OROMIYA NATIONAL REGIONAL STATE

Oromia Irrigation Development Authority (OIDA)

Feasibility Study, Detail Design of Wataba-Bedessa Small Scale irrigation Project:

Soil Survey and Land evaluation Study Report

Part-2: Land Evaluation Study Report

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

1.1 GENERAL

This report is the report of the study findings of the land suitability classification procedures and the suitability levels of the Wataba-Bedessa small scale Irrigation Project command area for different crops for surface irrigated development. The project site Wataba-Bedessa small scale irrigation project is located in Shirka woreda, Arsi administrative zone of Oromia regional state. The identified and proposed irrigation project site along with its command area is situated at a geographical location of 565255 - 568779E and 848756-847855N, and an altitude range from 1736 to 1662masl. The gross project area is 66.95ha.

The methodology followed for the evaluation process, of the Wataba-Bedessa Surface Irrigation Project command area, was entirely the FAO land suitability evaluation system and each mapping unit identified in the soil survey report was employed and the command area was evaluated for land utilization types (different crops such as sorghum, maize, wheat, sesame, onion, Haricot bean and pasture). The major land characters as identified in the routine soil survey work and detailed in the soil report as well as agronomy and hydrology reports were employed to rate the land qualities.

The land units were evaluated at class, subclass and order levels. Different crops as identified based on some defined criterion are evaluated and the suitability rating is made based on FAO systems. The land suitability maps for each crop in the surface irrigation are prepared and presented

1.2 OBJECTIVES

The general objective of the present work is to evaluate the suitability of the command area for the production of different crops so that the client can select among the many and cultivate and produce productive and profitable crops.

The specific objectives of the land suitability classification were:-

- To identify area of land suitable for surface irrigated agricultural development that is simultaneously confirmed to be technically feasible, economically viable, environmentally friendly and socially acceptable.
- To avoid the risk of farmer's crop failures due to shortage of rainfall, by helping the farmers to develop surface irrigated agriculture in the area in view of prevailing soil and land characteristics.
- To produce land suitability maps of the identified LUTs based on the LQs/LCs, thereby irrigation and drainage designing and planning could be possible.

1.3 Scope of the Work

The scopes of the present study are: -

- To compare the major land quality (actual conditions) of the study area with land use/environmental requirement of LUTs considered.
- To make detailed land suitability assessment of the study area for surface irrigated agriculture development (based on LUTs considered).
- To prepare land suitability maps at 1:10,000 scales for the LUTs considered.

The result will encompass the following, but not limited to:

- Standard land suitability classification report.
- Land suitability maps at 1:10,000 scales, for each land utilization types, indicating the suitability rating of each mapping unit.
- Detailed description of each rating per land unit and LUT and, summary tables showing suitability ratings and extent of each mapping units.
- Aspects of major soils and land management discussed and recommendations given.

2. LAND EVALUATION METHODOLOGY

2.1GENERAL

The land suitability evaluation method of FAO, (FAO, 1985 Guideline: Land evaluation for irrigated agriculture. Soils Bulletin No. 55) was employed for the evaluation of the soils of the Wataba-Bedessa project command area for surface irrigation development. The levels of classification of suitability classes (class, subclass, orders), as they all appear in the FAO guideline with the definition of terms and all procedures are taken from the same source. LUR were taken from Sys, et al (1993), Reddy (2004) and other sources.

In the process of evaluation, the values of each land quality/characteristic are checked against the class limits of land use requirements for each LUT and the suitability of the land units are thus rated for each LUR (land use requirement) separately. Partial suitability of the individual LURs for the LUTs are determined by determining the overall suitability of the land unit, on the basis of the suitability ratings. The suitability classes according to the suitability rating of the most limiting condition were assigned.

The overall procedures followed include, but not limited to:

- Selection and description of the land use types relevant to the development objectives
- Determination of the requirements of each selected land utilization types (LUTs)
- Translation of land characteristics to “land qualities” to be selected
- Matching comparing (factor rating) the requirements of the LUTs and land qualities of each of the mapping units, and
- Assessment of final land suitability evaluation for the LUT's to be considered.

The standard land suitability classification of FAO, which is employed in the current evaluation process, comprises three levels of evaluation (FAO, 1976). These are:-

1. The highest level of classification: - in this level two orders are distinguished: (suitable – S and unsuitable - N).
2. The second level of classification, which comprises the land suitability classes. These classes specify the degree to which land is suitable, and differentiates unsuitable land on the basis of the type of the prohibiting factor (economic, physical). At this level 3 subclasses are identified (S_1, S_2 & S_3).
3. The lowest level of classification: at this level sub-classes are identified which could reflect the type of limitation(s). The sub-classes reflect the type of limitations. They are indicated by single character. The subclass codes are defined specifically for the LUT under consideration.

2.2 Definition of Key Terms/Phrases

The FAO definition of key terms was employed in here as it appears. The entire land evaluation methodology used, as discussed in above was the FOA (1976) methodology and all key terms define those used and defined in the same source.

2.2.1 Land

Land is defined as a delineable area of the earth's terrestrial surface, encompassing all attributes of the biosphere immediately above or below this surface including those of the near-surface climate, the soil and terrain forms, the surface hydrology (including shallow lakes, rivers, marshes, and swamps), the near-surface sedimentary layers and associated groundwater reserve, the plant and animal populations, the human settlement pattern and physical results of past and present human activity, such as terracing, water storage or drainage structures, infrastructure, buildings (UN, 1995).

2.2.2 Land characteristics

Land Characteristic (LC): a simple attribute of the land that can be directly measured or estimated in routine survey in any operational sense, including by remote sensing and census as well as by natural resource inventory. Diagnostic land characteristics are the LCs that will be used to evaluate the land quality (LQ). They need to be measurable at the appropriate scale, and well related to the land quality (which is why they are called 'diagnostic').

2.2.3 Land qualities

Land Quality (LQ) is a complex attribute of land which acts in a manner distinct from the actions of other land qualities in its influence on the suitability of land for a specified kind of use; the ability of the land to fulfill specific requirements for a LUT.

2.2.4 Land use requirements

Land Use Requirement (LUR) is a condition of the land necessary for successful and sustained implementation of a specific Land Utilization Type.

2.2.5 Class determining factors

It is a variable affecting agronomic, management, land development, conservation, the environment, or socio-economic conditions that has an influence on the outputs and inputs of a specified kind of land use, and which is used to assess the suitability class in which a land unit should be placed for that use.

2.3 FAO level of classification

The levels of classification of the suitability of the soils for each specific crop or land utilization is based on the following FAO level of classification, in which each LUT can be rated to either of the five levels.

2.4 STRUCTURE OF THE FAO FRAMEWORK

The target set by the FAO framework is a four-category evaluation:
Land suitability orders: The first categorization is into Suitable/Not Suitable for a specified land use type:-

- ❖ Suitable means that sustained use of the kind under consideration will yield benefits, which justify the inputs without unacceptable risk of damage to land resources.
- ❖ Not Suitable means that the kind of land use is technically impracticable, or would cause unacceptable degradation of land resources, or that the values of expected benefits do not justify the expected costs of needed inputs.

Land suitability classes: These reflect degrees of suitability. FAO recommends three classes for the suitability order and two classes for the unsuitable order, as defined below.
Within the suitable order three classes are identified and discussed as below:

- ❖ Class S1: Land having no significant limitations to sustained use, or with only minor limitations that will not significantly reduce productivity or benefits and will not raise inputs above an acceptable level,
- ❖ Class S2: Land having limitations that, in aggregate, will reduce productivity or benefits and increase required inputs that the advantage to be gained from the land use, although still attractive, will be less than that expected on class S1 land,
- ❖ Class S3: Land having limitations that, in aggregate, are so severe for that expenditure on the land use will be only marginally justified

Within the order Not Suitable, there are two classes:

- ❖ Class N1: Currently not suitable. This land could be used for the purpose under consideration but the social or economic cost is, at present, unjustified;
- ❖ Class N2: permanently not suitable. Land having limitations that appear so severe that sustained use possible

<u>Land suitability subclasses</u>: These reflect the kinds of limitations, e.g. nutrient availability, workability - S3z, N2w. There are no subclasses within S1.

<u>Land suitability units:</u> these are subdivisions of a subclass, which differ in their response to management. Units are significant at the farm level.

Table 1: Description of Land Suitability Limitations suffixes

Subclass suffixes	Description of suffix designations
c	Climate (Temperature): **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. Surface 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 can be another solution.**
a	Sodicity: **The sodicity level of an area could be measured based on the ESP in percent of samples taken from the specific land area. Higher ESP values can cause hazardous problems due to higher sodium content.**
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, improve soil structure, and require fertilizer application.**
z	Nutrient availability: **Land having poor capacity to supply crop with nutrients, ascribed to pH, nutrient availability is lower in pH <6.0 and >7.5 by fixation.**
r	Rooting condition: **Land units with limited effective soil depth (effective depth is a depth to a limiting horizon having high amount of gravels, hard pan or toxic layers) and restrictive root penetration having massive, columnar or coarse sized structure coupled with very firm consistence and high amount of stones or gravels. Land having restrictive effective soil depth and/or penetrability, which impairs germination and hinders mechanical cultivation.**
w	Workability: **Land units with poor workability, ascribed to massive clays, poor organic matter content, very firm consistence and occurrence of high amount of stones and gravels in the surface layers.**
k	Potential for mechanization: **Land units having unfavorable slope steepness, rock hindrances, presence of large amount of surface stones and plastic heavy clays, which affects mechanized agricultural operations by any kind of implements.**

Subclass suffixes	Description of suffix designations
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.**
d'	Drainage: **Land having limitation caused by the extent of ground water level at, near or far from the surface of the land and worth impacting crop cultivation, and land having limitation related to the permeability of the soil.**
e	Erosion hazard: **Land having an increased water erosion risk under irrigation. Conservation practices and surface drainage control are required.**
f	Flood hazard: **Land having flooding problems due to high runoff resulting in higher and erratic rainfall. There may be higher to lower damage to crops at stand during germination through harvesting. The flood hazard could of lower in extent and less severe to higher and damaging type.**

Although currently Wataba-Bedessa small scale Irrigation project Command Area is completely used for agricultural cultivation purpose, mainly rain fed maize- sugar cane and vegetables (Tomato) based cropping system.

The most important crop currently grown in the project kebele Elile walena in general and the proposed Wataba-Bedessa project area in particular are maize, sugar cane and some vegetables (like Tomato)
Considering the current agricultural crops grown in the project surrounding area, the soil and climate condition, and the prevailing socio-economic aspects of the surrounding, about seven land utilization types (LUTs) were identified and defined in terms of their produce. The most viable crops selected for the evaluation purpose are , maize ,sugar cane, onion, pepper, haricot bean, Mung bean and tomato

The potential LUTs which have irrigation component and which are considered in the present land suitability assessment for the command area are:

- ❖ Irrigated maize Cultivation,
- ❖ Irrigated sugar cane Cultivation,
- ❖ Irrigated Tomato Cultivation,
- ❖ Irrigated Onion Cultivation,
- ❖ Irrigated Haricot Bean Cultivation
- ❖ Irrigated pepper Development.
- ❖ Irrigated Mung Bean Cultivation

2.5 LEVELS OF DEVELOPMENT

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

For the cultivation of these field crops a high to very high development inputs and normal to high recurring inputs are required and a lower employment opportunity with small to medium farm size is required assuming high technical know-how.

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 definitions of the land utilization types specified in thus refer strictly to factors which relate to the biophysical suitability of the land use and which are assumed not to change significantly with changes in farming systems, which can realistically be expected in the foreseeable future. Other factors, such as the use of improved seeds, fertilizers and degree of market orientation may change over a relatively short period, because of changes in the local production environment (eg. due to the construction of feeder road, subsidizing of inputs). These factors will affect the economic suitability of the land, but within the parameters defined above will not change the biophysical suitability of the land for that particular land use significantly.

The land use reflects the current land use practices that are not expected to change significantly in the near future without major interventions. The present land evaluation thus provides a systematic overview of the physical limitations of these land uses. This in turn provides a useful indication on opportunity, and type of improvements required to improve the systems.

The command area land of the Wataba-Bedessa project is mainly evaluated with these basic procedures and the land is evaluated with respect to its suitability for a given land use and the alternative land uses (i.e. LUTs) of interest were evaluated and decided separately. The relevant 'class-determining' factors that are expected to have influence on the suitability of land for the given LUT and that may vary from land unit to land unit were selected based on their impacts on its suitability. For each selected 'class-determining' factor, the appropriate land use requirement or limitations were entered into a tabular description form. For each mapping unit, land qualities and land characteristics, which are 'class-determining' with respect to the requirements and limitations of the LUT, were decided. For each land unit (identified and explained in the soil report), the appropriate values of the land qualities and land characteristics were compared. Critical limits of each land use requirement or limitation were matched with the selected land qualities/diagnostic land characteristics, to obtain a factor rating of S1, S2, S3, N1 or N2 for each combination of LUT and land unit. The factor ratings with the major limiting were presented to represent the suitability level of the mapping unit.

DATA SOURCES FOR THE LAND EVALUATION

The core land resources data of paramount importance for land evaluation are soils, climate, present land use and land cover. Therefore, the purpose of identifying land units is to provide a mapped basis of relatively homogeneous areas of land (land unit map) to be used as a building – block for land evaluation. The major data sources/information inputs for the current evaluation process are soil survey data, climatic data and hydrology data.

The soil resource was the most important and major data source for the land suitability evaluation mission. As to the practical purpose of the field and laboratory levels, soil survey was made to enable more numerous, more accurate and more useful predictions of the area for specific purposes/LUTs in the current evaluation process. The resource exploration includes:-

- the pattern of the soil cover was determined and this pattern was divided into relatively homogeneous units (mapping units),
- the distribution of these units was mapped, thereby prediction of the soil properties over any area was possible,
- The mapped units were characterized and useful statements were made about their land use potential and response to changes in management.

The soil map and mapping unit legends by themselves were not the aim of the soil survey; instead, it was entirely employed for the evaluation purpose, in which the suitability evaluation was made (based on soil/land characteristics).The other most important information for the land evaluation exercise in the evaluation of the current study area land is the climatic information. The climatic data include temperature, rainfall/precipitation, evaporation & transpiration, wind speed.

3 LAND QUALITIES/CHARACTERISTICS

3.1 DEFINITION OF LAND QUALITIES AND CHARACTERISTICS

Land qualities and characteristics are properties of land units and in this case the land unit map will be used to distinguish land units of differing suitability. As defined in chapter 2 of this report, Land quality is an attribute of land that acts in a distinct manner in its influence on suitability of land for specific type of use. Examples are temperature regime, moisture availability, toxicities, rooting conditions etc. There are a number of physical, economic and social factors, which affect the suitability of the land for any LUT.

Land characteristic is an attribute of land that can be measured or estimated and that can be used for distinguishing between land units and used as a means to describe land qualities. Example of land characteristics are pH, effective soil depth, stoniness, slope, salinity/sodicity, etc. Land qualities and characteristics are used for the present study. Some class determining factors that affect land suitability for surface irrigation like macro topography, soil depth and climate are permanent and others are modifiable at cost. The cost of necessary land improvements have to be estimated in detailed study to predict the economic and environmental consequences of development.

The assessment of land suitability for irrigated agriculture is done based on land qualities, inferred from measured land characteristics.

3.2 LAND CHARACTERISTICS OF THE PROJECT AREA

The Wataba-Bedessa SSIP area has a combination of very gently, gently and sloping to steep topography. Luvisols and Cambisols are the major soils of the command area.

The land characteristics of the area as described in the soil and other reports and analyzed exclusively for this report are presented as major land/soil physical and chemical properties. The most limiting factors for the proper utilization of the land selected and considered are, climate, land use and cover, soil erosion & land degradation, soil physical & chemical characteristics. These land characteristics were employed in the identification of the land-mapping units and are used in the evaluation of the study area to assess its potential for surface irrigation.

3.2.1Climatic Characteristics

The climatic data for the project area are taken from the report on hydrology study of the project and irrigation agronomy studies. According to the report the Mean Monthly Temperature in the Command Area is 26.47 ^{0}C with an average maximum and minimum of 30.77 to 21.78^{0}C respectively. The Mean monthly rainfall of the area is 983mm. The Relative Humidity, Sunshine hours and Wind Speed in the command area are 66%, 7 sunshine hrs and 105km/day respectively.

A maximum RH of 78% was observed during the month of July and after October reduces and reached a minimum of 53% during the month of December. A wet period provides predisposing conditions for the rapid multiplication of insect-pests and diseases and low humidity promotes water losses both from the plant body and the soil surface.

The relative Maximum sunshine hours were recorded during the months of November and December at actual values of 8.6 and 8.7hours per day, respectively. The minimum numbers of sunshine hours were recorded during July, and August amounting to 4.7 and 5.5hours/day respectively. Hence these available sunshine should be given a consideration for their adequacy for the plants to carry on photosynthesis, which affects plant productivity adversely.

The maximum wind velocity of 138km/day was observed in the month of June followed by the month of march130 km/day. High wind velocity in the month of June if accompanied by torrential/heavy rainfall is likely to be detrimental to the crops. During dry months on the contrary, wind velocity increases the loss of water both from the plant and the soil and hence frequent irrigation would be necessary, that is, total irrigation needs will increase proportionately. In a nut shell, the potential evaporation values would be relatively high. High wind velocity is likely to cause breakage of plant stems and tearing off leaves. Both of these conditions would cause a corresponding decrease in the plants photosynthetic activity and finally the productivity and production.

3.2.2 Land use condition of the project area

Land use is defined as the arrangements, activities and inputs people undertake in a certain land cover type to produce, change or maintain it (FAO 1997a). Land use defined in this way establishes a direct link between land cover and the actions of people in their environment. Not to be confused with land cover. A crop is not a land use. Recreation area is a land use term that may be applicable for different land cover types.

Land use has a major influence on the direction and rate of soil formation; its recording enhances the interpretative value of the soil data considerably. The most important crops in the Elile walena kebele in general where the current project is found, include, maize, sugar cane, vegetable (tomato). Grazing land also hosts different livestock population

3.2.4 Land cover

Land cover is the observed (bio)-physical cover on the earth's surface (FAO 1997a). When considering land cover in a strict sense it should be confined to describe the vegetation and the human-made features. However, absence of cover, as where the surface consists of bare rock or bare soil, or a shallow water surface, in practice is described under land cover as well. Land cover should not be confused with land use. For example, woodland or forest is a land cover, but the land use may be hunting or rubber tapping.

Agro ecologically, the Wataba-Bedessa small scale irrigation project area belongs to weyena dega where the monthly mean value rainfall ranges from 200.35 to 3 mm and the natural vegetation of the area are Weynadega vegetation types. The natural vegetation type and ground cover relatively follow certain pattern depending on soil types, soil depth, drainage pattern, etc. Accordingly, Mostly River and stream channels and relatively low lying plains are occupied by open woodlands. Deep green leaved trees are found along river course while the opposite occurs on the higher slopy lands soils where they are less used either for cultivation or grazing.

3.2.5 Soil erosion & land degradation in the study area

The history of erosion is an integral part of the history of agriculture, and wherever man has started agricultural practices there has been soil erosion and soil erosion has been observed and taken as one of the principal treating factor for the future development of the proposed project, due to the deterioration of the soil) in the Wataba-Bedessa area.

Soil erosion in the command area is expected to result in the loss of fine particles, nutrients and organic matter, and contributes to the loss of structural stability of the soil, surface compacting and sealing, reduced water infiltration and increased surface runoff, and therefore reducing agricultural production. The major type of soil erosion observed in the area is water erosion which is due to the high run off from the surrounding higher catchment.

Topographic features that influence erosion on the Wataba-Bedessa area are mainly higher steepness surrounding the command area. Most these flat lands are affected or faced an erosion problem due to runoff coming from the catchment area (upstream of the command area). The steepness of the topography surrounding the command area.

3.2.5 Physical & chemical soil characteristics of the study area

The physical & chemical soil characteristics worth to discuss and describe for the evaluation of the command area include the topography of the site, drainage and ground water table condition, soil depth and texture as well as stoniness/rockiness and the infiltration rate and permeability conditions of the area. Each soil characteristic is discussed for each mapping unit in Table 2.

Summary of the major land characteristics

Once after the finale soil survey report with its soil laboratory data analysis is completion, The major soil/land characteristics worth to affect the quality of the land in different aspects are will be summarized and put in below Table 2.

Table 2: Major Land characteristics of Wataba-Bedessa Irrigation project SSIP

No.	Mapping unit	Effective soil depth (cm)	Textural class top soil	BD (g/cm³) Top soil	IR (cm/hr)	HC (m/day)	pH (1:2.5 H_2O) Top soil	EC (1:2.5 H_2O) Top 100 cm	CEC me/100g of soil top soil	T.N (%) Top soil	OC (%) Top soil	C:N Top 100 cm	Av.P (ppm) top	ESP (%)Top 100 cm	AWHC mm/m	Drainage class	Slope (%)	PBS (%)Top 100 cm soils	Flooding	Area (ha)	Area (%)
1	SMU 1	200	CL	1.3	0.2-0.5	0.28	6.4	0.08	60.38	0.25	2.37	9.48	0.4	1.73	141	W	0.2-1	64.53	N	8.266	12.347
2	SMU 2	200	SCL	1.38	0.5-1	0.67	7.43	0.1	29.22	0.09	1.02	11.33	24.73	0.56	108.33	W	1-3	59.15	N	5.150	7.692
3	SMU 3	125	CL	1.33	0.8-1.5	0.4	7.4	0.03	37.2	0.1	1.35	12.37	5.80	0.73	118	W	0-2	46.71	N	11.447	17.099
4	SMU-4	145	CL	----	------	-----	7.4	0.03	37.2	0.1	1.35	12.37	5.80	0.73	118	W	2-5	46.71	N	12.247	18.293
5	SMU-5	135	SCL	-----	-----	----	----	-----	----	-----	-----	----	----	----	----	W-somewhat exce.	5-8	----	N	7.973	11.910
6	SMU-6	140	SCL	----	-----	-----	---	-----	-----	----	-----	-----	-----	-----	-----	W-somewhat exce.	8-15	-----	N	12.929	19.313
7	SMU-7	150	SCL	-----	----	------	-----	----	------	-----	----	------	-----	----	----	W-somewhat exce.	8-30	----	N	8.934	13.345
	Total area																			66.947	100.00

4. LAND USE TYPES & LAND USE REQUIREMENTS

4.1 LAND UTILIZATION TYPES

As pointed out in chapter 1, the main objective of the present study is to select optimum land use for each land units to be identified in the study area for surface irrigation. Land evaluation defines the suitability of a specific area of land (land unit) for specific LUT under stated system of management and input level. One major land use based on maize ,sorghum, wheat , high to medium scale surface irrigated agricultural development are considered for the evaluation.

The purpose of this land evaluation is to assess in qualitative terms, the biophysical suitability of the land for the land utilization, 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 at management and input levels. The land use reflects the current land use practices that are not expected to change significantly in the foreseeable future without major interventions. The present land evaluation thus will provide a systematic overview of the physical limitations of these land uses. This in turn provides a useful indication on opportunity, and type of improvements required to improve the systems. As discussed earlier, the potential LUTs which have irrigation component and which are considered in the present land suitability assessment for the command area are Irrigated Maiz Cultivation, Irrigated Haricot bean Cultivation Irrigated pepper Cultivation , Irrigated mung bean Cultivation , Irrigated onion Cultivation , Irrigated tomato Cultivation and Irrigated sugar cane, all under surface irrigation.

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

4.2 LAND USE REQUIREMENT

Of the many LURs that can be included in the definition of a LUT and hence in the evaluation, it is usually sufficient to select a small subset (FAO, 1976) and therefore, in the current evaluation attempt was made to select some critical/limiting land characteristics which are worth to limit the suitability of the Wataba-Bedessa irrigation area land for its intended purposes. Three criteria are employed for the purpose of selecting the LURs. These are:

- importance for the use;
- existence of critical values, and
- Availability of data with which to evaluate the corresponding LQ.

About 13 LQs/factor ratings (Table 3) were selected and matched to each LCs to evaluate each land mapping unit (LMU) against the identified LUTs.

Table 3: Land Quality/diagnostic factors

S/N	Description	Sub class Suffix
1	Climate	c
2	Moisture availability	m
3	Oxygen availability	d
4	Nutrient retention	n
5	Nutrient Availability	z
6	Rooting condition	r
7	Execs of salts	s
8	Toxicity	x
9	Workability	w'
10	Potential for mechanization	k
11	Land preparation and clearance	t
12	Drainage	d'
13	Erosion hazard	e

Different crops (LUTs), different irrigation methods and management systems have different ecological requirements. After considering various factors, namely agronomic, land development, management; conservation and environmental, the relevant class determining factors are defined as variables that affect the performance of LUTs on a land unit. The suitability of land for a specific use was established by taking each land unit map and rating, land qualities or land characteristics relevant to that LUT.

The crop requirements of all the selected crops are presented as mainly from Sys, C. et al. (1993) Land Evaluation (Part III): Crop requirement manual, Reddy (2004), Land Evaluation for Ethiopia guides, etc. The proposed crop requirements for surface irrigated agricultural development is based on research results in Ethiopia, and FAO & ITC guidelines & other sources. The Land use requirements are described by the land characteristics grouped to land qualities needed for the required sustained irrigated agricultural production as described below.

4.2. CROP/ENVIRONMENTAL REQUIREMENTS

Different crops require a land area of different climatic and soil properties. For example, the land, water and climatic requirement of vegetable crops greatly vary from those which are needed by field crops. Accordingly, the land use requirements of the different crops to be grown in the Wataba-Bedessa Irrigation project command area are all identified as presented in the following subsections. The crop requirements of all the selected crops are presented as it appears in the Sys, et al. (1993) Land Evaluation (Part III): Crop requirement, manual and other guides. The crop requirements are set at the surface irrigation level. The environmental requirements/crop requirements for each land utilization type are tabulated in the appendix part. About seven/six LUTs (maize, pepper, tomato, haricot bean, Mung bean, onion and sugar cane are selected and the LUR is put for these crops.

4.2.1 Environmental requirements for *Maize, (*Zea mays)

Maize because of its many divergent types, is grown over a wide range of climatic conditions, ranging from near sea-level to several thousand meter above sea-level from temperate to tropic. Maize is essentially a warm weather crop. It is widely cultivated from sea level up-to an altitude of 2,400m where mean daily temperatures are above 15^0c. Adaptability of varieties and hybrids in different climates vary widely. The right choice of the variety should be such that the length of growing period of crop matches with the length of growing season.

Maize is a sun and water-loving crop and long hot growing season with plenty of sunshine is favorable. If the mean daily temperature during the growing season is above 20^0c, the crop takes much less period to mature than in lower temperatures. At temperatures ranging between 10 to 15^0c, the seed setting is generally hampered. Optimum temperature for germination is 18^0 to 20^0c. The crop fails at temperatures above 45^0c. It can tolerate hot and dry weather conditions provided there is sufficient moisture in the soil. Temperature requirements, expressed as the sum of mean daily temperatures are 3,700 degree-days for late, 2,500 to 3,000 for medium and 1,800 degree-days for short duration varieties. Maize is very sensitive to frost particularly at seedling stage. The growing period can be reduced with irrigation.

Maize can grow on any type of soil ranging from deep heavy clays to light sandy ones. However, heavy dense clay and very sandy soils are not so suitable but heavy soils with clay content possess a high water holding capacity, organic matter and nutrients. Deep, fertile, well-drained medium soils (loam to silty loam) are most suited to the crop. The crop is susceptible to waterlogging and poor aeration conditions. The fertility demands for grain maize are relatively high and, in general, the crop can be grown continuously as long as the soil fertility is maintained. The crop is moderately sensitive to salinity but a soil PH in the range of 7.5 to 8.5 supports good crop growth. The yield decreases under increasing soil salinity.

A clean, smooth, deeply ploughed but firm seedbed is ideal. It is desirable to give first ploughing with mould board plough to bury the previous crop residues. Two to three subsequent harrowing may be done to obtain fine tilth. Surface drains can be provided under conditions where waterlogging is suspected.

Maize is a heavy feeder of nitrogen, phosphorous, potash, calcium and magnesium. Maize contains more N in its grains than any other soil-derived nutrients; hence require more of N for its production. Fertilizer application to provide 80-120 kg nitrogen, 40-60 kg P_2O_5 and 30-40 kg of K_2O per hectare may be given depending upon soil fertility, variety grown and adequacy of water availability. One-fourth of total nitrogen and total quantity of phsophatic and potassic fertilizers may be applied as basal dose at the time of sowing or applied in bands 5-7 cm deep before sowing. The rest of N should be applied in two equal doses as side dressing. When the crop is at knee high stage (20-30 days after germination) and rest of N should be applied after the emergence of flag leaf but before tassels emergence. Zinc sulphate @ 10 to 15 kg/ha may be applied as basal, if zinc is deficient. The fertilizer should be applied 10-12 cm away from the base of the plant to avoid any leaf injury.

Maize is an efficient user of water in terms of total dry matter production. It is potentially the highest yielding grain crop among cereals. The water requirement of medium duration crop is between 500 to 800 mm depending upon climatic conditions. The crop coefficient (Kc) for different growth stages are: initial stage 0.3-.0.5 (15 to 30 days), development stage 0.7-0.85 (30 to 45 days), mid season stage 1.05-1.2 (30 to 45 days), late season stage 0.8-0.9 and at harvest 0.55-0.6. Frequency and depth of irrigation has a pronounced effect on grain yield. Crop is tolerant to water deficits during vegetative and ripening periods and sensitive during flowering period including tasselling, silking and pollination. Severe water stress during flowering may result in little or no grain yield due to drying of silk. Water deficit during grain formation may lead to reduction in grain size and yield. Waterlogging, particularly during flowering and grain formation stages may reduce grain yield upto 50%.

Most of the roots of maize are concentrated in the upper 0.8 to 1.0 m depth and 80% water is depleted from this zone. The optimum water depletion level is about 40% in establishment period, between 55-65% during vegetative, flowering and grain formation periods and upto 80% during ripening period.

4.2.2 Environmental requirements for Sugarcane

Climate: Cane requires warm climate, during the growing season, with high incident of radiation. During ripening and harvesting high radiation is needed, but the weather should be drier, with cool, but frost-free temperatures (although very light frosts can be tolerated). However, frost is unknown in the Watabe beddesae area. The greater the radiation intensity, the higher will be the yield of sugarcane.

Sugarcane is best adapted to areas where the minimum mean air temperature for active growth is 20^{0}C, but variable from 18 to 22^{0}C, depending on crop variety, cultural factors (especially whether irrigated or not, because of effects on root temperatures). Foliage is harmed when air temperature for germination of sets is about >20^{0}C. The minimum mean temperatures below 13^{0}C are very important for proper sucrose accumulation during maturity period. Sugarcane growth is effectively curtailed in maximum air temperature above (soil) 38^{0}C, though, can have only very limited adverse effect. Root (soil) temperatures are more important than air temperatures.

Sugarcane grows in the range of 50-80% relative humidity values. Therefore, the relative humidity requirement for producing sugarcane can be considered as well suited (50.6%) in Watabe beddesae command area. Sugarcane requires extensive sunshine period of 12-15h/day for its growth. Therefore, the mean daily sunshine hours of the Watabe beddesae appear to be suitable for sugarcane plantation. Climatically the study area appears well suited for producing cane sugar.

Sugarcane cannot tolerate strong wind speed, because strong wind could be damaging through lodging of sugarcane.

The net water requirement of sugarcane is in the range of 1500-2500 mm/annum: equivalent to about 15000 to 25000 m^3/ha/seasons. Cane is a vegetative crop, the growth of which is directly proportional to water transpired, and therefore, maximum yields can be produced when water is freely available during growth periods. However, its greatest merit is reflected in its ability to produce compensatory re-growth after periods of water stress. It can tolerate short periods of 1 to 2 weeks of water logging or even flooding. However, this condition enhances the risk of fungal, viral and bacterial diseases. It is deep rooting crop and has high sensitivity to water supply. Hence, deep soils with high available water holding capacity of >150 mm/m is ideal.

Soils: The texture requirement of sugarcane ranges from loamy sand to permeable clays. Moderately structured friable clay loams to permeable clays, with a pore space of at least 50%, which, at field capacity, are only half-filled with water, are ideal for sugarcane. Therefore, most of the soils in the study area can be considered as moderately to marginally suitable from the context of sugarcane production. In fine textured soils, there will be a possibility of long lasting drainage problem, but cane is tolerant to short spells of water logging or even flooding. Capping (especially on silty soils) reduces water penetration and aeration.

Soils having coarse-textured and/or strong sub-soil are unsuited for surface irrigation, because during land preparation, subsoil horizons may be exposed near or at the surface, making it difficult to construct and maintain adequate furrows. In coarse textured soils nematode populations are easily built up. Infestations may be aggravated because cane is a perennial crop. The limited AWC may limit plant growth and fertilizer losses by leaching may be increased. The risk of cane crop damage from nematode infestation is higher in sandy soils. Deep and clayey soils that enable long furrows and channels to be dug and maintained without lining are the optimum requirements for surface irrigation, if the land is flat or almost flat. Soils with high infiltration rates of above 12.5 cm/hr are generally unsuited to furrow irrigation for sugarcane plantation, because an even distribution of water is difficult to maintain without the use of very short furrows. Loamy soils are considered marginally suitable, despite good drainage potential.

High bulk densities hinder root development in fine textured soils, if compacted. Cane is, moderately tolerant of periodic water logging. Germination of cane sets is substantially reduced in poorly drained soils. Thus sets subject to water logging, during heavy rains will likely show irregular germination. In general, soils of the project area are tillable over a wide to narrow range of moisture, depending on their textural differences.

Intervals can be comparatively medium to wide. In general, a well-planned drainage system and proper choice of agricultural machinery are essential to manage the soils successfully. For ease of field layout and harvesting cane, land should have long, smooth slopes of up to 1 to 3%, the higher values referring to heavier soils. Completely flat land produces problems of low runoff and under surface irrigation, of water distribution unless artificial slopes are constructed.

Groundwater table levels should be >1.5 to 2m. Cane can, however, grow successfully in conditions that are far from ideal. The groundwater table depth in the study area is sufficiently deep as to be unlikely to pose any drainage hazard. The optimum pH requirement of sugarcane is about 6.5. However, sugarcane grows in the pH range of 4.5 - 8.5, with proportional yield reduction but it can be rectified. Strongly acid soils (<4.5), however, are unsuitable. In viewing its high nutrient requirements, soils having a higher CEC are more suitable. Cane is sensitive to iron deficiency and to strongly calcareous soils that induce chlorisis. The soils of the study area are of high to moderate fertility level, and although all have low levels of organic carbon, which would respond to nitrogen fertilizer application, this can be easily rectified.

4.2.3 Environmental requirements for vegetables

4.1.1.1 Onions (Allium cepa) and cabbage (Brassica oleracea):

4.2.5 Environmental requirements for Onions (*Allium cepa*)

Onions (*Allium cepa*): These vegetables have more or less similar soil requirement. These vegetables prefer medium texture and well drained and well-structured soils. They have shallow rooting depth of less than 60 cm and require high nutrient. They grow in the pH range of 6.0 to 7.5.

Climate: During the early growth stage of onion cool conditions with adequate moisture supply is most suitable but warm and drier conditions are required at maturation, harvesting and curing stages. The optimum temperatures for germination of onion crop ranges from 10 - 25^{0}C, where early maturity and low yields occur at temperatures > 22^{0}C. The optimum precipitation for this crop is 350 to 600 mm in a given growth cycle and low air humidity and low temperatures lead to flowering.

Soil: Well aerated, Fertile and loamy textured and friable soils are suited for onion growing as long as sufficient water can be retained. The maximum rooting depth of the crop is 50 cm and onion can be successfully grown on peat soils.

Salinity & sodicity: The optimum pH range of the soils for this crop is 6.0 to 7.8 and a 50% yield reduction is observed at an ESP of 35%. No yield reduction has been experienced at an EC of <1.2 dS/m.

These crops can yield 140 to 200 Qt/ha on rain-fed good commercial management and 350 to 450 Qt/ha in irrigated but the same management. The production of the crop in irrigated average farmer level management is 100 to 200 Qt/ha.

4.2.3 Pepper (Capsium annum)

Climate: The optimum temperature for germination of pepper is 18 – 24^{0}C, with optimal growth temperature of 18 – 26^{0}C. The crop requires 600 – 1200 mm of

precipitation per growing cycle, and the rainfall need be well distributed. Heavy rain during flowering and fruiting is harmful to the crop, and the crop is sensitive to strong winds.
Soil: Light, deep and well-drained soils with an adequate water holding capacity are preferred with maximum rooting depth of 100 cm. The crop is sensitive to water logging.
Salinity and sodicity: The optimum pH should be 6.0 to 7.6 and at an exchangeable sodium percent (ESP) of 20, there could be a 50% yield reduction. No yield reduction is expected at an electrical conductivity (EC) of less than 1.5 dS/m and 100% yield reduction is observed at an EC of 8.5 dS/m and above.

4.2.4Tomato (Lycopersicum esculentum)

Climate: The germination of tomato seeds is observed at temperatures between 10 and 35^{0}C with an optimum temperature of 16 - 30^{0}C. An optimum growth can be accomplished at air temperature between 18 and 26^{0}C. The temperature range required at flowering is 18 - 24^{0}C and at fruit setting it is 12 - 32^{0}C; the optimum range is 16 - 22^{0}C. Tomato is sensitive to frost. Tomatoes are best grown in areas that have a rainfall of 400 - 700 mm per growing cycle, in which moisture is required from flowering to harvest and too high rainfall causes the fruit to rot. Tomato does not tolerate shade, and higher air humidity favors diseases occurrence. Hot and dry winds lead to flower drop and hence reduce yield.
Soil: Tomato grows on different textured soils, especially on light silt or clay loam textured soils with a maximum rooting depth of 0.6 meters and the soil depth is optimal if it is greater than 1.50 meters. Water logging is known to increase the incidence of disease to tomato production.
Sodicity & Salinity: The optimum pH of the soils for the crop could be with in a range of 6.0 – 7.5 and 50% yield reduction is observed at an ESP of 35%. Even if the crop is most sensitive at germination and early growth, no yield reduction is expected to an electrical conductivity of < 2.5 dS/m.
In well-managed commercial rain-fed cultivation, a yield of 45 to 50 ton/ha is observed and in irrigated cultivation, the yield increases to 45 to 65 ton/ha.

4.2.6 Environmental requirements for Haricot bean (Phaseolus vulgaris)

Climate: Beans are grown in the lowland humid tropics. The common temperature range for beans is 18-30oC.the optimum temperature range is 15-200C.the soil temperature for germination and should be > 150C.the crop is sensitive to temperature above 30^{o}C, especially at flowering and seed set. Beans are sensitive to frost, flowerings are damaged at 5^{o}C.the total precipitation should be 400-500mm/growing cycle. Moisture stress should be avoided in the flowering and setting periods. Dry weather is required at harvest. Excessive rain cause flowering crop and diseases. a medium to high relative air humidity is required, especially at flowering. Strong winds may damage the crop. Dry winds affects the pollination and therefore the yield.

Soil: Haricot bean grows on soils with a texture ranging from loamy sand to (Kaolinitic) clay, optimal texture is loam to clay loam. The minimum soil depth is

0.5m.the optimum soil depth is >0.75m. The maximum rooting depth of haricot beans is 1.00 to 1.5m.soils that show surface capping should be avoided. Moderately well rained soils are most suitable. The crop is sensitive to waterlogging, surface water standing for only a few hours damages the crop. The pH ranges 5.2 to 8.2 optimum pH= 6.0 to 7.

Salinity & sodicity: no yield reduction will take place at an electric conductivity(EC) of 1<ds/m, while the yield reduction is 10% at 1.5,25% at 2.3;50% at 3.6; 100% at 6.5% ds/m. Sodicity will have yield reduction of 50% at percentage of exchangeable sodium >15%.

5. LAND SUITABILITY CLASSIFICATION

Land can be evaluated for its current/actual suitability and its potential suitability. An actual suitability does not take in to account any improvements that will be made. In essence, it is a statement of the suitability of the land at the current state (Sogreah, 1982). Potential suitability refers to the situation of a land once specified measures have been taken to overcome major problems. The Wataba-Bedessa small scale surface irrigation project area is evaluated at the current condition in more detail and its potential suitability (for ease of showing the potential of the area) for the specified irrigation system.

5.1 LAND SUITABILITY CLASSIFICATION BY LAND UTILIZATION TYPES

The soil report for the study area has produced about 7 soil mapping units land units in the command area and each mapping unit is evaluated for its suitability to the intended surface irrigation project. In the Wataba-Bedessa command area all mapping units have got deficiencies to be rated as highly suitable for the selected land utilization types. Therefore, the entire area needs at least some treatments to discharge maximum profits expected from an ideal land area.

Soil mapping units-1, SMU-2 and SMU-3 are moderately suitable (S2cmd) for all proposed crops selected LUTs due climate, moisture availability and drainage problems.

SMU-4 is marginally suitable (S3tcmz) for pepper, tomato, haricot bean, Mung bean and sugar cane due to climate(c), nutrient availability (z), moisture availability (m) and land development (t) limiting problems.

SMU-5 currently not suitable (N1tdmwc) for tomato onion, pepper, Mung bean, haricot bean and permanently not suitable (N2t) for sugar can due to

SMU-6 is permanently not suitable (N2te) for all the selected crops except for maize which is rated as currently not suitable (N1te). SMU-7 is permanently not suitable (N2ted) for all the selected crop LUTs due to the land development (slope) and erosion

These mapping units which are moderately suitable and marginally suitable mapping units can be still upgraded by improving the prevailing conditions. Lands, which fall under marginally suitable are known to have physical and chemical limitations, such as low nutrient availability due to low pH, nd rooting condition due to low organic carbon contents, moisture availability due to moderate available water holding capacity, drainage problem due to low permeability, low oxygen availability due to drainage problem and problems in land preparation due to slope, erosion and vegetation cover

These marginally suitable areas are lands having limitations that, in aggregate, are severe so that expenditure on the land use will be only marginally justified. These lands need intensive management so that sustainable and improved utilization of the area could be possible. The evaluation of the mapping units for the selected LUTs is discussed as below and the actual land suitability results are presented in **Error! Reference source not found.** below.

Table 4: Summary of actual land suitability by LMU & LUT

Land Mapping unit(SMU)	Area		LUT						
	hac	%	MAIZ	Tomato	ONION	Pepper	Haricot bean	Mung bean	Sugar cane
SMU-1	8.266	12.347	S2	S2	S2	S2	S2	S2	S3
SMU-2	5.150	7.692	S2	S2	S2	S2	S2	S2	S2
SMU-3	11.447	17.099	S2	S2	S2	S2	S2	S2	S2
SMU-4	12.247	18.293	S2	S2	S2	S3	S3	S3	S3
SMU-5	7.973	11.910	S3	N1	N1	N1	N1	N1	N2
SMU-6	12.929	19.313	N1	N2	N2	N2	N2	N2	N2
SMU-7	8.934	13.345	N2	N2	N2	N2	N2	N2	N2
	66.947	100.00							

5.1.1 Land suitability for maize cultivation

Under the current suitability of the study area, 37.11ha(55.43%) of the total command area is moderately suitable (S2) for maize cultivation under surface irrigation, the major limiting factor of the unit is due to low organic carbon, low AWC, surface stoniness and climate(temperature) drainage limiting condition. While7.97ha (11.91%) of the total command area is currently marginally suitability (S3) for maize cultivation under surface irrigation, the major limiting factor of the unit is due to low OC , climate and slope limiting condition.
About 12.92ha (19.31%) and 21.86ha(32.66%) of the total command area is currently(N1) and permanently(N2) not suitable for maize cultivation under surface irrigation, respectively. the major limiting factor of the unit is due to high slope topography limiting condition.

5.1.3 Land suitability for sugar cane cultivation

Under the current suitability of the study area, 20.51ha(30.64%) of the total command area is Marginally suitable (S3) for sugar cane cultivation under surface irrigation, the major limiting factor of the unit is due to slope, drainage and climate(temperature and humidity) limiting condition.
About 16.59ha (28.29%) of the total command area is moderately suitable for sugar cane cultivation under surface irrigation, the major limiting factor of the unit is due to slope, AWC, and drainage limiting condition. while 29.84ha (44.57%) of the total command area is permanently not suitable (N2) for sugar cane cultivation under surface irrigation, the major limiting factor of the unit is due to high slope topography limiting condition.

Most of the potentially irrigable soils of the area are uniform, their land management requirements are nearly the same which make it easier to introduce and adapt nearly similar agricultural practices and management techniques.

5.1.4 Land suitability for VEGETABLES (ONION, TOMATO) CULTIVATION

Under the current suitability of the study area, 37.11ha(55.43%) of the total command area is moderately suitable(S2) to onion, and tomato cultivation under surface irrigation, the major limiting factor of the unit is due to slope, AWC, surface stoniness organic carbon and drainage limiting condition. Besides 7.97hac (11.91%) of the total command area are also currently not suitable (N1) due to the slope,.
About 21.87hac or 32.66% of the command area are permanently not suitable (N2) for onion, and tomato cultivation due to high slope topography.

5.1.5 Land suitability for VEGETABLES (HARICOT BEAN, PEPPER AND MUNG BEAN) cultivation

Under the current suitability of the study area, 24.86ha(37.14%) of the total command area is moderately suitable(S2) to Haricot bean,pepper and Mung bean cultivation under surface irrigation, the major limiting factor of the unit is due to slope, AWC, low OC, soil pH and surface stoniness limiting condition.

Besides 12.25hac (18.29%) of the total command area are also marginally suitable(S3) due to the slope, climate, AWC, low OC, low soil pH and surface stoniness are the limiting factor for cultivating these crops
About 7.97hac or 11.91% of the command area are currently not suitable (N1) for Haricot bean and Mung bean cultivation due to high slope topography and erosion

Besides 21.87hac (32.66%) of the total command area are also Permanently not suitable (N2) due to the higher slope, surface stoniness and erosion are the limiting factor for cultivating these crops

5.2 SUITABILITY BY MAPPING UNITS

5.2.1 SMU-1

The units rated as marginally suitable (S3) for the vegetables, sugar can and moderately suitable (S2cmr) for cereals (maize) proposed crops, with the extent of 8.266ha (12.347%) of the total area. This mapping unit is downgraded to S3 and S2, because of, climate (temperature) organic carbon, drainage soil permeability and available water holding capacity (m) limiting factor of the command area soil for the cultivation of vegetable, cereals and sugar cane.

5.2.2 Suitability of mapping units 2

The units rated as marginally suitable (S3) for the vegetables and sugar can while this mapping unit is moderately suitable(S2) for the cereals(maize) and all the proposed crops, with the extent of 5.150ha (7.692%) of the total area. This mapping unit is downgraded to S3 and S2, because of, climate (temperature) organic carbon, drainage soil permeability and available water holding capacity (m) limiting factor of the command area soil for the cultivation of vegetable cereals and sugar cane.

5.2.3 Suitability of Soil mapping units 3

This unit covered an area of 11.447ha (17.099%) of the total area. The mapping units are moderately suitable (S2) for vegetables, cereals and sugar cane proposed crops cultivation, due to the climate, available water holding capacity of the soil, surface stoniness, organic carbon soil drainage limiting factor.

But still this mapping unit could only be cultivated under rain fed agricultural system for its very high steep gradient.

5.2.4 Suitability of Soil mapping unit- 4

This unit covered an area of 12.247ha (18.293%) of the total command area. The mapping units are marginally suitable (S3) for sugar cane cultivation due to slope, climate and available water holding capacity limiting factors and moderately suitable (S2) for vegetables and cereals crop cultivation, slope, climate, AWC, surface stoniness, and OC drainage limiting factor.

5.2.5 Suitability of Soil mapping unit- 5

This unit covered an area of 7.973ha (11.910%) of the total area. The mapping units are permanently not suitable (N2t) for sugar cane cultivation due to high slope limiting factor and marginally suitable for vegetables and cereals due to slope, climate, AWC and drainage limiting factors.

5.2.6 Suitability of Soil mapping unit- 6

This unit covered an area of 12.929ha (19.313%) of the total area. The mapping units are permanently not suitable (N2t) for the proposed vegetables and sugar cane cultivation due to the high slope limiting factor. While this mapping unit is currently not suitable (N1) for cereals crop cultivation due to topography(slope) limiting factor.

But still this mapping unit could be cultivated with cereals under rain fed agricultural system

5.2.7 Suitability of Soil mapping unit- 7

This unit covered an area of 8.934ha (13.345%) of the total command area. The mapping unit is permanently not suitable (N2) for the cultivation of vegetables, cereals and sugar can proposed crops due to the topography of the mapping unit (high slope class) limiting factor.

Table 5: Land suitability classes, sub classes rating of Wataba Bedessa land units by LUTs and their extent

	Area(ha)	Area (%)	Vegetables(pepper, tomato, haricot bean)	CEREALS(maize)	SUGAR CANE	
SMU-1	8.266	12.347	S3dcm	S2cmd	S3dc	
SMU-2	5.150	7.692	S2cmnd	S2cmr	S2tmd	
SMU-3	11.447	17.099	S2cmd	S2cmr	S2md	
SMU-4	12.247	18.293	S2tcm	S2cmr	S3tdr	
SMU-5	7.973	11.910	S3tcmd	S3tc	N2t	
SMU-6	12.929	19.313	N2t	N1t	N2t	
SMU-7	8.934	13.345	N2t	N2t	N2t	
Total area	66.947	100.00				

5.3 Potential Land Suitability

Suitability ratings of a given land-mapping unit may change over time as a consequence of improvements. Land improvements can modify existing land qualities (a minor improvement is temporary in nature and lies within the technical capacity of an individual farmer e.g. fertilizer application). A major improvement is a large, non-recurrent input which causes a permanent change in the land qualities and which lie usually outside the technical capacity of an individual farmer (e.g. a regional drainage scheme) (FAO, 1983) or as a consequence to changes in one or more of the underlying assumptions (e.g. a change in input level).

The potential suitability values are drawn by undertaking mitigation measures on the limiting factors, which can be easily avoided. In some cases, most of the limiting factors which make the land unsuitable or marginally suitable for that plan might not be avoided at all or might need huge investment and higher standard technologies. In such cases, the land is considered as permanently not suitable due to physical and economic reasons. Therefore, most actually unsuitable lands are put as they appear.

5.3.1 Potential land suitability by LUT

As discussed in the introduction part of this chapter (chapter 5) an actual suitability does not take in to account any improvements that will be made. In essence, it is a statement of the suitability of the land at the current state (Sogreah, 1982). Potential suitability refers to the situation of a land once specified measures have been taken to overcome major problems. The Wataba-Bedessa SSIP area is evaluated at the current condition and its potential suitability for the specified irrigation system.

5.3.2 Potential land suitability by mapping unit

The major limiting factors for each mapping unit are rated for their suitability for future use but it could be possible by improving fertile characters and avoiding harsh characters of the limiting factors. The summary of the potential lands suitability is given as below in

Table 6, by LMU and LUT.

5.4 ACTUAL LAND SUITABILITY MAPS

The evaluation results are presented in the previous sections in reference to their actual and potentia1 suitability to the evaluated different LUTs or crop types. For ease of simple accessibility and understanding of each land units, the actual suitability results for each crop/land utilization type are presented as land suitability maps of the given crop, but the potential suitability maps are not included. The maps are presented employing the legends in

Table 8

Table 6: Actual or currently suitability class LUT by LMU

Ser. No	LUT	Area Coverage by Suitability level							Total (S+N)
		S_1	S_2	S_3	$S_1+S_2+S_3$	N_1	N_2	N_1+N_2	
1	Maize	0	37.1103	7.973101	***45.0834***	12.92944	8.934309	***21.86375***	**66.94715**
2	Haricot bean	0	24.86338	12.24692	***37.1103***	7.973101	21.86375	***29.83685***	**66.94715**
3	Tomato	0	37.1103	0	***37.1103***	7.973101	21.86375	***29.83685***	**66.94715**
4	Onion	0	37.1103	0	***37.1103***	7.973101	21.86375	***29.83685***	**66.94715**
5	Pepper	0	24.86338	12.24692	***37.1103***	7.973101	21.86375	***29.83685***	**66.94715**
6	Mung bean	0	24.86338	12.24692	***37.1103***	7.973101	21.86375	***29.83685***	**66.94715**
7	sugar can	0	16.59711	20.51319	***37.1103***	0	29.83685	***29.83685***	**66.94715**

Table 7: Summary of potential land suitability by LMU & LUT

Land Mapping unit(SMU)	Area ha	%	LUT MAIZ	Tomato	ONION	Pepper	Haricot bean	Mung bean	Sugar cane	
SMU-1	8.266	12.347	S2	S2	S2	S2	S2	S2	S2	
SMU-2	5.150	7.692	S2	S2	S2	S2	S2	S2	S2	
SMU-3	11.447	17.099	S2	S2	S2	S2	S2	S2	S2	
SMU-4	12.247	18.293	S2	S2	S2	S2	S2	S2	S2	
SMU-5	7.973	11.910	S2	S2	S2	S2	S2	S2	N2	
SMU-6	12.929	19.313	S2	N2	N2	N2	N2	N2	N2	
SMU-7	8.934	13.345	N2	N2	N2	N2	N2	N2	N2	
	66.947	100.00								

Table 8: Legend for actual land suitability maps

Class Code	**Description**	**Suitability level (area covered by each LUT)**						
		MAIZ	Tomato	ONION	Pepper	Haricot bean	Mung bean	Sugar cane
S1	Highly suitable	0.000	0.000	0.000	0.000	0.000	0.000	0.000
S2	moderately suitable	37.110	37.110	37.110	24.863	24.863	24.863	16.597
S3	marginally suitable	7.973	0.000	0.000	12.247	12.247	12.247	20.513
sub total	sub total	45.083	37.110	37.110	37.110	37.110	37.110	37.110
N1	currently unsuitable	12.929	7.973	7.973	7.973	7.973	7.973	0.000
N2	permanently unsuitable	8.934	21.864	21.864	21.864	21.864	21.864	29.837
sub total	sub total	21.864	29.837	29.837	29.837	29.837	29.837	29.837
Grand total	grand total	66.947	66.947	66.947	66.947	66.947	66.947	66.947

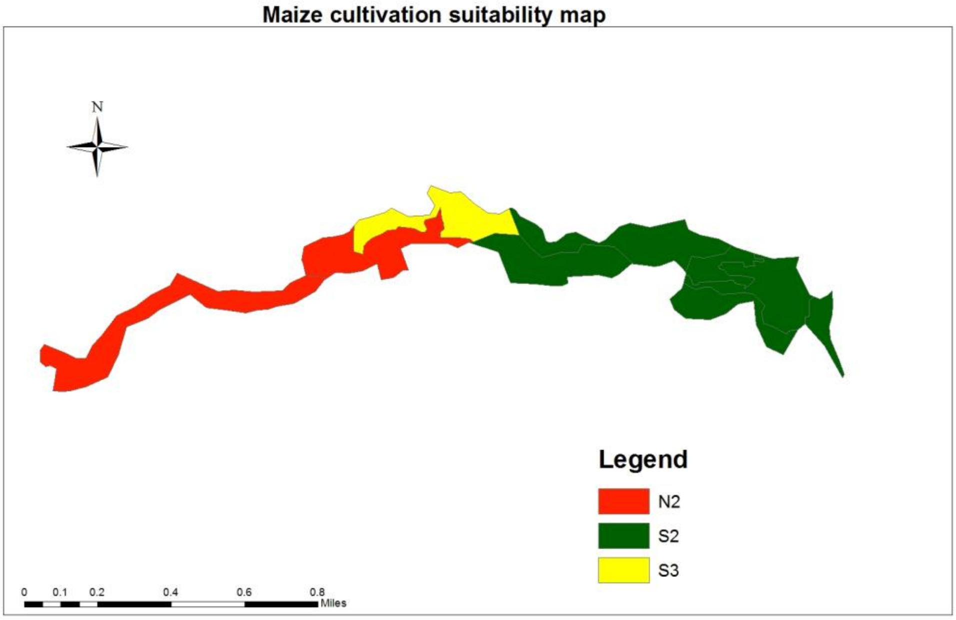

Figure 1: Actual Land Suitability Map for Surface Irrigated Maize Cultivation

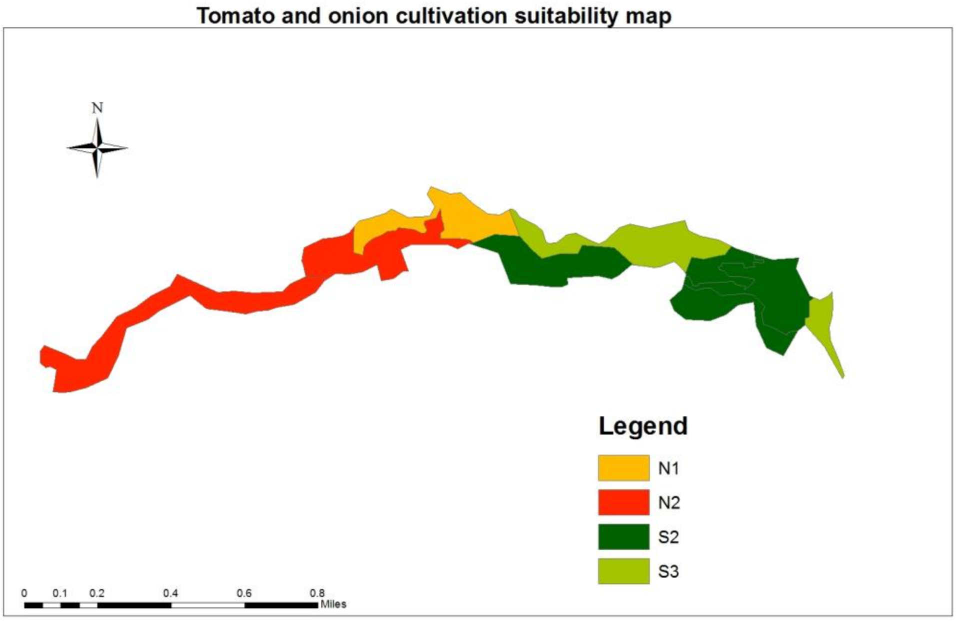

Figure 2: Actual Land Suitability Map for Surface Irrigated tomato and onion Cultivation

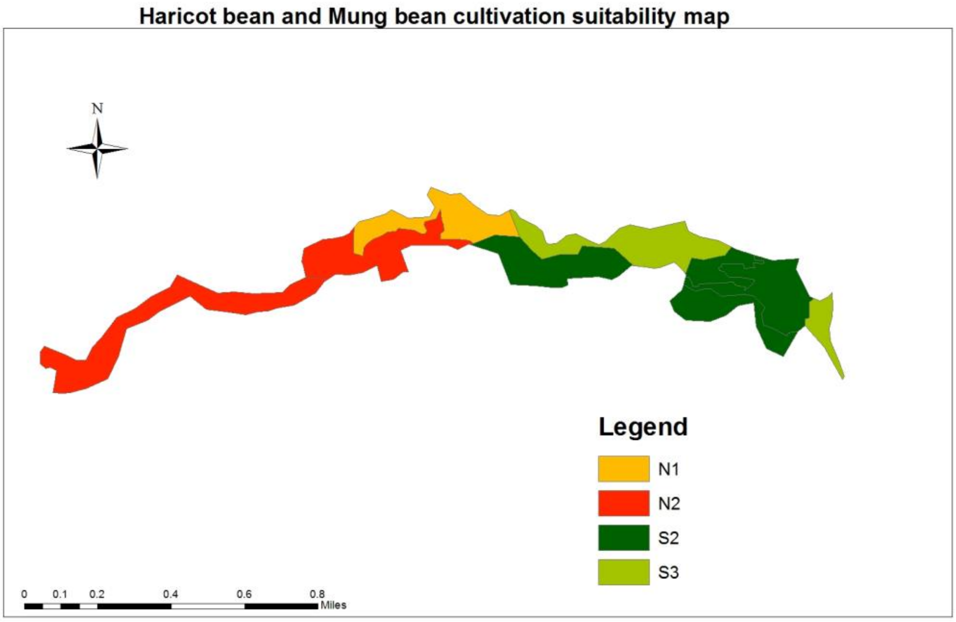

Figure 3: Actual Land Suitability Map for Haricot beans and Mung bean

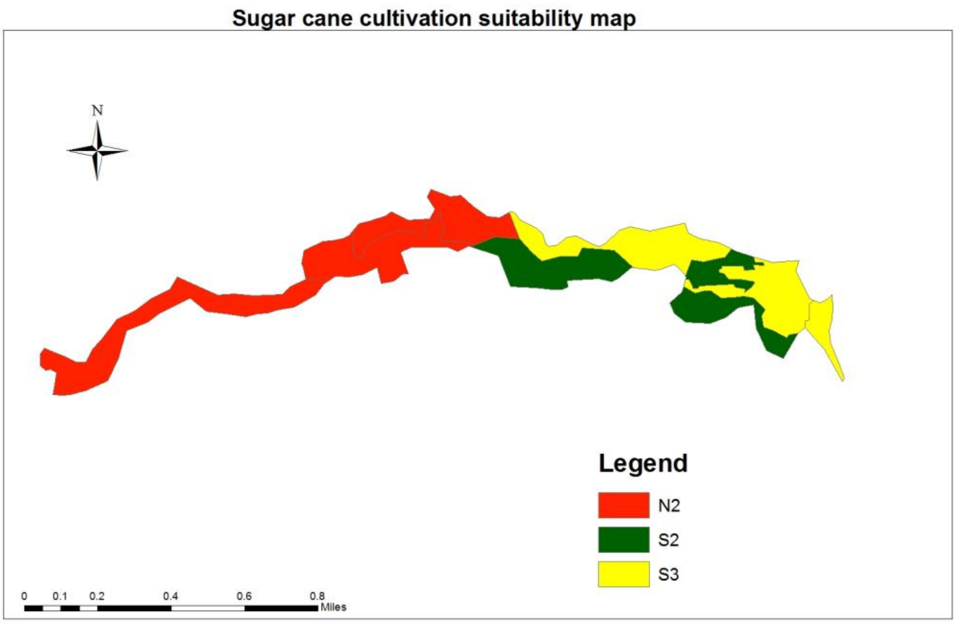

Figure 4: Actual Land Suitability Map for sugar cane cultivation

6. SOIL AND LAND MANAGEMENT

The main media of deal in the study of land suitability is the land with its components (like soil). The soil as a base for the land and its characteristics is selected to deal on more in the management aspect of the Wataba-Bedessa small scale irrigation project study. Therefore, the land area is discussed on the basis of the major soil types existing in the area in sub-section one of this chapter and the major land characteristics and their management aspects are dealt well in the second sub-section of the chapter.

6.1 Management Aspects by Major Land Qualities

6.1.1Soil cultivation and workability

The poor physical properties of the soils with high silty texture, identified in the study area are liable to be aggravated by poor timing of field operation under mechanized farming. This improvement can only be realized when the soil moisture content is not too high (wet and saturated soils) or too low (when dry soils). Using heavy tractors and plowing on the land when soil conditions are too wet will easily result in increasing bulk density and surface crusting, reducing soil aeration, surface infiltration and soil permeability through compaction. Thus, the mould board plough may be recommended in mechanized farming for cultivation. The aim is to diminish compaction as much as possible and to keep the biggest part of the residues on the soil surface. Addition of organic matter or mulching and better soil management may give better soil workability. The proper clearing and disposal of crop residues for prevention of carry over and spread of crop and soil borne pests and diseases are important.

6.1.2 Soil Erosion/ Soil Conservation

The soils with high silt content develop a surface crust, as a result of raindrop impact which aligns silt particles at right angles to the direction of impact and in time forms a hard crust, which inhibits infiltration and seed germination and increases runoff. Again mulching can improve organic matters as can discing the soil at regular intervals; preferably just before irrigation, to promote infiltration. However, the danger with this if the soil is dry for appreciable periods, and then this increases soil losses of erosion.

Furthermore, some soils occurring adjacent to uplands are slightly at risk from sheet wash and rill erosion and some of them are very susceptible to gully erosion if drainage lines become incised. There is a considerable run-off from the surrounding hills and ridges in the north east and south, which has caused sheet, rill and gully erosions. Constructing diversion ditches along the perimeter of the area in order to intercept the runoff water off the escarpment hills in the north east and south can control this. Therefore, careful planning and implementation of a properly laid out irrigation scheme is a pre-requisite.

6.1.3 Soil fertility

The percent base saturation and CEC contents of the soils of the Wataba-Bedessa small scale irrigation project SSIP study area are high to very high and while the OC and N are low to very low with high level of available P and K

Therefore, the soils might show higher to moderate response to application of fertilization. High pH values (especially above 8.0) resulted in decreased bacterial activity and hence nitrification of organic matter could be affected. At the same time higher pH values indicates boron toxicity. Soils in the Wataba-Bedessa area have pH values of 7.25 to 8.11 in most cases between 7.6 and 8.0 (mostly moderately to strongly alkaline, and it is evaluated as mostly favorable for most of the selected maize, wheat and sorghum LUTs, with the exception of SMU-2, SMU-3 and SMU-5 which have unfavorable high pH, for most sensitive crops selected like onion

Thus in order to maintain soil fertility nutrients removed from the soil by crop must be restored by the application of fertilizers and manure. Even in a highly fertile soil reserve nutrient gets exhausted as crops are grown and harvested continually and needs replacement.

As discussed earlier, the average maximum and average minimum available total soil nitrogen values are low to very low. Available N rates should be in excess of 0.25% for high demanding crops, such as vegetables (onions, potatoes), and even for relatively less demanding crops such as cereals. In general, response to N fertilizer is expected for most of the crops to be grown in the area. The average maximum and minimum values of organic carbon contents are low. This indicates that organic matter is adding little to the fertility of those soils with lower values, implying a requirement for fertilizer applications. Other implications are that soil structure with attendant impacts on soil-water infiltration; soil water holding capacity, surface workability and resistance to erosion will be reduced.

6.1.4 Soil drainage improvement

The effective utilization of soils with drainage problems requires the removal of excess soil water. This is done by improving soil percolation through soil horizons and installing surface drainage systems. The addition of organic matter or green manuring also help to improve soil structure and soil permeability.
Thus The application of appropriate surface drainage improvement practices or provision of adequate external drainage to improve the soil surface drainage.

7. CONCLUSSIONS & RECOMMENDATIONS

7.1 CONCLUSIONS

The main objective of the land evaluation mission of the project site is to assess the potential of the area for surface irrigation. The suitability evaluation results of the surveyed areas showed that a significant proportion of the area was found to be suitable for the intended irrigation purpose. All of the mapping units need some form of land management inputs and are all under such treatments that they can be utilized in a sustainable way, i.e without compromising the future use of the land areas. Sustainable use is a use of existing resources in a manner which the exploitation of resources, the direction of investments, the orientation of technological development, and institutional change are made consistent with the future as well as present needs.

The land evaluation process, as employed by matching the crop requirements and land characteristics/qualities for four different LUTs yields different results of suitability level, by which the investment of irrigation in the area is hoped to obtain the maximum expected from the investment without adversely affecting the land resources. The results are presented in class, subclass and order levels and suitability maps of each land mapping unit for each land utilization type for surface irrigation are presented as different figures, in sheets.

According to the evaluation some 37.11ha of land in the command area were moderately suitable (S_2) for maize, tomato onion and pepper cultivation and 20.51ha land of the command area were marginally suitable (S_3) for sugare cane and 12.25ha for pepper haricot bean and Mung bean and 7.97ha for maize cultivation.

The evaluation showed that those areas, which fall under moderately suitable, are known to have some physical limitations such as climate, low available water content, low nutrient availability, rooting condition These moderately suitable lands, in aggregate, will reduce productivity or benefits and increase required inputs that the advantage to be gained from the land use, although still attractive, will be less than the more suitable ones.

Lands, which fall under marginally suitable are known to have physical and chemical limitations, such as nutrient retention, rooting condition workability, nutrient availability, low oxygen availability and drainage due to low organic carbon, high soil pH, moderate AWHC and low permeability

These areas are lands having limitations that, in aggregate, are severe so that expenditure on the land use will be only marginally justified. These lands need intensive management so that sustainable and improved utilization of the area could be possible.

The land evaluation study has also sets an area of 8.93ha for all the selected crop(LUTs) was found permanently unsuitable due to its topography feature and rock outcrops and stoniness
It should be noted that these land areas (the evaluated and found suitable areas) include land that will eventually be lost to infrastructure. Therefore, for the NIA (net irrigable area) computation, these figures could be lowered by some amount that might be computed based on the infrastructures required to develop (during the irrigation detailed design stage as the land may be used for irrigation canals and other purposes). The results are summarized as in Table 9.

Table 9: Summary of Actual land Suitability over LUT

Ser. No	LUT	Area Coverage by Suitability level							Total (S+N)
		S_1	S_2	S_3	$S_1+S_2+S_3$	N_1	N_2	N_1+N_2	
1	Maize	0	37.1103	7.973101	***45.0834***	12.92944	8.934309	***21.86375***	**66.94715**
2	Haricot bean	0	24.86338	12.24692	***37.1103***	7.973101	21.86375	***29.83685***	**66.94715**
3	Tomato	0	37.1103	0	***37.1103***	7.973101	21.86375	***29.83685***	**66.94715**
4	Onion	0	37.1103	0	***37.1103***	7.973101	21.86375	***29.83685***	**66.94715**
5	Pepper	0	24.86338	12.24692	***37.1103***	7.973101	21.86375	***29.83685***	**66.94715**
6	Mung bean	0	24.86338	12.24692	***37.1103***	7.973101	21.86375	***29.83685***	**66.94715**
7	sugar can	0	16.59711	20.51319	***37.1103***	0	29.83685	***29.83685***	**66.94715**

Where S1 = highly suitable, S2=moderately suitable, S3 = marginally suitable, N1 = currently unsuitable and N2 = permanently unsuitable

7.2 RECOMMENDATIONS

Based on the above results and the conclusions made in section 7.1 above, the following recommendations are made. To maintain organic carbon mulching of crop residues after harvesting should be practiced with application of manure and compost. The use of plant species that are capable of fixing atmospheric nitrogen can improve soil fertility and reduce dependency on chemical fertilizer. The application of organic matter also improves the CEC of the soil.

In order to manage & maintain soil fertility in the project area organic manure and inorganic fertilizers should be utilized together. Sustainable soil management system, which include continuous crop cover, mulching and organic manuring with appropriate inorganic fertilizers should be practiced in order to maintain and to improve soil fertility and to control soil erosion.

In an explicit way, the best recommendations include the following: -

Cover cropping protects the soil from splashing raindrops and other means of water application to the soil (such as sprinkling) there by reduces soil sealing and compacting. If the soil matrix is not compacted it could enhance infiltration of water thereby increasing water storage in the soil. Cover crops either cover the whole area between fruit trees (overall covering) or they may grow in strips (strip covering) between the tree rows. Care should be taken in selecting the types of cover crops, because some crops might be sensitive to disease and pest, which might damage the main crop and some crops, might compete with the available water and nutrients.

Mulching is done by covering the soil between crop rows or around trees with grass, straw, crop residues or other plant materials. The layer of plant materials prevents the formation of soil crusting and soil sealing thereby compaction of the soil could be avoided. This in turn leads to improved water infiltration and better water storage in the soil matrix.

Mulching can be made on a seedbed or around planting holes. This is a good practice for fruits and other crops too. Mulch can also be applied in strips. A mix of fast and slow decomposing material is preferred and grasses should be allowed to dry before applying as this not only reduces the weight to be exerted on the soil, but also it reduces the chance of grass rooting. Mulching does have side effects. Some worth to mention are: - it requires large amount of material, it enables diseases and pests to survive, there may be a fire hazard.

Seasonal runoff might damage infrastructures (in this case any types of irrigation infrastructures) worth to assist the implementation of the project. Therefore, appropriate land runoff trap methods and drainage methods - surface and subsurface (if possible), are required to drain areas prone for runoff.

Green manuring is recommended in the entire command area. Green manuring consists of ploughing in green, where the plant materials can come from a crop that was grown after or between the main crop, or from a weed that grow during a fallow period, or it can also come from a shade plant or tree whose cuttings or fallen leaves are suitable for ploughing into the soil.

For green manuring, it is important to choose a plant that quickly covers the ground and produces a deep and extensive root system, so that the nutrient from the deep soil layers can be transported to the surface.

Some simple and less costly, but high output land management practices such as plantation of small scale tree species are recommended to plant in and around farm boundaries, so that soil erosion could be reduced and soil fertility could be improved.

The area is known to have high ET and therefore, it is recommended to exercise surface cover, there on moisture retention is possible. Mulching, improvement of the soil structure and overall condition by addition of green manures and composting reduce water evaporation from the soil.

Retaining crop residues and mulching are recommended to improve the level of carbon and improve the quality of organic matter.

Chemical fertilizers are recommended to apply to boost the productivity of the selected crops. Chemical fertilizers are known to add nutrients to the soil directly, even if it is not enough to retain a sufficient level of soil fertility. If the organic matter in the soil decreases, crop yield also decreases even if a chemical fertilizer is added. This is due to structural degradation of the soil, lower capacity of the soil to retain nutrients and water and other impacts. These soils are in need of application of chemical fertilizers, but in a lower rate than organic fertilizers.

The conventional ways of fertilizer application are broad casting and row application. These methods especially suited for surface irrigation by these methods will not be viable for surface irrigation. Therefore, chemigation/fertigation is proposed as the best method for surface irrigation water application systems like the Wataba-Bedessa project.

The application of nitrogen containing fertilizers for crops selected should be by split application depending on the growth stage of the crop. The concentration of phosphorous for most of the soils within the study area is found to be adequate and therefore, the soils would have moderate response to the application of fertilizer containing phosphorous.

Application of green manure increases utilization of phosphorus by the crop not from the added fertilizers but also from the reserve supplies of soil phosphorus. The available potassium concentration in the project area is found to be high even in most cases it is very high that could be rated as a toxic level and therefore, application of K fertilizer is not recommended.

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