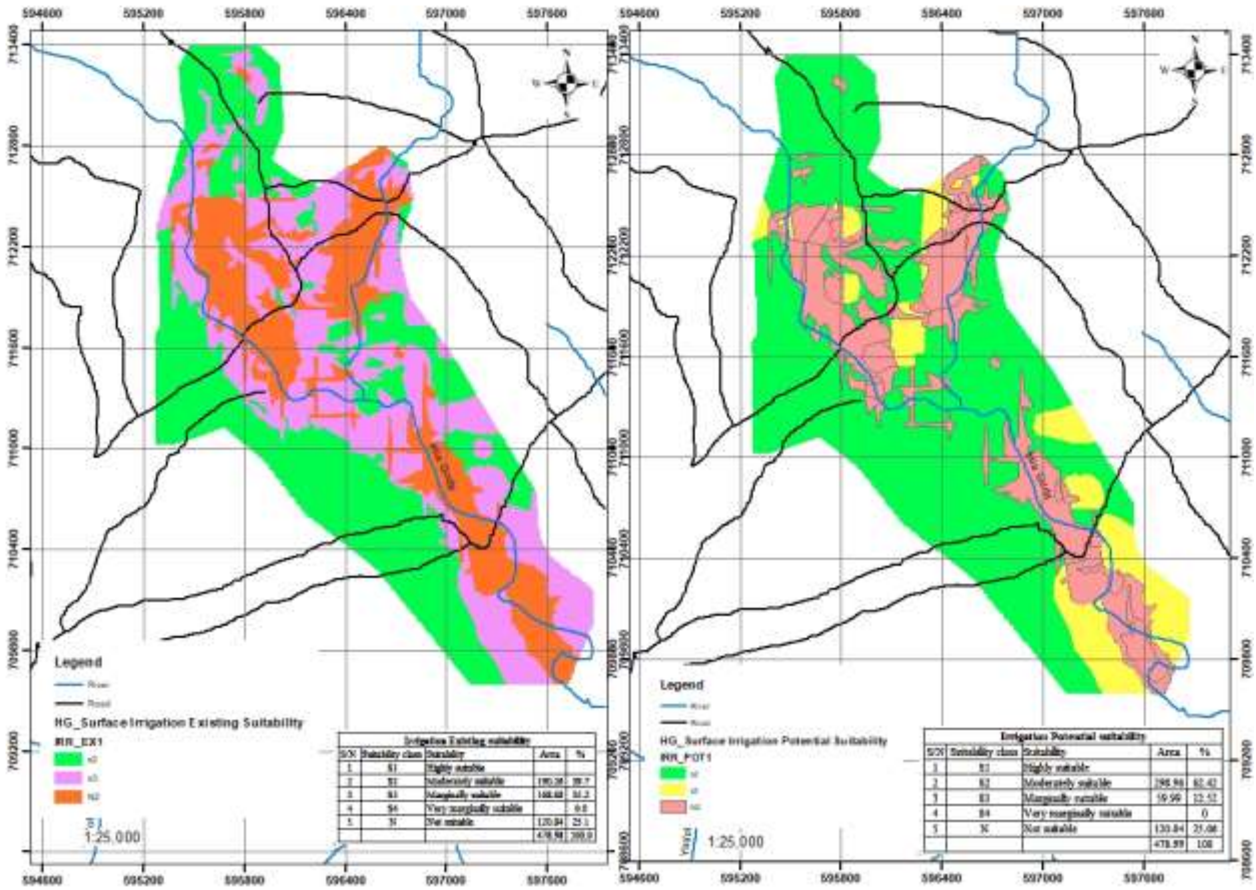
8.10.1. Existing Suitability for Surface Irrigation

The results of the suitability evaluation of the project area for surface irrigation are shown in Tables 26. The result indicates that a total of 190.26 ha (39.7%) of land is moderately suitable ,168.68 ha (35.2%) marginally suitable, and 120.04 ha (25.1%) permanentely not suitable for surface irrigation development. The areas identified as moderately suitable land constrained by depth, infiltration, PH and total nitrogen, where as marginally suitable land limited by AVP, total nitrogen, depth and slope, the permanentely not suitable for surface irrigation are constrained by slope.

Table 26: Existing Surface Irrigation Suitability by Area

Irrigation Existing suitability				
S/N	Suitability class	Suitability	Area	%
1	S1	Highly suitable		
2	S2	Moderately suitable	190.26	39.7
3	S3	Marginally suitable	168.68	35.2
4	S4	Very marginally suitable		0.0
5	N	Not suitable	120.04	25.1
			478.98	100.0

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 27. The result indicates that a total of 298.96 ha (62.42%) of land found to be moderately suitable and 59.99ha (12.52%) is found to be marginally suitable for surface irrigation development and some 120.04ha (25.06%) 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 infiltration and depth. The moderately suitable areas is constrained by Infiltration, and soil depth and require careful land management, application of good quality of water and teracing like bunch terace, this improve the suitability level.

Table 27 : Potential Surface Irrigation Suitability by Area

Irrigation Potential suitability				
S/N	Suitability class	Suitability	Area	%
1	S1	Highly suitable		
2	S2	Moderately suitable	298.96	62.42
3	S3	Marginally suitable	59.99	12.52
4	S4	Very marginally suitable		0
5	N	Not suitable	120.04	25.06
			478.99	100

Table 28: Results of Existing and Potential Land Suitability Evaluation for surface Irrigation by SMU

SMU	Area	Percentage	Existing sub class(IRR)	Existing suitability(IRR)	Class	Limitation	Potential sub class(IRR)	Potential suitability(IRR)	Class	Limitation
1C_r	0.433	0.090	s3n3n4	s3	Marginaly suitable	AvP,TN	s2m2r1	s2	Moderately suitable	Inf,depth
1CL_c	63.993	13.360	s2m2r1n4	s2	Moderately suitable	Inf,depth,PH,TN	s2m2r1	s2	Moderately suitable	Inf,depth
1CL_d	6.889	1.438	s3r1n3	s3	Marginaly suitable	depth,AvP	s3r1	s3	Marginaly suitable	depth
2C_r	7.297	1.523	s3n3n4	s3	Marginaly suitable	AvP,TN	s2m2r1	s2	Moderately suitable	Inf,depth
2CL_a	0.449	0.094	s3n3	s3	Marginaly suitable	AvP	s2m2	s2	Moderately suitable	Inf.
2CL_b	1.266	0.264	s2m2kn4	s2	Moderately suitable	Inf,Slope,PH,TN	s2m2	s2	Moderately suitable	Inf.
2CL_c	126.590	26.421	s3r1	s3	Marginaly suitable	depth	s3r1	s3	Marginaly suitable	depth
2CL_d	26.078	5.445	s3r1	s3	Marginaly suitable	depth	s3r1	s3	Marginaly suitable	depth
3CL_a	3.054	0.638	s3kn3	s3	Marginaly suitable	Slope,AvP	s2m2	s2	Moderately suitable	Inf.
3CL_b	0.666	0.139	s3k	s3	Marginaly suitable	slope	s2m2	s2	Moderately suitable	Inf.
3CL_c	95.458	19.929	s3k	s3	Marginaly suitable	slope	s2m2r1	s2	Moderately suitable	Inf,depth
3CL_cl	1.337	0.279	s3k	s3	Marginaly suitable	slope	s2m2r1	s2	Moderately suitable	Inf,depth
3CL_d	25.470	5.318	s3kr1	s3	Marginaly suitable	slope,depth	s3r1	s3	Marginaly suitable	depth
4CL_a	0.851	0.178	N2k	N2	Permanentely not suitable	slope	N2k	N2	Permanentely not suitable	slope
4CL_c	59.255	12.371	N2k	N2	Permanentely not suitable	slope	N2k	N2	Permanentely not suitable	slope
4CL_cl	3.927	0.820	N2k	N2	Permanentely not suitable	slope	N2k	N2	Permanentely not suitable	slope
4CL_d	27.710	5.785	N2k	N2	Permanentely not suitable	slope	N2k	N2	Permanentely not suitable	slope
4CL_dl	17.150	3.581	N2k	N2	Permanentely not suitable	slope	N2k	N2	Permanentely not suitable	slope
5CL_c	0.766	0.160	N2k	N2	Permanentely not suitable	slope	N2k	N2	Permanentely not suitable	slope
5CL_d	9.018	1.883	N2k	N2	Permanentely not suitable	slope	N2k	N2	Permanentely not suitable	slope
5CL_dl	1.370	0.286	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 : maize, sorghum, tomato, onion, pepper, haricot bean and head cabbage. The results of the crop suitability evaluation are shown in Table 29 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 for maize, sorghum, tomato, pepper and haricot bean some 75.59 ha, for onion 26.81ha and for head cabbage 0.443 ha of land found to be moderately suitable under existing condition,where 1.37 ha for maize and sorghum,115.76 ha for onion,390.97 ha for tomato,89.38 ha for prpper,153.29 ha for head cabbage and 78.14 ha for haricot bea found to be marginally suitable.The same way 76.77 ha ,392.24 ha,325.26ha,88.013 ha,314.01ha and 325.26 ha of lan very marginally suitable for maize, sorghum,onion, tomato, pepper and head cabbage respectively,325.26 ha of land permanentely not suitable for maize and haricot bean,9.78 ha of land currentely not suitable for sorgum and 11.15 ha of land for onion cultivation by Irrigation under existing condition. The major limitations that downgraded the suitability level of the area were for permanentely not suitable is low PH,low level of organic carbon, and steep slope,to that of very marginally suitability subclass are low Available phosporous, low level organic carbon, and low PH,low level of organic Carbon, where as for marginally suitable subclass low Available phosporous, slope and low PH,.In addition moderately suitable lands constrined by Infiltration, low Available phosporous, slope,soil depth and low PH,This indicates/implise that with increasing the level of management practices to correct the limitations, the suitability and expected crop yield could be increased.

Table 29 : Existing Crop Suitability by Area for Surface Irrigation

Existing crop suitability by Area for surface Irrigation						
Crop	s1	s2	s3	s4	N1	N2
	Highly suitable	Moderately suitable	Marginally suitable	Very marginally suitable	Currentely not suitable	Permanentely not suitable
	Area,ha	Area,ha	Area,ha	Area,ha	Area,ha	Area,ha
Maize		75.59	1.37	76.77		325.26
Sorgum		75.59	1.37	392.24	9.78	
Onion		26.81	115.76	325.26		11.15
Tomato			390.97	88.013		
Pepper		75.59	89.38	314.01		
Head Cabbage		0.443	153.29	325.26		
Haricot bean		75.58	78.14			325.26

From the above table: 29 by existing condition the command area is primerly/ranking best/ moderately suitable for maize, sorghum, pepper and haricot bean(75.59ha), followed by onion26.81 ha. Marginally suitable for tomato, head cabbage and Onion (390.97ha,153.29 ha and 115.76 ha respectively.

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

Crop	Existing suitability sub class comparing with crop for surface Irrigation								
Maize	Existing Sub class	N2z	s2m2n3z	s2m2n3zk	s2m2n3zrl	s2m2n3zrlk	s3k	s4n3	
	Area,ha	325.26	1.34	3.93	25.47	44.86	1.37	76.77	
Sorghum	Existing Sub class	N1n1	s2m2	s2m2kl	s2m2rl	s2m2rlk	s3k	s4nl	s4z
	Area,ha	9.78	1.34	3.93	25.47	44.86	1.37	66.99	325.26
Onion	Existing Sub class	N2k	s2m2zk	s3k	s3n3	s3n3k	s4z		
	Area,ha	11.15	26.81	48.79	7.73	59.26	325.26		
Tomato	Existing Sub class	s3n3	s3n3k	s3n3z	s4n3				
	Area,ha	75.59	1.37	314.011	88.013				
Pepper	Existing Sub class	s2m2z	s2m2zk	s3k	s3n3	s3n3k	s4z		
	Area,ha	26.81	48.79	1.37	78.23	9.78	314.011		
Head Cabbage	Existing Sub class	s2m2	s3k	s3z	s3zk	s4z			
	Area,ha	0.443	9.78	142.15	1.37	325.26			
Haricot bean	Existing Sub class	N2z	s2m2	s2m2k	s3k	s3n3	s3n3k		
	Area,ha	325.26	26.81	48.79	1.37	66.99	9.78		

8.11.2. Potential Crop Suitabilty Evaluation

The result indicated Table : 31 -37 and table 38and 39 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 and moderately suitable land for intended crop production.

Cereal crops

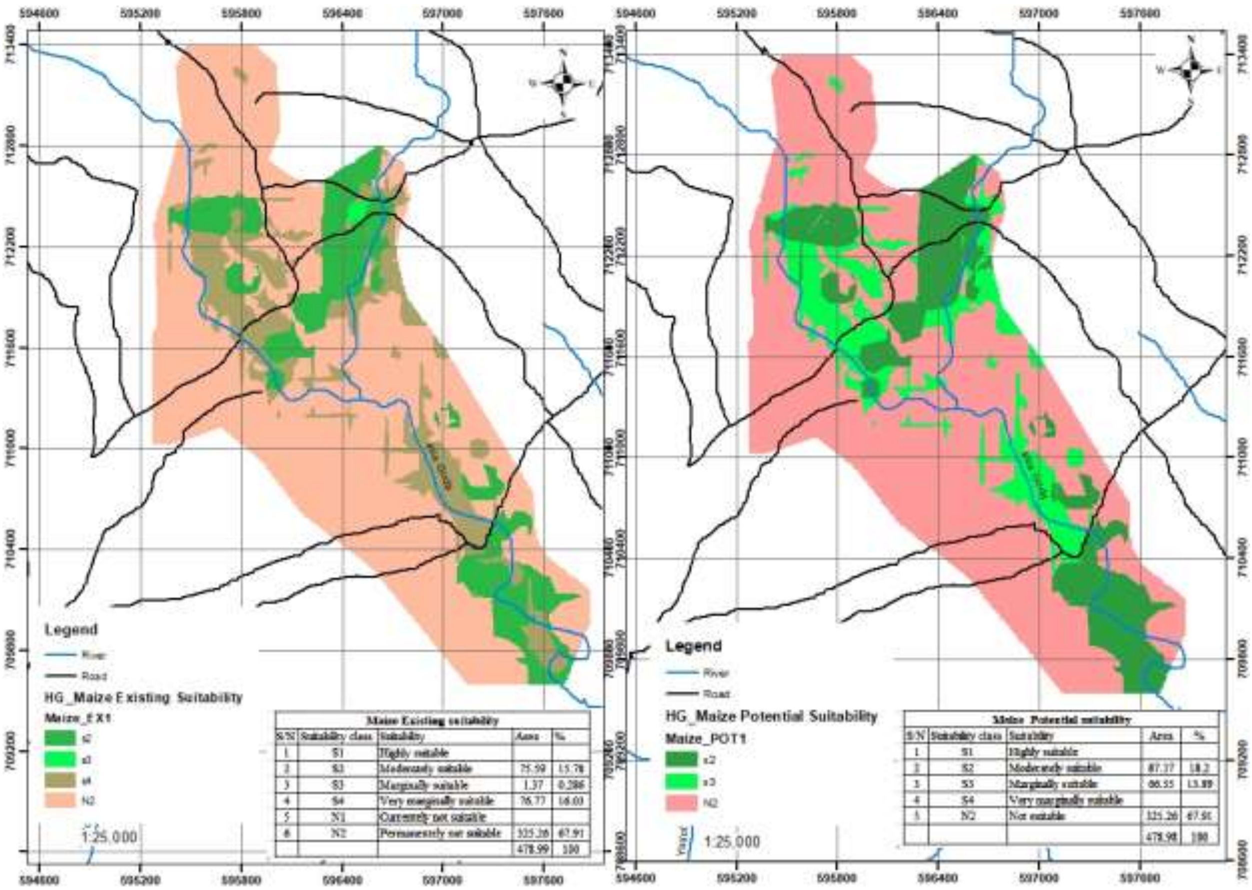
- **Maize potential suitability**

Potential land suitability for the crop maize can be grouped into three classes. These include the permanentely not suitable lands, marginally suitable lands and moderately suitable lands (Table 31 ,38 &39). Land units listed under the suitability sub class N2z cover an area of some 325.26 ha (Table 38,39 and 41) are classified as permanentely not suitable lands due to the soil reaction (PH), where as s3z land are classified as the marginally suitable land for maize crops production due to the soil reaction (PH) of the study area (Table 39). The area of these land units is also 66.55 ha. On the other hand, those land units listed under the suitability sub classes s2m1, s2m1r1, s2m2 and s2m2r1 are grouped under the moderately suitable lands. They are moderately limited by some physical properties of the soil like AWC, Infiltration rate and soil depth. The area coverage of these moderately suitable lands are 0.765ha,9.018 ha,5.697 ha, and 71.70 ha respectively

Table 31:Maize potential suitability

Maize Potential suitability				
S/N	Suitability class	Suitability	Area	%
1	S1	Highly suitable		
2	S2	Moderately suitable	87.17	18.2
3	S3	Marginally suitable	66.55	13.89
4	S4	Very marginally suitable		
5	N2	Not suitable	325.26	67.91
			478.98	100

Figure 5:Maze Existing and Potential suitability map



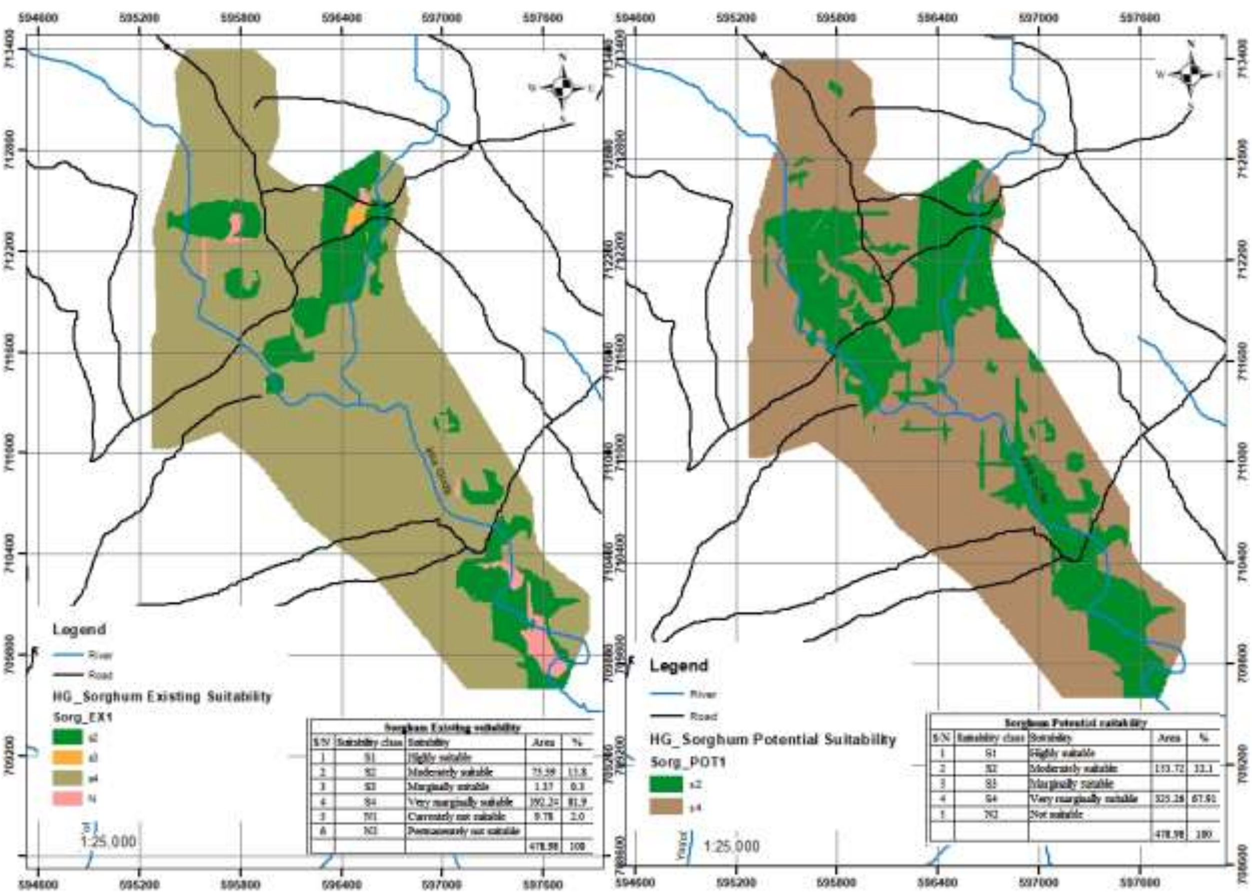
- **Sorghum potential suitability**

Potential land suitability for the crop sorghum can be grouped into three classes. These include the moderately suitable lands and very marginally suitable lands (Table 32,38 &39). Land units listed under the suitability sub class s2m2 and s2m2r1 (Table 38,39 and 41) are classified as the moderately suitable land for sorghum crops production due to infiltration rate and soil depth of the study area (Table 39). The area of these land units is 73.014 ha and 80.72 ha respectively. On the other hand, those land units listed under the suitability sub classes s4z is grouped under the very marginally suitable lands limited by soil reaction (PH), with the area coverage of 325.26 ha

Table 32: Sorghum potential suitability

Sorghum Potential suitability				
S/N	Suitability class	Suitability	Area	%
1	S1	Highly suitable		
2	S2	Moderately suitable	153.72	32.1
3	S3	Marginally suitable		
4	S4	Very marginally suitable	325.26	67.91
5	N2	Not suitable		
			478.98	100

Figure 6:Sorghum Existing and Potential suitability map



Vegitable crops

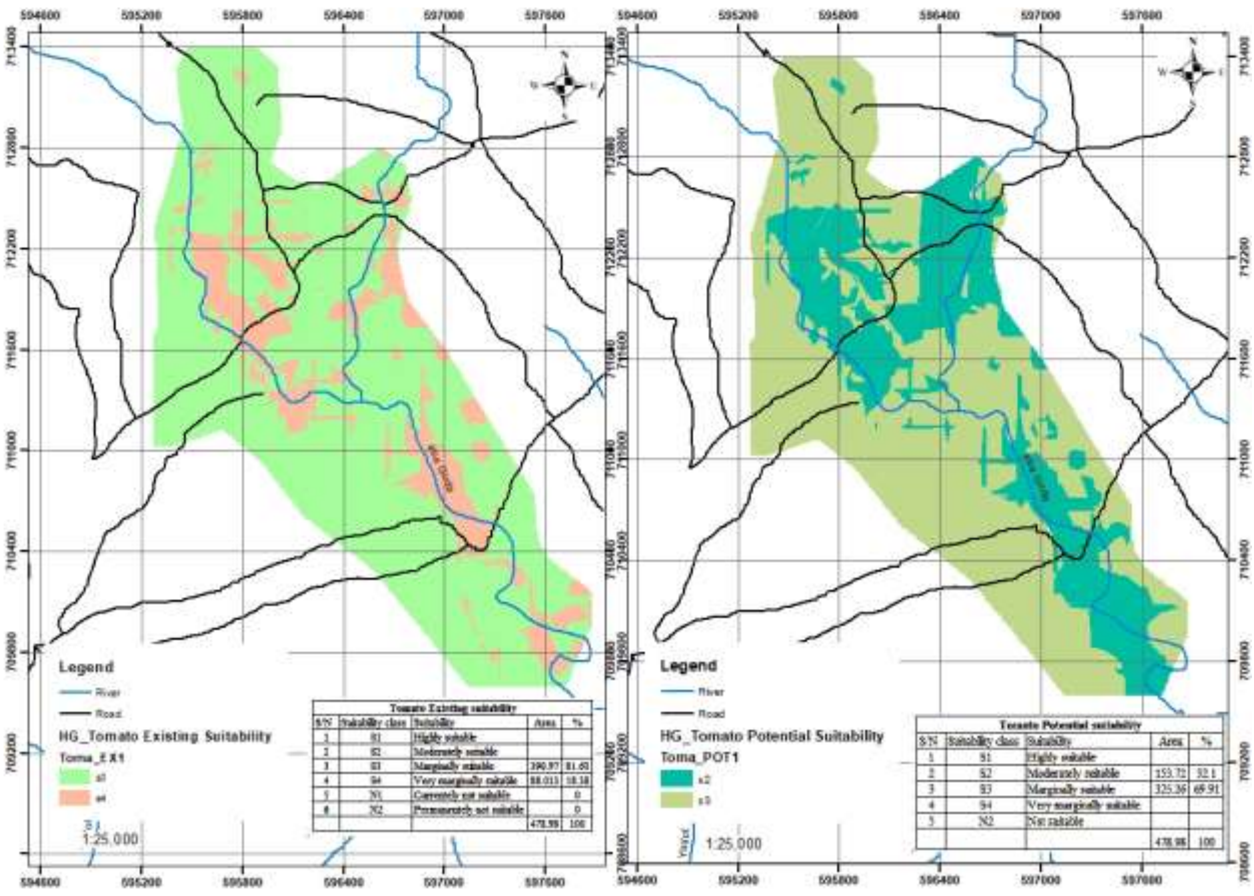
- **Tomato**

Accordingly, Potential land suitability for tomato can be grouped into three classes. These include the marginally suitable and moderately suitable lands (Table33,38 &39). Land units listed under the suitability sub class s3z (Table 38,39 and 41) are classified as the marginally suitable land for tomato due to the soil PH of the study area (Table 39). The area of these land units is also 325.26 ha. On the other hand, those land units listed under the suitability sub classes s2m2 and s2m2r1 are grouped under moderately suitable lands due to soil infiltration and soil depth, cover an area of 73.014 and 80.72 ha of land

Table 33: Tomato potential suitability

Tomato Potential suitability				
S/N	Suitability class	Suitability	Area	%
1	S1	Highly suitable		
2	S2	Moderately suitable	153.72	32.1
3	S3	Marginally suitable	325.26	69.91
4	S4	Very marginally suitable		
5	N2	Not suitable		
			478.98	100

Figure 7:Tomato Existing and Potential suitability map



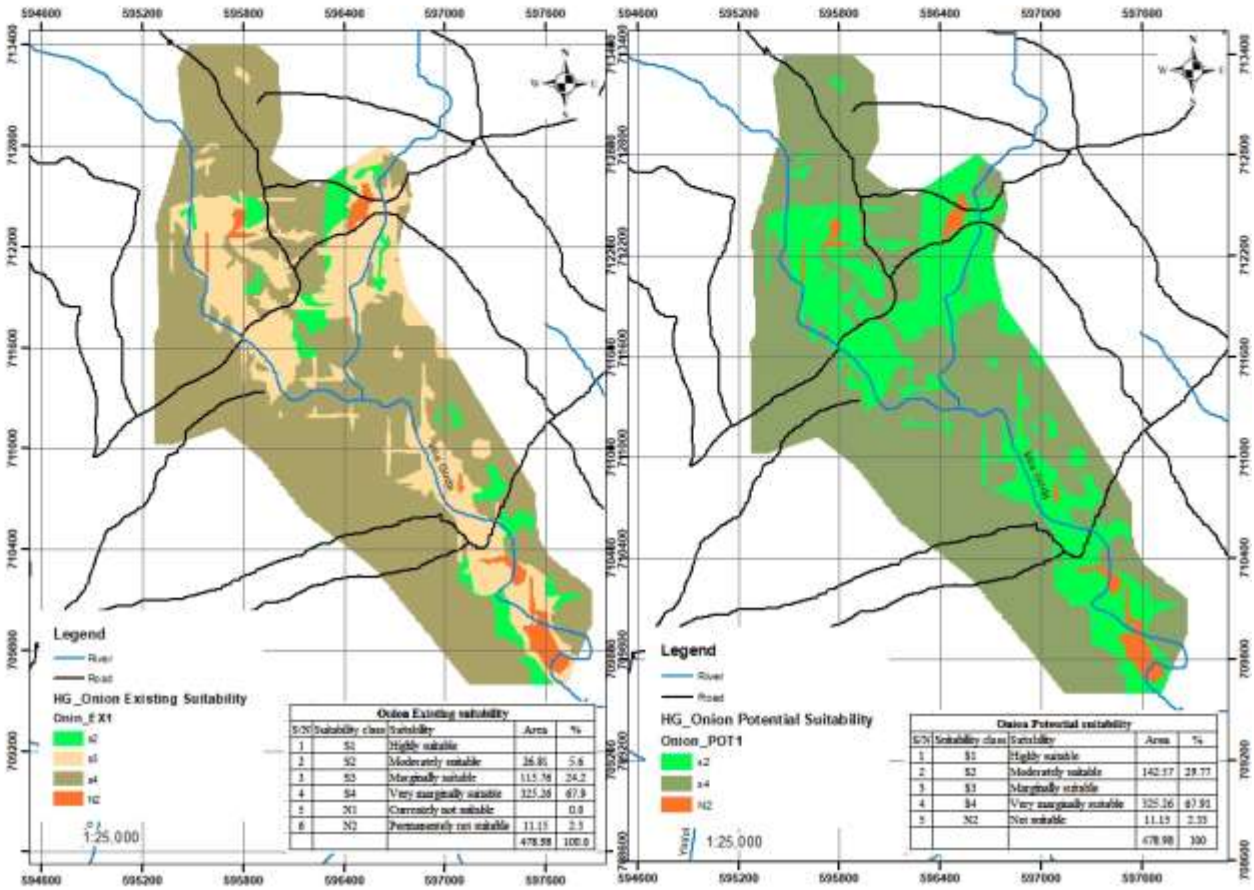
- **Onion**

Accordingly, Potential land suitability for onion can be grouped into three classes. These include the permanentely not suitable lands, very marginally suitable and moderately suitable lands (Table 34,38 &39). Land units listed under the suitability sub class N2k classified as the permanentely not suitable lands constrined by slope of land, and cover an area of 11.15 ha. Land units listed under the suitability sub class s4z (Table 38,39 and 41) are classified as the very marginally suitable land for onion due to the soil PH of the study area (Table 39). The area of these land units is also 325.26 ha. On the other hand, those land units listed under the suitability sub classes s2m2 grouped under moderately suitable lands due to soil infiltration rate and cover an area of 142.58 ha of land

Table 34:Onion potential suitability

Onion Potential suitability				
S/N	Suitability class	Suitability	Area	%
1	S1	Highly suitable		
2	S2	Moderately suitable	142.57	29.77
3	S3	Marginally suitable		
4	S4	Very marginally suitable	325.26	67.91
5	N2	Not suitable	11.15	2.33
			478.98	100

Figure 8:Onion Existing and Potential suitability map



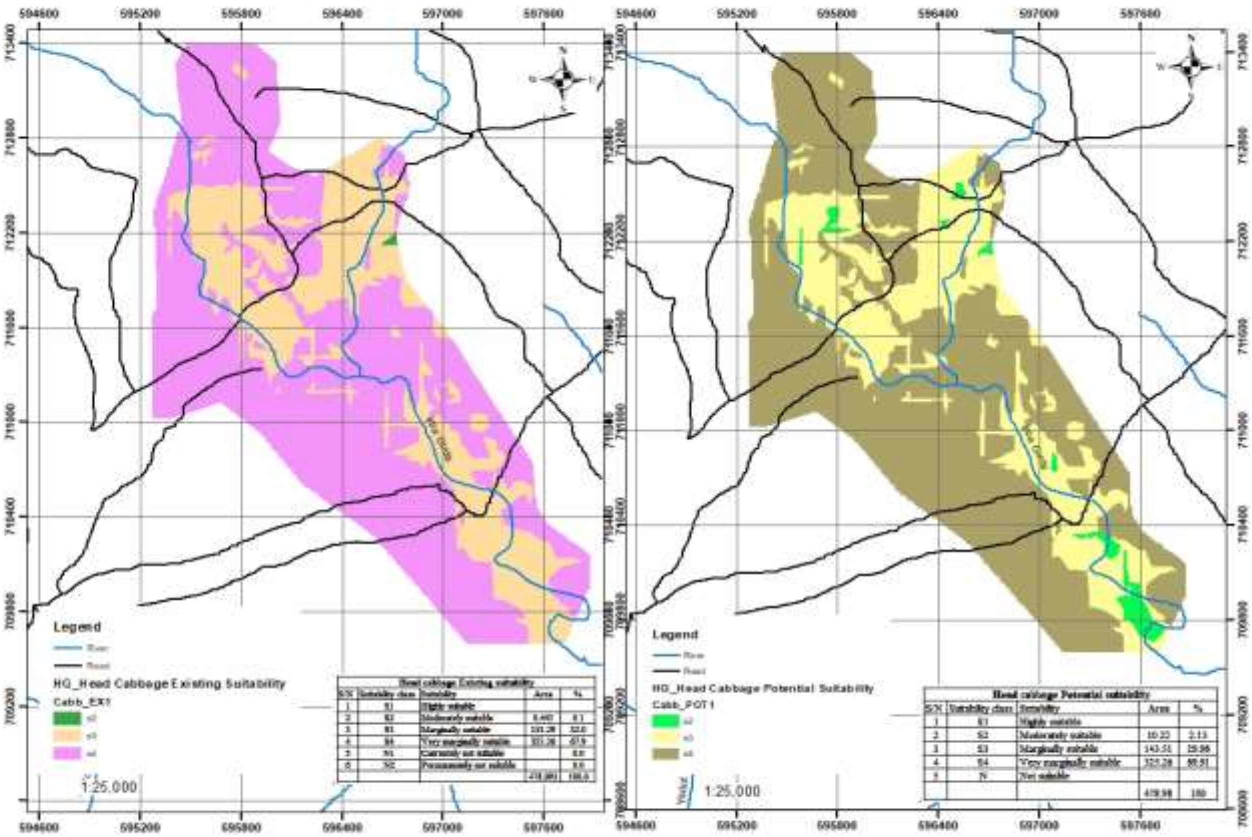
- **Head Cabbage**

The same way, Potential land suitability for head cabbage can be grouped into three classes. These include the very marginally suitable, marginally suitable and moderately suitable lands (Table 35,38 &39). Land units listed under the suitability sub class s4z is classified as the very marginally suitable soil PH and cover 325.26 ha. Land units listed under the suitability sub class s3z (Table 38,39 and 41) are classified as the marginally suitable land for head cabbage due to the soil PH of the study area (Table 39). The area of these land units is also 143.52 ha. On the other hand, those land units listed under the suitability sub classes s2m2 grouped under moderately suitable lands due to soil infiltration and cover an area of 10.22 ha of land

Table 35: Head cabbage potential suitability

Head cabbage Potential suitability				
S/N	Suitability class	Suitability	Area	%
1	S1	Highly suitable		
2	S2	Moderately suitable	10.22	2.13
3	S3	Marginally suitable	143.51	29.96
4	S4	Very marginally suitable	325.26	69.91
5	N	Not suitable		
			478.98	100

Figure 9:Head cabbage Existing and Potential suitability map



- **Pepper**

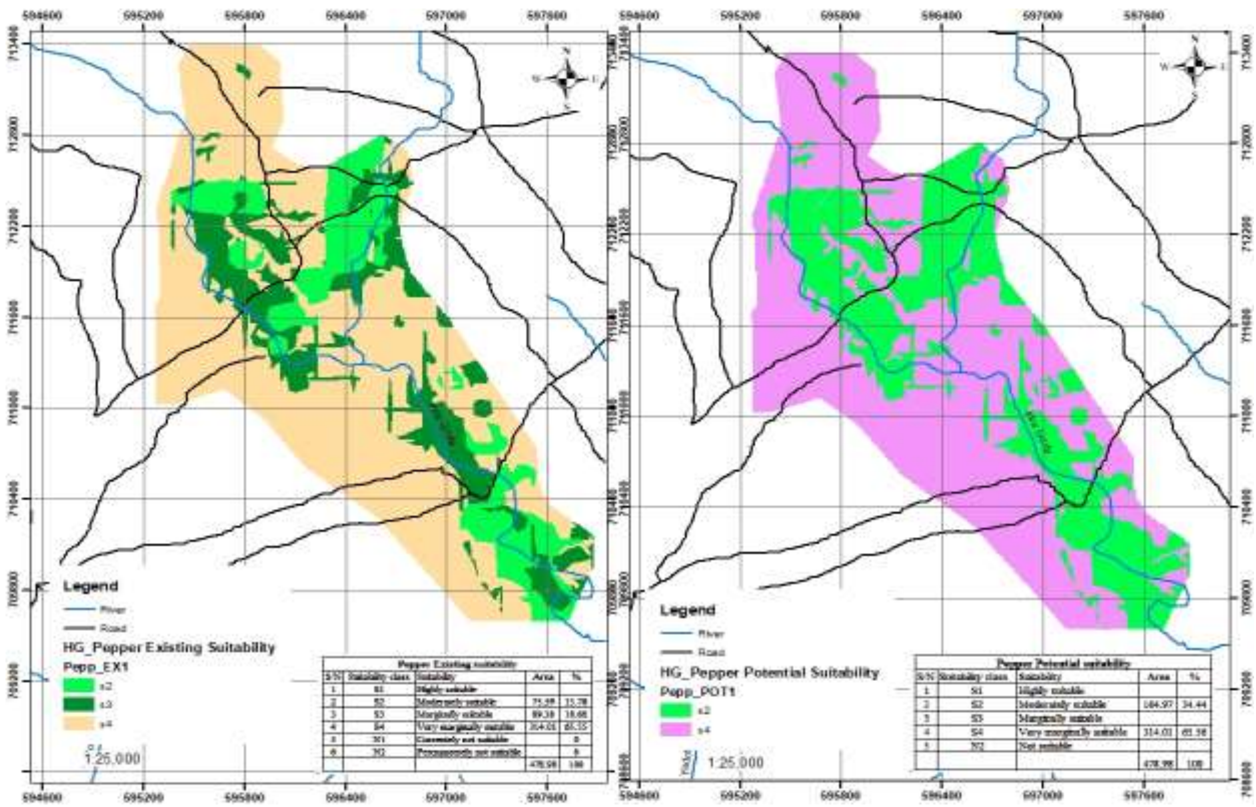
The Potential land suitability for pepper can be grouped into two class. That is the very marginally suitable and moderately suitable lands (Table 36,38 &39).). Land units listed under the suitability sub class s4z classified as the the very marginally suitable due to soil PH and cover 314.011 ha. Where land units listed under the suitability sub class s2m2 (Table

38,39 and 41) are classified as the moderately suitable land for pepper production due to the soil infiltration of the study area (Table 39). The area of these land units is cover 164.98 ha.

Table 36: Pepper potential suitability

Pepper Potential suitability				
S/N	Suitability class	Suitability	Area	%
1	S1	Highly suitable		
2	S2	Moderately suitable	164.97	34.44
3	S3	Marginally suitable		
4	S4	Very marginally suitable	314.01	65.56
5	N2	Not suitable		
			478.98	100

Figure 10:Pepper Existing and potential suitability map



Pulse crop

- **Haricot bean**

Potential land suitability for the crop haricot bean can be grouped into two classes. These include the permanentely not suitable lands and moderately suitable lands (Table37, 38 &39).

Land units listed under the suitability sub class N2z grouped under permanentely not suitable lands due to soil PH, and covers an area of 325.26 ha. Thus, thouse land units listed under the suitability sub class s2m2 (Table 38,39 and 41) are classified as the moderately suitable land for haricot bean crops production due to the soil infiltration of the study area (Table 39). The area of these land units is 153.73 ha.

Table 37: Haricot bean potential suitability

Haricot bean Potential suitability				
S/N	Suitability	Suitability	Area	%
1	S1	Highly suitable		
2	S2	Moderately suitable	10.22	2.13
3	S3	Marginally suitable	143.51	29.96
4	S4	Very marginally suitable	325.26	69.91
5	N	Not suitable		
			478.98	100

Figure 11:Haricot bean Existing and potential suitabiliyu map

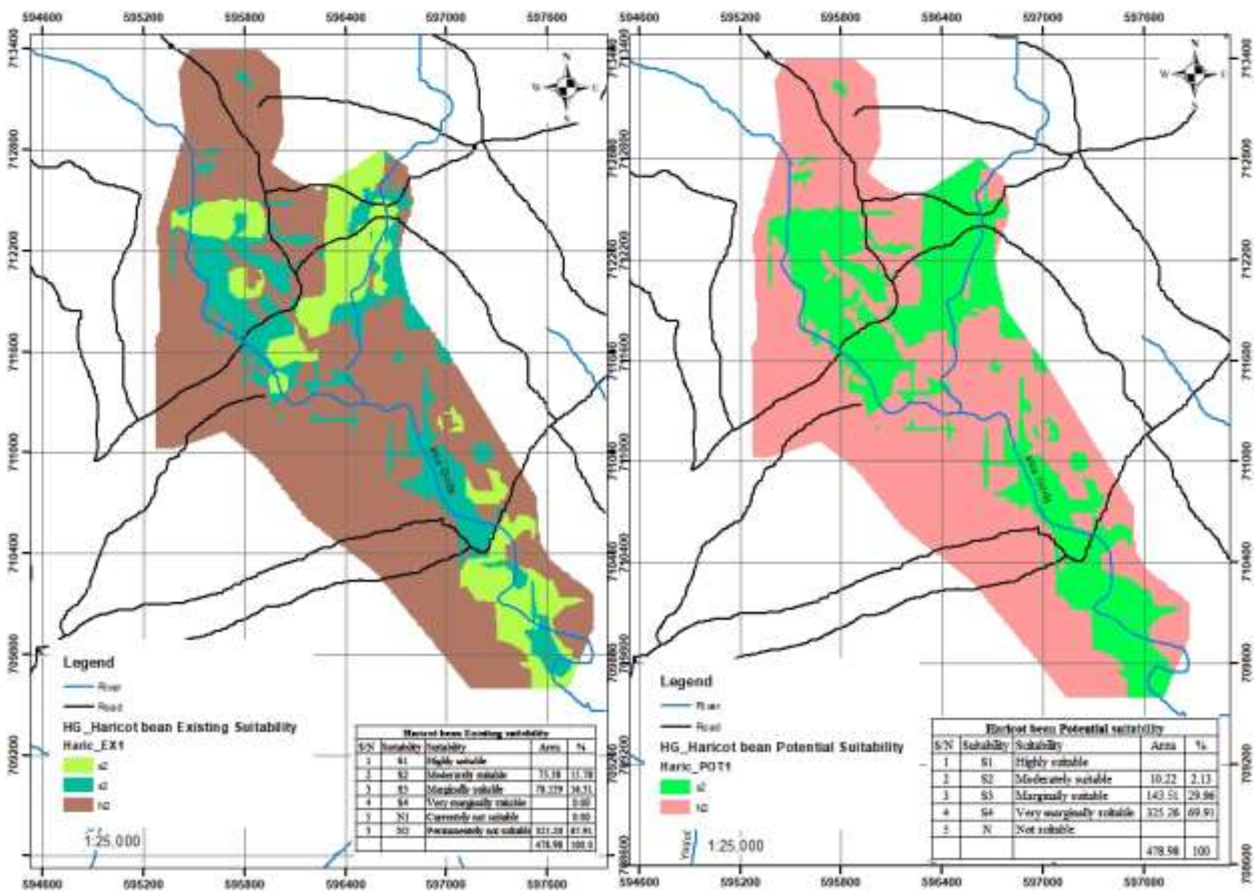


Table 38:All Crops Potential Suitability by Area for surface Irrigation

Potential crop suitability by Area for surface Irrigation						
Crop	s1	s2	s3	s4	N1	N2
	Highly suitable	Moderately suitable	Marginally suitable	Very marginally suitable	Currentely not suitable	Permanentely not suitable
	Area,ha	Area,ha	Area,ha	Area,ha	Area,ha	Area,ha
Maize		87.17	66.55			325.26
Sorgum		153.72		325.26		
Onion		142.57		325.26		11.15
Tomato		153.72	325.26			
Pepper		164.97		314.01		
Head Cabbage		10.22	143.51	325.26		
Haricot bean		10.22	143.51	325.26		

Table 39: Potential Crop Suitability by subclass and Area for surface Irrigation

Crop	Potential suitability sub class comparing with crop for surface Irrigation						
Maize	Potential Sub class	N2z	s2m1	s2m1r1	s2m2	s2m2r1	s3z
	Area,ha	325.26	0.77	9.02	5.697	71.7	66.55
Sorghum	Potential Sub class	s2m2	s2m2r1	s4z			
	Area,ha	73.04	80.72	325.26			
Onion	Potential Sub class	N2k	s2m2	s4z			
	Area,ha	11.15	142.58	325.26			
Tomato	Potential Sub class	s2m2	s3m2r1	s3z			
	Area,ha	73.014	80.72	325.26			
Pepper	Potential Sub class	s2m2	s4z				
	Area,ha	164.98	314.011				
Head Cabbage	Potential Sub class	s2m2	s3z	s4z			
	Area,ha	10.22	143.52	325.26			
Haricot bean	Potential Sub class	N2z	s2m2				
	Area,ha	325.26	153.73				

As indicated from the above table: 31 the potential condition of the command area is primerly/ranking best/ is moderately suitable for pepper (164.97 ha), sorghum and tomato (153.72 ha), onion (142.57 ha) and maize (87.17 ha) and Marginally suitable best for tomato (325.26 ha), for head cabbage and haricot bean (143.51 ha).

Table 40: Results of Crop Existing and Potential Suitability Class Evaluation

SMU	Area	Percentage	Maize		Sorghum		Tomato		Onion		Cabbage		Pepper		Haricot bean	
			Existing	Potential	Existing	Potential	Existing	Potential	Existing	Potential	Existing	Potential	Existing	Potential	Existing	Potential
1C_c	0.433	0.090	s4	s2	s4	s2	s4	s2	s3	s2	s2	s2	s3	s2	s3	s2
1CL_c	63.993	13.360	N2	N2	s4	s4	s3	s3	s4	s4	s4	s4	s4	s4	N2	N2
1CL_d	6.889	1.438	N2	N2	s4	s4	s4	s3	s4	s4	s4	s4	s3	s2	N2	N2
2C_c	7.297	1.523	s4	s3	s4	s2	s4	s2	s3	s2	s3	s3	s3	s2	s3	s2
2CL_a	0.449	0.094	N2	N2	s4	s4	s4	s3	s4	s4	s4	s4	s3	s2	N2	N2
2CL_b	1.266	0.264	N2	N2	s4	s4	s3	s3	s4	s4	s4	s4	s4	s4	N2	N2
2CL_c	126.550	26.421	N2	N2	s4	s4	s3	s3	s4	s4	s4	s4	s4	s4	N2	N2
2CL_d	26.078	5.446	N2	N2	s4	s4	s3	s3	s4	s4	s4	s4	s4	s4	N2	N2
3CL_a	3.054	0.638	N2	N2	s4	s4	s4	s3	s4	s4	s4	s4	s3	s2	N2	N2
3CL_b	0.666	0.139	N2	N2	s4	s4	s3	s3	s4	s4	s4	s4	s4	s4	N2	N2
3CL_c	95.458	19.929	N2	N2	s4	s4	s3	s3	s4	s4	s4	s4	s4	s4	N2	N2
3CL_c1	1.337	0.279	s2	s2	s2	s2	s3	s2	s2	s2	s3	s3	s2	s2	s2	s2
3CL_d	25.470	5.318	s2	s2	s2	s2	s3	s2	s2	s2	s3	s3	s2	s2	s2	s2
4CL_a	0.851	0.178	N2	N2	s4	s4	s4	s3	s4	s4	s4	s4	s3	s2	N2	N2
4CL_c	59.255	12.371	s4	s3	s4	s2	s4	s2	s3	s2	s3	s3	s3	s2	s3	s2
4CL_c1	3.927	0.820	s2	s2	s2	s2	s3	s2	s3	s2	s3	s3	s2	s2	s2	s2
4CL_d	27.710	5.786	s2	s2	s2	s2	s3	s2	s3	s2	s3	s3	s2	s2	s2	s2
4CL_d1	17.150	3.581	s2	s2	s2	s2	s3	s2	s3	s2	s3	s3	s2	s2	s2	s2
5CL_c	0.765	0.160	s4	s2	N	s2	s4	s2	N2	N2	s3	s2	s3	s2	s3	s2
5CL_d	9.018	1.883	s4	s2	N	s2	s4	s2	N2	N2	s3	s2	s3	s2	s3	s2
5CL_d1	1.370	0.286	s3	s2	s3	s2	s3	s2	N2	N2	s3	s3	s3	s2	s3	s2

Table 41: Results of Crop Existing and Potential SuitabilitySubclass Evaluation

SMU	Area	Percentage	Maize		Sorghum		Tomato		Onin		Cabbage		Pepper		Haricotbean	
	ha		Existing	Potential	Existing	Potential	Existing	Potential	Existing	Potential	Existing	Potential	Existing	Potential	Existing	Potential
1C_c	0.433	0.090	s4n3	s2m2	s4nl	s2m2	s4n3	s2m2	s3n3	s2m2	s2m2	s2m2	s3n3	s2m2	s3n3	s2m2
1CL_c	63.993	13.360	N2z	N2z	s4z	s4z	s3n3z	s3z	s4z	s4z	s4z	s4z	s4z	s4z	N2z	N2z
1CL_d	6.889	1.438	N2z	N2z	s4z	s4z	s4n3	s3z	s4z	s4z	s4z	s4z	s3n3	s2m2	N2z	N2z
2C_c	7.297	1.523	s4n3	s3z	s4nl	s2m2	s4n3	s2m2	s3n3	s2m2	s3z	s3z	s3n3	s2m2	s3n3	s2m2
2CL_a	0.449	0.094	N2z	N2z	s4z	s4z	s4n3	s3z	s4z	s4z	s4z	s4z	s3n3	s2m2	N2z	N2z
2CL_b	1.266	0.264	N2z	N2z	s4z	s4z	s3n3z	s3z	s4z	s4z	s4z	s4z	s4z	s4z	N2z	N2z
2CL_c	126.550	26.421	N2z	N2z	s4z	s4z	s3n3z	s3z	s4z	s4z	s4z	s4z	s4z	s4z	N2z	N2z
2CL_d	26.078	5.445	N2z	N2z	s4z	s4z	s3n3z	s3z	s4z	s4z	s4z	s4z	s4z	s4z	N2z	N2z
3CL_a	3.054	0.638	N2z	N2z	s4z	s4z	s4n3	s3z	s4z	s4z	s4z	s4z	s3n3	s2m2	N2z	N2z
3CL_b	0.666	0.139	N2z	N2z	s4z	s4z	s3n3z	s3z	s4z	s4z	s4z	s4z	s4z	s4z	N2z	N2z
3CL_c	95.458	19.929	N2z	N2z	s4z	s4z	s3n3z	s3z	s4z	s4z	s4z	s4z	s4z	s4z	N2z	N2z
3CL_cl	1.337	0.279	s2m2n3z	s2m2	s2m2	s2m2	s3n3	s2m2	s2m2zk	s2m2	s3z	s3z	s2m2z	s2m2	s2m2	s2m2
3CL_d	25.470	5.318	s2m2n3zrl	s2m2rl	s2m2rl	s2m2rl	s3n3	s2m2rl	s2m2zk	s2m2	s3z	s3z	s2m2z	s2m2	s2m2	s2m2
4CL_a	0.851	0.178	N2z	N2z	s4z	s4z	s4n3	s3z	s4z	s4z	s4z	s4z	s3n3	s2m2	N2z	N2z
4CL_c	59.255	12.371	s4n3	s3z	s4nl	s2m2	s4n3	s2m2	s3n3k	s2m2	s3z	s3z	s3n3	s2m2	s3n3	s2m2
4CL_cl	3.927	0.820	s2m2n3zk	s2m2	s2m2k	s2m2	s3n3	s2m2	s3k	s2m2	s3z	s3z	s2m2zk	s2m2	s2m2k	s2m2
4CL_d	27.710	5.785	s2m2n3zrlk	s2m2rl	s2m2rlk	s2m2rl	s3n3	s2m2rl	s3k	s2m2	s3z	s3z	s2m2zk	s2m2	s2m2k	s2m2
4CL_dl	17.150	3.581	s2m2n3zrlk	s2m2rl	s2m2rlk	s2m2rl	s3n3	s2m2rl	s3k	s2m2	s3z	s3z	s2m2zk	s2m2	s2m2k	s2m2
5CL_c	0.765	0.160	s4n3	s2ml	Nnl	s2m2	s4n3	s2m2	N2k	N2k	s3k	s2m2	s3n3k	s2m2	s3n3k	s2m2
5CL_d	9.018	1.883	s4n3	s2mlrl	Nnl	s2m2rl	s4n3	s2m2rl	N2k	N2k	s3k	s2m2	s3n3k	s2m2	s3n3k	s2m2
5CL_dl	1.370	0.286	s3k	s2m2rl	s3k	s2m2rl	s3n3k	s2m2rl	N2k	N2k	s3zk	s3z	s3k	s2m2	s3k	s2m2

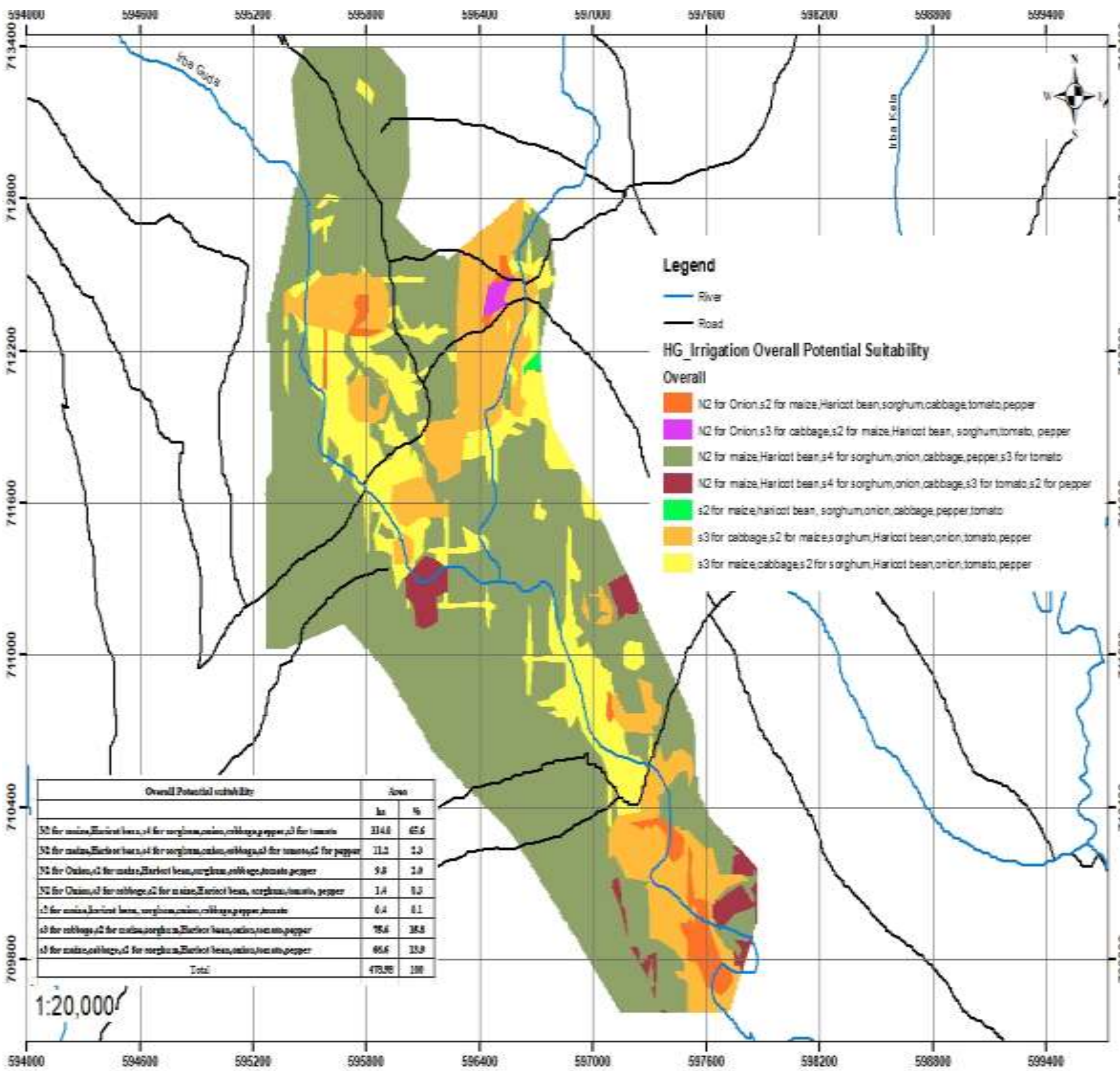
8.11.4. The Overall Crop Potential Suitability

The final Crop potential suitability is displayed briefly on Table : 42

Table 42: Final Crop Potential Suitability by SMU

SMU	Area	Percentage	Overall Potential suitability
1C_c	0.433	0.090	s2 for maize,haricot bean, sorghum,onion,cabbage,pepper,tomato
1CL_c	63.993	13.360	N2 for maize,Haricot bean,s4 for sorghum,onion,cabbage,pepper,s3 for tomato
1CL_d	6.889	1.438	N2 for maize,Haricot bean,s4 for sorghum,onion,cabbage,s3 for tomato,s2 for pepper
2C_c	7.297	1.523	s3 for maize,cabbage,s2 for sorghum,Haricot bean,onion,tomato,pepper
2CL_a	0.449	0.094	N2 for maize,Haricot bean,s4 for sorghum,onion,cabbage,s3 for tomato,s2 for pepper
2CL_b	1.266	0.264	N2 for maize,Haricot bean,s4 for sorghum,onion,cabbage,pepper,s3 for tomato
2CL_c	126.550	26.421	N2 for maize,Haricot bean,s4 for sorghum,onion,cabbage,pepper,s3 for tomato
2CL_d	26.078	5.445	N2 for maize,Haricot bean,s4 for sorghum,onion,cabbage,pepper,s3 for tomato
3CL_a	3.054	0.638	N2 for maize,Haricot bean,s4 for sorghum,onion,cabbage,s3 for tomato,s2 for pepper
3CL_b	0.666	0.139	N2 for maize,Haricot bean,s4 for sorghum,onion,cabbage,pepper,s3 for tomato
3CL_c	95.458	19.929	N2 for maize,Haricot bean,s4 for sorghum,onion,cabbage,pepper,s3 for tomato
3CL_c1	1.337	0.279	s3 for cabbage,s2 for maize,sorghum,Haricot bean,onion,tomato,pepper
3CL_d	25.470	5.318	s3 for cabbage,s2 for maize,sorghum,Haricot bean,onion,tomato,pepper
4CL_a	0.851	0.178	N2 for maize,Haricot bean,s4 for sorghum,onion,cabbage,s3 for tomato,s2 for pepper
4CL_c	59.255	12.371	s3 for maize,cabbage,s2 for sorghum,Haricot bean,onion,tomato,pepper
4CL_c1	3.927	0.820	s3 for cabbage,s2 for maize,sorghum,Haricot bean,onion,tomato,pepper
4CL_d	27.710	5.785	s3 for cabbage,s2 for maize,sorghum,Haricot bean,onion,tomato,pepper
4CL_d1	17.150	3.581	s3 for cabbage,s2 for maize,sorghum,Haricot bean,onion,tomato,pepper
5CL_c	0.765	0.160	N2 for Onion,s2 for maize,Haricot bean,sorghum,cabbage,tomato,pepper
5CL_d	9.018	1.883	N2 for Onion,s2 for maize,Haricot bean,sorghum,cabbage,tomato,pepper
5CL_d1	1.370	0.286	N2 for Onion,s3 for cabbage,s2 for maize,Haricot bean, sorghum,tomato, pepper

Figure 12: Final Overall Crop Potential Suitability map of Hirba Giristu 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(red) and clay loam 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. But during soil survey observed no coarse fragements, on the dominant soil mapping units except 5CL_d1,4CL-c1,3CL_c1 and 4CL_d1 with few fragements, so 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 and drainage problem, as such, in haplic Cambisols and Chromic Luvisol area

9.1.4. Flooding

In sloping area (slope 8-15 and 15-30%) only for few days might be observe flooding on cambisols and Luvisols 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 Cambisols and Luvisols area of all the soil mapping units(0-2% ,2-5% and 5-8% slope) are slightely affected by very few splash, and sheet erosion, where as the rest of soils of the soil mapping units (8-15% and 15-30% slope)are affecte by few splash sheet and rill erosion.The main causes of this splash and sheet erosion are considerable slight run off 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 area is uniform. The exchangeable Calcium is medium to high Ca (7.28 meq/100g soil to 16.31 meq/100g soil) and Mg high to very high (3 meq/100g soil to 9.47 meq/100g soil) in soils of the soil mapping units and identifyed Cambisols and chromic Luvisols. The level of Potassum (K) is very low to high (0.03 meq/100g soil to 0.87 meq/100g soil). Where, all soils of the soil mapping units are medium to high level of CEC (20.96 meq/100g soil to 42.82 meq/100g soil) and medium to high level of BSP (47.48% to 64.82%). The PH value for most of the soils in the study area varies from 5.0 to 6.30, which is very strongly acid to sligtely acid. As indicated in Land evaluation result one of the major limitation (potential suitability) for most crop is soil reaction(PH),soil depth,infiltration rate and slope.**Calcium to Magnesium ratio** for the dominant soil mapping units are 10.44:1 to 12.02:1(high), which is approximately optimum for most crops.The AVP content for soils of the soil mapping units are low to medium (0.04ppm to 8.12 ppm) it needs application of organic fertilizer like compost is to considered. The total Nitrogen contents of the soils mapping unit’s is low to high (0.05% to high 0.32% 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 21 soil mapping units in Hirba Giristu 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, Guji- Bale Integrated Land Use Planning Study Genale Sub-Basin Final Soil survey report. The study was conducted by OWWDSE, The Client of the project is Oromia Rural Land Administration and Use Bureau,2016. 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 478.98 ha at detailed level (1:10,000). Some 81 auger observation and 3 profiles were dug and described and 11 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 Hirba Giristu SSIP are soil reaction(PH),soil depth,slope and infiltratition rate of the soil in the study area.As limitation few flooding problem for few days in soils of the soil mapping units (5CL_c,5CL_d_5CL_d1 with slope of 15-30%),and some SMU(with slope 8-15%) are slightely affected by sheet and splash erosion (4CL_c,4CL_a,4CL_c1 and 4CL_d), where as soils of all soil mapping units are un satisfactory in availability of AVP content,K and very strong soil PH

Therefore, the following recommendations are suggested :

- Application of organic fertilzer like compost, and/or chemical fertilzer improves the availability of phousphrous, potassium 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.
- Irrigation of the soil with good quality of irrigation water to reduce the PH to neutral level,this in turn improve the not suitable land for surface irrigation to highly and moderately suitability class.
- In very small area if possible, liming to improve the soil PH
- Application of organic fertilzer like compost, and/or chemical fertilzer improves the availability of phousphrous and improve the not suitable land for surface irrigation to highly and moderately suitability class.

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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**

Hirbaa Giristuu small scale project

Soil profile description **Profile code:** *HGDB-1* **mapping unit:** **Status:** *PS*

Date: *02/02/2019*	**Long. in utm (E):** *596108*
Author(s): *Sisay/Wako*	**Lat. in utm (N):** *711272*
Region *Oromia*	**Elevation:** *1279 meter*
Zone: *bale roobee*	**Parent material:** *basalt*
Soil classification FAO: *Luvisols*	**Rock out crops:** *none*
Human influence: *ploughing*	**Erosion:** *sheet, splash*
Land form: *low gradient*	**Depth to bed rock:** *350cm*
Regional slope: *strongly rolling*	**Surface stones/gravels:** *none*
Position: *medium*	**Micro topography:** *Animal track, termite mold*
Slope class; *8-15%*	**Surface sealing:** *None*
Slope aspect: *west/east*	**Drainage class:** *well*
Slope gradient:	**Fertilizers:** *Unknown*
Drainage external: *rapidly*	**Vegetation types:** *open wood land*
Slope form: *concave*	**Dissection:** *None*
Drainage internal: *well*	**Moisture condition:** 0-30cm is dry; 30-350 cm is slightly moist
Ground water *none*	**Flooding:** *none*
Surface cracks: *few*	**Land use:** *cultivated land*
Existing crops: *tomato, maize*	**Dominant species:** *bakanisaa*

0-30cm Clear smooth boundary; Moisture status (5YR4/4) when dry, when moist(5YR3/3); no mottling; clay loam texture; moderate, fine to medium ,sub angular blocky structure; few crack; slightly hard, friable when moist, sticky and plastic when wet; no cutans; none cemented; none mineral nodules, many fine, fine medium, very few to coarse roots; common fine, many medium, fine to coarse pores; non calcareous.

30-100cm Clear gradual boundary; Moisture status, when moist(2.5YR4/6); no mottling; clay texture; moderate, fine to medium , angular blocky structure; few crack; friable when moist, sticky and plastic when wet; no cutans; none cemented; none mineral nodules, few medium, very few to coarse roots; many medium, fine to coarse pores; non calcareous.

100-200cm Moisture status, when moist(2.5YR4/8); no mottling, clay texture, weak, fine to medium , angular blocky structure; none crack; friable when moist, sticky and plastic when wet; no cutans; none cemented; none mineral nodules, few medium, very few to coarse roots; many medium, fine to coarse pores; non calcareous.

200-250cm deep boring, Moisture status, when moist(2.5YR4/6); no mottling, clay texture, weak, fine to medium, angular blocky structure; none crack; friable when moist, very sticky and very plastic when wet; no cutans; none cemented; none mineral nodules; non calcareous.

250-350cm deep boring, Moisture status, when moist(2.5YR3/4); no mottling, clay texture, weak, fine to medium, angular blocky structure; none crack; friable when moist, very sticky and very plastic when wet; no cutans; none cemented; none mineral nodules; non calcareous.

Cont'd

Hirbaa Giristuu small scale project

Soil profile description **Profile code:** *HGP-2* **mapping unit:** **Status:** *PS*

Date: *04/02/2019*	**Long. in utm (E):** *596562*
Author(s): *Sisay/wako*	**Lat. in utm (N):** *711234*
Region *Oromia*	**Elevation:** *1256 meter*
Zone: *bale roobee*	**Parent material:** *basalt*
Soil classification FAO: *Luvisols*	**Rock out crops:** *none*
Human influence: *ploughing, vegetation disturbance*	**Erosion:** *sheet/splash*
Land form: *plan*	**Depth to bed rock:** *200cm*
Regional slope: *undulating sloping*	**Surface stones/gravels:** *none*
Position: *medium*	**Micro topography:** *Animal track, termite mold*
Slope class: *5-8%*	**Surface sealing:** *None*
Slope aspect: *north, south*	**Drainage class:** *well*
Slope gradient:	**Fertilizers:** *Unknown*
Drainage external: *well*	**Vegetation types:** *open wood land*
Slope form: *uniform*	**Dissection:** *None*
Drainage internal: *well*	**Moisture condition:** 0-30cm; 30-200cm is slightly moist
Ground water *none*	**Flooding:** *none*
Surface cracks: *none*	**Land use:** *cultivated*
Existing crops: *maize*	**Dominant species:** *bakanisaa*

0-30cm Clear smooth boundary; Moisture status (5YR3/3) when dry, when moist(5YR3/2); none mottling; clay loam texture; none coarse fragments; moderate, fine to medium, sub-angular blocky structure; few crack; slightly hard; friable when moist; slightly sticky and slightly plastic when wet; no cutans; none cemented; none mineral nodules; many, fine, few medium, very to coarse roots; common fine, many medium, few to coarse pores; non calcareous.

30-80cm diffuse irregular boundary; slightly moisture status; 5YR4/6(moist) color; none mottling; clay texture ; none coarse fragment; moderate, fine to medium, angular blocky structure; few crack; when dry none; friable (moist), sticky and plastic(wet) consistency; none cutanic features; none cemented and none compacted ;none mineral nodules; few medium, very few to coarse root ;many medium pores; none calcareous..

80-150cm diffuse irregular boundary; slightly moisture status; 2.5YR3/6(moist) color; none mottling; clay texture ; none coarse fragment; weak, fine to medium, angular blocky structure; none crack; when dry none; friable to firm (moist), very sticky and very plastic(wet) consistency; none cutanic features; none cemented and none compacted ;none mineral nodules; few medium, very few to coarse root ;many medium pores; none calcareous..

150-200cm slightly moisture status; 2.5YR4/6(moist) color; none mottling; clay texture ; none coarse fragment; weak, fine to medium, angular blocky structure; none crack; when dry none; friable to firm (moist), very sticky and very plastic(wet) consistency; none cutanic features; none cemented and none compacted ;none mineral nodules; few medium, very few to coarse root ;many medium, few to coarse pores; none calcareous..

Cont'd

Hirbaa Giristuu small scale project

Soil profile description **Profile code:** *HGP-3* **mapping unit** **Status;** ***PS***

Date: *05/02/2019*	**Long. in utm (E):** *596424*
Author(s): *wako/Sisay*	**Lat. in utm (N):** *712231*
Region *Oromia*	**Elevation:** *1276 meter*
Zone: *bale roobee*	**Parent material:** *Basalt*
Soil classification FAO: *Cambisols*	**Rock out crops:** *common*
Human influence: *ploughing, vegetation disturbance*	**Erosion:** *rill*
Land form: *small gradient hill*	**Depth to bed rock:** *80cm*
Regional slope: *steep*	**Surface stones/gravels:** *none*
Position: *high*	**Micro topography:** *Animal track, termite mold*
Slope class: *:15-30%*	**Surface sealing:** *None*
Slope aspect: *north to south*	**Drainage class:** *well*
Slope gradient:	**Fertilizers:** *Unknown*
Drainage external: *rapidly*	**Vegetation types:** *open wood land*
Slope form: *concave*	**Dissection:** *None*
Drainage internal: *well*	**Moisturecondition:**0-30cmdry,30-80cmis slightly moist
Ground water *none*	**Flooding:** *none*
Surface cracks: *few*	**Land use:** *cultivated land*
Existing crops: *chat, papaya, mango*	**Dominant species:** *bakanisaa*

0-30cm Clear smooth boundary; Moisture status (5YR3/3) when dry; when moist(5YR3/2); no mottling; clay loam texture; common coarse fragments; moderate, fine to medium ,sub angular blocky structure; none crack; slightly hard, friable when moist, slightly sticky and slightly plastic when wet; no cutans; none cemented; none mineral nodules, many, fine, few medium, very few to coarse roots; many, fine to medium pores; non calcareous.

30-80cm slightly moisture status; 5YR4/6(moist) color; none mottling; clay texture ; many fine to medium coarse fragment; weak, fine ,sub-angular blocky structure; none crack; none when(dry); friable (moist), sticky and plastic(wet) consistency; none cutanic features; none cemented and none compacted ;none mineral nodules; few, medium, very few to coarse root ;many, fine to medium pores; none calcareous..

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

Field No(Profile description)	X	Y
HGDBP-1	596108	711272
HGP-2	596562	711234
HGP-3	596424	712231

Field No	*X*	*Y*	*Field No*	*X*	*Y*	*Field No*	*X*	*Y*	*Field No*	*X*	*Y*
HG-1	595590	710991	HG-17	596006	712413	HG-35	596408	711800	HG-55	596812	711007
HG-1A	595598	710611	HG-18	596014	712194	HG-36	596398	711591	HG-56	596805	711196
HG-2	595590	711194	HG-19	596005	711984	HG-37	596407	711401	HG-57	596807	711407
HGA-2A	595600	710813	HG-20	595799	710786	HG-38	596407	711191	HG-58	596807	711605
HG-3	595593	711408	HG-21	596010	711774	HG-39	596403	710995	HG-59	596807	711795
HG-4	595587	711589	HG-22A	595798	710599	HG-40	596404	710787	HG-60	596811	711999
HG-5	595603	711792	HG-22	596011	711606	HG-41	596605	710403	HG-61	597001	711786
HG-6	595591	712001	HG-23	596005	711397	HG-42	596611	710614	HG-62	597004	711599
HG-7	595591	712194	HG-24	596015	711188	HG-43	596597	710811	HG-63	596999	711396
HG-8	595602	712402	HG-25	596195	711026	HG-44	596608	710996	HG-64	597009	711199
HG-9	595808	712371	HG-26	596196	711211	HG-45	596603	711191	HG-65	597005	710993
HG-10	595808	712175	HG-27	596199	711411	HG-46	596602	711418	HG-66	597003	710793
HG-11A	595591	712602	HG-28	596195	711628	HG-47	596600	711599	HG-67	596999	710599
HG-11	595807	712009	HG-29	596201	711835	HG-48	596602	711799	HG-68	597004	710393
HG_12A	595795	712609	HG-30	596198	712002	HG-49	596618	711997	HG-69	597402	710398
HG-12	595798	711843	HG-31	596195	712215	HG-50	596598	712212	HG-70	597204	710409
HG-13	595802	711605	HG-32	596193	712416	HG-51	596605	712406	HG-71	597206	710595
HG-14	595801	711416	HG-33A	596409	712394	HG-52	596807	710393	HG-72	597203	710805
HG-15	595799	711209	HG-33	596408	712196	HG-53	596806	710602	HG-73	597206	710999
HG-16	595798	711012	HG-34	596409	711999	HG-54	596812	710805	HG-74	597207	711194
									HG-75	597203	711402

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 AND SUPERVISION ENTERPRISE

Project : Hiriba Giristu SSI | **Location** - Dalo Mana Woreda, Bale Robe

LAB NO	Field Code	Depth	P^H -Water	E.C	P^H - KCl	Particle Size Distribution Sand	SILT	CLAY	TEXTURAL CLASS
		Cm	1:2.5	ds/m	1:2.5	%	%	%	
243 /19	DBHGP - 1	0-30	5.1	0.057	4.7	34	36	30	Clay loam
244 /19		30-100	5.0	0.016	4.7	16	14	70	clay
245 /19		100-200	5.5	0.026	5.0	14	18	68	clay
246 /19		200-250	5.7	0.012	5.3	6	18	76	clay
247 /19		250-350	5.5	0.011	5.0	30	4	66	clay
248 /19	HGP - 2	0-30	5.0	0.077	4.7	34	38	28	Clay loam
249 /19		30-80	5.6	0.054	5.2	30	24	46	clay
250 /19		80-150	6.0	0.045	5.5	20	18	62	clay
251 /19		150-200	5.7	0.055	5.2	12.00	18	70	clay
252 /19	HGP - 3	0-30	5.8	0.180	5.5	36.00	32	32	Clay loam
253 /19		30-80	6.3	0.047	5.7	26.00	26	48	clay

Cont'd

LAB NO	Na	K	Ca	Mg	SUM	CEC	BS	EX. Acidity	Ex. Al^{3+}
	Cmol(+)Kg^{-1}						%	Cmol(+)Kg-1	
243 /19	0.15	0.27	7.28	4.30	11.99	23.7	51	0.08	0.00
244 /19	0.15	0.04	7.49	3.58	11.24	18.9	59	2.32	0.96
245 /19	0.16	0.02	7.49	3.49	11.15	18.2	61	0.80	0.00
246 /19	0.15	0.85	8.00	5.06	14.06	22.2	63	_	_
247 /19	0.15	0.10	7.98	3.68	11.91	18.7	64	4.56	3.12
248 /19	0.16	0.35	12.54	4.63	17.68	37.2	47	0.32	0.00
249 /19	0.13	0.05	14.37	3.00	17.55	34.6	51	_	_
250 /19	0.15	0.03	8.31	5.10	13.59	21.0	65	_	_
251 /19	0.13	0.02	5.90	4.93	10.98	20.8	53	_	_
252 /19	0.22	0.87	16.31	9.47	26.88	41.8	64	_	_
253 /19	0.16	0.34	13.07	5.88	19.45	39.9	49	_	_

Cont'd

LAB NO	T.N	O.C	O.M	C/N	Av.K	Av.P	P_2O_5	$CaCO_3$	
	%	%	%		PPM	PPM		%	gram kg^{-1}
243 /19	0.22	2.34	4.03	11	98.70	0.58	1.33	_	_
244 /19	0.05	0.61	1.05	11	33.70	0.06	0.14	_	_
245 /19	0.03	0.28	0.48	9	28.90	0.04	0.09	_	_
246 /19	0.02	0.18	0.31	9	287.70	0.04	0.09	_	_
247 /19	0.02	0.15	0.26	8	47.80	0.14	0.32	_	_
248 /19	0.24	2.66	4.58	11	137.90	5.40	12.37	_	_
249 /19	0.08	0.96	1.66	12	27.80	0.08	0.18	_	_
250 /19	0.05	0.53	0.91	11	23.70	0.04	0.09	_	_
251 /19	0.04	0.45	0.78	11	26.90	0.06	0.14	_	_
252 /19	0.32	3.34	5.76	10	288.70	8.12	18.59	_	_
253 /19	0.08	0.94	1.62	11	142.70	0.10	0.23	_	_

Remarks

Checked By ______________________ Signature ____________ Date __________

Approved By ____________ Signature ____________ Date ________

Cont'd

Name of Customer : OROMIA WATER WORKS DESIGN AND SUPERVISION ENTERPRISE

Project : Hiriba Giristu SSI | Location -Dalo Mana Woreda, Bale Robe

LAB NO	Field Code	Depth	Core Samples		
			Bulk Density	F. Capacity	P.Wilting Point
		Cm	g/ Cm^3	%	
262 /19	DBHGPcs - 1	0-30	1.40	36.8	23.7
263 /19		30-100	1.20	37.2	24.1
264 /19		100-200	1.36	35.8	24.9
265 /19	HGPcs - 2	0-30	1.34	32.8	22.1
266 /19		30-80	1.25	38.7	25.6
267 /19		80-150	1.28	38.1	26.2

Remarks

Checked By ______________________ Signature ____________ Date __________

Approved By Signature Date

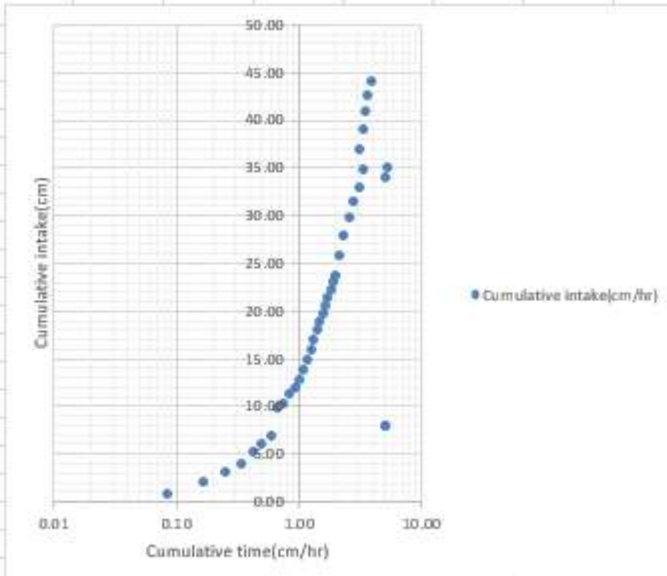
Appendix table 6: Soil infiltration and permeability test

I-Infiltration

Date:21/01/19/Depth of insertion of ring(cm):10cm			GPS Reading/N:711272/E:596108/Elevation:1279			Land Form:LL/Slope Class:2-5		Micro Topography:AT/Soil Type: LV	
				Pre-wetting time (hrs):				Replication No.:1	
Local	Time	Interval(hr)columo	Cumulative	Cumulative	Depth of water in	Intake(cm)	Cumulative	Infiltration rate(cm/hr)	
								immediate(instantar	mean
1	2	3.00	4	5	6.0	7	8	9=7/3	10=8/5
03:00	0	0.00	0	0	13.0	0	0		
	5	0.08	5	0.08	12.0	1.0	0.9	12	10.80
	5	0.08	10	0.17	10.8	1.2	2.2	14.4	13.20
	5	0.08	15	0.25	9.9	0.9	3.1	10.8	12.40
	5	0.08	20	0.33	8.9	1.0	4.1	12	12.30
	5	0.08	25	0.42	7.7	1.2	5.3	14.4	12.72
	5	0.08	30	0.50	7.0	0.7	6.0	8.4	12.00
	5	0.08	35	0.59	7.9	0.9	6.9	10.8	11.83
	5	0.08	40	0.67	5.1	2.8	9.9	33.6	14.85
	5	0.08	45	0.75	4.4	0.7	10.4	8.4	13.87
	5	0.08	50	0.83	3.5	0.9	11.3	10.8	13.56
	5	0.08	55	0.92	2.9	0.6	11.9	7.2	12.98
	5	0.08	60	1.00	2.0	0.9	12.8	10.8	12.80
RE					13.0			#DIV/0!	#DIV/0!
	5	0.08	65	1.10	12.1	1.1	13.9	13.2	12.64
	5	0.08	70	1.17	11.0	1.1	15.0	13.2	12.82
	5	0.08	75	1.25	10.0	1.0	16.0	12	12.80
	5	0.08	80	1.33	9.0	1.0	17.0	12	12.78
	5	0.08	85	1.41	8.0	1.0	18.0	12	12.77
	5	0.08	90	1.49	7.1	0.9	18.9	10.8	12.68
	5	0.08	95	1.59	6.3	0.8	19.7	9.6	12.39
	5	0.08	100	1.65	5.5	0.8	20.5	10	12.42
	5	0.08	105	1.73	4.8	0.7	21.5	8.4	12.43
	5	0.08	110	1.81	4.0	0.8	22.3	9.6	12.32
	5	0.08	115	1.89	3.1	0.9	23.2	10.8	12.28
	5	0.08	120	1.97	2.5	0.6	23.8	7.2	12.08
RE					13.0			#DIV/0!	#DIV/0!
	15	0.25	130	2.14	11.0	2.0	25.8	8	12.06
	15	0.25	145	2.31	8.9	2.1	27.9	8.4	12.08
	15	0.25	160	2.56	6.9	2.0	29.9	8	11.68
	15	0.25	150	2.81	5.2	1.7	31.6	6.8	11.25
	15	0.25	160	3.06	3.8	1.4	33.0	5.6	10.78
	15	0.25	170	3.31	2.0	1.8	34.8	7.2	10.51
RE					13.0			#DIV/0!	#DIV/0!
	20	0.33	180	3.15	10.8	2.2	37.0	6.6	11.75
	20	0.33	190	3.32	8.8	2.0	39.0	6	11.75
	20	0.33	200	3.49	6.8	2.0	41.0	6	11.75
	20	0.33	210	3.66	5.1	1.7	42.7	5.1	11.67
	20	0.33	220	3.83	3.7	1.4	44.1	4.2	11.51
	20	0.33	230	3.85	8.1	0.7	15.1	2.1	3.92
RE	20	0.33			13.0			0	#DIV/0!
	20	0.25	245	4.08	10.0	2.3	43.0	9.2	10.54
	30	0.25	260	4.33	6.8	2.2	42.0	8.8	9.70
	30	0.25	275	4.58	4.0	2.1	41.0	8.4	8.95
	30	0.25	210	3.34	9.9	2.0	40.0	8	11.98
RE	30				13.0	1.9	39.0	#DIV/0!	#DIV/0!
	30	0.25	230	4.83	9.8	1.8	38.0	7.2	7.87
	30					1.7	37.0	#DIV/0!	#DIV/0!
	30	0.25	250	5.08	6.8	1.6	36.0	6.4	7.09
	30	0.25	265	5.33	4.3	1.5	35.0	6	6.57

Worked Example of Basic Infiltration rate using Logarithimic paper

Cumulative time(hr)	Cumulative intake(cm/hr)
5.00	8.00
0.00	0.00
0.08	0.90
0.17	2.20
0.25	3.10
0.33	4.10
0.42	5.30
0.50	6.00
0.58	6.90
0.67	9.90
0.75	10.40
0.83	11.30
0.92	11.90
1.00	12.80
1.10	13.90
1.17	15.00
1.25	16.00
1.33	17.00
1.41	18.00
1.49	18.90
1.59	19.70
1.65	20.50
1.73	21.50
1.81	22.30
1.89	23.20
1.97	23.80
2.14	25.80
[illegible]	[illegible]
2.31	27.90
2.56	29.90
2.81	31.60
3.06	33.00
3.31	34.80
3.15	37.00
3.32	39.00
3.49	41.00
3.66	42.70
3.83	44.10
5.165	34.00
5.33	35.00



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 (5.33, 35) and (5.165, 34), and the slope is calculated as,

Slope= Y2-Y1/X2-X1

= 35-34/5.33-5.164=6

Cont'd

Double Ring Infiltrometer Field Data						Project: HGSP		Site:HGHGD	Soil Type: LV
Date:21/01/19/Author: Wako/Sisay			GPS Reading/N:711272/E:596108/Elevation:1279			Land Form:LL		Micro Topography:AT	
Depth of insertion of ring(cm):10cm			Pre-wetting time (hrs):			Slope Class:2-5			Replication No.:2
Local	Time	Interval(hr)columon 2	Cumulative	Cumulative	Depth of water in	Intake(cm)	Cumulative	Infiltration rate(cm/hr)	
								immediate(instantar	mean
1	2	3.00	4	5	6.0	7	8	9=7/3	10=8/5
03:00	0	0.00	0	0	13.0	0	0		
	5	0.08	5	0.08	10.0	3.0	3.0	36	36.00
	8	0.13	13	0.22	7.5	2.5	5.5	18.75	25.38
	10	0.17	23	0.38	5.5	2.0	7.5	12	19.57
	12	0.20	20	0.58	3.5	2.0	9.5	10	16.29
	12	0.20	30	0.78	2.0	2.5	12.0	12.5	15.32
RE		0.00			13.0			#DIV/0!	#DIV/0!
	12	0.20	42	0.98	10.6	2.4	14.4	12	14.64
	12	0.20	54	1.18	8.5	2.1	16.5	10.5	13.94
	12	0.20	66	1.38	6.6	1.9	18.4	9.5	13.30
	12	0.20	78	1.58	5.0	1.6	20.0	8	12.63
	12	0.20	90	1.78	3.5	1.5	21.5	7.5	12.06
	12	0.20	102	1.98	2.0	1.5	23.0	7.5	11.60
	12	0.20	60	2.18	2.0	0.9	12.8	4.5	5.86
RE	12	0.20			13.0			0	#DIV/0!
	12	0.20	60	2.18	11.0	2.0	25.0	10	11.45
	12	0.20	65	2.38	8.9	2.1	27.1	10.5	11.37
	12	0.20	70	2.58	6.5	2.4	29.5	12	11.42
	12	0.20	75	2.78	4.8	1.7	31.2	8.5	11.21
	12	0.20	80	2.98	3.3	1.5	32.7	7.5	10.96
	12	0.20	85	3.18	2.0	1.3	34.0	6.5	10.68

Cont'd

RE	12	0.20			13.0			0	#DIV/0!
	12	0.20	90	3.38	10.6	2.4	36.4	12	10.76
	12	0.20	95	3.58	8.7	1.9	38.3	9.5	10.69
	12	0.20	100	3.78	6.8	1.9	40.2	9.5	10.63
	12	0.20	105	3.98	5.3	1.5	41.7	7.5	10.47
	12	0.20	110	4.18	3.9	1.4	43.1	7	10.30
	12	0.20	115	4.38	2.1	1.8	44.9	9	10.24
RE	12	0.20			13.0			0	#DIV/0!
	12	0.20	120	4.58	11.0	2.0	46.9	10	10.23
	12	0.20	125	4.78	9.0	2.0	48.9	10	10.22
	12	0.20	130	4.98	7.0	2.0	50.9	10	10.21
	12	0.20	135	5.18	5.3	1.7	52.6	8.5	10.15
	12	0.20	140	5.38	4.0	1.3	53.9	6.5	10.01
	12	0.20	145	5.58	2.5	1.5	55.4	7.5	9.92
RE	12	0.20			13.0			0	#DIV/0!
	12	0.20	150	5.78	11.0	2.0	57.4	10	9.93
	12	0.20	155	5.98	9.0	2.0	59.4	10	9.93
	12	0.20	160	6.18	7.4	1.6	61.0	8	9.87
	12	0.20	165	6.38	5.8	1.6	62.6	8	9.81
	12	0.20	170	6.58	4.3	1.5	64.1	7.5	9.74
	12	0.20	175	6.78	2.8	1.5	65.6	7.5	9.67
RE	12	0.20			13.0			0	#DIV/0!
	12	0.20	180	6.98	11.0	2.0	67.6	10	9.68
	12	0.20	185	7.18	9.0	2.0	69.6	10	9.69
	12	0.20	190	7.38	7.0	2.0	71.6	10	9.70
	12	0.20	195	7.58	5.2	1.8	73.4	9	9.68
	12	0.20	200	7.78	3.8	1.4	74.8	7	9.61
	12	0.20	205	7.98	2.5	1.3	76.1	6.5	9.53

Cont'd

RE	12	0.20			13.0			0	#DIV/0!
	12	0.20	210	8.18	11.0	2.0	78.1	10	9.54
	12	0.20	215	8.38	9.0	2.0	80.1	10	9.55
	12	0.20	220	8.58	7.0	1.7	81.8	8.5	9.53
	12	0.20	225	8.78	5.7	1.6	83.4	8	9.50
	12	0.20	230	8.98	4.3	1.4	84.8	7	9.44
	12	0.20	235	9.18	2.8	1.5	86.3	7.5	9.40
RE	12	0.20			13.0			0	#DIV/0!
	12	0.20	240	9.38	11.0	2.0	88.3	10	9.41
	12	0.20	245	9.58	9.5	1.5	89.8	7.5	9.37
	12	0.20	250	9.78	8.1	1.4	91.2	7	9.32
	12	0.20	255	9.98	6.0	2.1	93.3	10.5	9.35
	12	0.20	260	10.18	4.5	1.5	94.8	7.5	9.31
	12	0.20	265	10.38	3.2	1.3	96.1	6.5	9.26
RE	12	0.20			13.0			0	#DIV/0!
	12	0.20	270	10.58	11.0	2.0	98.1	10	9.27
	12	0.20	275	10.78	9.4	1.6	99.7	8	9.25
	12	0.20	280	10.98	7.5	1.9	101.6	9.5	9.25
	12	0.20	285	11.18	6.0	1.5	103.1	7.5	9.22
	12	0.20	290	11.38	4.5	1.5	104.6	7.5	9.19
	12	0.20	295	11.58	3.5	1.0	105.6	5	9.12
RE	12	0.20			13.0			0	#DIV/0!
	12	0.20	300	11.78	11.2	1.5	80.0	7.5	6.79
	12	0.20	305	11.98	9.5	1.4	79.0	7	6.59
	12	0.20	310	12.18	7.7	1.3	78.0	6.5	6.40
	12	0.20	315	12.38	6.0	1.2	77.0	6	6.22
	12	0.20	320	12.58	5.0	1.1	76.0	5.5	6.04
	12	0.20	325	12.78	3.4	1.0	75.0	5	5.87

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.

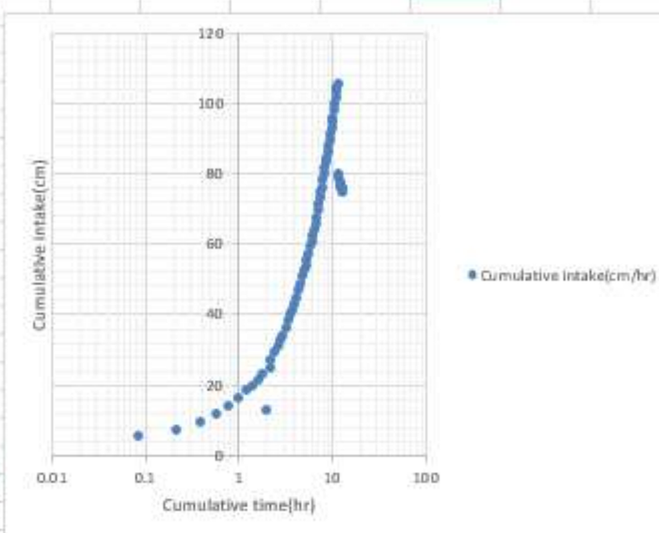
For the above example the reading are (12.78, 76) and (12.58,75), and the slope is calculated as,

Slope= Y2-Y1/X2-X1

= 76-75/12.78-12.58=5

Worked Example of Basic Infiltration rate using Logarithimic paper

Cumulative time(hr)	Cumulative intake(cm/hr)
0	3
0.06	5.5
0.22	7.5
0.38	9.5
0.58	12.0
0.78	14.4
0.98	16.5
1.18	18.4
1.38	20.0
1.58	21.5
1.78	23.0
1.98	12.8
2.18	25.0
2.18	27.1
2.38	29.5
2.58	31.2
2.78	32.7
2.98	34.0
3.18	36.4
3.38	38.3
3.58	40.2
3.78	41.7
3.98	43.1
4.18	44.3
4.38	46.3
4.58	48.3
4.78	50.9
10.58	99.7
10.78	101.6
10.98	103.1
11.18	104.6
11.38	105.6
11.58	80.0
11.78	79.0
11.98	78.0
12.18	77.0
12.38	76.0
12.58	75.0
12.78	75.0
12.78	76.0



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Date:21/01/19/Author: Wako/Sisay			GPS Reading/N:711272/E:596108/Elevation:1279			Land Form:LL/Slope Class:2-5		Micro Topography:AT	
Depth of insertion of ring(cm):10cm				Pre-wetting time (hrs):				Replication No.:3	
time(hr:mins)	Interval(mins)	÷ 60mins	time(mins)	time(hr).	infiltrometer(cm)	Intake(cm)	intake(cm/hr)	Infiltration rate(cm/hr)	
								immediate(ins	mean
1	2	3.00	4	5	6.0	7	8	9=7/3	10=8/5
03:00	0	0.00	0	0	13.0	0	0		
	5	0.08	5	0.08	10.4	1.5	2.6	18	31.20
	5	0.08	10	0.17	7.9	1.4	4.0	16.8	24.00
	5	0.08	15	0.25	5.9	1.3	5.3	15.6	21.20
	5	0.08	20	0.33	3.8	1.2	6.5	14.4	19.50
	5	0.08	25	0.41	2.5	1.1	7.6	13.2	18.54
	5	0.08	30	0.49	1.0	1.0	8.6	12	17.55
	11	0.18	41	0.67	10.9	1.5	10.1	8.182	15.00
	11	0.18	52	0.86	8.5	1.4	11.5	7.636	13.42
	11	0.18	63	1.04	6.5	1.3	12.8	7.091	12.31
	11	0.18	74	1.22	4.8	1.2	14.0	6.545	11.44
	11	0.18	85	1.41	3.3	1.1	15.1	6.000	10.73
	11	0.18	96	1.59	2.0	1.5	16.6	8.182	10.44
	11	0.18	60	1.77	2.0	0.9	12.8	4.909	7.22
	11	0.18	60	1.59	11.0	1.5	16.6	8.182	10.44
	11	0.18	65	1.77	9.3	1.4	18.0	7.636	10.15
	11	0.18	70	1.96	7.0	1.3	19.3	7.091	9.86
	11	0.18	75	2.14	5.4	1.2	20.5	6.545	9.58
	11	0.18	80	2.32	3.7	1.1	21.6	6.000	9.30
	11	0.18	85	2.51	2.2	1.0	22.6	5.455	9.02
	11	0.18	90	2.69	11.0	1.5	24.1	8.182	8.96
	11	0.18	95	2.87	9.2	1.4	25.5	7.636	8.87

……Cont'd

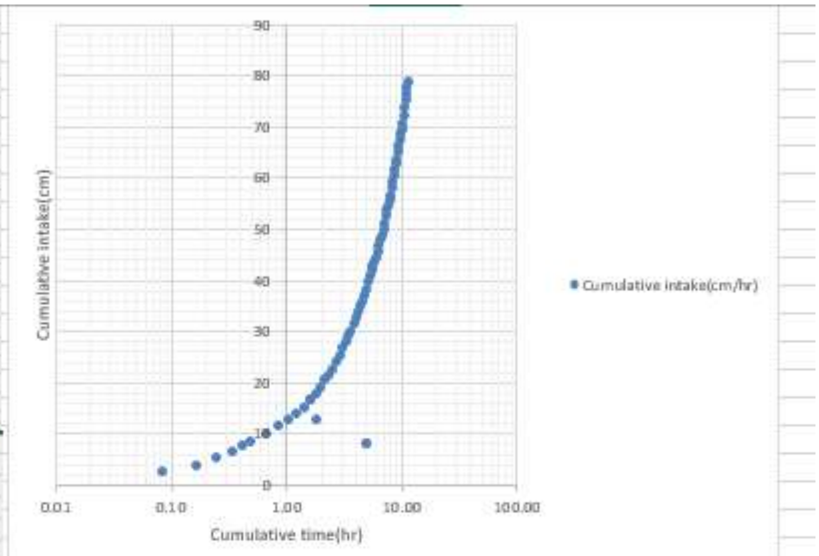
	11	0.18	100	3.06	7.5	1.3	26.8	7.091	8.77
	11	0.18	105	3.24	5.7	1.2	28.0	6.545	8.64
	11	0.18	110	3.42	4.1	1.1	29.1	6.000	8.50
	11	0.18	115	3.61	3.0	1	30.1	5.455	8.35
	11	0.18	120	3.79	11.0	1.4	31.5	7.636	8.31
	11	0.18	125	3.97	9.2	1.3	32.8	7.091	8.26
	11	0.18	130	4.16	7.3	1.2	34.0	6.545	8.18
	11	0.18	135	4.34	5.5	1.1	35.1	6.000	8.09
	11	0.18	140	4.52	4.0	1.0	36.1	5.455	7.98
	11	0.18	145	4.71	2.8	0.9	37.0	4.909	7.86
	11	0.18	150	4.89	11.0	1.4	38.4	7.636	7.85
	11	0.18	155	5.07	8.9	1.3	39.7	7.091	7.83
	11	0.18	160	5.26	7.1	1.2	40.9	6.545	7.78
	11	0.18	165	5.44	5.5	1.1	42.0	6.000	7.72
	11	0.18	170	5.62	3.7	1.0	43.0	5.455	7.65
	11	0.18	175	5.81	2.8	0.9	43.9	4.909	7.56
	11	0.18	175	5.99	11.5	1.4	44.4	7.636	7.41
	11	0.18	180	6.17	9.6	1.3	45.7	7.091	7.40
	11	0.18	185	6.36	7.8	1.2	46.9	6.545	7.38
	11	0.18	190	6.54	5.8	1.1	48.0	6.000	7.34
	11	0.18	195	6.72	4.5	1.0	49.0	5.455	7.29
	11	0.18	200	6.91	3.0	0.9	49.9	4.909	7.22
	11	0.18	205	7.09	11.0	1.4	51.3	7.636	7.24
	11	0.18	210	7.27	9.5	1.3	52.6	7.091	7.23
	11	0.18	215	7.46	7.1	1.2	53.8	6.545	7.22
	11	0.18	220	7.64	5.5	1.1	54.9	6.000	7.19
	11	0.18	225	7.82	4.0	1.0	55.9	5.455	7.15
	11	0.18	230	8.01	2.5	0.9	56.8	4.909	7.09

……Cont'd

	11	0.18	235	8.19	11.0	1.4	58.2	7.636	7.11
	11	0.18	240	8.37	9.0	1.3	59.5	7.091	7.11
	11	0.18	245	8.56	7.5	1.2	60.7	6.545	7.09
	11	0.18	250	8.74	5.5	1.1	61.8	6.000	7.07
	11	0.18	255	8.92	4.0	1.0	62.8	5.455	7.04
	11	0.18	265	9.11	3.2	0.9	63.7	4.909	6.99
	11	0.18	260	9.29	11.0	1.4	65.1	7.636	7.01
	11	0.18	265	9.47	9.4	1.3	66.4	7.091	7.01
	11	0.18	270	9.66	7.5	1.2	67.6	6.545	7.00
	11	0.18	275	9.84	5.5	1.1	68.7	6.000	6.98
	11	0.18	280	10.02	4.0	1.0	69.7	5.455	6.95
	11	0.18	285	10.21	2.5	0.9	70.6	4.909	6.92
	11	0.18	290	10.39	11.0	1.7	72.3	9.055	6.95
	11	0.18	295	10.57	9.5	1.6	73.8	8.455	6.98
	11	0.18	300	10.76	7.5	1.4	75.3	7.855	7.00
	11	0.18	305	10.94	5.9	1.3	76.6	7.255	7.00
	11	0.18	310	11.12	4.5	1.2	77.8	6.655	6.99
	11	0.18	315	11.31	3.0	1.1	78.9	6.055	6.98

Worked Example of Basic Infiltration rate using Logarithimic paper

Cumulative time(hr)	Cumulative intake(cm/hr)
5.00	8
0.00	0
0.08	2.6
0.17	4
0.25	5.3
0.33	6.5
0.41	7.6
0.49	8.6
0.67	10.1
0.86	11.5
1.04	12.8
1.22	14
1.41	15.1
1.59	16.6
1.77	12.8
1.59	16.6
1.77	18
1.96	19.3
2.14	20.5
2.32	21.6
2.51	22.6
2.69	24.1
8.74	61.8
8.92	62.8
9.11	63.7
9.29	65.1
9.47	66.4
9.66	67.6
9.84	68.7
10.02	69.7
10.21	70.6
10.39	72.26
10.57	73.81
10.76	75.25
10.94	76.58
11.12	77.8
11.31	78.91



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 (11.31,78.91) and (11.12, 77.8), and the slope is calculated as,

Slope= Y2-Y1/X2-X1

= 78.91-77.8/11.31-11.13=6.01

Hydraulic conductivity (permiability)

Saturated hydraulic conductivity measurement form								Project: HGSP				Site: HG				
/Author:Wako/Sisay			GPS Reading/N:711272/E: 596108/Elevation: 1279					Land form : LL/Slope: 2-5/Soil Type: LV				Micro topography:-AT,IMAB/Radius(cm): 4				
Depth of insertion of auger (cm)													Depth of insertion of auger (cm)			
Replication No. 1/Depth(cm) :30							Replication No. 2/Depth(cm):60						Replication No. 1/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)	ti, sec	h'(t1),cm	h(ti),cm	h(t1+r/2),cm	Hydraulic Conductivity (m/day)
0	0					0	0					0	0			
2	2	28		30	**2.285**	2	2		58	60	**2.71**	2	2	88	90	**1.405**
6	3	27		29		4	3		57	59		4	4	86	88	
12	4	26		28		6	4		56	58		6	6	84	86	
20	5	25		27		8	6		54	56		8	8	82	84	
30	6	24		26		10	7		53	55		12	14	76	78	
50	7	23		25		20	10		50	52		17	19	71	73	
70	8	22		24		40	14		46	48		20	22	68	70	
190	9	21		23		100	24		36	38		32	23	67	69	
200	10	20		23		220	37		30	32		42	22	66	68	
						340	42		30	32		82	21	65	67	
						400	42		30	32		382	21	64	66	
	HC_Rep1=2.285+2.71+1.0405=2.13															

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Saturated hydraulic conductivity measurement form/Elevation: 1279								Project: HGSP				Site: HG				
Date: 06/01/19/Author:Wako/Sisay			GPS Reading/N:711272/E: 596108/Radius(cm): 4					Land form : LL/Soil Type: LV/Slope: 2-5				Micro topography:-AT,IMAB				
			Replication No. fall					Replication No. 1					Depth of insertion of auger (cm)			
Depth of insertion of auger (cm)													Replication No. 2			
Depth(cm) :30							Depth(cm):60						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)	ti, sec	h'(t1),cm	h(ti),cm	h(t1+r/2),cm	Hydraulic Conductivity (m/day)
0	0					0	0					0	0			
2	2	28		30	**Fall**	2	2	58	58	60	**2.05**	2	5	85	87	**2.22**
4	3	27		29		4	3	57	57	59		4	10	80	82	
8	6	24		26		6	6	54	54	56		6	12	78	80	
12	9	21		23		8	11	49	49	51		8	16	74	76	
20	12	18		20		10	13	47	47	49		12	24	66	68	
80	18	12		14		12	15	45	45	47		22	28	62	64	
140	23	7		9		22	16	44	44	46		32	32	58	60	
						82	23	37	43	45		62	35	55	57	
						142	30	30	42	44		400	40	50	52	
						300	41	19	40	42						
	HC_Rep2=2.05+2.22=2.14															

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Saturated hydraulic conductivity measurement form									Project: HGSP			Site: HG				
Date: 06/01/19			GPS Reading/N:711272/E: 596108/Elevation: 1279						Land form : LL/Soil Type: LV			Micro topography:-AT,TMAB				
Author: Wako/Sisay/			Radius(cm): 4						Slope: 2-5							
Replication No. 1							Replication No. 2						Replication No. 3			
Depth(cm) :30							Depth(cm):60						Depth(cm) : 90			
ti, sec	h'(ti),cm	h(ti),cm		h(ti−r/2),cm	Hydraulic Conductivity (m/day)	ti,sec	h'(ti),cm		h(ti),cm	h(ti−r/2),cm	Hydraulic Conductivity (m/day)	ti, sec	h'(ti),cm	h(ti),cm	h(ti−r/2),cm	Hydraulic Conductivity (m/day)
0	0					0	0					0	0			
2	3	27		29	Fall	4	2		58	60	2.52	2	3	87	89	1.3
4	4	26		28		10	4		56	58		4	4	86	88	
6	5	25		27		26	6		54	56		8	7	83	85	
10	7	23		25		62	23		40	42		14	10	80	82	
20	10	20		22		122	33		39	41		20	16	74	76	
40	14	16		18		278	43		38	40		30	18	72	74	
100	24	6		8								90	20	70	72	
												333	22	68	70	
					HC_Rep3=2.52+1.30=1.91											