# National Regional State of Oromia

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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

The soil survey of the Hidha-sombo small scale irrigation Project (HSSSIP) 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 31 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 266.82 ha and of which crop cultivation practiced widely. The proposed crops that can be cultivated by using irrigation are four Hidha-sombo small scale irrigation Project (HSSSIP) 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 (33augers and 3 Profile pits) were describes for the study area. The detail level soil survey study enabled the identification of 31, 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 four LUTs for surface irrigation methods were therefore identified. These LUTs include Potato, onion, tomato and cabbage 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 Hidha-Sombo 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.

Hidha-Sombo Irrigation based dvelopment Project is located in east harerge Zone, Jarso district, bedesa kebele of the Oromia Regional State. The study area has surrounded by high mountanious relief hills and have a slope ranging from 0-2 up to 30-45% currentely cultivated land with wheat, chat, potato, sorghum, and teff. The present study area covers about 266.82ha 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, Hidha-Sombo small scale irrigation project, is located in the Oromia Regional State, east harerge Zone, Jarso district, Bedesa kebele, south from the main road Ejersa goro to ale, dawe. The study area is close to the east of Gefera and Bosensa river. Irrigation to be used from Spring. More precisely it falls in between 1044980 to 1046689 UTM $^{N}$ and 203480 to 206296 UTM $^{E.}$ The targeted area of the project is 266.82ha. The altitude of the the study area ranges from 2229-2436 masl. There is accesses road (dry weather road) in the study area.

## 2.2. Climate

The Project area Is caractérise by Low land Semi Arid (LGP 103 days). There is two rainy season in the study area. The first rainy season is from early April to june and the second one (when the highest rain fall is received) is from September to November. There is two cropping calendar for major crops in the area. These are mid March and mid June.

Arbaminch station is used as an alternative station located in the same climatic condition to the project area. The mean annual rainfall is 946 mm and its mean minimum annual temprature is 12.4 $^{0}$C while the mean maximum annual Temprature is 29.3$^{o}$C. The annual mean annual temperature of thestudy area is 15.53 $^{o}$C.

## 2.3. Physiograpy and Geology

Residual land form with slope of 0-2 % rise up to 30-45%, developed on Mesozoic Volcanos, moderate to high relief hills and severly dissected sideslope and plateaux, hamale series, lower-upper Jurassic, limestone, oolitic limestone and lower bed of the uarandab seriesand form on gneisses, granite, shallow colluvium over gnesiss, and granite. limestone and marl

## 2.4. Vegetation and Land Use

The vegetation cover is dominantly open wood land, Intensevely to peredominantely cultivation land on Cambisols and Luvisols, with traditional irrigation practice. Chat, wheat, and sweet

potato are cultivated in the command area, the vegetation cover is dominantly with eucaluptus tree

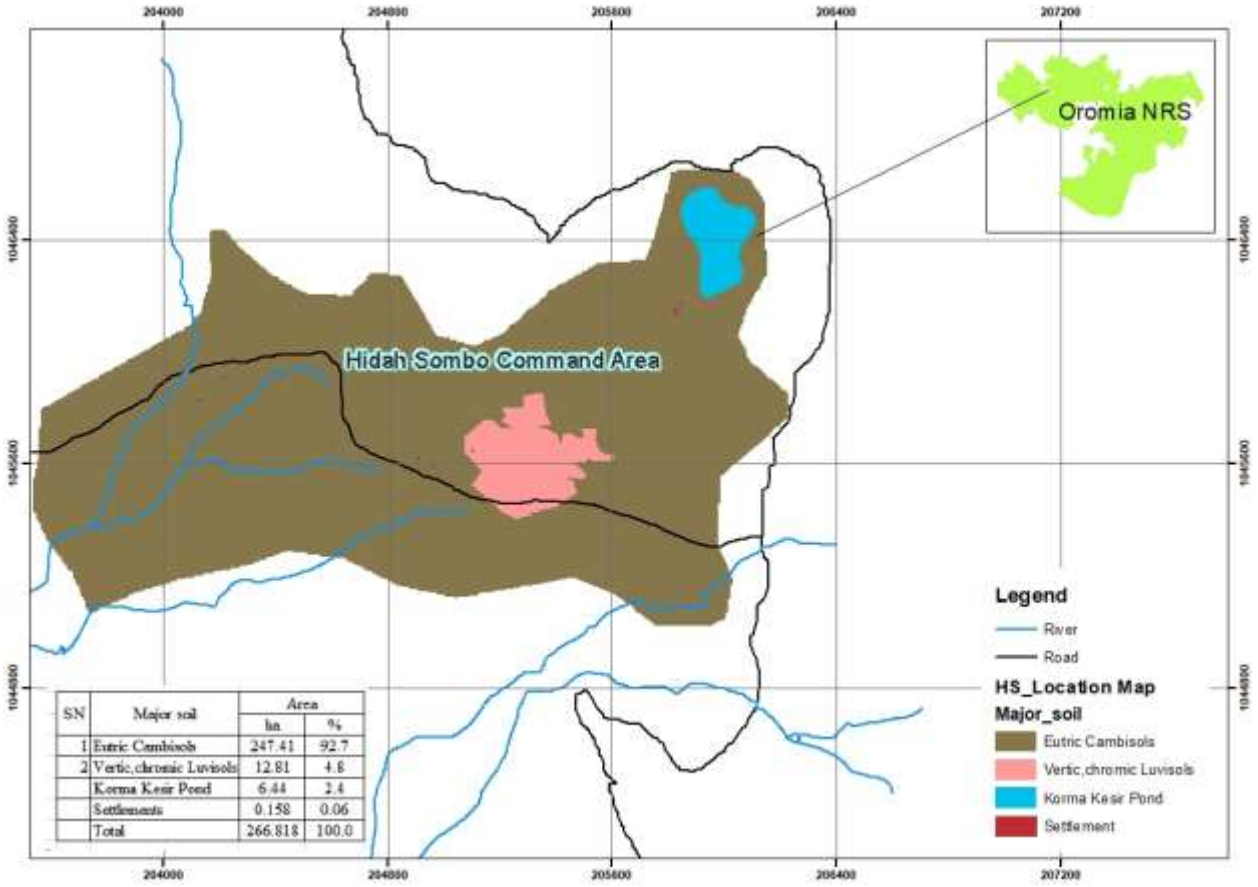



Figure 1: Location Map of Hidha sombo small scale irrigation project

# 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.

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

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

The major soil groups in the study area fall into 15 major soil groupings in the FAO – UNESCO – ISRIC (1988) system : *vis*, Andosols, Arenosols, Cambisols, Calcisols, Chernozems, Fluvisols, Gleysols, Gypsisols, Leptosols, Luvisols, Nitisols, Phaeozems, Regosols, and Solonchaks, Vertisols. And, 30 soil units in detail in the SOTER maps of the basin at the scale of 1 :250,000.

Likewise, a total of 61 soil-mapping units were distinguished for the basin. Location and distribution of soil survey observation points, major soil types and soil mapping units of the Wabi Shebele River basin were presented. In this report indicated that a total of 4028 soil observations were made (PS-130, PW-71, AS-12, AW-3752, CS-8 and O-55). The necessary data collected by this study has been carefully reviewed and considered for the included areas of the sub basin study. According to this study Luvisols and Leptosols fall in this new small-scale irrigation project (Hidha sombo)

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

**Soil survey**

Erer-Mojo-Gobale sub-basin in this project is limited to the part of the Erer and Mojo Rivers drainage system within East Harerge zone of Oromia region. The extent of the sub basin ranges from 41° 34' 59.19" E to 42° 30' 55.51" East longitude from 7° 34' 02.69" N to 7° 34' 59.19" North latitude.

The purpose of soil survey of Erer-Mojo-Gobale sub basin conducted at pre-feasibility level is to generate database of soil resources for integrated land use planning and Natural Resources management. The study objectives specifically focus on identifying the qualities and characteristics of soils and related land resources, their potentials and constraints for different uses of the various topographic forms, present land use patterns etc and avail the data sources and proposed soil based sustainable use options.

During soil resource investigation total observation of 431 at different representative sites was conducted. Out of these 77 soil profile pits was dug and carefully studied, for detail observation of soil landscape units 354 auger whole without sampling was conducted (observed).

The soil survey of Erer-Mojo-Gobale sub basin at a semi detailed scale of 1:50,000 were carried out by free survey method. Soil description and classification was made according to world reference base for soil resources considering soil characteristics observed in the field and chemical analytical results from OWWDSE soil testing laboratory. investigated 14 (fourteen) soil mapping units, 5 (four) major soils, and four associated soils. The major soils are Vertisol,

Luvisol, Cambisol, Fluvisol and Leptosol. According to this study Luvisols and cambisols fall in this new small-scale irrigation project (Hidha sombo)

**Land evaluation**

The objectives of the evaluation were :

- Identification of the sub basin's resource potentials and constraints for rain-fed agriculture, and irrigated agriculture
- Classification of land into suitability classes and subclasses according to limitations
- Suggesting alternative suitable uses and management interventions for the design of appropriate LUP

**Land evaluation Rainfed**

In defining the land utilization types for rainfed agriculture the following determinant factors have been considered : Government's need (policy), technology, production, labor, capital, management, market, size of the farms, technical skills and other socio-economic conditions

Based on the above considerations the following specific land utilization types under rainfed agriculture have been defined for the Erer Mojo Sub Basin. These are ; Small holder rainfed cultivation of Lowland Maize, Highland Maize, Lowland Sorghum, Highland Sorghum, groundnut, haricot bean, bread wheat, Food Barley, potato, chili, banana and coffee.

**Land evaluation Irrigation**

The general objective of this part of the study is to assess and delineate potentially suitable from non-suitable land units for the intended land use (i.e. irrigation) indicating constraints for use of the land. Therefore, in the present study surface and sprinkle irrigation potentials were assessed and provisionally potential irrigable areas were indicated.

Percentage of land suitability class is estimated as 6.37 per cent moderately suitable, 10.75 per cent marginally suitable, 18.95 per cent currently not suitable and 63.92 per cent permanently not suitable under low input agriculture. However, under high input technology, if we correct the fertility limitation, we can increase the potential area for surface irrigation. Accordingly, after improvement the moderately suitable area would be estimated as 11.14 per cent and the

marginally suitable area estimated to be 24.94 per cent, while the remaining 63.92 per cent area is unsuitable.

There is considerable potential for sprinkler irrigation in the sub basin and the percentage of suitable land is estimated to be 77.91 per cent, out of this 0.24 per cent is highly suitable, 71.56 per cent is moderately suitable, while the rest 6.11 per cent is marginally suitable. 22.08 per cent of the area is permanently not suitable. The suitability is mainly limited by shallow soil depth, steep slope and poor texture.

# 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 | 33 |
| 2 | Soil profile description | 3 |
| 3 | Soil samples | 7 |
| 4 | Infiltration and hydraulic conductivity | 1 |
| 5 | Soil profile not sampled | 3 |
| 6 | Undisturbed core samples | 3 |

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

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

General pattern of drainage, Land use (i.e., the kind of crop grown and other plant species). Moreover, some internal characteristics such as soil depth, texture, nodules (such as iron, manganese, etc) mottling, etc, were further evaluated. During profile pit analysis more information was recorded (i.e. from each horizon structural development and form, consistence, porosity, roots cutans, slickenside, etc. From the analysis, it is noted that, textural class determination by hand fill method in the field is slightly underestimated than the clay content result in the laboratory. Under such condition where there are differences, values of the laboratory results have been considered.

## 4.4. Post Fieldwork

After completion of the fieldwork, field data compilation and encoding, field and laboratory data interpretation and report writing was conducted. Legend was developed for the mapping units. Soil mapping units have been established based on slope, soil texture and soil depth and soil unit. A total of 31 SMU were identified on the basis of the above three criteria.

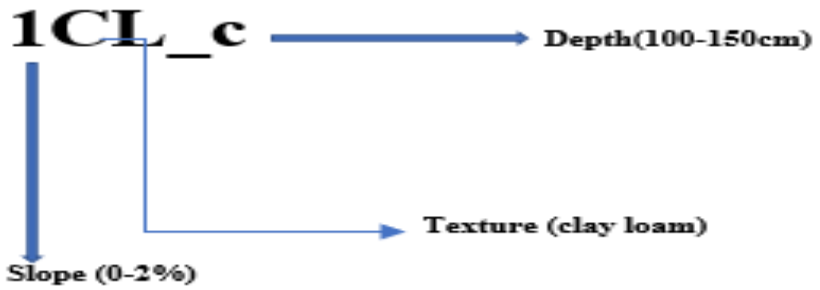
Table 2: Soil properties used for the definition of SMU

| Slope | | Texture | | Depth | | Soil units |
|---|---|---|---|---|---|---|
| Percent | Map symbol | class | Map symbol | cm | Map symbol | |
| 0-2 | 1 | Clay loam | CL | 150-200 | b | Eutric cambisols |
| 2-5 | 2 | Sandy clay loam | SCL | 100-150 | c | Vertic,chromic Luvisols |
| 5-8 | 3 | | | 50-100 | d | |
| 8-15 | 4 | | | 25-50 | e | |
| 15-30 | 5 | | | | | |
| 30-45 | 6 | | | | | |

Accordingly based on slope, top soil texture, soil depth and soil units of the study area 31 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 Hidha-Sombo 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 Hidha-Sombo small scale Irrigation project has been presented on 1:10,000 scale maps.

## I- Cambisols

Cambisols mainly distributed in all part of the study area. dark brown (7.5YR 3/2 Dry); and very dark brown (7.5YR 2.5/2 moist) colored, Clay loam, clay and,loam textured, Shallow to very deep soil (25-50, 50-100,100-150,150-200 to >200 cm), The soil is well drained and developed on flat plain (0-2 per cent) to steep slope (>15-30 per cent) .The cambisols are with an area coverage of 247.41 ha which constitutes 92.73**%** of the total area. This soil has weak evidence of stratification in soil profile, which is indicated by soil color and texture change.

They are moderately developed soils characterized by slight or moderate weathering of parent material and by the absence of appreciable quantities of accumulated clay, organic matter having

moderately developed Cambic B horizon overlying subsoil which has a base saturation (by 1M NH4OAc) of >50 per cent for Cambisols. Cambisols are soils those lacks hydromorphic and permafrost within 100 cm and 200 cm of the surface respectively. In the study area identified **Eutric 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); Representative profile JP-1 and JP-2, 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 12.81 ha which constitutes 4.8% of the total area.

The Luvisols of the study area are classified as Veertic, chromic Luvisols, with representative profile JP-3.

The surface textures of the Luvisols are clay loam (the dominant) and sandy clay loam and the effective depth range is from 25 to 200cm.

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

| Soil physical and chemical characteristice | Units | | Luvisols | | Cambisols | |
|---|---|---|---|---|---|---|
| | | | Value | Remark | Value | Remark |
| PH | water | Top | 6.2 | slightly acid | 6.6 | Neutral |
| | | Sub | 6.48 | slightly acid | 6.9 | Neutral |
| EC | ds/m | Top | 0.101 | salt free | 0.1 | salt free |
| | | Sub | 0.1175 | salt free | 0.1 | salt free |
| Na | meq/100g soil | Top | 0.21 | low | 0.2 | low |
| | | Sub | 0.305 | low | 0.2 | low |
| Ca | meq/100g soil | Top | 28.81 | very high | 18.4 | high |
| | | Sub | 29.66 | very high | 18.9 | high |
| Mg | meq/100g soil | Top | 8.13 | very high | 4.7 | high |
| | | Sub | 8.87 | very high | 6.7 | high |
| K | meq/100g soil | Top | 0.37 | medium | 0.6 | medium |
| | | Sub | 0.245 | low | 1.3 | very high |
| CEC | meq/100g soil | Top | 43.7 | very high | 30.7 | high |
| | | Sub | 46.25 | very high | 33 | high |
| BS | % | Top | 86 | high | 80.6 | high |
| | | Sub | 84.5 | high | 81.8 | high |
| ESP | % | Top | 0.47 | low | 0.6 | low |
| | | Sub | 0.66 | low | 0.55 | low |
| TN | % | Top | 0.08 | low | 0.1 | low |
| | | Sub | 0.06 | low | 0.1 | low |
| OM | % | Top | 1.69 | medium | 2.2 | medium |
| | | Sub | 1.15 | medium | 0.8 | low |
| AVP | ppm | Top | 35.72 | high | 20.3 | high |
| | | Sub | 6.12 | medium | 8.3 | medium |
| Texture | class | Top | CL | | CL to SCL | |
| | | Sub | CL | | C | |
| Depth | cm | Top | 30 | | 30 | |
| | | Sub | 160 | | 120 | |

# 6. DESCRIPTION OF SOIL PHYSICAL AND CHEMICAL PROPERTIES

## 6.1. Soil Physical Properties

The soil physical characteristics of Hidha-Sombo 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 Hidha-Sombo Small scale irrigation project are shallow to very deep (25-50cm to150-200 cm respectively), so have no limitation for normal rooting for most cultivated crops, grazing herbages, bushes and shrubs.

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

| Depth (cm) | Area (ha) | % |
|---|---|---|
| 150-200 | 7.624 | 2.9 |
| 100-150 | 20.34 | 7.6 |
| 50-100 | 226.5 | 84.9 |
| 25-50 | 5.76 | 2.2 |
| Korma Kesir Pond | 6.44 | 2.4 |
| Settlements | 0.158 | 0.1 |
| Total | 266.822 | 100.0 |

### 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 (Eutric) is dominantly moderate, fine to medium to sub angular blocky type. and Luvisols(Vertic,chromic) have dominantly moderate,fine to coarse sub angular blocky structure in their surface soils and moderate,fine to medium sub angular block structure in their sub soils.

### 6.1.4. Consistence

The consistence of soils varies with their textural composition Eutric Cambisols have sligtely hard(dry), friable(moist), slightely stick and slightely plastic and for vertic, chromic Luvisols of the study area have sligtely hard consistence when dry, friable to firm when moist and sticky and plastic consistence when wet.

### 6.1.5. Texture

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

### 6.1.6. Soil Color

Soil color was measured under dry and moist condition by determining the hue, value and chroma of the soil using Munsell color chart. The soil color of the survey area is mainly related to drainage and the parent material. Accordingly, well drained soils Eutric cambisols of the project area have dark brown (7.5YR3/4) when dry and very dark brown (7.5YR3/3) when moist while for well drained vertiv, chromic Luvisols very dark brown (10YR2/2) when when moist in color.

### 6.1.7. Soil Drainage

Soil drainage relates the frequency and duration of periods when the soil is free of saturation or partially saturated. The soil drainage classes reflect the effect of climate, landscape and soil. Rainfall, seepage, internal vertical and lateral water movement and external surface run-off and run-on affect soil drainage. Based on this, soil drainage is classified as well drained, moderately well drained, imperfectly drained, poorly drained and very poorly drained

Soils of the Hidha-Sombo SSIP study area have well drained in cambisols and 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 **8.8 cm/hr**, which is **marginally suitable** this implies the ranking result is suitable for surface irrigation and the mean average infiltration rate of **12.45 cm/hr,**is **marginally suitable(too rapid)** this implies the ranking result is marginaly suitable for surface irrigation ,as a result soils of the project area have a m**arginally suitable** infiltration rate.which implies small basins needed

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

| Soil unit | Texture | surface Textute | Immediate(instantani | | SUM | Range of IR | Immediate(instantanious) Average_IR | Ranking for surface irrigation development |
|---|---|---|---|---|---|---|---|---|
| | | | IR_Rep1 | Rep2 | | | | |
| | class | | cm/ha | cm/ha | | cm/ha | cm/ha | |
| Vertic,chromic Luvisols | Medium | CL | 9.2 | 8.4 | 17.6 | 8.4-9.2 | **8.8** | **Marginally suitable(too rapid),small basin is needed** |

| Soil unit | Texture | surface Textute Class | an infiltration Rate cn | | SUM | Range of IR | Mean Average_IR | Ranking for surface irrigation development |
|---|---|---|---|---|---|---|---|---|
| | | | Rep1 | Rep2 | | | | |
| | class | | cm/ha | cm/ha | | cm/ha | cm/ha | |
| Vertic,chromic Luvisols | Medium | CL | 13.5 | 11.4 | 24.9 | 11.4-13.5 | **12.45** | **Marginally suitable(too rapid),small basin is needed** |

## 6.1.9. Hydraulic Conductivity

The hydraulic conductivity or permeability of a soil defines the volume of water which will pass through unit cross sectional area of a soil in unit time given a unit difference in water potential. The measurement of hydraulic conductivity is done for comparison of hydraulic conductivity rates of different soil horizons, particularly as a guide to water movement and possible drainage problems within soil profiles (Landon, 1991). The tests were carried out by inverse auger-hole method, near/at the representative soil profile. The results indicate that average hydraulic conductivity of **1.495 m/day** for soils of the study area. The result indicates that, the water movement is **moderately rapid**. this is because plant root penetration and some gravels found down to the soil profile. Hydraulic conductivity is affected by texture and structure of the soils.

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

| Study Area | Major soil | Textute | Texture | Hydraulic conductivity (Rep 1) | Hydraulic conductivity (Rep 2) | Hydraulic conductivity (Rep 1 and Rep2) Range | Average Hydraulic conductivity | Hydraulic conductivity value |
|---|---|---|---|---|---|---|---|---|
| | | Type | class | m/day | m/day | m/day | m/day | Rating |
| Hidi Sombo | Vertic,chromic Luvisols | CL | Medium | 1.22 | 1.77 | 1.22-1.77 | **1.495** | Moderately 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 **1.49 g/cm$^3$** and sub soil **1.33 g/cm$^3$**. The result shows **moderate scale,** that the bulk density of soils of the study area is in normal range and it is not causing hindrance to root penetration as such except clay soil.

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

| S/N | Soil units | Rep.Profile | Soil depth | Texture | Bulck density(gm/cm3) | Bulck density(gm/cm3) | Rating | Effect on soil condition |
|---|---|---|---|---|---|---|---|---|
| 1 | Vertic,chromic Luvisols | JP_3 | 0-30 | Clay loam | 1.49 | 1.49 | *Moderate | |
| | | | 30-80 | Clay | 1.22 | 1.33 | *Moderate | *Some too Compact |
| | | | 80-160 | Clay | 1.43 | | | *Very compact |
| | *Source :Harle(pers.comm)/Handerch&Black(1984)/Hunt&Gilkes(1992) | | | | | | | |

## 6.1.11. Field capacity (FC)

Field capacity of a soil is the maximum water content the soil will hold following free draining by gravity force. Field capacity (FC) is the term used to describe the maximum water content that the soil will hold following free drainage. It does not therefore correspond to a fixed soil-water potential, but instead represents the condition of each individual soil after the larger pores have drained freely under gravity (Landon, 1991). The field capacity of the soils of the study area falls in the range of **34.60 %** in the top soil and **38.40%** in the sub soils. The following table shows the field capacity results of the study area versus texture.

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

| S/N | Soil units | Rep.Profile | Soil depth | Texture | FC(0.33bar) | Horizon | FC(0.33bar) |
|---|---|---|---|---|---|---|---|
| 1 | **Vertic,chromic Luvisols** | JP_3 | 0-30 | Clay loam | 34.60 | Top | **34.60** |
| | | | 30-55 | Clay | 44.10 | Sub | **38.40** |
| | | | 55-120 | Clay | 32.70 | | |

## 6.1.12. Permanent wilting point (PWP)

Permanent wilting point is the soil moisture content at which plants can no longer obtain enough moisture to meet evapotranspiration requirements and remain wilted unless water is added to the soil. Permanent wilting pointis the moisture content level at which the plants are water stressed and irreversibly wilt. If water is continually taken-up by plants and no additional water is added to the soil in the form of precipitation or irrigation water, the medium and small soil pores will be emptied of water. With time, the plant will eventually wilt when it cannot extract more water. The soil is said to be at the permanent wilting point when plants can no longer exert enough force to extract the remaining soil water. At the permanent wilting point, water is held in the soil at about 1.5 MPa (15 bars). The permanent wilting points of the soils of the study area fall in the range of **23.70%** in the top soil and **24.50%** in the sub soil.

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

| S/N | Soil units | Rep.Profile | Soil depth | Texture | PWP(15bar) | Horizon | PWP(15bar) |
|---|---|---|---|---|---|---|---|
| 1 | **Vertic,chromic Luvisols** | JP_3 | 0-30 | Clay loam | 23.70 | Top | **23.70** |
| | | | 30-55 | Clay | 27.10 | sub | **24.50** |
| | | | 55-120 | Clay | 21.90 | | |

## 6.1.13. Available water capacity (AWC)

Available water capacity is the volume of water retained between field capacity and permanent wilting point. However, not all available moisture is accessible to plants due to imperfect drainage, hydraulic conductivity of the soil, impenetrable depths, and root concentration at

different depths and stage of plant growth. About 50-70% of available moisture is considered readily available water (RAW). Readily available moisture is considered 60% of total available water as a rule. In general principle results of **AWC <120mm/m, 120-180 mm/m and >180 mm/m has low, medium and high rate for irrigation suitability respectively.**

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

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

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

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

Table 10: shows the average available water capacity (AWC) and readily available water capacity (RAWC) value for the Representative profile of the soils of the study area.

| major soil | Field_Code | Horizon | Depth | D_Thickness | Depth | Texture | | FC | PWP | FC_PWP | BD | AWC | AWC | TAWC | TRAWC | AWC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | cm | cm | cm | mm | class | | 0.33bar | 15bar | | gm/cm3 | cm | mm | mm/m | mm/m | |
| Vertic,chromic Luvisols | JP_3 | Top | 0-30 | 30 | 300 | CL | Medium | 34.60 | 23.70 | 10.90 | 1.49 | 4.87 | 48.72 | **141.83** | 94.55 | medium |
| | | sub | 30-60 | 30 | 300 | C | Medium | 44.10 | 27.10 | 17.00 | 1.22 | 6.22 | 62.22 | | | |
| | | sub | 60-90 | 30 | 300 | C | Medium | 32.70 | 21.90 | 10.80 | 1.43 | 4.63 | 46.33 | | | |

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

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

| Dominant_Soil Units | Field_Code | Texture class | Horizon | Bulk density g/cm3 | Total porosity % | FC (0.33bar) | Air-filled porosity % | Effect on soil codittion |
|---|---|---|---|---|---|---|---|---|
| Vertic,chromic Luvisols | JP_3 | Clay loam | Top soil | 1.49 | 43.77 | 34.60 | 9.17 | |
| | | Clay | 0.3-0.6m | 1.22 | 53.96 | 44.10 | 9.86 | Some too compact |
| | | Clay | 0.6-0.9m | 1.43 | 46.04 | 32.70 | 13.34 | Very compact |

## 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 sheetand splash observed both on site and in the surrounding for slope up to 5% (vertic, chromic Luvisols), where as for Eutric Cambisols, with

slope ≥8% slight splash, sheet, rill and some guly observed, in addition in some elevated (15-30%) area of the site and the surrounding observed sheet, rill and guly erosion

### 6.1.18. Flooding

For the majority of the soil mapping units, the flooding status of the command area is generally none, there is no evidence of flooding hazared, except for soils of some elevated part (15-30%) of the surrounding are affected by slight flooding during the rainy seasons for less than 15 days

## 6.2. Soils Chemical Properties

### 6.2.1. Soil Reaction (pH)

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

The overall pH value of the project area in soil-water suspension varies from **6.18 to 7.0** with an average of **6.63**. Which increase from top to sub soil. This range of soil pH is normally termed as slightly acid to Neutral soil, but the average value is slightly 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 **0.06-0.15 dS**/m with anaverage of **0.11** dS/m. A soil saturation extract was prepared, allowed to equilibrate and then the saline soil water

removed by suction and analyzed for EC. The range of **ECe** measured for the soil of the study area was salt free to moderately saline i.e varying from **0.47 -1.19 dS**/m with anaverage of **0.90 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 **0.31% to 1.43%** with average of **0.90 %** which it is rated as very 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 **0.53% to 2.46 %** the average organic matter content of the soils of the study area is **1.55%** and is rated as low to medium level. Generally, in all soils, organic carbon content decreases from top to sub soil indicating relatively better accumulation of decomposable organic materials in the surface horizons than in the subsurface.

### 6.2.4. Total Nitrogen

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

Results show that generally total nitrogen ranges from **0.04 to 0.14** percent with an average of 0.08% which indicate that the total nitrogen content is very low to low 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 7.75 to 13.90. The average value is 10.51

### 6.2.6. Available Phosphorus

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

The available phosphorus content of the soils of the project area varies from 4 ppm to 36.7 ppm with average of 17.2ppm where the value is low to high in top soil, with average range of high value. Generally the available phosphorus of the soils of the soil mapping units is rated as in adequate for crops.

### 6.2.7. Cation Exchange Capacity (CEC)

The Cation Exchange Capacity (CEC) measured as meq/100g soil is important indication or criteria in soil classification and can be used as an overall assessment of the potential fertility of the soils and possible response to fertilizer. CEC is often used as characteristics in determination of nutrient retention for land quality assessment in land evaluation. The higher the CEC, the greater will be the ability to retain cations. It should be noted that CEC values critically depend on pH. The overall values of CEC lie in the range of 22.92 meq/100g soil to 47.06 meq/100g. CEC values between this ranges are rated as high to very high, which in turn mean good agricultural soil in terms of plant nutrition.

## 6.2.8. Base Saturation Percentage (BSP)

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

The calculated BSP of the project area was found between 69.57% to 91.87% indicating very high value. In other words, such higher levels of BSP mean that the exchangeable complex is saturated with exchangeable cations.

## 6.2.9. Exchangeable Calcium (Ca)

Normally calcium deficiency in a plant nutrient occurs only in soils of low CEC at PH of 5.5 or less, Calcium also effectively deficient at high PH level when there is excessive sodium content. Large input of potassium fertilizer or high natural potassium may however inhibit plant uptake of calcium in the soil having more neutral reaction. If other factors are conducive a level of 6 meq/100g soil of exchangeable calcium is generally sufficient to ensure crop production (FAO, 1979). The value of exchangeable calcium in the study area is 15.40 cmol (+)/kg soil to 30.13 cmol (+)/kg soil with average value of 21.96 cmol (+)/kg soil, which indicate that high to very high level

## 6.2.10. Exchangeable Magnesium (Mg)

Exchangeable magnesium which is greater than 3cmol (+)/kg soil is believed to be adequate for plant nutrition. The amount of exchangeable magnesium reported for the soils of the study area varies from 3.44 to 9.54cmol (+)/kg soil with average value of 6.46 cmol (+)/kg soil. The result shows that the level of Mg is high to very high

## 6.2.11. Exchangeable Potassium (K)

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

considered deficient, from 0.1 to 0.2cmol (+)/kg intermediate and greater than 0.2cmol (+)/kg adequate.

Soils of the study area have exchangeable K value ranging from 0.19 to 2.05 cmol (+)/kg soil. Which indicates that the level of K is low to very high. The average value is 0.76 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 0.12 to 0.33 cmol(+)/kg of soil, which is low to medium level,with mean value of 0.21 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 0.40 % to 0.70% with avegage value of 0.60% it is below the allowable limit and there is no sodicity problem in the study area and no need of amendments.

## 6.2.14. Calcium carbonete

The calcium carbonate equivalent of >15 per cent is used in the FAO definition of Calcic horizon. High level of calcium carbonate >15 per cent affect the physical and chemical characteristics of a soil besides normal root penetration. The term Calcaric which refers to soils which are calcareous (show strong effervescence with 10 per cent HCL), in most of the fine earth or which contain more than 2 per cent calcium carbonate equivalent. The calcium carbonate

content of most of the soils in the study area **(Hidha-Sombo 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 0.03 and 0.47(Average value is 0.17: 1, indicating an optimum situation for production of most field crops, vegetables and fruits.

## 6.2.16. Calcium to Magnesium Ratio (Ca : Mg)

The ratio of calcium to magnesium (Ca : Mg) in most soils of the project area is moderately low to moderately high 2.47 to 4.76. Which indicate that the level is less favorable(low) to moderately high favorable.

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

If the ratio of K: CEC is less than two per cent, it suggests a minimum level to avoid K deficiency and soils with more than 25% ratio is considered to be potassium rich soil. The minimum K: CEC ratio of the soil units in project area was 0.01 and maximum was 0.07 Hence, most of the soils in the project area have the ratio less than minimum level which indicates K deficiency.

## 6.2.18. Available Potassium (Avk)

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

1. Dry soil will mean K cannot be accessed, due to limited diffusion

2. In high yielding situations K diffusion can be slow and may not meet crop demands

3. Rooting patterns differ among crops, with fibrous rooted plants tend to exploit more K than that of tap rooted plants

4. Different species have different K demands

5. Other Cations can affect K demand through competition, substitution or physical disruption

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

In the study area the available K ranges from 89.8ppm(low) to 788.9 ppm(high), with average value of 297 ppm which is a high 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 37.0 to 80.9 (medium to high) this indicates crop response is possible to unlikely.

# 7. DESCRIPTION SOIL MAPPING UNITS

### 4.3.1. General

The soils of the project area are mapped and described based on their similar soil characteristics and constraints. The soils of the study area have been classified in to 28 soil mapping units. The soil mapping units were classified based on soil phase's criteria. The dominant characteristics considered in mapping the soil unit are like slope, texture, and soil depth, and other relevant soil drainage, and soil physical and chemical properties. Based on this, the following soil mapping units were identified

Table 12 : Area distribution of major soil groups in Hidha-Sombo small scale Irrigation Projectes

| SN | Major soi group(FAO,1998,2006,WRB,2014) | Identifayed soil units(FAO,1998,2006,WRB,2014) | SMU | Area | |
|---|---|---|---|---|---|
| | | | | ha | % |
| 1 | Cambisols | Eutric Cambisols | 1CL_c | 3.14 | 1.18 |
| | | | 1CL_d | 0.60 | 0.23 |
| | | | 2CL_c | 6.73 | 2.52 |
| | | | 2CL_d | 4.83 | 1.81 |
| | | | 2SCL_c | 0.91 | 0.34 |
| | | | 2SCL_d | 0.29 | 0.11 |
| | | | 3CL_c | 1.83 | 0.68 |
| | | | 3CL_d | 6.46 | 2.42 |
| | | | 3SCL_d | 1.69 | 0.63 |
| | | | 4CL_c | 2.16 | 0.81 |
| | | | 4CL_e | 1.22 | 0.46 |
| | | | 4CL_d | 41.03 | 15.38 |
| | | | 4SCL_c | 0.73 | 0.27 |
| | | | 4SCL_e | 1.06 | 0.40 |
| | | | 4SCL_d | 24.74 | 9.27 |
| | | | 5CL_c | 2.65 | 0.99 |
| | | | 5CL_e | 2.56 | 0.96 |
| | | | 5CL_d | 75.06 | 28.13 |
| | | | 5SCL_c | 2.19 | 0.82 |
| | | | 5SCL_e | 0.92 | 0.35 |
| | | | 5SCL_d | 41.12 | 15.41 |
| | | | 6CL_d | 19.24 | 7.21 |
| | | | 6SCL_d | 6.27 | 2.35 |
| 2 | Luvisols | Vertic,chromic Luvisols | 2CL_b1 | 0.99 | 0.37 |
| | | | 2CL_d1 | 0.64 | 0.24 |
| | | | 3CL_b1 | 1.88 | 0.71 |
| | | | 4CL_b1 | 2.66 | 1.00 |
| | | | 4CL_d1 | 0.75 | 0.28 |
| | | | 4SCL_b1 | 0.50 | 0.19 |
| | | | 5CL_b1 | 1.59 | 0.60 |
| | | | 5CL_d1 | 3.79 | 1.42 |
| | | | Settlement | 0.16 | 0.06 |
| | | | Pond | 6.44 | 2.41 |
| | | Total | | 266.82 | 100.00 |

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

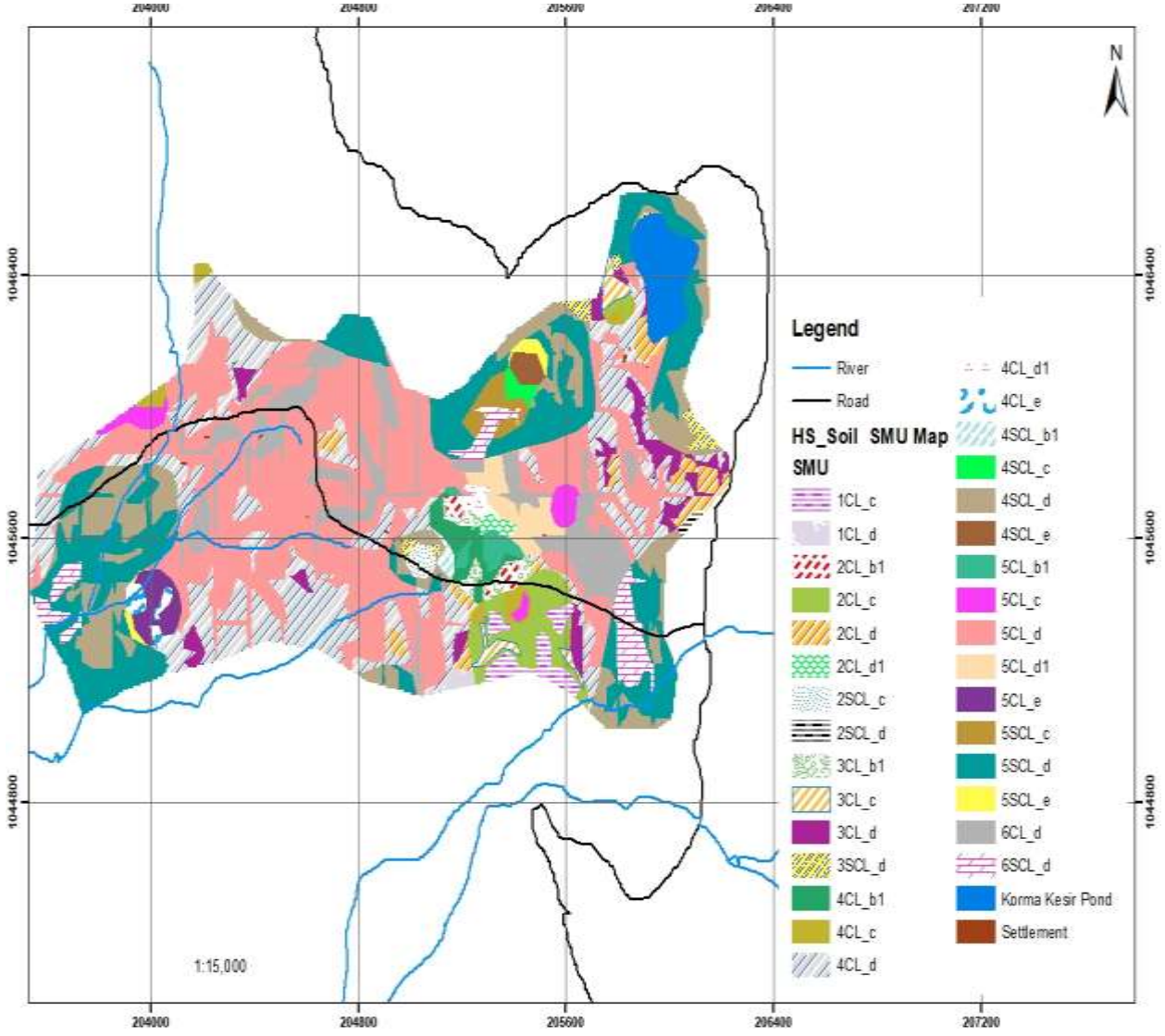
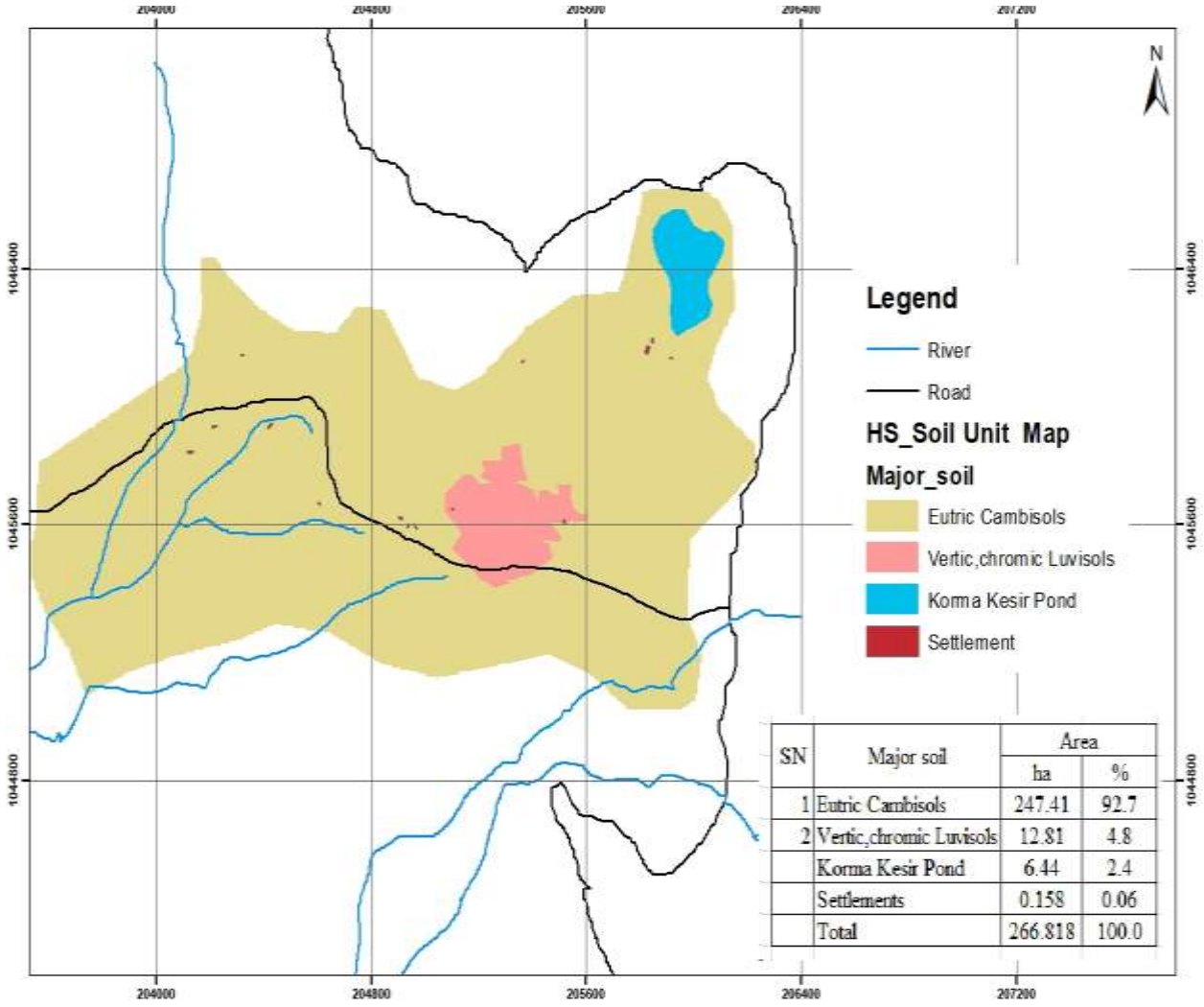


Figure 3: Soil Maps of the study area by Soil units




| SN | Major soil | Area | |
|---|---|---|---|
| | | ha | % |
| 1 | Eutric Cambisols | 247.41 | 92.7 |
| 2 | Vertic,chromic Luvisols | 12.81 | 4.8 |
| | Korma Kesir Pond | 6.44 | 2.4 |
| | Settlements | 0.158 | 0.06 |
| | Total | 266.818 | 100.0 |

## Soil Mapping units :

### 1CL-c

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

The average infiltration rate (IR) of this unit is categorized as marginaly suitable (8.80 cm/hr) and the average hydraulic conductivity (HC) is 1.495 m/day, which is moderately rapid.

The pH value is 6.60 in the top soil and 6.9 in the sub soil indicating that the soil is neutral. The overall organic carbon content of this soil unit is 1.08% in the top soil and 0.31 % in sub soil, which indicates low level of organic matter content. Total nitrogen content ranges 0.09% in the top and 0.04 % in sub soil which shows low to very low level status of the total nitrogen. This soil mapping unit has low to medium available phosphorus (4ppm in the top soil &9.58ppm in the sub soil), high CEC level (38.46 & 35.3Meq/100g of soilin top and sub soil respecti vely) and very high base saturation percentage (69.57% in the top soil and 92% in the sub soil. The soil units is Eutric Cambisols. The total extent of this mapping unit is 3.136 ha %.

## 1CL-d

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

The average infiltration rate (IR) of this unit is categorized as marginaly suitable (8.80 cm/hr) and the average hydraulic conductivity (HC) is 1.495 m/day, which is moderately rapid.

The pH value is 6.85 in the top soil indicating that the soil is neutral. The overall organic carbon content of this soil unit is 0.31% in the top soil, which indicates very low level of organic matter content. Total nitrogen content ranges 0.04% in the top which shows very low level of the total nitrogen. This soil mapping unit has moderate available phosphorus (9.58 ppm in the top), very high CEC level (35.28 Meq/100g of soil in top) and high base saturation percentage (91.87% in top. The soil units is Eutric Cambisols.The total extent of this mapping unit is 0.601 ha.

## 2CL-b1

This mapping unit refers to soils developed on 2-5% slope with deep profile (150-200cm). The soils are well drained with moderate, fine to medium sub angular blocky structure and have Clayloam (CL) texture.

The average infiltration rate (IR) of this unit is categorized as marginaly suitable (8.80 cm/hr) and the average hydraulic conductivity (HC) is 1.495 m/day, which is moderately rapid.

The pH value is 6.32 in the top soil indicating that the soil is sligtely acid. The overall organic carbon content of this soil unit is 0.97% in the top soil, which indicates very low level of organic matter content. Total nitrogen content ranges 0.07% in the top which shows low level of the total

nitrogen. This soil mapping unit has medium available phosphorus (4 ppm in the top), very high CEC level (45.44 Meq/100g of soil in top) and high base saturation percentage (85.48% in top. The soil units is vertic, chromic Luvisols.The total extent of this mapping unit is 0.994 ha.

## 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 Clayloam (CL) texture.

The average infiltration rate (IR) of this unit is categorized as marginaly suitable (8.80 cm/hr) and the average hydraulic conductivity (HC) is 1.495 m/day, which is moderately rapid.

The pH value is 6.85 in the top soil indicating that the soil is neutral. The overall organic carbon content of this soil unit is 0.31% in the top soil, which indicates very low level of organic matter content. Total nitrogen content ranges 0.04% in the top which shows very low level of the total nitrogen. This soil mapping unit has moderate available phosphorus (9.58 ppm in the top), very high CEC level (35.28 Meq/100g of soil in top) and high base saturation percentage (91.87% in top. The soil units is Eutric Cambisols.The total extent of this mapping unit is 6.74 ha.

## 2CL-d

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

The average infiltration rate (IR) of this unit is categorized as marginaly suitable (8.80 cm/hr) and the average hydraulic conductivity (HC) is 1.495 m/day, which is moderately rapid.

The pH value is 6.85 in the top soil indicating that the soil is neutral. The overall organic carbon content of this soil unit is 0.31% in the top soil, which indicates very low level of organic matter content. Total nitrogen content ranges 0.04% in the top which shows very low level of the total nitrogen. This soil mapping unit has moderate available phosphorus (9.58 ppm in the top), very high CEC level (35.28 Meq/100g of soil in top) and high base saturation percentage (91.87% in top. The soil units is Eutric Cambisols.The total extent of this mapping unit is 4.83 ha.

## 2CL-d1

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

The average infiltration rate (IR) of this unit is categorized as marginaly suitable (8.80 cm/hr) and the average hydraulic conductivity (HC) is 1.495 m/day, which is moderately rapid.

The pH value is 6.18 in the top soil indicating that the soil is sligtely acid. The overall organic carbon content of this soil unit is 0.98% in the top soil, which indicates very low level of organic matter content. Total nitrogen content ranges 0.08% in the top which shows low level of the total nitrogen. This soil mapping unit has high available phosphorus (35.72 ppm in the top), very high CEC level (43.74 Meq/100g of soil in top) and high base saturation percentage (85.81% in top. The soil units is vertic, chromic Luvisols.The total extent of this mapping unit is 0.64 ha.

## 2SCL-c

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

The average infiltration rate (IR) of this unit is categorized as marginaly suitable (8.80 cm/hr) and the average hydraulic conductivity (HC) is 1.495 m/day, which is moderately rapid.

The pH value is 6.60 in the top soil and 6.9 in the sub soil indicating that the soil is neutral. The overall organic carbon content of this soil unit is 1.08% in the top soil and 0.31 % in sub soil, which indicates low level of organic matter content. Total nitrogen content ranges 0.09% in the top and 0.04 % in sub soil which shows low to very low level status of the total nitrogen. This soil mapping unit has low to medium available phosphorus (4ppm in the top soil &9.58ppm in the sub soil), high CEC level (38.46 & 35.3Meq/100g of soilin top and sub soil respecti vely) and very high base saturation percentage (69.57% in the top soil and 92% in the sub soil. The soil units is Eutric Cambisols. The total extent of this mapping unit is 0.910 ha %.

## 2SCL-d

This mapping unit refers to soils developed on 2-5% slope with moderate profile (50-100cm). The soils are well drained with moderate, fine to medium sub angular blocky structure and have Sandy Clayloam (SCL) texture.

The average infiltration rate (IR) of this unit is categorized as marginaly suitable (8.80 cm/hr) and the average hydraulic conductivity (HC) is 1.495 m/day, which is moderately rapid.

The pH value is 6.85 in the top soil indicating that the soil is neutral. The overall organic carbon content of this soil unit is 0.31% in the top soil, which indicates very low level of organic matter content. Total nitrogen content ranges 0.04% in the top which shows very low level of the total nitrogen. This soil mapping unit has moderate available phosphorus (9.58 ppm in the top), very high CEC level (35.28 Meq/100g of soil in top) and high base saturation percentage (91.87% in top. The soil units is Eutric Cambisols. The total extent of this mapping unit is 0.29 ha.

## 3CL-b1

This mapping unit refers to soils developed on 5-8% slope with deep profile (150-200cm). The soils are well drained with moderate, fine to medium sub angular blocky structure and have Clayloam (CL) texture.

The average infiltration rate (IR) of this unit is categorized as marginaly suitable (8.80 cm/hr) and the average hydraulic conductivity (HC) is 1.495 m/day, which is moderately rapid.

The pH value is 6.32 in the top soil indicating that the soil is sligtely acid. The overall organic carbon content of this soil unit is 0.97% in the top soil, which indicates very low level of organic matter content. Total nitrogen content ranges 0.07% in the top which shows low level of the total nitrogen. This soil mapping unit has medium available phosphorus (4 ppm in the top), very high CEC level (45.44 Meq/100g of soil in top) and high base saturation percentage (85.48% in top. The soil units is vertic, chromic Luvisols. The total extent of this mapping unit is 1.88 ha.

## 3CL-e

This mapping unit refers to soils developed on 5-8 % slope with Shallow profile (25-50cm). The soils are well drained with fine & medium sub angular blocky structure and have clay loam (CL) texture.

The average infiltration rate (IR) of this unit is categorized as marginaly suitable (8.80 cm/hr) and the average hydraulic conductivity (HC) is 1.495 m/day, which is moderately rapid.

The pH value is 6.60 in the top soil and 6.9 in the sub soil indicating that the soil is neutral. The overall organic carbon content of this soil unit is 1.08% in the top soil and 0.31 % in sub soil, which indicates low level of organic matter content. Total nitrogen content ranges 0.09% in the top and 0.04 % in sub soil which shows low to very low level status of the total nitrogen. This soil mapping unit has low to medium available phosphorus (4ppm in the top soil &9.58ppm in the sub soil), high CEC level (38.46 & 35.3Meq/100g of soilin top and sub soil respecti vely) and very high base saturation percentage (69.57% in the top soil and 92% in the sub soil. The soil units is Eutric Cambisols. The total extent of this mapping unit is 1.83 ha %.

## 3CL-d

This mapping unit refers to soils developed on 5-8 % slope with Shallow profile (50-100cm). The soils are well drained with fine & medium sub angular blocky structure and have clay loam (CL) texture.

The average infiltration rate (IR) of this unit is categorized as marginaly suitable (8.80 cm/hr) and the average hydraulic conductivity (HC) is 1.495 m/day, which is moderately rapid.

The pH value is 6.60 in the top soil and 6.9 in the sub soil indicating that the soil is neutral. The overall organic carbon content of this soil unit is 1.08% in the top soil and 0.31 % in sub soil, which indicates low level of organic matter content. Total nitrogen content ranges 0.09% in the top and 0.04 % in sub soil which shows low to very low level status of the total nitrogen. This soil mapping unit has low to medium available phosphorus (4ppm in the top soil &9.58ppm in the sub soil), high CEC level (38.46 & 35.3Meq/100g of soilin top and sub soil respecti vely) and very high base saturation percentage (69.57% in the top soil and 92% in the sub soil. The soil units is Eutric Cambisols. The total extent of this mapping unit is 6.46 ha %.

## 3SCL-d

This mapping unit refers to soils developed on 5-8% slope with moderate profile (50-100-cm). The soils are well drained with moderate, fine to medium sub angular blocky structure and have Clayloam (CL) texture.

The average infiltration rate (IR) of this unit is categorized as marginaly suitable (8.80 cm/hr) and the average hydraulic conductivity (HC) is 1.495 m/day, which is moderately rapid.

The pH value is 6.85 in the top soil indicating that the soil is neutral. The overall organic carbon content of this soil unit is 0.31% in the top soil, which indicates very low level of organic matter content. Total nitrogen content ranges 0.04% in the top which shows very low level of the total nitrogen. This soil mapping unit has moderate available phosphorus (9.58 ppm in the top), very high CEC level (35.28 Meq/100g of soil in top) and high base saturation percentage (91.87% in top. The soil units is Eutric Cambisols. The total extent of this mapping unit is 1.69 ha.

## 4CL-b1

This mapping unit refers to soils developed on 8-15% slope with deep profile (150-200cm). The soils are well drained with moderate, fine to medium sub angular blocky structure and have Clayloam (CL) texture.

The average infiltration rate (IR) of this unit is categorized as marginaly suitable (8.80 cm/hr) and the average hydraulic conductivity (HC) is 1.495 m/day, which is moderately rapid.

The pH value is 6.32 in the top soil indicating that the soil is sligtely acid. The overall organic carbon content of this soil unit is 0.97% in the top soil, which indicates very low level of organic matter content. Total nitrogen content ranges 0.07% in the top which shows low level of the total nitrogen. This soil mapping unit has medium available phosphorus (4 ppm in the top), very high CEC level (45.44 Meq/100g of soil in top) and high base saturation percentage (85.48% in top. The soil units is vertic, chromic Luvisols. The total extent of this mapping unit is 2.67 ha.

## 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 Clayloam (CL) texture.

The average infiltration rate (IR) of this unit is categorized as marginaly suitable (8.80 cm/hr) and the average hydraulic conductivity (HC) is 1.495 m/day, which is moderately rapid.

The pH value is 7 in the top soil indicating that the soil is neutral. The overall organic carbon content of this soil unit is 0.67% in the top soil, which indicates very low level of organic matter content. Total nitrogen content ranges 0.07% in the top which shows low level of the total

nitrogen. This soil mapping unit has medium available phosphorus (7.04ppm in the top), high CEC level (30.64 Meq/100g of soil in top) and high base saturation percentage (71.69% in top. The soil units is Eutric Cambisols.The total extent of this mapping unit is 2.16 ha

## 4CL-d

This mapping unit refers to soils developed on 8-15% slope with moderate profile (50-100cm). The soils are well drained with moderate, fine to medium sub angular blocky structure and have Clayloam (CL) texture.

The average infiltration rate (IR) of this unit is categorized as marginaly suitable (8.80 cm/hr) and the average hydraulic conductivity (HC) is 1.495 m/day, which is moderately rapid.

The pH value is 6.65 in the top soil indicating that the soil is sligtely acid. The overall organic carbon content of this soil unit is 1.43% in the top soil, which indicates very low level of organic matter content. Total nitrogen content ranges 0.14% in the top which shows medium level of the total nitrogen. This soil mapping unit has high available phosphorus (36.08ppm in the top), medium CEC level (22.92 Meq/100g of soil in top) and high base saturation percentage (91.69% in top. The soil units is Eutric Cambisols.The total extent of this mapping unit is 41.05 ha

## 4CL-d1

This mapping unit refers to soils developed on 8-15% slope with moderate profile (50-100-cm). The soils are well drained with moderate, fine to medium sub angular blocky structure and have Clayloam (CL) texture.

The average infiltration rate (IR) of this unit is categorized as marginaly suitable (8.80 cm/hr) and the average hydraulic conductivity (HC) is 1.495 m/day, which is moderately rapid.

The pH value is 6.18 in the top soil indicating that the soil is sligtely acid. The overall organic carbon content of this soil unit is 0.98% in the top soil, which indicates very low level of organic matter content. Total nitrogen content ranges 0.08% in the top which shows low level of the total nitrogen. This soil mapping unit has high available phosphorus (35.72 ppm in the top), very high CEC level (43.74 Meq/100g of soil in top) and high base saturation percentage (85.81% in top. The soil units is vertic, chromic Luvisols.The total extent of this mapping unit is 0.754 ha.

## 4CL-e

This mapping unit refers to soils developed on 8-15% slope with shallow profile (25-50cm). The soils are well drained with moderate, fine to medium sub angular blocky structure and have Clayloam (CL) texture.

The average infiltration rate (IR) of this unit is categorized as marginaly suitable (8.80 cm/hr) and the average hydraulic conductivity (HC) is 1.495 m/day, which is moderately rapid.

The pH value is 6.65 in the top soil indicating that the soil is sligtely acid. The overall organic carbon content of this soil unit is 1.43% in the top soil, which indicates very low level of organic matter content. Total nitrogen content ranges 0.14% in the top which shows medium level of the total nitrogen. This soil mapping unit has high available phosphorus (36.08ppm in the top), medium CEC level (22.92 Meq/100g of soil in top) and high base saturation percentage (91.69% in top. The soil units is Eutric Cambisols.The total extent of this mapping unit is 1.22 ha

## 4SCL-b1

This mapping unit refers to soils developed on 8-15% slope with deep profile (150-200cm). The soils are well drained with moderate, fine to medium sub angular blocky structure and have Sandy Clayloam (SCL) texture.

The average infiltration rate (IR) of this unit is categorized as marginaly suitable (8.80 cm/hr) and the average hydraulic conductivity (HC) is 1.495 m/day, which is moderately rapid.

The pH value is 7 in the top soil indicating that the soil is neutral. The overall organic carbon content of this soil unit is 0.67% in the top soil, which indicates very low level of organic matter content. Total nitrogen content ranges 0.07% in the top which shows low level of the total nitrogen. This soil mapping unit has medium available phosphorus (7.04ppm in the top), high CEC level (30.64 Meq/100g of soil in top) and high base saturation percentage (71.69% in top. The soil units is Eutric Cambisols.The total extent of this mapping unit is 0.497 ha

## 4SCL-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 Sandy Clayloam (SCL) texture.

The average infiltration rate (IR) of this unit is categorized as marginaly suitable (8.80 cm/hr) and the average hydraulic conductivity (HC) is 1.495 m/day, which is moderately rapid.

The pH value is 7 in the top soil indicating that the soil is neutral. The overall organic carbon content of this soil unit is 0.67% in the top soil, which indicates very low level of organic matter content. Total nitrogen content ranges 0.07% in the top which shows low level of the total nitrogen. This soil mapping unit has medium available phosphorus (7.04ppm in the top), high CEC level (30.64 Meq/100g of soil in top) and high base saturation percentage (71.69% in top. The soil units is Eutric Cambisols.The total extent of this mapping unit is 0.731 ha

## 4SCL-d

This mapping unit refers to soils developed on 8-15% slope with moderate profile (50-100cm). The soils are well drained with moderate, fine to medium sub angular blocky structure and have Sandy Clayloam (SCL) texture.

The average infiltration rate (IR) of this unit is categorized as marginaly suitable (8.80 cm/hr) and the average hydraulic conductivity (HC) is 1.495 m/day, which is moderately rapid.

The pH value is 6.65 in the top soil indicating that the soil is sligtely acid. The overall organic carbon content of this soil unit is 1.43% in the top soil, which indicates very low level of organic matter content. Total nitrogen content ranges 0.14% in the top which shows medium level of the total nitrogen. This soil mapping unit has high available phosphorus (36.08ppm in the top), medium CEC level (22.92 Meq/100g of soil in top) and high base saturation percentage (91.69% in top. The soil units is Eutric Cambisols.The total extent of this mapping unit is 24.75 ha

## 4SCL-e

This mapping unit refers to soils developed on 8-15% slope with Shallow profile (25-50cm). The soils are well drained with moderate, fine to medium sub angular blocky structure and have Sandy Clayloam (SCL) texture.

The average infiltration rate (IR) of this unit is categorized as marginaly suitable (8.80 cm/hr) and the average hydraulic conductivity (HC) is 1.495 m/day, which is moderately rapid.

The pH value is 7 in the top soil indicating that the soil is neutral. The overall organic carbon content of this soil unit is 0.67% in the top soil, which indicates very low level of organic matter content. Total nitrogen content ranges 0.07% in the top which shows low level of the total

nitrogen. This soil mapping unit has medium available phosphorus (7.04ppm in the top), high CEC level (30.64 Meq/100g of soil in top) and high base saturation percentage (71.69% in top. The soil units is Eutric Cambisols.The total extent of this mapping unit is 1.06 ha

## 5CL-b1

This mapping unit refers to soils developed on 15-30% slope with deep profile (150-200cm). The soils are well drained with moderate, fine to medium sub angular blocky structure and have Clayloam (CL) texture.

The average infiltration rate (IR) of this unit is categorized as marginaly suitable (8.80 cm/hr) and the average hydraulic conductivity (HC) is 1.495 m/day, which is moderately rapid.

The pH value is 6.32 in the top soil indicating that the soil is sligtely acid. The overall organic carbon content of this soil unit is 0.97% in the top soil, which indicates very low level of organic matter content. Total nitrogen content ranges 0.07% in the top which shows low level of the total nitrogen. This soil mapping unit has medium available phosphorus (4 ppm in the top), very high CEC level (45.44 Meq/100g of soil in top) and high base saturation percentage (85.48% in top. The soil units is vertic, chromic Luvisols.The total extent of this mapping unit is 1.59 ha.

## 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 Clayloam (CL) texture.

The average infiltration rate (IR) of this unit is categorized as marginaly suitable (8.80 cm/hr) and the average hydraulic conductivity (HC) is 1.495 m/day, which is moderately rapid.

The pH value is 6.32 in the top soil indicating that the soil is sligtely acid. The overall organic carbon content of this soil unit is 0.36% in the top soil, which indicates very low level of organic matter content. Total nitrogen content ranges 0.04% in the top which shows very low level of the total nitrogen. This soil mapping unit has medium available phosphorus (8.24ppm in the top), very high CEC level (47.06 Meq/100g of soil in top) and high base saturation percentage (83.57% in top. The soil units is Eutric Cambisols.The total extent of this mapping unit is 2.65 ha.

## 5CL-d

This mapping unit refers to soils developed on 15-30% slope with moderate profile (50-100cm). The soils are well drained with moderate, fine to medium sub angular blocky structure and have Clayloam (CL) texture.

The average infiltration rate (IR) of this unit is categorized as marginaly suitable (8.80 cm/hr) and the average hydraulic conductivity (HC) is 1.495 m/day, which is moderately rapid.

The pH value is 6.65 in the top soil indicating that the soil is sligtely acid. The overall organic carbon content of this soil unit is 1.43% in the top soil, which indicates very low level of organic matter content. Total nitrogen content ranges 0.14% in the top which shows medium level of the total nitrogen. This soil mapping unit has high available phosphorus (36.08ppm in the top), medium CEC level (22.92 Meq/100g of soil in top) and high base saturation percentage (91.69% in top. The soil units is Eutric Cambisols.The total extent of this mapping unit is 75.1 ha

## 5CL-d1

This mapping unit refers to soils developed on 15-30% slope with moderate profile (50-100-cm). The soils are well drained with moderate, fine to medium sub angular blocky structure and have Clayloam (CL) texture.

The average infiltration rate (IR) of this unit is categorized as marginaly suitable (8.80 cm/hr) and the average hydraulic conductivity (HC) is 1.495 m/day, which is moderately rapid.

The pH value is 6.18 in the top soil indicating that the soil is sligtely acid. The overall organic carbon content of this soil unit is 0.98% in the top soil, which indicates very low level of organic matter content. Total nitrogen content ranges 0.08% in the top which shows low level of the total nitrogen. This soil mapping unit has high available phosphorus (35.72 ppm in the top), very high CEC level (43.74 Meq/100g of soil in top) and high base saturation percentage (85.81% in top. The soil units is vertic, chromic Luvisols.The total extent of this mapping unit is 3.796 ha.

## 5CL-e

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

The average infiltration rate (IR) of this unit is categorized as marginaly suitable (8.80 cm/hr) and the average hydraulic conductivity (HC) is 1.495 m/day, which is moderately rapid.

The pH value is 6.32 in the top soil indicating that the soil is sligtely acid. The overall organic carbon content of this soil unit is 0.36% in the top soil, which indicates very low level of organic matter content. Total nitrogen content ranges 0.04% in the top which shows very low level of the total nitrogen. This soil mapping unit has medium available phosphorus (8.24ppm in the top), very high CEC level (47.06 Meq/100g of soil in top) and high base saturation percentage (83.57% in top. The soil units is Eutric Cambisols.The total extent of this mapping unit is 2.56 ha.

## 5SCL-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 Sandy Clayloam (SCL) texture.

The average infiltration rate (IR) of this unit is categorized as marginaly suitable (8.80 cm/hr) and the average hydraulic conductivity (HC) is 1.495 m/day, which is moderately rapid.

The pH value is 6.32 in the top soil indicating that the soil is sligtely acid. The overall organic carbon content of this soil unit is 0.36% in the top soil, which indicates very low level of organic matter content. Total nitrogen content ranges 0.04% in the top which shows very low level of the total nitrogen. This soil mapping unit has medium available phosphorus (8.24ppm in the top), very high CEC level (47.06 Meq/100g of soil in top) and high base saturation percentage (83.57% in top. The soil units is Eutric Cambisols.The total extent of this mapping unit is 2.195 ha.

## 5SCL-d

This mapping unit refers to soils developed on 15-30% slope with moderate profile (50-100cm). The soils are well drained with moderate, fine to medium sub angular blocky structure and have Sandy Clayloam (SCL) texture.

The average infiltration rate (IR) of this unit is categorized as marginaly suitable (8.80 cm/hr) and the average hydraulic conductivity (HC) is 1.495 m/day, which is moderately rapid.

The pH value is 6.65 in the top soil indicating that the soil is sligtely acid. The overall organic carbon content of this soil unit is 1.43% in the top soil, which indicates very low level of organic matter content. Total nitrogen content ranges 0.14% in the top which shows medium level of the total nitrogen. This soil mapping unit has high available phosphorus (36.08ppm in the top), medium CEC level (22.92 Meq/100g of soil in top) and high base saturation percentage (91.69% in top. The soil units is Eutric Cambisols.The total extent of this mapping unit is 41.12 ha

## 5SCL-e

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

The average infiltration rate (IR) of this unit is categorized as marginaly suitable (8.80 cm/hr) and the average hydraulic conductivity (HC) is 1.495 m/day, which is moderately rapid.

The pH value is 6.65 in the top soil indicating that the soil is sligtely acid. The overall organic carbon content of this soil unit is 1.43% in the top soil, which indicates very low level of organic matter content. Total nitrogen content ranges 0.14% in the top which shows medium level of the total nitrogen. This soil mapping unit has high available phosphorus (36.08ppm in the top), medium CEC level (22.92 Meq/100g of soil in top) and high base saturation percentage (91.69% in top. The soil units is Eutric Cambisols.The total extent of this mapping unit is 0.923 ha

## 6CL-d

This mapping unit refers to soils developed on 30-45% slope with moderate profile (50-100cm). The soils are well drained with moderate, fine to medium sub angular blocky structure and have Sandy Clayloam (SCL) texture.

The average infiltration rate (IR) of this unit is categorized as marginaly suitable (8.80 cm/hr) and the average hydraulic conductivity (HC) is 1.495 m/day, which is moderately rapid.

The pH value is 6.65 in the top soil indicating that the soil is sligtely acid. The overall organic carbon content of this soil unit is 1.43% in the top soil, which indicates very low level of organic matter content. Total nitrogen content ranges 0.14% in the top which shows medium level of the

total nitrogen. This soil mapping unit has high available phosphorus (36.08ppm in the top), medium CEC level (22.92 Meq/100g of soil in top) and high base saturation percentage (91.69% in top. The soil units is Eutric Cambisols.The total extent of this mapping unit is 19.26 ha

## 6SCL-d

This mapping unit refers to soils developed on 15-30% slope with moderate profile (50-100cm). The soils are well drained with moderate, fine to medium sub angular blocky structure and have Sandy Clayloam (SCL) texture.

The average infiltration rate (IR) of this unit is categorized as marginaly suitable (8.80 cm/hr) and the average hydraulic conductivity (HC) is 1.495 m/day, which is moderately rapid.

The pH value is 6.65 in the top soil indicating that the soil is sligtely acid. The overall organic carbon content of this soil unit is 1.43% in the top soil, which indicates very low level of organic matter content. Total nitrogen content ranges 0.14% in the top which shows medium level of the total nitrogen. This soil mapping unit has high available phosphorus (36.08ppm in the top), medium CEC level (22.92 Meq/100g of soil in top) and high base saturation percentage (91.69% in top. The soil units is Eutric Cambisols.The total extent of this mapping unit is 6.27 ha

# 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, Hidha-Sombo 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 clay, clayloam and Loam in texture and prone to water logging (for clay soil). Thus the land is Moderately to marginally suitable (65.99ha or 38.14%) for surface irrigation. See Table below

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

| S/N | Limiting factors | Suitability Classes | | | | |
|---|---|---|---|---|---|---|
| | | S1 | S2 | S3 | N1 | N2 |
| 1 | Slopes (%) | 0 - 3 | 3-5 | 5-8 | - | >8 |
| 2 | Drainage | W | MW | I | P&E | VP |
| 3 | Depth (cm) | >200 | 120-200 | 60-120 | 30-60 | <30 |
| 4 | Soil texture | SL-CL | SL-C | LS & HC | S | VCS |
| 5 | Structure | SAB | SAB | Platy | Massive | - |
| 6 | Salinity (ds/m) | <4 | 4-8 | 8-12 | 12-16 | >16 |
| 7 | ESP (%) | <10 | 10-15 | 15-20 | >20 | >20 |
| 8 | CEC (meq/100g) | >20 | 5-20 | 1-5 | <1 | <1 |
| 9 | OM (%) | 3-5 | 1-3 | <1 | <1 | - |
| 10 | Total N (%) | >0.5 | 0.2-0.5 | 0.1-0.2 | - | <0.1 |
| 11 | Av. P (ppm) | >15 | 5-15 | <5 | - | <2 |
| 12 | C/N | 10-12 | 6-10 | <6 | <6 | - |
| 13 | PH | 5.5-7 | 5-5.5 & 7-8 | 4.5-5 & 8-8.5 | 8.5-9 | <4.5 &>9 |
| 14 | Fertility index | High | Moderate | Low | Very low | - |
| 15 | IR (Cm/hr) | 0.5-3.5 | 0.1-0.5 | 6.5-10.0 | 10-25 | <0.1, >25 |
| 16 | | - | 3.5-6.5 | - | - | - |
| 17 | HC (m/day) | >1.5 | 1.5-0.5 | 0.5-0.2 | <0.2 | - |
| 18 | AWC (mm/m) | >150 | 100-150 | 75-100 | 50-75 | <50 |

## 8.7. Land Utilization Types (LUTs)

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

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

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

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

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

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

1. Irrigated vegetable cultivation (Sweet Potato, Tomato, Pepper and Onion)
2. Irrigated Low land maize cultivation

The evaluation has been carried out assuming moderately inputs management levels, moderate capital investment and high labor intensity. Thus, the LUTs can be defined, as medium input level of fertilizer and herbicide, moderate capital investment, medium to high labor intensity, 100% private

property, with moderate management level by using surface irrigation and improved agronomic cultural practices, for local consumption and market orientation.

Table 15: Description of management levels

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

Source : Modified after UNEP and FAO (1999)

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

| Landuse Requirements for surface Irrigated Onion cultivation | | | | | | | |
|---|---|---|---|---|---|---|---|
| Land quality/diag.factors | Subclass | Land characteristices | unit | S1 | S2 | S3 | S |
| climate(c1) | c | Mean air temperature | oc | 16-22 | 13-16/22-323 | 10-13/23-25 | |
| Moisture availability(m) | m1 | AWC | mm/m | >180 | 120-180 | 60-120 | |
| | 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 | |
| | m3 | Hydraulic conductivity | m/day | 1.4-3 | 0.5-1.4 | 0.2-0.5 | |
| Oxygen availability(d) | d | drainage | class | wd/mwd | ID | Poor &aeric | poor &d |
| 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 |
| Rooting condition(r1) | r | Effective soil depth | cm | >75 | 50-75 | 20-50 | |
| 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 | |
| Potential for mechanization(k) | k | slope | % | 0-8 | 8-15 | 15-30 | |
| Land preparation(t) | t | vegitation clearance | cover/ha | open | light | medium | dense |
| | | stone/Rocks | | <15 | 15-35 | | |
| Flood hazard(f) | f | Flooding | | FO | | F1 | |
| Erosion Hazared(e) | e | sheet | class | no | slight | moderate | |
| | | Gully | class | none | none | slight | moderat |
| | | Caco3 | % | 0-5 | 5-10 | 10-20 | |

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(c1) | 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 : potato (Ipomoea batatas)-Crop Environmental Requirements

| Landuse Requirements for surface Irrigated Potato cultivation | | | | | | | |
|---|---|---|---|---|---|---|---|
| Land quality/diag.factors | Subclass | Land characteristices | unit | S1 | S2 | S3 | S4 |
| climate(c1) | c | Mean air temperature | oc | 14-22 | 12-14/22-24 | 11-12/24-26 | 10-11/26-27 |
| Moisture availability(m) | m1 | AWC | mm/m | >180 | 120-180 | 60-120 | |
| | 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 | |
| | m3 | Hydraulic conductivity | m/day | 1.4-3 | 0.5-1.4 | 0.2-0.5 | |
| Oxygen availability(d) | d | drainage | class | wd/mwd/SE/E | ID | | I |
| Nutrient retantion(n) | n1 | Organic carbon | % | >0.8 | 0.5-0.8 | <0.5 | |
| | n3 | AVP | ppm | >15 | 8-15 | 4-8 | <4 |
| | n4 | TN | % | ≥0.1 | <0.1 | NE | NE |
| | n5 | OM | % | >3 | 2.5-3 | 2-2.5 | 1-2 |
| Nutient Availability(z) | z | Soil reaction | | 5.5-6.5 | 5.4-5.5/6.5-7 | 5.2-5.4/7-7.5 | 4.8-5.2/7-8.2 |
| Rooting condition(r1) | r | Effective soil depth | cm | >50 | 25-50 | | 10-25 |
| Workability(w) | w | Texture | class | cl/scl/sil/sicl/sic/sc/L | c>60(red)/sl/ls | sc/ls | clay(black) |
| Potential for mechanization(k) | k | slope | % | 0-8 | 8-15 | 15-30 | |
| Land preparation(t) | t | vegitation clearance | cover/ha | open | light | medium | dense |
| | | stone/Rocks | | <0.1 | 0.1-3 | 3-15 | |
| Flood hazard(f) | f | Flooding | | none | | exceptional | |
| Erosion Hazared(e) | e | sheet | class | no | slight | moderate | |
| | | Gully | class | none | none | slight | moderate |
| Frost hazard | fl | frost | sensetivity | nil/slight/MD | | Sever | |

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(c1) | 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 |

## 8.8. Land Characteristics (LCs) and Land Qualities (LQs)

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

Land quality is an attribute of land which acts in a distinct manner in its influence on the suitability of the land for specific kind of land use. Examples of land qualities that are widely applicable to Rainfed cropping are temperature regime, moisture availability, drainage, and nutrient supply, rooting condition, potential for mechanization and erosion hazard (FAO, 1983). See more table : 21 below

Land qualities and land characteristics selected for influencing irrigated agriculture are listed below. The field survey data comprising each land qualities and land characteristics of the study area are however displayed in detail on Table 22. These survey data were used for matching of land qualities and land characteristic with land use requirements.

**Temperature regime**

There are three main effects of temperature on plant growth

I) Growth ceases below critical temperature, varying with the plant, but typically $6.5^0$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 $30^0$C. 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 20: Land suitability Limitations (sub-classes)

| Sub-class/suffixes | Description |
|---|---|
| **c** | **Climate (Temperature regime) :** Land units having either very low or very high temperatures below or above the critical temperatures, which may cease the plant growth and may have adverse effect on rate of plant growth, depending on the type of plants and varieties to be grown. Thus adaptable crops should be carefully selected for evaluation. |
| **m** | **Moisture availability**: Land units having soil moisture deficiencies, there is a need for an increased amount and frequency of irrigation and/or selection of draught-resistant crop varieties. Overhead irrigation may be more cost effective. |
| **d** | **Oxygen availability**: Land units having soil drainage deficiencies, ascribed to poor soil drainage that may be due to high ground water table, flooding, slow infiltration, slow permeability, slow surface drainage (low physiographic position) or some combination of these. Sub-soiling, diversion ditches and under drainage may be required. Selection of more tolerant crops like rice can be another solution. |
| **n** | **Nutrient retention**: Land units having poor capacity of soil to retain added nutrients as against loses caused by leaching, ascribed to low CEC, and these by organic matter. Thus, additional input is required to conserve organic matter and improve soil structure and require fertilizer application. |
| **z** | **Nutrient availability:** Land having poor capacity to supply crop with nutrients, ascribed to pH, nutrient availability is lower in pH <6.0 and >7.5 by fixation. |
| **r** | **Rooting condition :** Land units with limited effective soil depth (effective depth is a depth to a limiting horizon having high amount of gravels, hard pan or toxic layers) and restrictive root penetration having massive, columnar or coarse sized structure coupled with very firm consistence and high amount of stones or gravels. Land having restrictive effective soil depth and/or penetrability, which impairs germination and hinders mechanical cultivation. |
| **w** | **Workability :** Land units with poor workability, ascribed to massive clays, poor organic matter content, very firm consistence and occurrence of high amount of 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 21: 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 22: Summarized Land Quality and Characteristics of the SMU

| SMU | Slope | Texture | Depth | Major_soil | Temperature | Drainage | Flooding | Erosion | IR_Rep1 | IR_Rep2 | Ave_IR | Rank_IR | M_IR_R1 | M_IR_R2 | Ave_MIR | Rank_MIR | HC_Rep1 | HC_Rep2 | Ave_HC | Area |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | type | oc | class | class | class | cm/hr | cm/hr | cm/hr | | cm/hr | cm/hr | cm/hr | | m/day | m/day | m/day | ha |
| 1CL_e | 0-2 | CL | 100-150 | Eutric Cambisols | 21.66 | N | N | S/R/G | 8.40 | 9.20 | 8.80 | Marginally suitable | 11.4 | 13.5 | 12.5 | Marginally suitable | 1.220 | 1.770 | 1.495 | 3.14 |
| 1CL_d | 0-2 | CL | 50-100 | Eutric Cambisols | 21.66 | N | N | S/R/G | 8.40 | 9.20 | 8.80 | Marginally suitable | 11.4 | 13.5 | 12.5 | Marginally suitable | 1.220 | 1.770 | 1.495 | 0.60 |
| 2CL_e | 2-5 | CL | 100-150 | Eutric Cambisols | 21.66 | N | N | S/R/G | 8.40 | 9.20 | 8.80 | Marginally suitable | 11.4 | 13.5 | 12.5 | Marginally suitable | 1.220 | 1.770 | 1.495 | 6.73 |
| 2CL_b1 | 2-5 | CL | 150-200 | Vertic,chromic Luvisols | 21.66 | N | N | S/R/G | 8.40 | 9.20 | 8.80 | Marginally suitable | 11.4 | 13.5 | 12.5 | Marginally suitable | 1.220 | 1.770 | 1.495 | 0.99 |
| 2CL_d | 2-5 | CL | 50-100 | Eutric Cambisols | 21.66 | N | N | S/R/G | 8.40 | 9.20 | 8.80 | Marginally suitable | 11.4 | 13.5 | 12.5 | Marginally suitable | 1.220 | 1.770 | 1.495 | 4.83 |
| 2CL_d1 | 2-5 | CL | 50-100 | Vertic,chromic Luvisols | 21.66 | N | N | S/S | 8.40 | 9.20 | 8.80 | Marginally suitable | 11.4 | 13.5 | 12.5 | Marginally suitable | 1.220 | 1.770 | 1.495 | 0.64 |
| 2SCL_e | 2-5 | SCL | 100-150 | Eutric Cambisols | 21.66 | N | N | S/R/G | 8.40 | 9.20 | 8.80 | Marginally suitable | 11.4 | 13.5 | 12.5 | Marginally suitable | 1.220 | 1.770 | 1.495 | 0.91 |
| 2SCL_d | 2-5 | SCL | 50-100 | Eutric Cambisols | 21.66 | N | N | S/R/G | 8.40 | 9.20 | 8.80 | Marginally suitable | 11.4 | 13.5 | 12.5 | Marginally suitable | 1.220 | 1.770 | 1.495 | 0.29 |
| 3CL_e | 5-8 | CL | 100-150 | Eutric Cambisols | 21.66 | N | N | S/R/G | 8.40 | 9.20 | 8.80 | Marginally suitable | 11.4 | 13.5 | 12.5 | Marginally suitable | 1.220 | 1.770 | 1.495 | 1.83 |
| 3CL_b1 | 5-8 | CL | 150-200 | Vertic,chromic Luvisols | 21.66 | N | N | S/R/G | 8.40 | 9.20 | 8.80 | Marginally suitable | 11.4 | 13.5 | 12.5 | Marginally suitable | 1.220 | 1.770 | 1.495 | 1.88 |
| 3CL_d | 5-8 | CL | 50-100 | Eutric Cambisols | 21.66 | N | N | S/R/G | 8.40 | 9.20 | 8.80 | Marginally suitable | 11.4 | 13.5 | 12.5 | Marginally suitable | 1.220 | 1.770 | 1.495 | 6.46 |
| 3SCL_d | 5-8 | SCL | 50-100 | Eutric Cambisols | 21.66 | N | N | S/R/G | 8.40 | 9.20 | 8.80 | Marginally suitable | 11.4 | 13.5 | 12.5 | Marginally suitable | 1.220 | 1.770 | 1.495 | 1.69 |
| 4CL_e | 8-15 | CL | 100-150 | Eutric Cambisols | 21.66 | N | N | S/R/G | 8.40 | 9.20 | 8.80 | Marginally suitable | 11.4 | 13.5 | 12.5 | Marginally suitable | 1.220 | 1.770 | 1.495 | 2.16 |
| 4CL_b1 | 8-15 | CL | 150-200 | Vertic,chromic Luvisols | 21.66 | N | N | S/R/G | 8.40 | 9.20 | 8.80 | Marginally suitable | 11.4 | 13.5 | 12.5 | Marginally suitable | 1.220 | 1.770 | 1.495 | 2.66 |
| 4CL_e | 8-15 | CL | 25-50 | Eutric Cambisols | 21.66 | N | N | S/R/G | 8.40 | 9.20 | 8.80 | Marginally suitable | 11.4 | 13.5 | 12.5 | Marginally suitable | 1.220 | 1.770 | 1.495 | 1.22 |
| 4CL_d | 8-15 | CL | 50-100 | Eutric Cambisols | 21.66 | N | N | S/R/G | 8.40 | 9.20 | 8.80 | Marginally suitable | 11.4 | 13.5 | 12.5 | Marginally suitable | 1.220 | 1.770 | 1.495 | 41.03 |

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| SMU | Rank_HC | Bd | FC | PWP | AWC | TAWC | RAWC | B_TAWC | T_Poro | AF_Poro | PH | EC | ECe | ESP | Na | K | Ca | Mg | SUM | CEC | BS | ESP | TN | OC | OM | C_N | AvK | AvP | P2O5 | Ca+Mg | K+Mg | K:CEC | Ca+mg:k | Area |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | g/cm3 | % | % | mm | mm/m | mm/m | | % | % | kDo | ds/m | ds/m | kxl | Cmol/kgm | | | | | | % | % | % | % | % | ratio | ppm | ppm | % | ratio | ratio | ratio | ratio | ha |
| 1CL_c | Moderately rapid | 1.5 | 34.6 | 23.7 | 48.7 | 141.3 | 94.6 | Medium | 43.77 | 9.17 | 6.60 | 0.07 | 0.70 | 6.00 | 0.20 | 0.19 | 20.40 | 5.97 | 26.76 | 38.46 | 69.57 | 0.52 | 0.09 | 1.08 | 1.86 | 12.00 | 89.8 | 4.0 | 9.2 | 3.42 | 0.03 | 0.00 | 52.07 | 3.14 |
| 1CL_d | Moderately rapid | 1.5 | 34.6 | 23.7 | 48.7 | 141.3 | 94.6 | Medium | 43.77 | 9.17 | 6.95 | 0.06 | 0.47 | 6.30 | 0.24 | 0.62 | 22.46 | 9.09 | 32.41 | 35.20 | 91.87 | 0.68 | 0.04 | 0.31 | 0.53 | 7.75 | 239.8 | 9.6 | 21.9 | 2.47 | 0.07 | 0.02 | 37.07 | 0.60 |
| 2CL_c | Moderately rapid | 1.5 | 34.6 | 23.7 | 48.7 | 141.3 | 94.6 | Medium | 43.77 | 9.17 | 6.95 | 0.06 | 0.47 | 6.30 | 0.24 | 0.62 | 22.46 | 9.09 | 32.41 | 35.20 | 91.87 | 0.68 | 0.04 | 0.31 | 0.53 | 7.75 | 239.8 | 9.6 | 21.9 | 2.47 | 0.07 | 0.02 | 37.07 | 6.73 |
| 2CL_b1 | Moderately rapid | 1.5 | 34.6 | 23.7 | 48.7 | 141.3 | 94.6 | Medium | 43.77 | 9.17 | 6.52 | 0.13 | 0.95 | 5.80 | 0.20 | 0.22 | 30.13 | 0.21 | 30.84 | 45.44 | 68.48 | 0.61 | 0.07 | 0.97 | 1.68 | 13.90 | 97.8 | 4.0 | 9.2 | 3.67 | 0.03 | 0.00 | 66.72 | 0.99 |
| 2CL_d | Moderately rapid | 1.5 | 34.6 | 23.7 | 48.7 | 141.3 | 94.6 | Medium | 43.77 | 9.17 | 6.95 | 0.06 | 0.47 | 6.30 | 0.24 | 0.62 | 22.46 | 9.09 | 32.41 | 35.20 | 91.87 | 0.68 | 0.04 | 0.31 | 0.53 | 7.75 | 239.8 | 9.6 | 21.9 | 2.47 | 0.07 | 0.02 | 37.07 | 4.03 |
| 2CL_d1 | Moderately rapid | 1.5 | 34.6 | 23.7 | 48.7 | 141.3 | 94.6 | Medium | 43.77 | 9.17 | 6.18 | 0.10 | 0.87 | 5.80 | 0.32 | 0.39 | 20.81 | 0.13 | 37.53 | 43.74 | 85.81 | 0.47 | 0.08 | 0.98 | 1.69 | 12.24 | 147.8 | 16.7 | 81.8 | 3.54 | 0.05 | 0.01 | 49.81 | 0.64 |
| 3CL_c | Moderately rapid | 1.5 | 34.6 | 23.7 | 48.7 | 141.3 | 94.6 | Medium | 43.77 | 9.17 | 6.60 | 0.07 | 0.70 | 6.00 | 0.20 | 0.19 | 20.40 | 5.97 | 26.76 | 38.46 | 69.57 | 0.52 | 0.09 | 1.08 | 1.86 | 12.00 | 89.8 | 4.0 | 9.2 | 3.42 | 0.03 | 0.00 | 52.07 | 0.91 |
| 3CL_d | Moderately rapid | 1.5 | 34.6 | 23.7 | 48.7 | 141.3 | 94.6 | Medium | 43.77 | 9.17 | 6.95 | 0.06 | 0.47 | 6.30 | 0.24 | 0.62 | 22.46 | 9.09 | 32.41 | 35.20 | 91.87 | 0.68 | 0.04 | 0.31 | 0.53 | 7.75 | 239.8 | 9.6 | 21.9 | 2.47 | 0.07 | 0.02 | 37.07 | 0.29 |
| 3CL_c | Moderately rapid | 1.5 | 34.6 | 23.7 | 48.7 | 141.3 | 94.6 | Medium | 43.77 | 9.17 | 6.60 | 0.07 | 0.70 | 6.00 | 0.20 | 0.19 | 20.40 | 5.97 | 26.76 | 38.46 | 69.57 | 0.52 | 0.09 | 1.08 | 1.86 | 12.00 | 89.8 | 4.0 | 9.2 | 3.42 | 0.03 | 0.00 | 52.07 | 1.83 |
| 3CL_b1 | Moderately rapid | 1.5 | 34.6 | 23.7 | 48.7 | 141.3 | 94.6 | Medium | 43.77 | 9.17 | 6.52 | 0.13 | 0.95 | 5.80 | 0.20 | 0.22 | 30.13 | 0.21 | 30.84 | 45.44 | 68.48 | 0.61 | 0.07 | 0.97 | 1.68 | 13.90 | 97.8 | 4.0 | 9.2 | 3.67 | 0.03 | 0.00 | 66.72 | 1.88 |
| 3CL_d | Moderately rapid | 1.5 | 34.6 | 23.7 | 48.7 | 141.3 | 94.6 | Medium | 43.77 | 9.17 | 6.60 | 0.07 | 0.70 | 6.00 | 0.20 | 0.19 | 20.40 | 5.97 | 26.76 | 38.46 | 69.57 | 0.52 | 0.09 | 1.08 | 1.86 | 12.00 | 89.8 | 4.0 | 9.2 | 3.42 | 0.03 | 0.00 | 52.07 | 6.46 |
| 3SCL_d | Moderately rapid | 1.5 | 34.6 | 23.7 | 48.7 | 141.3 | 94.6 | Medium | 43.77 | 9.17 | 6.95 | 0.06 | 0.47 | 6.30 | 0.24 | 0.62 | 22.46 | 9.09 | 32.41 | 35.20 | 91.87 | 0.68 | 0.04 | 0.31 | 0.53 | 7.75 | 239.8 | 9.6 | 21.9 | 2.47 | 0.07 | 0.02 | 37.07 | 1.69 |
| 4CL_c | Moderately rapid | 1.5 | 34.6 | 23.7 | 48.7 | 141.3 | 94.6 | Medium | 43.77 | 9.17 | 7.00 | 0.15 | 1.09 | 6.60 | 0.22 | 0.46 | 15.40 | 4.39 | 21.96 | 30.64 | 71.69 | 0.48 | 0.07 | 0.67 | 1.15 | 9.53 | 788.9 | 7.0 | 16.1 | 3.51 | 0.47 | 0.07 | 17.54 | 2.16 |
| 4CL_b1 | Moderately rapid | 1.5 | 34.6 | 23.7 | 48.7 | 141.3 | 94.6 | Medium | 43.77 | 9.17 | 6.52 | 0.13 | 0.95 | 5.80 | 0.20 | 0.22 | 30.13 | 0.21 | 30.84 | 45.44 | 68.48 | 0.61 | 0.07 | 0.97 | 1.68 | 13.90 | 97.8 | 4.0 | 9.2 | 3.67 | 0.03 | 0.00 | 66.72 | 2.66 |
| 4CL_e | Moderately rapid | 1.5 | 34.6 | 23.7 | 48.7 | 141.3 | 94.6 | Medium | 43.77 | 9.17 | 6.65 | 0.14 | 1.19 | 6.30 | 0.16 | 1.08 | 16.34 | 1.44 | 21.02 | 22.32 | 91.69 | 0.69 | 0.14 | 1.43 | 2.46 | 10.18 | 417.8 | 16.7 | 84.0 | 4.76 | 0.32 | 0.06 | 19.52 | 1.22 |
| 4CL_d | Moderately rapid | 1.5 | 34.6 | 23.7 | 48.7 | 141.3 | 94.6 | Medium | 43.77 | 9.17 | 6.65 | 0.14 | 1.19 | 6.30 | 0.16 | 1.08 | 16.34 | 1.44 | 21.02 | 22.32 | 91.69 | 0.69 | 0.14 | 1.43 | 2.46 | 10.18 | 417.8 | 16.7 | 84.0 | 4.76 | 0.32 | 0.06 | 19.52 | 41.03 |

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| SMU | Slope | Texture | Depth | Major_soil | Temperature | Drainage | Flooding | Erosion | IR_Rep1 | IR_Rep2 | Ave_IR | Rank_IR | M_IR_R1 | M_IR_R2 | Ave_MIR | Rank_MIR | HC_Rep1 | HC_Rep2 | Ave_HC | Area |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | type | oc | class | class | class | cm/hr | cm/hr | cm/hr | | cm/hr | cm/hr | cm/hr | | m/day | m/day | m/day | ha |
| 4CL_d1 | 8-15 | CL | 50-100 | Vertic,chromic Luvisols | 21.66 | N | N | SS | 8.40 | 9.20 | 8.80 | Marginally suitable | 11.4 | 13.5 | 12.5 | Marginally suitable | 1.220 | 1.770 | 1.495 | 0.75 |
| 4SCL_e | 8-15 | SCL | 100-150 | Eutric Cambisols | 21.66 | N | N | SRG | 8.40 | 9.20 | 8.80 | Marginally suitable | 11.4 | 13.5 | 12.5 | Marginally suitable | 1.220 | 1.770 | 1.495 | 0.73 |
| 4SCL_h1 | 8-15 | CL | 150-200 | Vertic,chromic Luvisols | 21.66 | N | N | SRG | 8.40 | 9.20 | 8.80 | Marginally suitable | 11.4 | 13.5 | 12.5 | Marginally suitable | 1.220 | 1.770 | 1.495 | 0.50 |
| 4SCL_e | 8-15 | SCL | 25-50 | Eutric Cambisols | 21.66 | N | N | SRG | 8.40 | 9.20 | 8.80 | Marginally suitable | 11.4 | 13.5 | 12.5 | Marginally suitable | 1.220 | 1.770 | 1.495 | 1.06 |
| 4SCL_d | 8-15 | SCL | 50-100 | Eutric Cambisols | 21.66 | N | N | SRG | 8.40 | 9.20 | 8.80 | Marginally suitable | 11.4 | 13.5 | 12.5 | Marginally suitable | 1.220 | 1.770 | 1.495 | 24.74 |
| 5CL_c | 15-30 | CL | 100-150 | Eutric Cambisols | 21.66 | N | N | SRG | 8.40 | 9.20 | 8.80 | Marginally suitable | 11.4 | 13.5 | 12.5 | Marginally suitable | 1.220 | 1.770 | 1.495 | 2.65 |
| 5CL_h1 | 15-30 | CL | 150-200 | Vertic,chromic Luvisols | 21.66 | N | N | SRG | 8.40 | 9.20 | 8.80 | Marginally suitable | 11.4 | 13.5 | 12.5 | Marginally suitable | 1.220 | 1.770 | 1.495 | 1.59 |
| 5CL_e | 15-30 | CL | 25-50 | Eutric Cambisols | 21.66 | N | N | SRG | 8.40 | 9.20 | 8.80 | Marginally suitable | 11.4 | 13.5 | 12.5 | Marginally suitable | 1.220 | 1.770 | 1.495 | 2.56 |
| 5CL_d | 15-30 | CL | 50-100 | Eutric Cambisols | 21.66 | N | N | SRG | 8.40 | 9.20 | 8.80 | Marginally suitable | 11.4 | 13.5 | 12.5 | Marginally suitable | 1.220 | 1.770 | 1.495 | 75.06 |
| 5CL_d1 | 15-30 | CL | 50-100 | Vertic,chromic Luvisols | 21.66 | N | N | SS | 8.40 | 9.20 | 8.80 | Marginally suitable | 11.4 | 13.5 | 12.5 | Marginally suitable | 1.220 | 1.770 | 1.495 | 3.79 |
| 5SCL_e | 15-30 | SCL | 100-150 | Eutric Cambisols | 21.66 | N | N | SRG | 8.40 | 9.20 | 8.80 | Marginally suitable | 11.4 | 13.5 | 12.5 | Marginally suitable | 1.220 | 1.770 | 1.495 | 2.19 |
| 5SCL_e | 15-30 | SCL | 25-50 | Eutric Cambisols | 21.66 | N | N | SRG | 8.40 | 9.20 | 8.80 | Marginally suitable | 11.4 | 13.5 | 12.5 | Marginally suitable | 1.220 | 1.770 | 1.495 | 0.92 |
| 5SCL_d | 15-30 | SCL | 50-100 | Eutric Cambisols | 21.66 | N | N | SRG | 8.40 | 9.20 | 8.80 | Marginally suitable | 11.4 | 13.5 | 12.5 | Marginally suitable | 1.220 | 1.770 | 1.495 | 41.12 |
| 6CL_d | 30-45 | CL | 50-100 | Eutric Cambisols | 21.66 | N | N | SRG | 8.40 | 9.20 | 8.80 | Marginally suitable | 11.4 | 13.5 | 12.5 | Marginally suitable | 1.220 | 1.770 | 1.495 | 19.24 |
| 6SCL_d | 30-45 | SCL | 50-100 | Eutric Cambisols | 21.66 | N | N | SRG | 8.40 | 9.20 | 8.80 | Marginally suitable | 11.4 | 13.5 | 12.5 | Marginally suitable | 1.220 | 1.770 | 1.495 | 6.27 |
| Settlement | Settlement | Settlem | Settlem | Settlement | 21.66 | Settlemer | Settlemer | Settlem | Settlemer | Settlemer | Settlem | Settlement | Settlemer | Settlemer | Settlemer | Settlement | Settlemer | Settlemer | Settlemer | 0.158 |
| Pond | Pond | Pond | Pond | Pond | 21.66 | Pond | Pond | Pond | Pond | Pond | Pond | Pond | Pond | Pond | Pond | Pond | Pond | Pond | Pond | 6.44 |

Cont'd

| SMU | Bank_HC | Bd | FC | PWP | AWC | TAWC | RAWC | R_TAWC | T_Poro | AF_Poro | PH | EC | ECe | PH | Na | K | Ca | Mg | SUM | CEC | BS | ESP | TN | OC | OM | C_N | AvK | AvP | P2O5 | Ca+Mg | K+Mg | K+CEC | Ca+mg+k | Area |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | g/cm3 | % | % | mm | mm/m | mm/m | | % | % | h2o | ds/m | ds/m | kcl | Cmol/kgm | | | | | | % | % | % | % | % | ratio | ppm | ppm | % | ratio | ratio | ratio | ratio | ha |
| 4CL_d1 | Moderately rapid | 1.5 | 34.6 | 23.7 | 48.7 | 141.8 | 94.6 | Medium | 43.77 | 9.17 | 6.18 | 0.10 | 0.87 | 5.80 | 0.21 | 0.39 | 28.81 | 8.13 | 37.53 | 43.74 | 85.81 | 0.47 | 0.08 | 0.98 | 1.69 | 12.24 | 147.8 | 35.7 | 81.8 | 3.54 | 0.05 | 0.01 | 49.81 | 0.75 |
| 4SCL_e | Moderately rapid | 1.5 | 34.6 | 23.7 | 48.7 | 141.8 | 94.6 | Medium | 43.77 | 9.17 | 7.00 | 0.15 | 1.09 | 6.60 | 0.12 | 2.05 | 15.40 | 4.39 | 21.96 | 30.64 | 71.69 | 0.40 | 0.07 | 0.67 | 1.15 | 9.53 | 788.9 | 7.0 | 16.1 | 3.51 | 0.47 | 0.07 | 17.54 | 0.73 |
| 4SCL_b1 | Moderately rapid | 1.5 | 34.6 | 23.7 | 48.7 | 141.8 | 94.6 | Medium | 43.77 | 9.17 | 7.00 | 0.15 | 1.09 | 6.60 | 0.12 | 2.05 | 15.40 | 4.39 | 21.96 | 30.64 | 71.69 | 0.40 | 0.07 | 0.67 | 1.15 | 9.53 | 788.9 | 7.0 | 16.1 | 3.51 | 0.47 | 0.07 | 17.54 | 0.50 |
| 4SCL_e | Moderately rapid | 1.5 | 34.6 | 23.7 | 48.7 | 141.8 | 94.6 | Medium | 43.77 | 9.17 | 7.00 | 0.15 | 1.09 | 6.60 | 0.12 | 2.05 | 15.40 | 4.39 | 21.96 | 30.64 | 71.69 | 0.40 | 0.07 | 0.67 | 1.15 | 9.53 | 788.9 | 7.0 | 16.1 | 3.51 | 0.47 | 0.07 | 17.54 | 1.06 |
| 4SCL_d | Moderately rapid | 1.5 | 34.6 | 23.7 | 48.7 | 141.8 | 94.6 | Medium | 43.77 | 9.17 | 6.65 | 0.14 | 1.19 | 6.30 | 0.16 | 1.08 | 16.34 | 3.44 | 21.02 | 22.82 | 91.69 | 0.69 | 0.14 | 1.43 | 2.46 | 10.18 | 417.8 | 36.7 | 84.0 | 4.76 | 0.31 | 0.05 | 19.52 | 24.74 |
| 5CL_e | Moderately rapid | 1.5 | 34.6 | 23.7 | 48.7 | 141.8 | 94.6 | Medium | 43.77 | 9.17 | 6.66 | 0.11 | 0.81 | 6.00 | 0.33 | 0.27 | 29.19 | 9.54 | 39.33 | 47.06 | 83.57 | 0.71 | 0.04 | 0.36 | 0.63 | 9.07 | 103.5 | 8.2 | 18.9 | 3.06 | 0.03 | 0.01 | 65.16 | 2.66 |
| 5CL_b1 | Moderately rapid | 1.5 | 34.6 | 23.7 | 48.7 | 141.8 | 94.6 | Medium | 43.77 | 9.17 | 6.32 | 0.13 | 0.95 | 5.80 | 0.28 | 0.22 | 30.13 | 8.21 | 38.84 | 45.44 | 85.48 | 0.61 | 0.07 | 0.97 | 1.68 | 13.96 | 97.8 | 4.0 | 9.2 | 3.67 | 0.03 | 0.00 | 66.72 | 1.59 |
| 5CL_e | Moderately rapid | 1.5 | 34.6 | 23.7 | 48.7 | 141.8 | 94.6 | Medium | 43.77 | 9.17 | 6.66 | 0.11 | 0.81 | 6.00 | 0.33 | 0.27 | 29.19 | 9.54 | 39.33 | 47.06 | 83.57 | 0.71 | 0.04 | 0.36 | 0.63 | 9.07 | 103.5 | 8.2 | 18.9 | 3.06 | 0.03 | 0.01 | 65.16 | 2.56 |
| 5CL_d | Moderately rapid | 1.5 | 34.6 | 23.7 | 48.7 | 141.8 | 94.6 | Medium | 43.77 | 9.17 | 6.65 | 0.14 | 1.19 | 6.30 | 0.16 | 1.08 | 16.34 | 3.44 | 21.02 | 22.82 | 91.69 | 0.69 | 0.14 | 1.43 | 2.46 | 10.18 | 417.8 | 36.7 | 84.0 | 4.76 | 0.31 | 0.05 | 19.52 | 75.06 |
| 5CL_d1 | Moderately rapid | 1.5 | 34.6 | 23.7 | 48.7 | 141.8 | 94.6 | Medium | 43.77 | 9.17 | 6.18 | 0.10 | 0.87 | 5.80 | 0.21 | 0.39 | 28.81 | 8.13 | 37.53 | 43.74 | 85.81 | 0.47 | 0.08 | 0.98 | 1.69 | 12.24 | 147.8 | 35.7 | 81.8 | 3.54 | 0.05 | 0.01 | 49.81 | 3.79 |
| 5SCL_e | Moderately rapid | 1.5 | 34.6 | 23.7 | 48.7 | 141.8 | 94.6 | Medium | 43.77 | 9.17 | 6.66 | 0.11 | 0.81 | 6.00 | 0.33 | 0.27 | 29.19 | 9.54 | 39.33 | 47.06 | 83.57 | 0.71 | 0.04 | 0.36 | 0.63 | 9.07 | 103.5 | 8.2 | 18.9 | 3.06 | 0.03 | 0.01 | 65.16 | 2.19 |
| 5SCL_e | Moderately rapid | 1.5 | 34.6 | 23.7 | 48.7 | 141.8 | 94.6 | Medium | 43.77 | 9.17 | 6.65 | 0.14 | 1.19 | 6.30 | 0.16 | 1.08 | 16.34 | 3.44 | 21.02 | 22.82 | 91.69 | 0.69 | 0.14 | 1.43 | 2.46 | 10.18 | 417.8 | 36.7 | 84.0 | 4.76 | 0.31 | 0.05 | 19.52 | 0.92 |
| 5SCL_d | Moderately rapid | 1.5 | 34.6 | 23.7 | 48.7 | 141.8 | 94.6 | Medium | 43.77 | 9.17 | 6.65 | 0.14 | 1.19 | 6.30 | 0.16 | 1.08 | 16.34 | 3.44 | 21.02 | 22.82 | 91.69 | 0.69 | 0.14 | 1.43 | 2.46 | 10.18 | 417.8 | 36.7 | 84.0 | 4.76 | 0.31 | 0.05 | 19.52 | 41.12 |
| 6CL_d | Moderately rapid | 1.5 | 34.6 | 23.7 | 48.7 | 141.8 | 94.6 | Medium | 43.77 | 9.17 | 6.65 | 0.14 | 1.19 | 6.30 | 0.16 | 1.08 | 16.34 | 3.44 | 21.02 | 22.82 | 91.69 | 0.69 | 0.14 | 1.43 | 2.46 | 10.18 | 417.8 | 36.7 | 84.0 | 4.76 | 0.31 | 0.05 | 19.52 | 19.24 |
| 6SCL_d | Moderately rapid | 1.5 | 34.6 | 23.7 | 48.7 | 141.8 | 94.6 | Medium | 43.77 | 9.17 | 6.65 | 0.14 | 1.19 | 6.30 | 0.16 | 1.08 | 16.34 | 3.44 | 21.02 | 22.82 | 91.69 | 0.69 | 0.14 | 1.43 | 2.46 | 10.18 | 417.8 | 36.7 | 84.0 | 4.76 | 0.31 | 0.05 | 19.52 | 6.27 |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.158 |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 6.44 |

## 8.10. Results of Land Suitability Evaluation for Surface Irrigation

### 8.10.1. Existing Suitability for Surface Irrigation

The results of the suitability evaluation of the project area for surface irrigation are shown in Tables 24. The result indicates that a total of 260.22 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, total nitrogen.

Table 23: Existing Surface Irrigation Suitability by Area

| Surface Irrigation Existing suitability | | | | |
|---|---|---|---|---|
| S/N | Suitability class | Suitability | Area | % |
| 1 | S1 | Highly suitable | | |
| 2 | S2 | Moderately suitable | | |
| 3 | S3 | Marginally suitable | | |
| 4 | S4 | Very marginally suitable | | |
| 5 | N2 | Not suitable | 260.22 | 97.53 |
| | Pond | | 6.443 | 2.41 |
| | Settlements | | 0.158 | 0.06 |
| | | | 266.821 | 100.00 |

Figure 4: Existing and Potential Surface Irrigation Suitability Map

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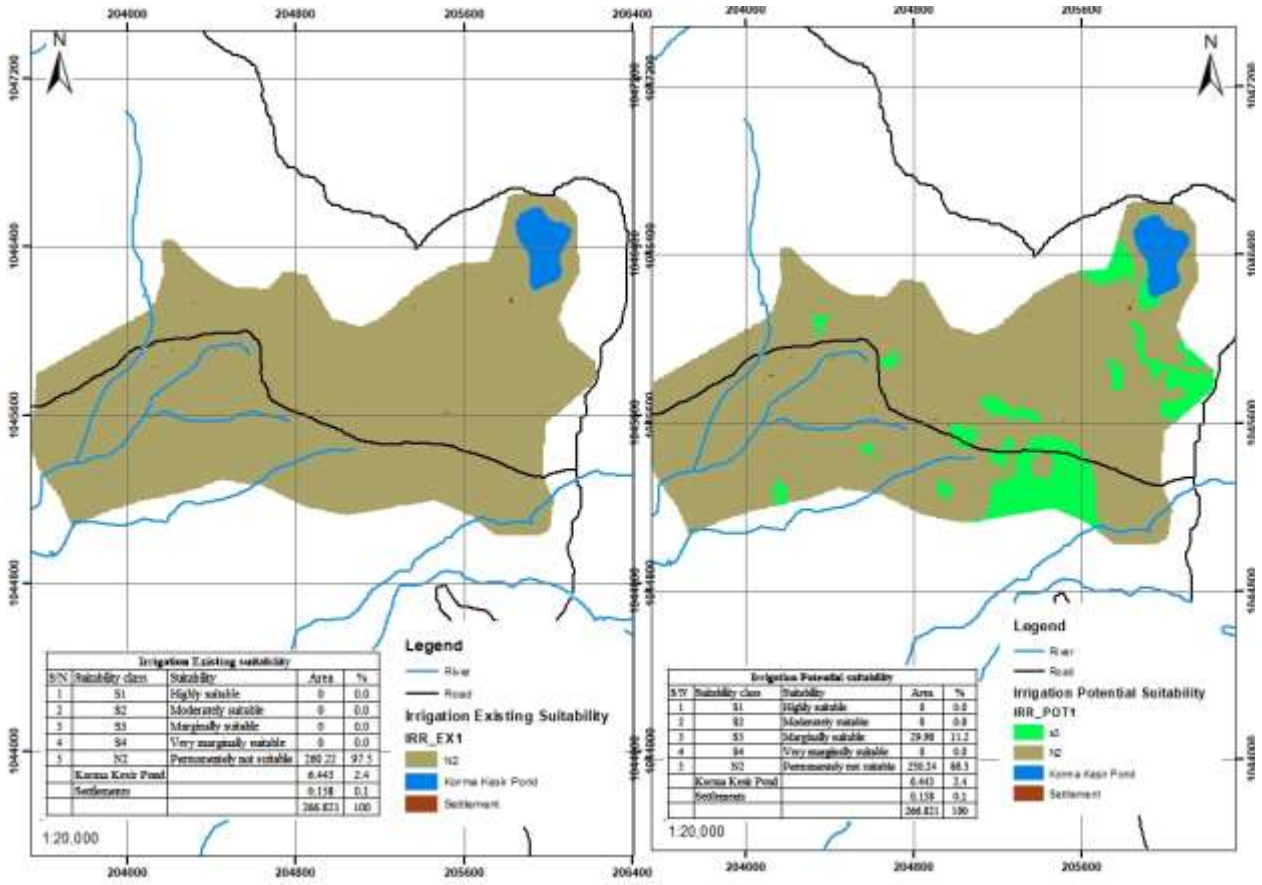



## 8.10.2. Potential Suitability for Surface Irrigation

The results of the potential suitability evaluation of the project area for surface irrigation are shown in Tables 25. The result indicates that a total of **29.98** is found to be marginally suitable for surface irrigation development and some 230.241 ha of land is permanentely not suitable for surface irrigation development. The areas identified as permanentely not suitable for surface irrigation are constrained by slope. The area identified as marginally suitable for surface irrigation is constrained by slope, and Infiltration rate. The marginally suitable areas require careful land management, application of good quality of water and teracing like bunch terace, this improve the suitability level to moderately suitable.

Table 24 : Potential Surface Irrigation Suitability by Area

| Surface Irrigation Potential suitability | | | | |
|---|---|---|---|---|
| S/N | Suitability class | Suitability | Area | % |
| 1 | S1 | Highly suitable | | |
| 2 | S2 | Moderately suitable | | |
| 3 | S3 | Marginally suitable | 29.98 | 11.24 |
| 4 | S4 | Very marginally suitable | | |
| 5 | N2 | Not suitable | 230.241 | 86.29 |
| | Pond | | 6.443 | 2.41 |
| | Settlements | | 0.158 | 0.06 |
| | | | 266.822 | 100.00 |

Table 25: Results of Existing and Potential Land Suitability Evaluation for surface Irrigation by SMU

| SMU | Area,ha | Existing sub class(IRR) | Existing Suitability(IRR) | Class | Limitation | Potential sub class(IRR) | Potential suitability(IRR) | Class | Limitation |
|---|---|---|---|---|---|---|---|---|---|
| 1CL_c | 3.1363 | N2n4 | N2 | not suitable | Total nitrogen | s3m2 | s3 | Marginally suitable | Infiltration |
| 1CL_d | 0.6008 | N2n4 | N2 | not suitable | Total nitrogen | s3m2r1 | s3 | Marginally suitable | Infiltration, depth |
| 2CL_c | 6.7348 | N2n4 | N2 | not suitable | Total nitrogen | s3m2 | s3 | Marginally suitable | Infiltration |
| 2CL_h1 | 0.9938 | N2n4 | N2 | not suitable | Total nitrogen | s3m2 | s3 | Marginally suitable | Infiltration |
| 2CL_d | 4.8267 | N2n4 | N2 | not suitable | Total nitrogen | s3m2r1 | s3 | Marginally suitable | Infiltration, depth |
| 2CL_d1 | 0.6402 | N2n4 | N2 | not suitable | Total nitrogen | s3m2r1 | s3 | Marginally suitable | Infiltration, depth |
| 2SCL_c | 0.9101 | N2n4 | N2 | not suitable | Total nitrogen | s3m2 | s3 | Marginally suitable | Infiltration |
| 2SCL_d | 0.2865 | N2n4 | N2 | not suitable | Total nitrogen | s3m2r1 | s3 | Marginally suitable | Infiltration, depth |
| 3CL_c | 1.8261 | N2n4 | N2 | not suitable | Total nitrogen | s3m2 | s3 | Marginally suitable | Infiltration |
| 3CL_h1 | 1.8813 | N2n4 | N2 | not suitable | Total nitrogen | s3m2 | s3 | Marginally suitable | Infiltration |
| 3CL_d | 6.4593 | N2n4 | N2 | not suitable | Total nitrogen | s3m2r1 | s3 | Marginally suitable | Infiltration, depth |
| 3SCL_d | 1.6863 | N2n4 | N2 | not suitable | Total nitrogen | s3m2r1 | s3 | Marginally suitable | Infiltration, depth |
| 4CL_c | 2.1579 | N2kn4 | N2 | not suitable | Slope,total nitrogen | N2k | N2 | not suitable | Slope |
| 4CL_h1 | 2.6620 | N2kn4 | N2 | not suitable | Slope,total nitrogen | N2k | N2 | not suitable | Slope |
| 4CL_e | 1.2159 | N2k | N2 | not suitable | Slope | N2k | N2 | not suitable | Slope |

Cont'd

| SMU | Area,ha | Existing sub class(IRR) | Existing Suitability(IRR) | Class | Limitation | Potential sub class(IRR) | Potential suitability(IRR) | Class |
|---|---|---|---|---|---|---|---|---|
| 4CL_d | 41.0269 | N2k | N2 | not suitable | Slope | N2k | N2 | not s |
| 4CL_d1 | 0.7542 | N2k | N2 | not suitable | Slope | N2k | N2 | not s |
| 4SCL_c | 0.7307 | N2kn4 | N2 | not suitable | Slope,total nitrogen | N2k | N2 | not s |
| 4SCL_b1 | 0.4967 | N2kn4 | N2 | not suitable | Slope,total nitrogen | N2k | N2 | not s |
| 4SCL_e | 1.0578 | N2kn4 | N2 | not suitable | Slope,total nitrogen | N2k | N2 | not s |
| 4SCL_d | 24.7403 | N2k | N2 | not suitable | Slope | N2k | N2 | not s |
| 5CL_c | 2.6536 | N2kn4 | N2 | not suitable | Slope,total nitrogen | N2k | N2 | not s |
| 5CL_b1 | 1.5901 | N2kn4 | N2 | not suitable | Slope,total nitrogen | N2k | N2 | not s |
| 5CL_e | 2.5622 | N2kn4 | N2 | not suitable | Slope,total nitrogen | N2k | N2 | not s |
| 5CL_d | 75.0600 | N2k | N2 | not suitable | Slope | N2k | N2 | not s |
| 5CL_d1 | 3.7902 | N2k | N2 | not suitable | Slope | N2k | N2 | not s |
| 5SCL_c | 2.1902 | N2kn4 | N2 | not suitable | Slope,total nitrogen | N2k | N2 | not s |
| 5SCL_e | 0.9228 | N2k | N2 | not suitable | Slope | N2k | N2 | not s |
| 5SCL_d | 41.1185 | N2k | N2 | not suitable | Slope | N2k | N2 | not s |
| 6CL_d | 19.2433 | N2k | N2 | not suitable | Slope | N2k | N2 | not s |
| 6SCL_d | 6.2667 | N2k | N2 | not suitable | Slope | N2k | N2 | not s |

## 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 : Tomato, Onion, Potato, and cabbage. The results of the crop suitability evaluation are shown in Table 27 and maps.

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

### 8.11.1. Existing Crop Suitabilty Evaluation

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

Table 26 : Existing Crop Suitability by Area for Surface Irrigation

| Existing crop suitability by area for surface Irrigation | | | | | |
|---|---|---|---|---|---|
| Crop | s1 | s2 | s3 | s4 | N |
| | Highly suitable | Moderately suitable | Marginally suitable | Very Marginally suitable | not suitable |
| | Area,ha | Area,ha | Area,ha | Area,ha | Area,ha |
| Potato | | 82.15 | 77.14 | 25.51 | |
| Onion | | 201.21 | 33.5 | | 25.51 |
| Tomato | | 67.162 | 167.55 | | 25.51 |
| Cabbage | | 102.55 | 132.16 | | 25.51 |

From the above table: 27 by existing condition the command area is primerly/ranking best/moderately suitable for Onion (201.21ha of land), and following for cabbage (102.55 ha), potato (82.15ha), and for tomato is about (67.2ha)

Table 27: Existing Crop Suitability by subclass and Area for surface Irrigation

| Crop | Existing suitability sub class comparing with crop for surface Irrigation | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Potato | Existing sub class | s2ml | s2mlk | s2mln3zn4 | s2mlzk | s2mlzrlk | s3k | s3n3 | s3n3k | s4k | | | | | |
| | Area,ha | 0.64 | 0.754 | 14.14 | 65.77 | 1.22 | 128.298 | 22.31 | 1.59 | 25.51 | | | | | |
| Onion | Existing sub class | N2k | s2mlnln3 | s2mlnln3k | s2mlnln3rl | s2mlnlrl | s2mlnlrlk | s2mlrlk | s3k | s3nl | s3nlk | s3nlrl | s3nlrlk | s3rl | s3rlk |
| | Area,ha | 25.51 | 8.75 | 2.66 | 6.46 | 0.64 | 0.75 | 65.77 | 121.56 | 17.52 | 4.84 | 1.06 | 2.56 | 1.22 | 0.923 |
| Tomato | Existing sub class | N2k | s2mlnlrl | s2mlnlrlk | s2mlrlk | s3k | s3nln3 | s3nln3k | s3nln3rl | s3nln3rlk | s3n3 | s3n3k | s3rl | s3rlk | |
| | Area,ha | 25.51 | 0.64 | 0.75 | 65.77 | 119.97 | 17.52 | 4.84 | 1.06 | 2.56 | 17.87 | 1.59 | 1.22 | 0.923 | |
| Cabbage | Existing sub class | N2k | s2mlnl | s2mlnlnln3k | s2mlnlrl | s2mlnln3 | s2mlnln3k | s2mlnln3rl | s2mlrl | s2mlrlk | s3k | s3rl | s3rlk | | |
| | Area,ha | 25.51 | 6.735 | 3.39 | 7.4 | 8.75 | 2.66 | 6.46 | 0.64 | 66.52 | 126.4 | 2.27 | 3.48 | | |

## 8.11.2. Potential Crop Suitabilty Evaluation

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

**Vegitable crops**

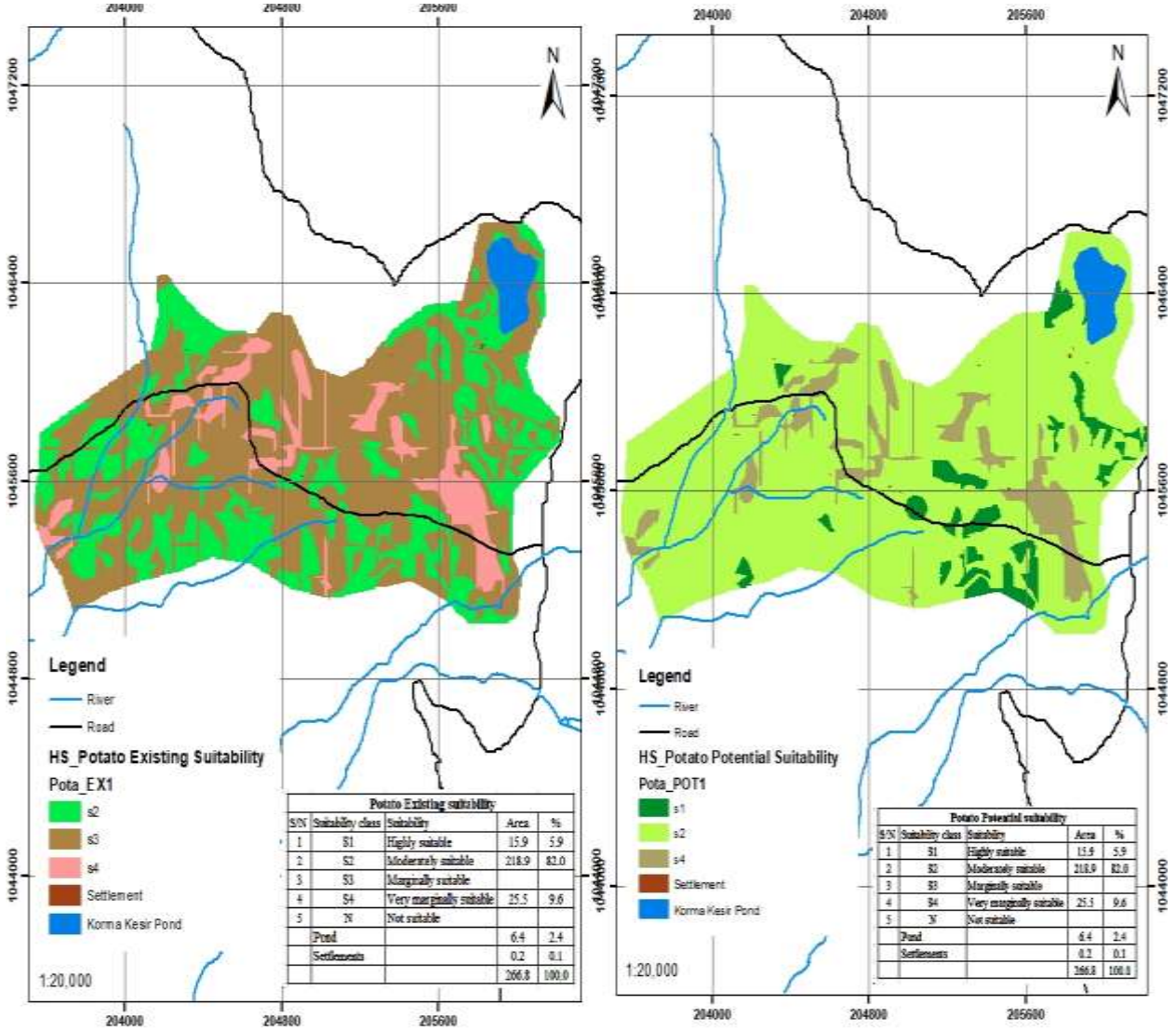
- **potato**

Potential land suitability for the crop potato can be grouped into three classes. These include the very marginally suitable lands, moderately suitable lands and highly suitable lands (Table 29

&30). Land units listed under the suitability sub class s4k (Table 29,30 and 32) are classified as the very marginally suitable land for potato crops production due to the slope of the study area (Table 32). The area of these land units is also 25.51 ha. On the other hand, land units listed under the suitability sub classes s2m1, s2m1z and s2m1zr1 are grouped under the moderately suitable lands. They are moderately limited by some chemical and physical properties of the soil like soil AWC, PH and soil depth. The area coverage of these moderately suitable lands are 8.797 ha,204.31ha and 5.76 ha respectively. On the other hand, those land units listed under the suitability sub classes s1 is grouped under the highly suitable lands. The area coverage of this highly suitable lands is 15.85ha

| Potato Potential suitability | | | | |
|---|---|---|---|---|
| S/N | Suitability class | Suitability | Area | % |
| 1 | S1 | Highly suitable | 15.9 | 5.9 |
| 2 | S2 | Moderately suitable | 218.9 | 82.0 |
| 3 | S3 | Marginally suitable | | |
| 4 | S4 | Very marginally suitable | 25.5 | 9.6 |
| 5 | N | Not suitable | | |
| | Pond | | 6.4 | 2.4 |
| | Settlements | | 0.2 | 0.1 |
| | | | 266.8 | 100.0 |

Figure 5: Potato Existing and Potential Suitability Map



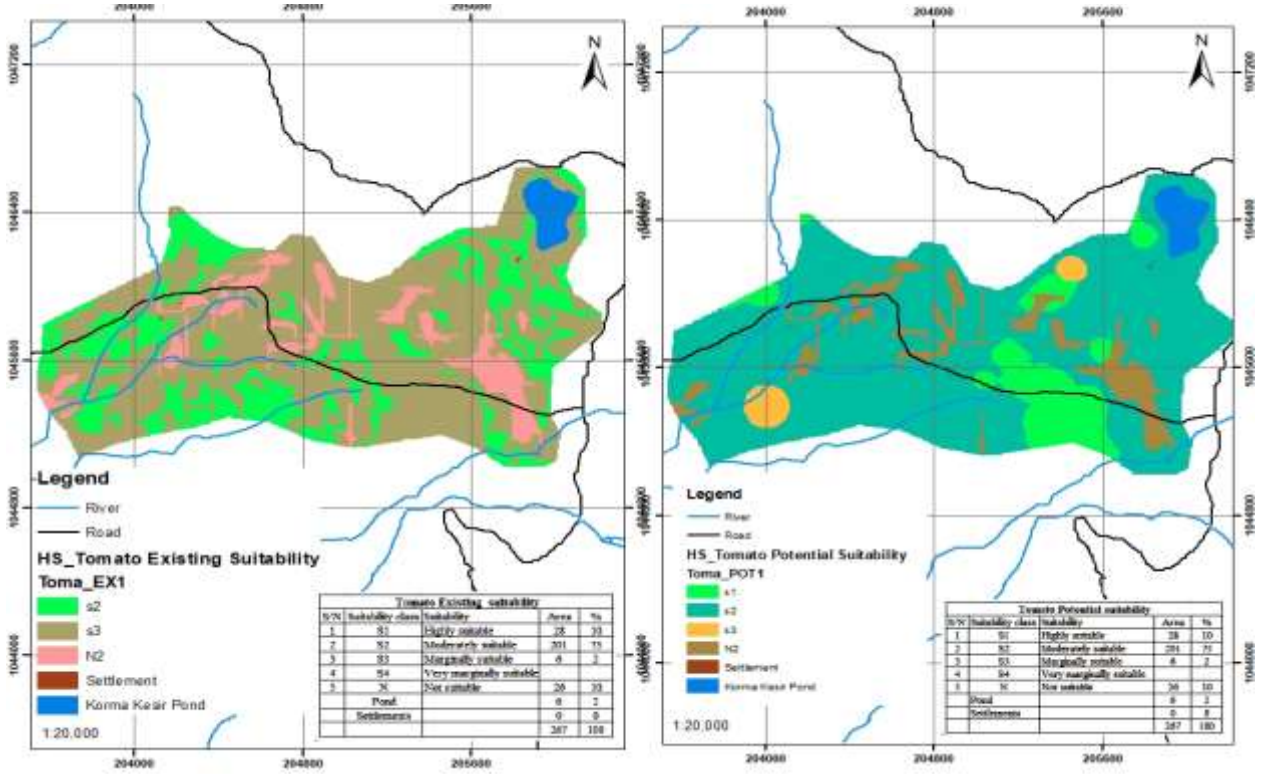

- **Tomato**

Potential land suitability for the crop tomato can be grouped into four classes. These include the permanentely not suitable lands, marginally suitable lands, moderately suitable lands and highly suitable lands (Table 29 &30). Land units listed under the suitability sub class N2k (Table 29,30 and 32) are classified as the permanentely not suitable lands due to slope of the land covers 25.51 ha, Land units s3r1is classified as marginally suitable land for tomato crops production due to soil depth of the study area (Table 32). The area of these land units is also 5.56 ha. On the other hand, land units listed under the suitability sub classes s2m1r1 is grouped under the moderately

suitable lands. They are moderately limited by some physical properties of the soil like soil AWC and soil depth. The area coverage of these moderately suitable lands are 200.96 ha. On the other hand, those land units listed under the suitability sub classes s1 is grouped under the highly suitable lands. The area coverage of this highly suitable lands is 27.96ha

| Tomato Potential suitability | | | | |
|---|---|---|---|---|
| S/N | Suitability class | Suitability | Area | % |
| 1 | S1 | Highly suitable | 27.96 | 10 |
| 2 | S2 | Moderately suitable | 200.99 | 75 |
| 3 | S3 | Marginally suitable | 5.76 | 2 |
| 4 | S4 | Very marginally suitable | | |
| 5 | N | Not suitable | 25.51 | 10 |
| | Pond | | 6 | 2 |
| | Settlements | | 0 | 0 |
| | | | 267 | 100 |

Figure 6: Tomato Existing and Potential Suitability Map

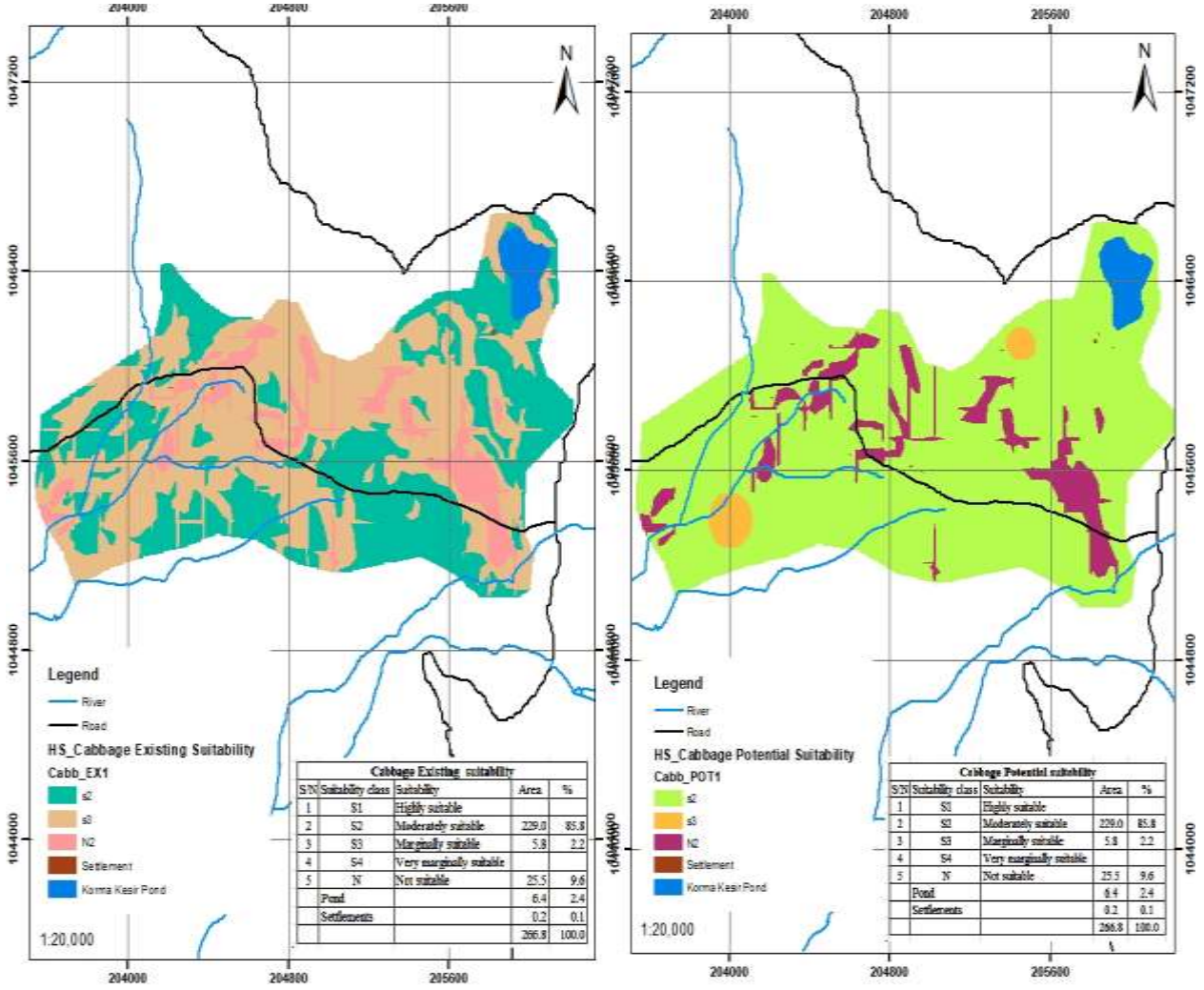


- **Cabbage**

Potential land suitability for the crop cabbage can be grouped into four classes. These include the permanentely not suitable lands, marginally suitable lands, moderately suitable lands and highly suitable lands (Table 29 &30). Land units listed under the suitability sub class N2k (Table 29,30 and 32) are classified as the permanentely not suitable lands due to slope of the land covers 25.51 ha, Land units s3r1is classified as marginally suitable land for cabbage crops production due to soil depth of the study area (Table 32). The area of these land units is also 5.56 ha. On the other hand, land units listed under the suitability sub classes s2m1r1 is grouped under the moderately suitable lands. They are moderately limited by some physical properties of the soil like soil AWC and soil depth. The area coverage of these moderately suitable lands are 200.96 ha. On the other hand, those land units listed under the suitability sub classes s1 is grouped under the highly suitable lands. The area coverage of this highly suitable lands is 27.96ha

| Cabbage Potential suitability | | | | |
|---|---|---|---|---|
| S/N | Suitability class | Suitability | Area | % |
| 1 | S1 | Highly suitable | | |
| 2 | S2 | Moderately suitable | 229.0 | 85.8 |
| 3 | S3 | Marginally suitable | 5.8 | 2.2 |
| 4 | S4 | Very marginally suitable | | |
| 5 | N | Not suitable | 25.5 | 9.6 |
| | Pond | | 6.4 | 2.4 |
| | Settlements | | 0.2 | 0.1 |
| | | | 266.8 | 100.0 |

Figure 7: Cabbage Existing and Potential Suitability Map




- **Onion**

Accordingly, Potential land suitability for the crop onion can be grouped into four classes. These include the permanentely not suitable lands, marginally suitable lands, moderately suitable lands and highly suitable lands (Table 29 &30). Land units listed under the suitability sub class N2k listed under the suitability sub classes permanentely not suitable lands due to slope of the study area, covers an area of about 25.51 ha. Where as land units classifayed as s3r1 (Table 29,30 and 32) are classified as the marginally suitable land for onion crops production due to the soil depth of the study area (Table 32). The area of these land units is also 5.76 ha. On the other hand, those land units listed under the suitability sub classes s2m1 and s2m1r1 are grouped under the moderately suitable lands. They are moderately limited by some chemical and physical

properties of the soil like soil AWC and soil depth. The area coverage of these moderately suitable lands are 21.33 ha and 200.99 ha respectively. On the other hand, those land units listed under the suitability sub classes s1 is grouped under the Highly suitable lands. The area coverage of this highly suitable lands is 6.735ha

| Onion Potential suitability | | | | |
|---|---|---|---|---|
| S/N | Suitability class | Suitability | Area | % |
| 1 | S1 | Highly suitable | 6.7 | 2.5 |
| 2 | S2 | Moderately suitable | 222.2 | 83.3 |
| 3 | S3 | Marginally suitable | 5.8 | 2.2 |
| 4 | S4 | Very marginally suitable | | |
| 5 | N | Not suitable | 25.5 | 9.6 |
| | Pond | | 6.4 | 2.4 |
| | Settlements | | 0.2 | 0.1 |
| | | | 266.8 | 100.0 |

Figure 8: Onion Existing and Potential Suitability Map

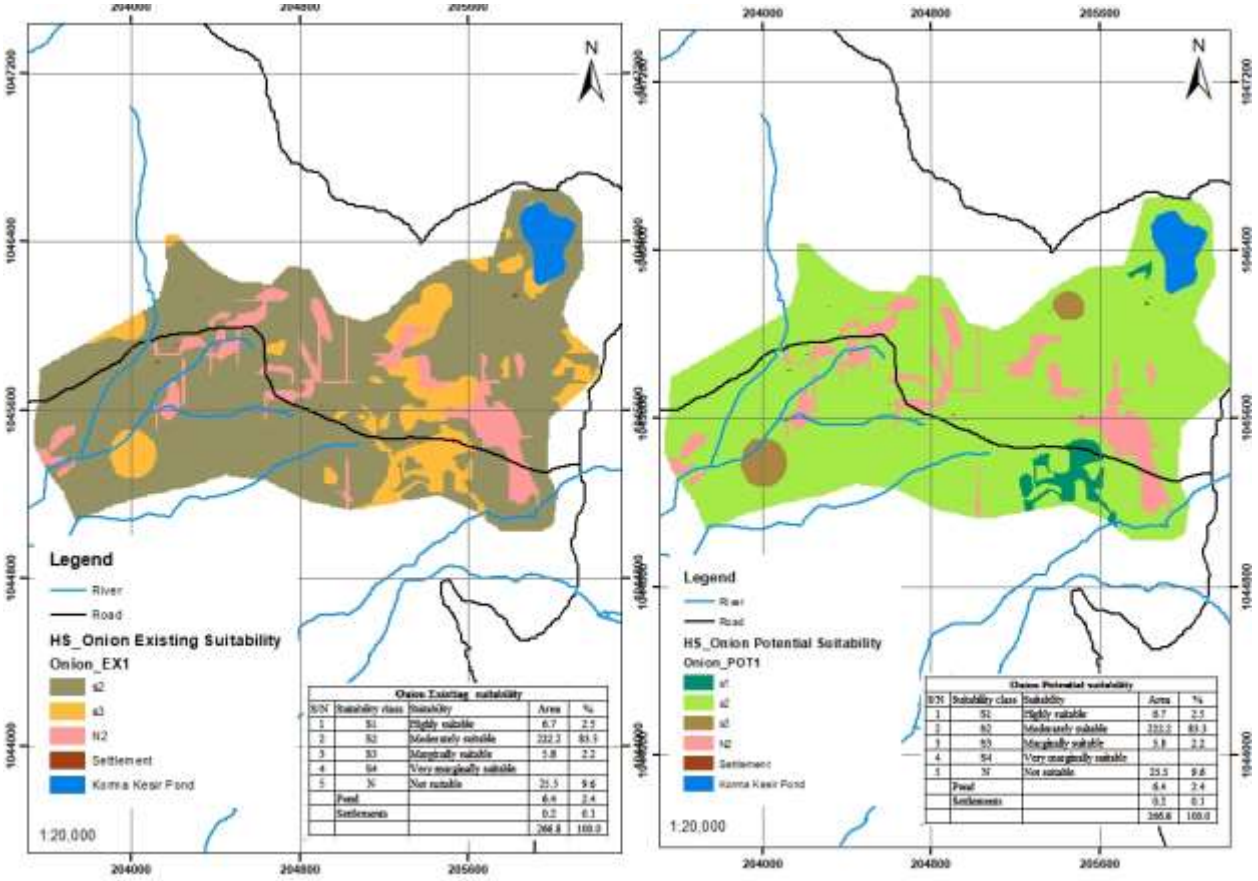



Table 28: Potential Crop Suitability by Area for surface Irrigation

| Potentaial crop suitability by area for surface Irrigation | | | | | |
|---|---|---|---|---|---|
| Crop | s1 | s2 | s3 | s4 | N |
| | Highly suitable | Moderately suitable | Marginally suitable | Very Marginally suitable | not suitable |
| | Area,ha | Area,ha | Area,ha | Area,ha | Area,ha |
| Potato | 15.85 | 218.87 | | 25.51 | |
| Onion | 6.73 | 222.22 | 5.76 | | 25.51 |
| Tomato | 27.96 | 200.99 | 5.76 | | 25.51 |
| Cabbage | | 228.95 | 5.76 | | 25.51 |

Table 29: Potential Crop Suitability by subclass and Area for surface Irrigation

| Crop | Potential suitability sub class comparing with crop for surface Irrigation | | | | | | |
|---|---|---|---|---|---|---|---|
| Potato | Potential sub class | s1m3d1n3zr1wn4k | s1m3d1zr1wn4k | s2m1 | s2m1z | s2m1zr1 | s4k |
| | Area,ha | 0.64 | 15.21 | 8.797 | 204.31 | 5.76 | 25.51 |
| Onion | Potential sub class | N2k | s1c1m3d1n3zr1wk | s2m1 | s2m1r1 | s3r1 | |
| | Area,ha | 25.51 | 6.735 | 21.23 | 200.99 | 5.76 | |
| Tomato | Potential sub class | N2k | s1m3d1n2zr1wk | s2m1r1 | s3r1 | | |
| | Area,ha | 25.51 | 27.96 | 200.96 | 5.56 | | |
| Cabbage | Potential sub class | N2k | s2m1 | s2m1r1 | s3r1 | | |
| | Area,ha | 25.51 | 27.96 | 200.99 | 5.76 | | |

Table 30: Results of Crop Existing and Potential Suitability Class Evaluation

| SMU | Area | Tomato | Tomato | Onion | Onion | Cabbage | Cabbage | Potato | Potato |
|---|---|---|---|---|---|---|---|---|---|
| | ha | Existing | Potential | Existing | Potential | Existing | Potential | Existing | Potential |
| 1CL_c | 3.1363 | s3 | s1 | s2 | s2 | s2 | s2 | s3 | s1 |
| 1CL_d | 0.6008 | s3 | s2 | s3 | s2 | s2 | s2 | s2 | s2 |
| 2CL_c | 6.7348 | s3 | s1 | s3 | s1 | s2 | s2 | s2 | s2 |
| 2CL_b1 | 0.9938 | s3 | s1 | s2 | s2 | s2 | s2 | s3 | s1 |
| 2CL_d | 4.8267 | s3 | s2 | s3 | s2 | s2 | s2 | s2 | s2 |
| 2CL_d1 | 0.6402 | s2 | s2 | s2 | s2 | s2 | s2 | s2 | s1 |
| 2SCL_c | 0.9101 | s3 | s1 | s2 | s2 | s2 | s2 | s3 | s1 |
| 2SCL_d | 0.2865 | s3 | s2 | s3 | s2 | s2 | s2 | s2 | s2 |
| 3CL_c | 1.8261 | s3 | s1 | s2 | s2 | s2 | s2 | s3 | s1 |
| 3CL_b1 | 1.8813 | s3 | s1 | s2 | s2 | s2 | s2 | s3 | s1 |
| 3CL_d | 6.4593 | s3 | s2 | s2 | s2 | s2 | s2 | s3 | s1 |
| 3SCL_d | 1.6863 | s3 | s2 | s3 | s2 | s2 | s2 | s2 | s2 |
| 4CL_c | 2.1579 | s3 | s1 | s3 | s2 | s2 | s2 | s3 | s2 |
| 4CL_b1 | 2.6620 | s3 | s1 | s2 | s2 | s2 | s2 | s3 | s2 |
| 4CL_e | 1.2159 | s3 | s3 | s3 | s3 | s3 | s3 | s2 | s2 |
| 4CL_d | 41.0269 | s2 | s2 | s2 | s2 | s2 | s2 | s2 | s2 |
| 4CL_d1 | 0.7542 | s2 | s2 | s2 | s2 | s2 | s2 | s2 | s2 |

Cont'd

| SMU | Area | Tomato | Tomato | Onion | Onion | Cabbage | Cabbage | Pot |
|---|---|---|---|---|---|---|---|---|
| | ha | Existing | Potential | Existing | Potential | Existing | Potential | Exis |
| 4SCL_c | 0.7307 | s3 | s1 | s3 | s2 | s2 | s2 | s |
| 4SCL_b1 | 0.4967 | s3 | s1 | s3 | s2 | s2 | s2 | s |
| 4SCL_e | 1.0578 | s3 | s3 | s3 | s3 | s3 | s3 | s |
| 4SCL_d | 24.7403 | s2 | s2 | s2 | s2 | s2 | s2 | s |
| 5CL_c | 2.6536 | s3 | s1 | s3 | s2 | s3 | s2 | s |
| 5CL_b1 | 1.5901 | s3 | s1 | s3 | s2 | s3 | s2 | s |
| 5CL_e | 2.5622 | s3 | s3 | s3 | s3 | s3 | s3 | s |
| 5CL_d | 75.0604 | s3 | s2 | s2 | s2 | s3 | s2 | s |
| 5CL_d1 | 3.7902 | s3 | s2 | s3 | s2 | s3 | s2 | s |
| 5SCL_c | 2.1902 | s3 | s1 | s3 | s2 | s3 | s2 | s |
| 5SCL_e | 0.9228 | s3 | s3 | s3 | s3 | s3 | s3 | s |
| 5SCL_d | 41.1185 | s3 | s2 | s2 | s2 | s3 | s2 | s |
| 6CL_d | 19.2433 | N2 | N2 | N2 | N2 | N2 | N2 | s |
| 6SCL_d | 6.2667 | N2 | N2 | N2 | N2 | N2 | N2 | s |
| Settlement | 0.1580 | Settlement | Settlement | Settlement | Settlement | Settlement | Settlement | Settle |
| Pond | 6.4427 | Pond | Pond | Pond | Pond | Pond | Pond | Po |

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

| SMU | Area | Tomato | Tomato | Onion | Onion | Cabbage | Cabbage | Potato | Potato |
|---|---|---|---|---|---|---|---|---|---|
| | ha | Existing | Potential | Existing | Potential | Existing | Potential | Existing | Potential |
| 1CL_c | 3.1363 | s3n3 | s1m3d1n2zr1wk | s2m1n1n3 | s2m1 | s2m1n3 | s2m1 | s3n3 | s1m3d1zr1wn4k |
| 1CL_d | 0.6008 | s3n1n3 | s2m1r1 | s3n1 | s2m1r1 | s2m1n1r1 | s2m1r1 | s2m1n3zn4 | s2m1z |
| 2CL_c | 6.7348 | s3n1n3 | s1m3d1n2zr1wk | s3n1 | s1c1m3d1n3zr1wk | s2m1n1 | s2m1 | s2m1n3zn4 | s2m1z |
| 2CL_b1 | 0.9938 | s3n3 | s1m3d1n2zr1wk | s2m1n1n3 | s2m1 | s2m1n3 | s2m1 | s3n3 | s1m3d1zr1wn4k |
| 2CL_d | 4.8267 | s3n1n3 | s2m1r1 | s3n1 | s2m1r1 | s2m1n1r1 | s2m1r1 | s2m1n3zn4 | s2m1z |
| 2CL_d1 | 0.6402 | s2m1n1r1 | s2m1r1 | s2m1n1r1 | s2m1r1 | s2m1r1 | s2m1r1 | s2m1 | s1m3d1n3zr1wn4k |
| 2SCL_c | 0.9101 | s3n3 | s1m3d1n2zr1wk | s2m1n1n3 | s2m1 | s2m1n3 | s2m1 | s3n3 | s1m3d1zr1wn4k |
| 2SCL_d | 0.2865 | s3n1n3 | s2m1r1 | s3n1 | s2m1r1 | s2m1n1r1 | s2m1r1 | s2m1n3zn4 | s2m1z |
| 3CL_c | 1.8261 | s3n3 | s1m3d1n2zr1wk | s2m1n1n3 | s2m1 | s2m1n3 | s2m1 | s3n3 | s1m3d1zr1wn4k |
| 3CL_b1 | 1.8813 | s3n3 | s1m3d1n2zr1wk | s2m1n1n3 | s2m1 | s2m1n3 | s2m1 | s3n3 | s1m3d1zr1wn4k |
| 3CL_d | 6.4593 | s3n3 | s2m1r1 | s2m1n1n3r1 | s2m1r1 | s2m1n3r1 | s2m1r1 | s3n3 | s1m3d1zr1wn4k |
| 3SCL_d | 1.6863 | s3n1n3 | s2m1r1 | s3n1 | s2m1r1 | s2m1n1r1 | s2m1r1 | s2m1n3zn4 | s2m1z |
| 4CL_c | 2.1579 | s3n1n3 | s1m3d1n2zr1wk | s3n1 | s2m1 | s2m1n1n3k | s2m1 | s3n3 | s2m1z |
| 4CL_b1 | 2.6620 | s3n3 | s1m3d1n2zr1wk | s2m1n1n3k | s2m1 | s2m1n3k | s2m1 | s3n3 | s2m1 |
| 4CL_e | 1.2159 | s3r1 | s3r1 | s3r1 | s3r1 | s3r1 | s3r1 | s2m1zr1k | s2m1zr1 |
| 4CL_d | 41.0269 | s2m1r1k | s2m1r1 | s2m1r1k | s2m1r1 | s2m1r1k | s2m1r1 | s2m1zk | s2m1z |
| 4CL_d1 | 0.7542 | s2m1n1r1k | s2m1r1 | s2m1n1r1k | s2m1r1 | s2m1r1k | s2m1r1 | s2m1k | s2m1 |

Cont'd

| SMU | Area | Tomato | Tomato | Onion | Onion | Cabbage | Cabbage | Potato |
|---|---|---|---|---|---|---|---|---|
| | ha | Existing | Potential | Existing | Potential | Existing | Potential | Existing |
| 4SCL_c | 0.7307 | s3n1n3 | s1m3d1n2zr1wk | s3n1 | s2m1 | s2m1n1n3k | s2m1 | s3n3 |
| 4SCL_b1 | 0.4967 | s3n1n3 | s1m3d1n2zr1wk | s3n1 | s2m1 | s2m1n1n3k | s2m1 | s3n3 |
| 4SCL_e | 1.0578 | s3n1n3r1 | s3r1 | s3n1r1 | s3r1 | s3r1 | s3r1 | s3n3 |
| 4SCL_d | 24.7403 | s2m1r1k | s2m1r1 | s2m1r1k | s2m1r1 | s2m1r1k | s2m1r1 | s2m1zk |
| 5CL_c | 2.6536 | s3n1n3k | s1m3d1n2zr1wk | s3n1k | s2m1 | s3k | s2m1 | s3k |
| 5CL_b1 | 1.5901 | s3n3k | s1m3d1n2zr1wk | s3k | s2m1 | s3k | s2m1 | s3n3k |
| 5CL_e | 2.5622 | s3n1n3r1k | s3r1 | s3n1r1k | s3r1 | s3r1k | s3r1 | s3k |
| 5CL_d | 75.0604 | s3k | s2m1r1 | s3k | s2m1r1 | s3k | s2m1r1 | s3k |
| 5CL_d1 | 3.7902 | s3k | s2m1r1 | s3k | s2m1r1 | s3k | s2m1r1 | s3k |
| 5SCL_c | 2.1902 | s3n1n3k | s1m3d1n2zr1wk | s3n1k | s2m1 | s3k | s2m1 | s3k |
| 5SCL_e | 0.9228 | s3r1k | s3r1 | s3r1k | s3r1 | s3r1k | s3r1 | s3k |
| 5SCL_d | 41.1185 | s3k | s2m1r1 | s3k | s2m1r1 | s3k | s2m1r1 | s3k |
| 6CL_d | 19.2433 | N2k | N2k | N2k | N2k | N2k | N2k | s4k |
| 6SCL_d | 6.2667 | N2k | N2k | N2k | N2k | N2k | N2k | s4k |
| Settlement | 0.1580 | Settlement | Settlement | Settlement | Settlement | Settlement | Settlement | Settlemen |
| Pond | 6.4427 | Pond | Pond | Pond | Pond | Pond | Pond | Pond |

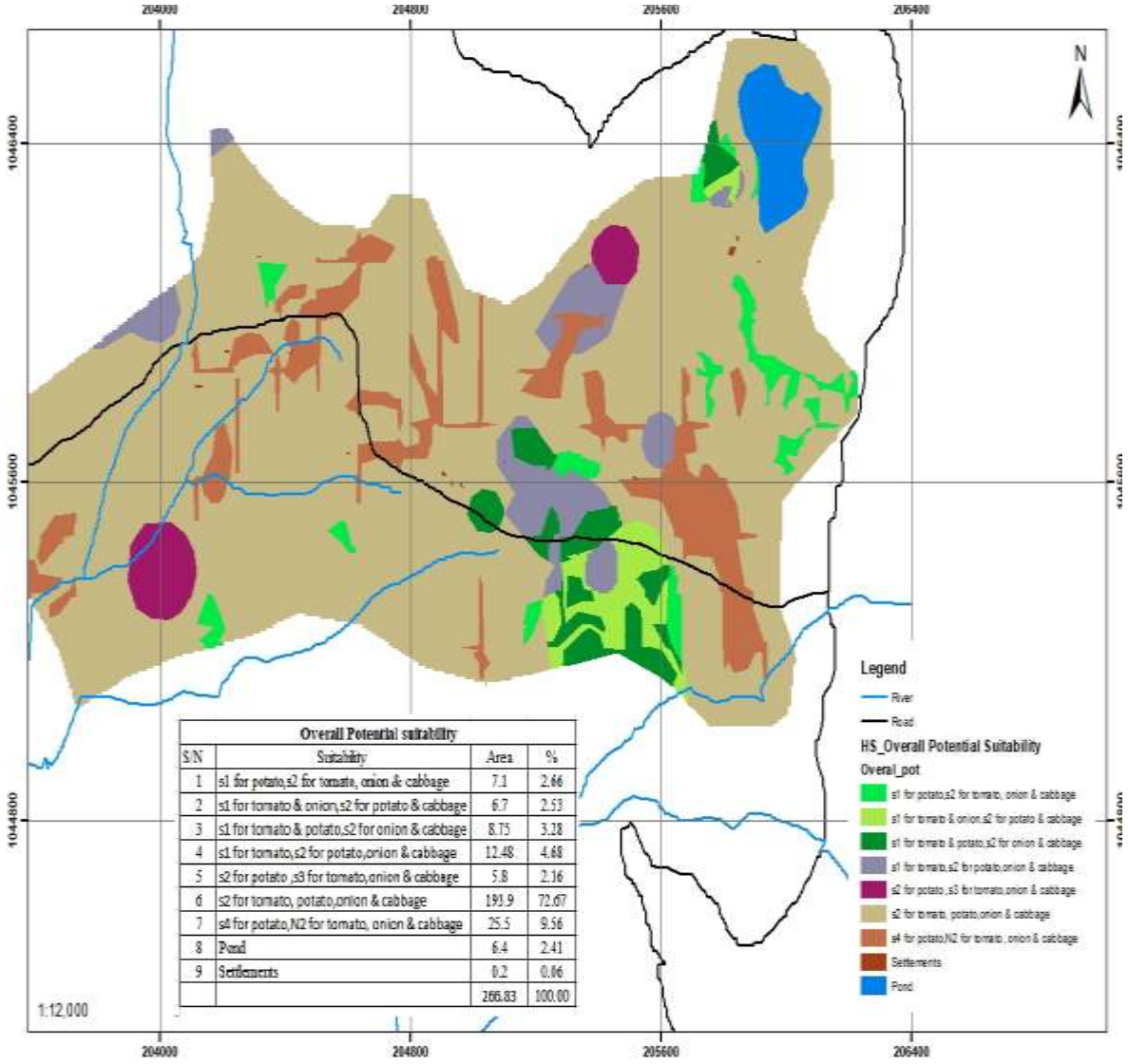
## 8.11.4. The Overall Crop Potential Suitability

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

Table 32: Final Crop Potential Suitability by SMU

| SMU | Area_ha | Overall Potential suitability by SMU | SMU | Area_ha | Overall Potential suitability by SMU |
|---|---|---|---|---|---|
| 1CL_c | 3.136 | s1 for tomato & potato,s2 for onion & cabbage | 4SCL_c | 0.731 | s1 for tomato,s2 for potato,onion & cabbage |
| 1CL_d | 0.601 | s2 for tomato, potato,onion & cabbage | 4SCL_b1 | 0.497 | s1 for tomato,s2 for potato,onion & cabbage |
| 2CL_c | 6.735 | s1 for tomato & onion,s2 for potato & cabbage | 4SCL_e | 1.058 | s2 for potato ,s3 for tomato,onion & cabbage |
| 2CL_b1 | 0.994 | s1 for tomato & potato,s2 for onion & cabbage | 4SCL_d | 24.740 | s2 for tomato, potato,onion & cabbage |
| 2CL_d | 4.827 | s2 for tomato, potato,onion & cabbage | 5CL_c | 2.654 | s1 for tomato,s2 for potato,onion & cabbage |
| 2CL_d1 | 0.640 | s1 for potato,s2 for tomato, onion & cabbage | 5CL_b1 | 1.590 | s1 for tomato,s2 for potato,onion & cabbage |
| 2SCL_c | 0.910 | s1 for tomato & potato,s2 for onion & cabbage | 5CL_e | 2.562 | s2 for potato ,s3 for tomato,onion & cabbage |
| 2SCL_d | 0.286 | s2 for tomato, potato,onion & cabbage | 5CL_d | 75.060 | s2 for tomato, potato,onion & cabbage |
| 3CL_c | 1.826 | s1 for tomato & potato,s2 for onion & cabbage | 5CL_d1 | 3.790 | s2 for tomato, potato,onion & cabbage |
| 3CL_b1 | 1.881 | s1 for tomato & potato,s2 for onion & cabbage | 5SCL_c | 2.190 | s1 for tomato,s2 for potato,onion & cabbage |
| 3CL_d | 6.459 | s1 for potato,s2 for tomato, onion & cabbage | 5SCL_e | 0.923 | s2 for potato ,s3 for tomato,onion & cabbage |
| 3SCL_d | 1.686 | s2 for tomato, potato,onion & cabbage | 5SCL_d | 41.119 | s2 for tomato, potato,onion & cabbage |
| 4CL_c | 2.158 | s1 for tomato,s2 for potato,onion & cabbage | 6CL_d | 19.243 | s4 for potato,N2 for tomato, onion & cabbage |
| 4CL_b1 | 2.662 | s1 for tomato,s2 for potato,onion & cabbage | 6SCL_d | 6.267 | s4 for potato,N2 for tomato, onion & cabbage |
| 4CL_e | 1.216 | s2 for potato ,s3 for tomato,onion & cabbage | Settlement | 0.158 | Settlements |
| 4CL_d | 41.027 | s2 for tomato, potato,onion & cabbage | Korma Kesir Pond | 6.443 | Korma Kesir Pond |
| 4CL_d1 | 0.754 | s2 for tomato, potato,onion & cabbage | | | |

Figure 9: Final Overall Crop Potential Suitability map of Hidha sombo SSIP




| Overall Potential suitability | | | |
|---|---|---|---|
| S/N | Suitability | Area | % |
| 1 | s1 for potato,s2 for tomato, onion & cabbage | 7.1 | 2.66 |
| 2 | s1 for tomato & onion,s2 for potato & cabbage | 6.7 | 2.53 |
| 3 | s1 for tomato & potato,s2 for onion & cabbage | 8.75 | 3.28 |
| 4 | s1 for tomato,s2 for potato,onion & cabbage | 12.48 | 4.68 |
| 5 | s2 for potato ,s3 for tomato,onion & cabbage | 5.8 | 2.16 |
| 6 | s2 for tomato, potato,onion & cabbage | 193.9 | 72.67 |
| 7 | s4 for potato,N2 for tomato, onion & cabbage | 25.5 | 9.56 |
| 8 | Pond | 6.4 | 2.41 |
| 9 | Settlements | 0.2 | 0.06 |
| | | 266.83 | 100.00 |

# 9. SOIL MANAGEMENT AND RECLAMATION

## 9.1. Soil Physical Soil factors

### 9.1.1. Workability

During soil survey observed no drainage proble as well as the soil texture is identified as clay loam, and Sandy 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. During soil survey observed from few fine to medium fragements, but this fragements cause no limitation for irrigation development in the study area. Surface course fragements less than 2 per cent in abundance considered as very low.

### 9.1.3. Soil Drainage

The study area is well drained and observed no flooding problem, as such, but in sloping area (slope8-15,and15-30%on Cambisols and Luvisols area of SMU 4CL_b1,4CL_c,4CL_d,4CL_d1,4CL_e,4SCL_b1,4SCL_c,4SCL_d,4SCL_e and 30-45% of SMU 5CL_b1,5CL_c,5CL_d,5CL_d1,5CL_e,5SCL_c,5SCL_d,5SCL_e,6CL_d,6SCL_d) only for few days might be observe flooding

### 9.1.4. Flooding

In sloping area (slope 8-15,15-30% and 30-45%) 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 SMU 4CL_b1,4CL_c,4CL_d,4CL_d1,4CL_e,4SCL_b1,4SCL_c,4SCL_d,4SCL_e and 30-45% of SMU 5CL_b1,5CL_c,5CL_d,5CL_d1,5CL_e,5SCL_c,5SCL_d,5SCL_e,6CL_d,6SCL_d) are slightely affected by very few splash,sheet,rill and guley erosion, where as the rest of soils of the soil mapping units are not affecte by erosion.The main causes of this splash and sheet erosion are considerable slight run off (8-15 %,15-30% and 30-45% slope land or SMU during the rainy session from the surrounding.The risk of erosion can be effectively controlled by terracing, and contour construction

## 9.2. Chemical Factores

### 9.2.1. Soil Fertility

The distributions of nutrients in the entire study are is uniform. The exchangeable Ca and Mg are high to very high in soils of the soil mapping units and identifyed Eutric Cambisols and Vertic, chromic Luvisols. The level of Potassum (K) is low to very high. Where, all soils of the soil mapping units are medium to very high level of CEC (22.29 meq/100g soil to47.06 meq/100g soil) and high level of BSP (69.57% to 91.87%). The PH value for most of the soils in the study area varies from 6.18 to 7, which is sligtely acid to neutral. As indicated in Land evaluation result the major limitation (potential suitability) for most crop is Available water holding capacity,soil depth,PH and Slope( for potato) .**Calcium to Magnesium ratio** for the dominant soil mapping units are 2.27:1 to 4.76:1(low to moderately high), which is approximately optimum for most crops.The AVP content for soils of the soil mapping units are low (4ppm) to high(36.68ppm) it needs application of organic fertilizer like compost is to considered. The total Nitrogen contents of the soils mapping unit's uniform across the entire units (that is low to very low 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 31 soil mapping units in Hidha-Sombo SSIP. The soil map is prepared at 1:10,000 scale. Geomorphology and Soils Map of Ethiopian prepared by the then Land use planning and Regulatory Department LUPRD of the Ministry of Agriculture, The Wabi Shebele River basin integrated development master plan study Project (2004) at the scale of 1 :250,000 and Erer-Mojo-Gobale Sub basin landuse study project at the scale of 1:250,000. By OWWDSE,2010, Study has been reviewed and compiled. Currently the field soil survey was carried out by Oromia Water Works Design and Supervision Enterprise. The soil survey was carried out over a gross area of some 266.82 ha at detailed level (1:10,000). Some 33 auger observation and 3 profiles were dug and described and 7 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 Hidha-Sombo SSIP are Avalable water holding capacity,soil depth and temperature(for sweet potato) Limitted flooding problem in soils of the soil mapping units( 5CL_a,5CL_c,5CL_d,5CL_and 5L_e with slope of 8-15% and 15-30%), are slightely affected by sheet, and splash erosion, where as soils of the soil mapping units 1CL_a, 1CL_c, 1CL_d, 2CL_a, 2CL_a(f), 2CL_c, 2CL_c(f), 2CL_d, 2CL_e,

2L_e, 3C_e, 3CL_a(f), 3CL_c, 3CL_c(f), 3CL_d, 3CL_d, 4CL_a, 4CL_c, 4CL_c(f), 4CL_e, 5CL_a, 5CL_c, and 5L_e are low in AVP

Therefore, the following recommendations are suggested :

- Application of organic fertilzer like compost, and/or chemical fertilzer improves the availability of phousphrous and improve the not suitable land for surface irrigation to highly and moderately suitability class.
- Some of the soil mapping units can be affected by sheet, and splash erosion. This can be controlled through careful planning and implementation Integrated Watershed Development. Technologies such as proper erosion control mechanism, such as, plantation of cover grasses, contouring and conservation structures can be incorporated specific to site condition.
- In farming areas improved agronomic practices specific to the site condition is recommended, because it is essential for controlling soil productivity, increases its water holing capacity, provide take full advantage of fertilizer, prevent the unbalanced depletion of plant nutrients improving soil condition, cover, soil and water conservation, plant protection, yields and counter acts developments of the toxic substance, if any.

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# 12. LIST OF APPENDIXES

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

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

Appendix Table 1. Continued.

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

Appendix Table 1. Continued.

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

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

Appendix Table 2: **Typical profile descriptions**

| Soil profile Description | Profile code:JP_1 | Mapping code: | Status:PS |
|---|---|---|---|
| Date | | UTM(X) | 203799 |
| Auter(s) | M &B | UTM(Y) | 1045743 |
| Region | Oromia | Elivation | 1610 |
| Zone | | Parent material | LS |
| Wereda | | Rock type | none |
| Soil classification | Cambisols | Effective soil depth | 80 |
| Human influence | PL,IU | Rockout crop | c(surrounding) |
| Landform | LT | Depth to bed rock | |
| Regional slope | | Surface coarse fragement | |
| Position | U | Micro topography | AB/AT |
| Slopeclass | 15-30% | Surfce sealing | none |
| slope aspect | | Drainage class | s/r |
| slope gradient | | Internal drainage | |
| slope form | Moderately steep | slope length | |
| Drainage(external | | Ground water | |
| erosion status | s/r/g | Surface crack | none |
| Fertilizer | | Flooding | None |
| Existing crop | Chat | Dissection | |
| Landcover | CP2 | Moisture condition | |
| Vegtaation type | WL2 | Grazing land | |

| | |
|---|---|
| 0-30 | texture,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 to coarse roots; many, fine to medium pores; non calcareous. |
| 30-80cm | slightly moisture status; 5YR3/4(moist) color;none mottling;clay texture ; many fine to medium coarse fragment; moderate, 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,fine to medium root ;few,fine to medium pores;none calcerous.. |

Cont'd

| Soil profile Description | Profile code:JP_2 | Mapping code: | Status:PS |
|---|---|---|---|
| Date | | UTM(X) | 205280 |
| Auter(s) | M &B | UTM(Y) | 1045974 |
| Region | Oromia | Elivation | 1610 |
| Zone | | Parent material | LS |
| Wereda | | Rock type | none |
| Soil classification | cambisols | Effective soil depth | 120 |
| Human influence | PL,IU | Rockout crop | c(surrounding) |
| Landform | LT | Depth to bed rock | |
| Regional slope | | Surface coarse fragement | |
| Position | U | Micro topography | AB/AT |
| Slopeclass | 15-30% | Surfce sealing | none |
| slope aspect | | Drainage class | s/r |
| slope gradient | | Internal drainage | |
| slope form | Moderately steep | slope length | |
| Drainage(external | | Ground water | |
| erosion status | s/r/g | Surface crack | none |
| Fertilizer | | Flooding | None |
| Existing crop | at,Wheat,sweet pot | Dissection | |
| Landcover | CL4,CP2 | Moisture condition | |
| Vegtaation type | WL2 | Grazing land | |

| | |
|---|---|
| 0-30 | Clear smooth boundary;Moisture status (10YR2/2) when dry,when moist(10YR2/1); no mottling,clay loam texture,strong,coarse ,angular blocky structure; none crack; hard, friable to firm when moist, slightly sticky and slightly plastic when wet; no cutans; none cemented; none mineral nodules,many, fine to coarse roots; few, fine to medium pores; non calcareous. |
| 30-120cm | slightly moisture status; 10YR2/3(moist) color;none mottling;clay texture ; none coarse fragment;moderate,fine to medium ,sub-angular blocky structure; none crack; when dry none; friable (moist), sticky and plastic(wet) consistency; none cutanic features;none cemented and none compacted ;none mineral nodules;few,fine root ;few,fine to medium pores;none calcerous.. |

Cont'd

| Soil profile Description | Profile code:JP_3 | Mapping code: | Status:PS |
|---|---|---|---|
| Date | | UTM(X) | 205126 |
| Auter(s) | M &B | UTM(Y) | 1048661 |
| Region | Oromia | Elivation | 1610 |
| Zone | | Parent material | LS |
| Wereda | | Rock type | none |
| Soil classification | Luvisols | Effective soil depth | 160 |
| Human influence | PL,IU | Rockout crop | c(surrounding) |
| Landform | LL | Depth to bed rock | |
| Regional slope | | Surface coarse fragement | |
| Position | middle | Micro topography | AB/AT |
| Slopeclass | 8-15% | Surfce sealing | none |
| slope aspect | | Drainage class | I/S |
| slope gradient | | Internal drainage | |
| slope form | strongely slopping | slope length | |
| Drainage(external | | Ground water | |
| erosion status | s/s | Surface crack | none |
| Fertilizer | | Flooding | None |
| Existing crop | Chat,Wheat | Dissection | |
| Landcover | CL3,CP2 | Moisture condition | |
| Vegtation type | WL2 | Grazing land | |

| | |
|---|---|
| 0-30 | clear and smooth boundary,moist moisture status;10YR3/1(moist) color;none mottling;clayloam texture ;none coarse fragment; strong, fine to coarse ,angular blocky structure; medium crack;slightlyhard(dry); friable to firm(moist), sticky and plastic(wet) consistency; none cutanic features;none cemented and none compacted ;none mineral nodules;few,fine to medium root ;few,fine pores;none calcerous. |
| 30-80 | clear and smooth boundary,moist moisture status;10YR2/2(moist) color;none mottling;clay texture ; common,none coarse fragment; moderate, fine to moderate,angular blockystructure; none crack;none(dry); friable (moist), sticky and plastic(wet) consistency; none cutanic features;none cemented and none compacted ;few,black/reddish,both,iron-manganese nodules mineral nodules;common,fine to medium root ;many,fine to coarse pores;none calcerous. |
| 80-160 | moist moisture status;10YR2/2(moist) color;none mottling;clay texture ;none coarse fragment; moderate, fine to medium,sub angular blockystructure; none crack;none(dry); friable to firm (moist), very sticky and very plastic(wet) consistency; none cutanic features;none cemented and compacted ; none mineral nodules;few,fine root ;few,fine pores;none calcerous |

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

| SN | Field_No(Profile description) | X | Y |
|---|---|---|---|
| 1 | JP1 | 203799 | 1045743 |
| 2 | JP2 | 205280 | 1045974 |
| 3 | JP3 | 205126 | 1045661 |

| S/S | Field No | X | Y | Elevation | S/S | Field No | X | Y | Elevation |
|---|---|---|---|---|---|---|---|---|---|
| 1 | JA1 | 205842 | 1046168 | 2431 | 18 | JA18 | 205600 | 1045700 | 2326 |
| 2 | JA2 | 205800 | 1046300 | 2436 | 19 | JA19 | 205400 | 1045700 | 2330 |
| 3 | JA3 | 205600 | 1046300 | 2414 | 20 | JA20 | 205200 | 1045700 | 2316 |
| 4 | JA4 | 205457 | 1046138 | 2358 | 21 | JA21 | 205000 | 1045700 | 2389 |
| 5 | JA5 | 205200 | 1046000 | 2315 | 22 | JA22 | 205000 | 1045400 | 2281 |
| 6 | JA6 | 205000 | 1046000 | 2333 | 23 | JA23 | 204800 | 1045400 | 2269 |
| 7 | JA7 | 204570 | 1046000 | 2229 | 24 | JA24 | 204600 | 1045400 | 1961 |
| 8 | JA8 | 204600 | 1046000 | 1787 | 25 | JA25 | 204400 | 1045400 | 2202 |
| 9 | JA9 | 204400 | 1046000 | 1767 | 26 | JA26 | 204200 | 1045400 | 2188 |
| 10 | JA10 | 204200 | 1046000 | 1739 | 27 | JA27 | 204000 | 1045400 | 2157 |
| 11 | JA11 | 204000 | 1046000 | 1721 | 28 | JA28 | 203800 | 1045400 | 2130 |
| 12 | JA12 | 203800 | 1046000 | 1700 | 29 | JA29 | 203800 | 1045700 | 2166 |
| 13 | JA13 | 203600 | 1046000 | 1677 | 30 | JA30 | 204000 | 1045700 | 2159 |
| 14 | JA14 | 204800 | 1046000 | 1821 | 31 | JA31 | 204200 | 1045700 | 2179 |
| 15 | JA15 | 206224 | 1045731 | 2392 | 32 | JA32 | 204400 | 1045700 | 2208 |
| 16 | JA16 | 206000 | 1045700 | 2394 | 33 | JA33 | 204600 | 1045700 | 2248 |
| 17 | JA17 | 205800 | 1045700 | 2339 | | | | | |

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 : Small Scale Irrigation | | | | | | Location - Hidha sombo | | | |
| | | | | | | Particle Size Distribution | | | TEXTURAL |
| LAB NO | Field Code | Depth | $P^H$ -Water | E.C | $P^H$ - KCl | Sand | SILT | CLAY | CLASS |
| | | Cm | 1:2.5 | ds/m | 1:2.5 | % | % | % | |
| 109 /19 | JP - 1 | 0-30 | 6.7 | 0.138 | 6.3 | 42 | 26 | 32 | Clay loam |
| 110 /19 | | 30-80 | 7.0 | 0.145 | 6.6 | 30 | 18 | 52 | clay |
| 111 /19 | JP - 2 | 0-30 | 6.6 | 0.074 | 6.0 | 52 | 16 | 32 | Sandy clay loam |
| 112 /19 | | 30-120 | 6.9 | 0.062 | 6.3 | 28 | 26 | 46 | clay |
| 113 /19 | JP - 3 | 0-30 | 6.2 | 0.101 | 5.8 | 36 | 36 | 28 | Clay loam |
| 114 /19 | | 30-80 | 6.3 | 0.127 | 5.8 | 34 | 22 | 44 | clay |
| 115 /19 | | 80-160 | 6.7 | 0.108 | 6.0 | 32 | 18 | 50 | clay |
| | | | Core Samples | | | | | | |
| | | | Bulk Density | | F. Capacity | | P.Wilting Point | | |
| | | | g/ $Cm^3$ | | % | | | | |
| 116 /19 | JP - 3 | 0-30 | 1.49 | | 34.6 | | 23.7 | | |
| 117 /19 | | 30-60 | 1.22 | | 44.1 | | 27.1 | | |
| 118 /19 | | 60-90 | 1.43 | | 32.7 | | 21.9 | | |

Cont'd

| LAB NO | Na | K | Ca | Mg | SUM | CEC | BS | EX. Acidity | Ex. $Al^{3+}$ |
|---|---|---|---|---|---|---|---|---|---|
| | Cmol(+)$Kg^{-1}$ | | | | | | % | Cmol(+)Kg-1 | |
| 109 /19 | 0.16 | 1.08 | 16.34 | 3.44 | 21.02 | 22.9 | 92 | _ | _ |
| 110 /19 | 0.12 | 2.05 | 15.40 | 4.39 | 21.96 | 30.6 | 72 | _ | _ |
| 111 /19 | 0.20 | 0.19 | 20.40 | 5.97 | 26.76 | 38.5 | 70 | _ | _ |
| 112 /19 | 0.24 | 0.62 | 22.46 | 9.09 | 32.41 | 35.3 | 92 | _ | _ |
| 113 /19 | 0.21 | 0.39 | 28.81 | 8.13 | 37.53 | 43.7 | 86 | _ | _ |
| 114 /19 | 0.28 | 0.22 | 30.13 | 8.21 | 38.84 | 45.4 | 85 | _ | _ |
| 115 /19 | 0.33 | 0.27 | 29.19 | 9.54 | 39.33 | 47.1 | 84 | _ | _ |
| LAB NO | T.N | O.C | O.M | C/N | Av.K | Av.P | $P_2O_5$ | $CaCO_3$ | |
| | % | % | % | | PPM | PPM | | % | gram $kg^{-1}$ |
| 109 /19 | 0.14 | 1.43 | 2.46 | 10 | 417.80 | 36.68 | 84.00 | _ | _ |
| 110 /19 | 0.07 | 0.67 | 1.15 | 10 | 788.90 | 7.04 | 16.12 | _ | _ |
| 111 /19 | 0.09 | 1.08 | 1.86 | 12 | 89.80 | 4.00 | 9.16 | _ | _ |
| 112 /19 | 0.04 | 0.31 | 0.53 | 8 | 239.80 | 9.58 | 21.94 | _ | _ |
| 113 /19 | 0.08 | 0.98 | 1.69 | 12 | 147.80 | 35.72 | 81.80 | _ | _ |
| 114 /19 | 0.07 | 0.97 | 1.68 | 14 | 97.80 | 4.00 | 9.16 | _ | _ |
| 115 /19 | 0.04 | 0.36 | 0.63 | 9 | 103.50 | 8.24 | 18.87 | _ | _ |
| Remarks | | | | | | | | | |

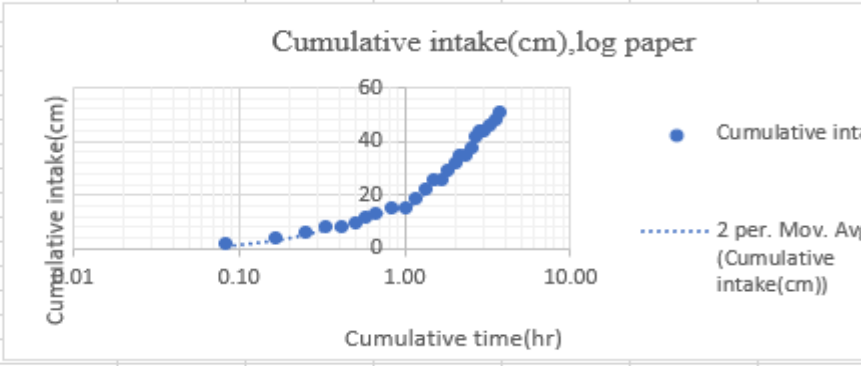
Appendix table 6**: Soil infiltration and permeability test**

I-Infiltration

| Double Ring Infiltrometer Field Data | | | | | | Project: Hidha sombo | | Site:badhadhaa | |
|---|---|---|---|---|---|---|---|---|---|
| Date:18/05/18Author: MB | | | GPS Reading:N:1046217/E:265937/Elevation:2427 | | | Land Form:LT | | Micro Topography:AT,AB | |
| Depth of insertion of ring(cm):10cm | | | Pre-wetting time (hrs)/Soil Type: chromic vertisol | | | Slope Class:8-16 | | Replication No.:1 | |
| Local time(hr:mins) | Time Interval(mins) | Interval(hr)column 2 ÷ 60mins | Cumulative time(mins) | Cumulative time(hr), column 4 ÷ 60mins | Depth of water in infiltrometer(cm) | Intake(cm) | Cumulative intake(cm/hr) | Immediate(instantanious) | mean |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9=7*3 | 10=8/5 |
| 8.00 | 0 | 0.00 | 0 | 0.00 | 15.0 | | 0 | | |
| | 5 | 0.08 | 5 | 0.08 | 13.0 | 2.0 | 2.0 | 24.0 | 24.0 |
| | 5 | 0.08 | 10 | 0.17 | 10.8 | 2.2 | 4.2 | 26.4 | 25.2 |
| | 5 | 0.08 | 15 | 0.25 | 8.8 | 2.0 | 6.2 | 24.0 | 24.8 |
| | 5 | 0.08 | 20 | 0.33 | 7.0 | 1.8 | 8.0 | 21.6 | 24.0 |
| | 5 | 0.08 | 25 | 0.42 | 15.0 | | 8.0 | 0.0 | 19.2 |
| | 5 | 0.08 | 30 | 0.50 | 13.0 | 2.0 | 10.0 | 24.0 | 20.0 |
| | 5 | 0.08 | 35 | 0.58 | 11.0 | 2.0 | 12.0 | 24.0 | 20.6 |
| | 5 | 0.08 | 40 | 0.67 | 9.5 | 1.5 | 13.5 | 18.0 | 20.3 |
| | 10 | 0.17 | 50 | 0.83 | 7.5 | 2.0 | 15.5 | 12.0 | 18.6 |
| 9.00 | 10 | 0.17 | 60 | 1.00 | 15.0 | | 15.5 | 0.0 | 15.5 |
| | 10 | 0.17 | 70 | 1.17 | 11.5 | 3.5 | 19.0 | 21.0 | 16.3 |
| | 10 | 0.17 | 80 | 1.33 | 8.0 | 3.5 | 22.5 | 21.0 | 16.9 |
| | 10 | 0.17 | 90 | 1.50 | 5.0 | 3.0 | 25.5 | 18.0 | 17.0 |
| | 10 | 0.17 | 100 | 1.67 | 15.0 | | 25.5 | 0.0 | 15.3 |
| | 10 | 0.17 | 110 | 1.83 | 11.5 | 3.5 | 29.0 | 21.0 | 15.8 |
| 10.00 | 10 | 0.17 | 120 | 2.00 | 8.4 | 3.1 | 32.1 | 18.6 | 16.1 |
| | 10 | 0.17 | 130 | 2.17 | 5.5 | 2.9 | 35.0 | 17.4 | 16.2 |
| | 10 | 0.17 | 140 | 2.33 | 15.0 | | 35.0 | 0.0 | 15.0 |
| | 10 | 0.17 | 150 | 2.50 | 12.0 | 3.0 | 38.0 | 18.0 | 15.2 |
| | 10 | 0.17 | 160 | 2.67 | 8.5 | 3.5 | 41.5 | 21.0 | 15.6 |
| | 10 | 0.17 | 170 | 2.83 | 6.0 | 2.5 | 44.0 | 15.0 | 15.5 |
| 11.00 | 10 | 0.17 | 180 | 3.00 | 15.0 | | 44.0 | 0.0 | 14.7 |
| | 15 | 0.25 | 195 | 3.25 | 13.0 | 2.0 | 46.0 | 8.0 | 14.2 |
| | 15 | 0.25 | 210 | 3.50 | 10.7 | 2.3 | 48.3 | 9.2 | 13.8 |
| | 15 | 0.25 | 225 | 3.75 | 8.4 | 2.3 | 50.6 | 9.2 | 13.5 |

Worked Example of Basic Infiltration rate using Logarithimic paper

| Cumulative time(hr) | Cumulative intake(cm) |
|---|---|
| 0.00 | 0 |
| 0.08 | 2 |
| 0.17 | 4.2 |
| 0.25 | 6.2 |
| 0.33 | 8 |
| 0.42 | 8 |
| 0.50 | 10 |
| 0.58 | 12 |
| 0.67 | 13.5 |
| 0.83 | 15.5 |
| 1.00 | 15.5 |
| 1.17 | 19 |
| 1.33 | 22.5 |
| 1.50 | 25.5 |
| 1.67 | 25.5 |
| 1.83 | 29 |
| 2.00 | 32.1 |
| 2.17 | 35 |
| 2.33 | 35 |
| 2.50 | 38 |
| 2.67 | 41.5 |
| 2.83 | 44 |
| 3.00 | 44 |
| 3.25 | 46 |
| 3.50 | 48.3 |
| 3.75 | 50.6 |




*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 (3.75, 50.6) and (3.50, 48.3), and the slope is calculated as,*

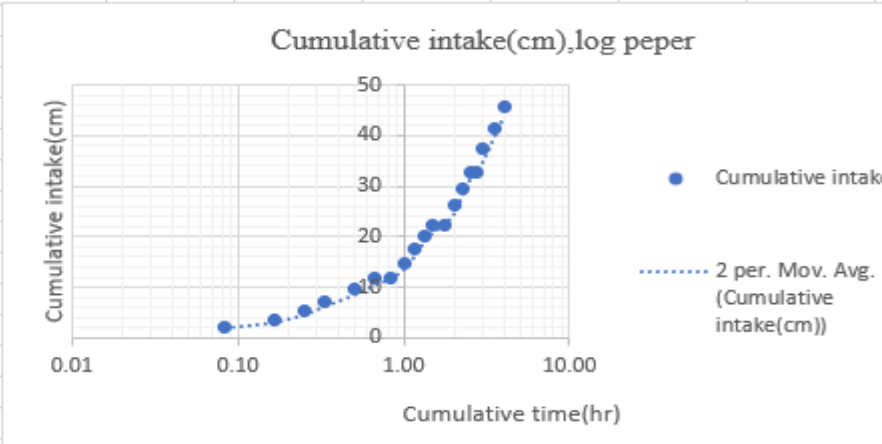
***Slope= Y2-Y1/X2-X1***

***= 50.6-48.3/3.75-3.50=9.2***

| Double Ring Infiltrometer Field Data | | | | | | Project: Hidha sombo | | Site:badhdhaa | |
|---|---|---|---|---|---|---|---|---|---|
| Date:18/05/11Author: M/B | | | GPS Reading/N:1046217/E:2959971Elevation:2427 | | | Land Form:LT | | Micro Topography:AT,AB | |
| Depth of insertion of ring(cm):10cm | | | Soil Type: chromic vertisolPre-wetting time (hrs):1Replication No.:2 | | | Slope Class:8-15 | | filtration rate(cm/hr) | |
| Local time(hr:mins) | Time Interval(mins) | Interval(hr)columon 2 ÷ 60mins | Cumulative time(mins) | Cumulative time(hr), columon 4 ÷ 60mins | Depth of water in infiltrometer(cm) | Intake(cm) | Cumulative intake(cm/hr) | immediate(instantanious | mean |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9=7/3 | 10=8/5 |
| 8.00 | 0 | 0.00 | 0 | 0.00 | 15.0 | | | | |
| | 5 | 0.08 | 5 | 0.08 | 12.0 | 2.0 | 2.0 | 24.0 | 24.0 |
| | 5 | 0.08 | 10 | 0.17 | 11.3 | 1.7 | 3.7 | 20.4 | 22.2 |
| | 5 | 0.08 | 15 | 0.25 | 9.5 | 1.8 | 5.5 | 21.6 | 22.0 |
| | 5 | 0.08 | 20 | 0.33 | 8.0 | 1.5 | 7.0 | 18.0 | 21.0 |
| | 10 | 0.17 | 30 | 0.50 | 5.4 | 2.6 | 9.6 | 15.6 | 19.2 |
| | 10 | 0.17 | 40 | 0.67 | 3.2 | 2.2 | 11.8 | 13.2 | 17.7 |
| | 10 | 0.17 | 50 | 0.83 | 15.0 | | 11.8 | 0.0 | 14.2 |
| 9.00 | 10 | 0.17 | 60 | 1.00 | 12.0 | 3.0 | 14.8 | 18.0 | 14.8 |
| | 10 | 0.17 | 70 | 1.17 | 9.3 | 2.7 | 17.5 | 16.2 | 15.0 |
| | 10 | 0.17 | 80 | 1.33 | 6.8 | 2.5 | 20.0 | 15.0 | 15.0 |
| | 10 | 0.17 | 90 | 1.50 | 4.7 | 2.1 | 22.1 | 12.6 | 14.7 |
| | 15 | 0.25 | 105 | 1.75 | 15.0 | | 22.1 | 0.0 | 12.6 |
| 10.00 | 15 | 0.25 | 120 | 2.00 | 11.0 | 4.0 | 26.1 | 16.0 | 13.1 |
| | 15 | 0.25 | 135 | 2.25 | 7.7 | 3.3 | 29.4 | 13.2 | 13.1 |
| | 15 | 0.25 | 150 | 2.50 | 4.3 | 3.4 | 32.8 | 13.6 | 13.1 |
| | 15 | 0.25 | 165 | 2.75 | 15.0 | | 32.8 | 0.0 | 11.9 |
| 11.00 | 15 | 0.25 | 180 | 3.00 | 10.5 | 4.5 | 37.3 | 18.0 | 12.4 |
| | 30 | 0.50 | 210 | 3.50 | 6.3 | 4.2 | 41.5 | 8.4 | 11.9 |
| 12.00 | 30 | 0.50 | 240 | 4.00 | 2.1 | 4.2 | 45.7 | 8.4 | 11.4 |

Worked Example of Basic Infiltration rate using Logarithimic paper

| Cumulative time(hr) | Cumulative intake(cm) |
|---|---|
| 0.00 | |
| 0.08 | 2 |
| 0.17 | 3.7 |
| 0.25 | 5.5 |
| 0.33 | 7 |
| 0.50 | 9.6 |
| 0.67 | 11.8 |
| 0.83 | 11.8 |
| 1.00 | 14.8 |
| 1.17 | 17.5 |
| 1.33 | 20 |
| 1.50 | 22.1 |
| 1.75 | 22.1 |
| 2.00 | 26.1 |
| 2.25 | 29.4 |
| 2.50 | 32.8 |
| 2.75 | 32.8 |
| 3.00 | 37.3 |
| 3.50 | 41.5 |
| 4.00 | 45.7 |




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

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

***Slope= Y2-Y1/X2-X1***

***= 45.7-41.5/4.00-3.50=8.4***

Hydraulic conductivity (permiability)

| **Saturated hydraulic conductivity** | | **measurement form** | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | **GPS Reading** | | | | | **Site:Hidi sombo** | | |
| **Date: 18/05/11** | | **N:1046217** | | | | | | | |
| **Author:M/B** | | **E: 205957** | | | | | **Elevation: 2427** | | |
| Depth of insertion of auger (cm) | | Radius(cm): 4 | | | | | | | |
| Replication No. 1 | | | | | | Replication No. 2 | | | |
| Depth(cm) :90 | | | | | | Depth(cm):90 | | | |
| **ti, sec** | **h'(t1),cm** | **h(ti),cm** | **h(t1+r/2),cm** | **Hydraulic Conductivity (m/day)** | **ti,sec** | **h'(t1),cm** | **h(ti),cm** | **h(t1+r/2),cm** | **Hydraulic Conductivity (m/day)** |
| 0 | 90 | 0 | | | 0 | 90 | 0 | | |
| 300 | 35 | 55 | 57 | **1.22** | 300 | 65 | 25 | 27 | **1.77** |
| 600 | 65 | 25 | 27 | | 600 | 67 | 23 | 25 | |
| 650 | 67 | 23 | 25 | | 650 | 69 | 21 | 23 | |
| 1200 | 70 | 20 | 22 | | 900 | 73 | 17 | 19 | |
| 1800 | 76 | 14 | 16 | | 950 | 76 | 14 | 16 | |
| | | | | | 1200 | 79 | 11 | 13 | |
| | | | | | 1250 | 80 | 10 | 12 | |
| | | | | | 1800 | 85 | 5 | 7 | |