

TABLE OF CONTENTS

1	IRRIGATION AGRONOMY	1
1.1	Introduction	1
1.2	Objective	2
1.3	Methodology	2
2.	GENERAL DESCRIPTION OF PROJECT AREA	4
2.1	Location	4
2.2	Climate	4
2.2.1	Rainfall	5
2.2.2	Temperature	5
2.2.3	Soil	6
2.2.4	Length of Growing Period	6
3.	EXISTING FARMING SYSTEM	9
3.1	Land Tenure System	9
3.1.1	Land Use Pattern	9
3.2	Existing Crop Production System	10
3.2.1	Rain fed Agriculture	10
3.2.2	Current Traditional Irrigation Practice	12
3.3	Agricultural Techniques	13
3.4	Major Constraints	13
3.5	Livestock production	14
4.	CONSTRAINTS AND OPPORTUNITIES OF IRRIGATION AGRICULTURE DEVELOPMENT	16
4.1	Agricultural development constraints	16
4.1.1	Social Constraints	16
4.1.2	Institutional Constraints	16
4.1.3	Agronomic Constraints	16
4.2	Opportunities for Irrigated Agriculture Development	17
4.3	Government Development Policies and Strategies	17
5.	IRRIGATION AGRICULTURAL DEVELOPMENT PLAN	19
5.1	Selection of Crops	19
5.1.1	Crop Basket Determination	19
5.1.2	Crop Selection Criteria and Selection Process	20
5.1.3	Selection Criteria	20
5.2	Proposed Crops	22
5.2.1	Details of Selected Crops	22
5.3	Irrigation Seasons	24
5.4	Proposed Cropping Pattern and Intensity	24
5.5	Agricultural Inputs	25
5.6	Seeds Requirement	26
5.6.1	Determining Crop Seeds	26
	Table 5-5: Summary of Seed Requirement	27
5.6.2	Potential Source of Improved Seeds	27
5.7	Fertilizer Requirements	27
5.7.1	Fertilizer Application	28
5.8	Agro-chemicals	29
5.9	Human Labor Requirements	30

5.10	Crop Yield and Projection Estimates.....	35
5.10.1	Yield Projection Estimates	35
6.	CROP WATER REQUIREMENT.....	37
6.1	Reference Crop Evapo-Transpiration (ETo)	37
6.2	Length of Crop Growth Stage	38
6.3	Crop Coefficient (Kc).....	39
6.4	Effective Rainfall	39
6.5	Irrigation Efficiency	41
6.6	Result of Irrigation Water Requirement Analysis	42
6.7	Irrigation Scheduling.....	42
6.7.1	Depth of Irrigation Application (d)	43
6.7.2	Irrigation Application Interval (i)	44
6.8	Determination of water stress period of selected crops	45
7.	AGRONOMIC PRACTICES FOR PROPOSED IRRIGATION CROPS.....	46
7.1	Onion - (Allium spp.)	46
7.2	Maize- (Zea mays)	55
7.3	Carrot (Daucus carota L.).....	64
7.4	Potato /Solanum tuberosum -L./	68
8.	POST-HARVEST MANAGEMENT ACTIVITIES	78
8.1	Post-harvest handling	79
8.1.1	Handling immediately after harvest	79
8.1.2	Separating the desired plant part.....	80
8.1.3	Washing and cleaning.....	80
8.1.4	Dehydration.....	81
8.1.5	Crop rotation	82
9.	AGRICULTURAL SUPPORTING SERVICES	84
9.1	Agricultural extension	84
9.2	Supply of agricultural inputs	85
9.3	Credits and marketing	86
10.	ESTABLISHMENT OF WATER USERS ASSOCIATION.....	87
10.1	The management committee	88
10.2	Rights and obligation of water user association members	89
10.3	The by-laws of water user association	90
11.	CONCLUSION AND RECOMMENDATION	91
11.1	Conclusion.....	91
11.2	Recommendation	91
12.	REFERENCES.....	92

List of Tables

Table 2-1:	Monthly rain and Effective rain fall of project area	5
Table 2-2:	Minimum, Maximum and monthly average temperature project area	6
Table 2-3:	Length of Growing Period Classes.....	7
Table 3-1:	Land use type in district and study kebele ... Error! Bookmark not defined.	
Table 3-2:	Crop type and yield of rain fed agriculture in the district 2009/2010	11
Table 3-3:	Cropping calendar for traditional irrigation in & around project area	12
Table 3-4:	Livestock population in district and project Kebele.....	15
Table 3-5:	Possible List of crops basket in project area	19
Table 3-6:	Cropping Patterns and Intensity.....	25
Table 6-1:	Climate data of project area	37
Table 6-2:	length of growing stages and kc of proposed crops	39

Table 6-3: Effective Rain Fall for the Project Area.....	40
Table 6-4: Depth of Application during peak water requirement	44
Table 6-5: Irrigation Interval during peak water requirement	45

List of Figure

Figure 2-1: Local growing season of the project area	8
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List of Annex

Annex 1: Crop Water Requirement Calculation for Onion	93
Annex 2: Crop Water Requirement Calculation for Maize	94
Annex 3: Crop Water Requirement Calculation for Pepper Fresh	95
Annex 4: Crop Water Requirement Calculation for Potato	96

1 IRRIGATION AGRONOMY

1.1 Introduction

Agriculture is the leading sector in the regional economy of Oromia. The predominant agricultural system is based on small holder production and the crop production is entirely dependent on rain fed agriculture with limited areas currently developed under irrigation. The natural supply of water to the agricultural land for crop production purpose is usually received from natural sources such as precipitation/rain, other atmospheric water, ground water and flood water. But the amount, frequency and distribution of rainfall, which is the principal source of water for crop production, is becoming more unpredictable and inadequate. Furthermore, the rainfall nature may be insufficient and untimely and the groundwater may be too deep in the soil profile beyond the active root zone, which is unavailable to the plant roots. In areas that face such problem, successful crop production is only possible with support of irrigation.

Irrigation is an artificial application of water to irrigated crop fields to supplement the natural sources of water to satisfy the crop water requirements and increase crop yields on sustainable basis without causing damage to the land and soils. Irrigation is generally considered as a means of modernizing the country's agricultural economy in general and the agricultural economy of Oromia region in particular and is an important investment for improving the real income through increased agricultural production and productivity.

It is also central for reducing the ever increasing pressure on land, especially up in the high lands primarily by increasing the productivity per a unit of land and to some extent by bringing new land under cultivation, particularly in the low lands where population density is relatively lower and uncultivated land abundantly available. Moreover, irrigation plays an important role in combating the effects of recurrent droughts and sustains production with efficient and effective use of available resources; namely, water and land in order to primarily alleviate the problem of food insecurity, improve nutritional status of the rural population and in the long-run alleviating poverty. It is through irrigation and integrated crop development that sustainable crop production can be ensured.

In general, this irrigation agronomy feasibility study was done based on the agreement that have been made between BBG Engineering P.L.C and Oromia Irrigation Development Authority to study and design 145 ha of gross command area. Nevertheless, in this document, data analysis was done only for 103 ha of net command area.

1.2 Objective

General Objectives

- ❑ Through the introduction of irrigated agriculture over an area increasing crop production and thereby achieving stable food self-sufficiency and increasing farm income.

Specific Objectives

- ❑ Assessment of the existing crop production activities in the study area including major crops grown, their productivity, the cropping pattern, cropping calendar and farming practices;
- ❑ Study of the agro climatic condition of the area for irrigated agriculture;
- ❑ Selection of suitable crops to be proposed to be grown during the project implementation period;
- ❑ Estimation of yield projection for the selected crops
- ❑ Computation of crop water requirements for the proposed crops;
- ❑ Recommendation of input requirements and improved agronomic practices for irrigated crops, etc.

1.3 Methodology

The methodology used during the study is collection of pertinent information regarding the proposed project area from potential sources of information using questionnaires and by field observation. Prior to the field visit, questionnaires were prepared and incorporated in the overall study approach and methodology. Relevant crop data, crop management practices, farming systems, production constraints of the area are collected both from Shirka District Agricultural Development Office and Sole Chisa kebele development centre. Ticho meteorological Station is the nearest station from which the climatic data were inferred.

Calculations of water and irrigation requirements utilize inputs of climatic, crop and soil data, as well as irrigation and rain data. The climatic input data required are reference crop evapotranspiration (monthly/decade) and rainfall (monthly/decade/daily). Reference crop evapotranspiration can be calculated from actual temperature, humidity, and sunshine/radiation and wind-speed data, according to the FAO Penman-Monteith method (FAO, 1998). The soil data include information on total available soil water content and the maximum infiltration rate for runoff estimates. In addition, the initial soil water content at the start of the season is needed.

Cropwat is a computer program for irrigation planning and management, developed by the Land and Water Development Division of FAO (FAO, 1998). Its basic functions include the calculation of reference crop evapotranspiration, crop water requirements, and crop and scheme irrigation. Generally, in computing crop water requirement, Microsoft Excel Sheet programme and ClimWat 2.0, CropWat 8.0 and NewLocClim_1.10 software's were used for analysis purposes.

2. GENERAL DESCRIPTION OF PROJECT AREA

2.1 Location

Calle irrigation project is found in Oromia Regional State, Arsi Zone, Shirka District and Sole Chisa kebele. The command area is failed in an altitude range between 2114-2141 masl which is characterized by plain to gentle slope lands. More over the project site is far 9 km distance from district capital.

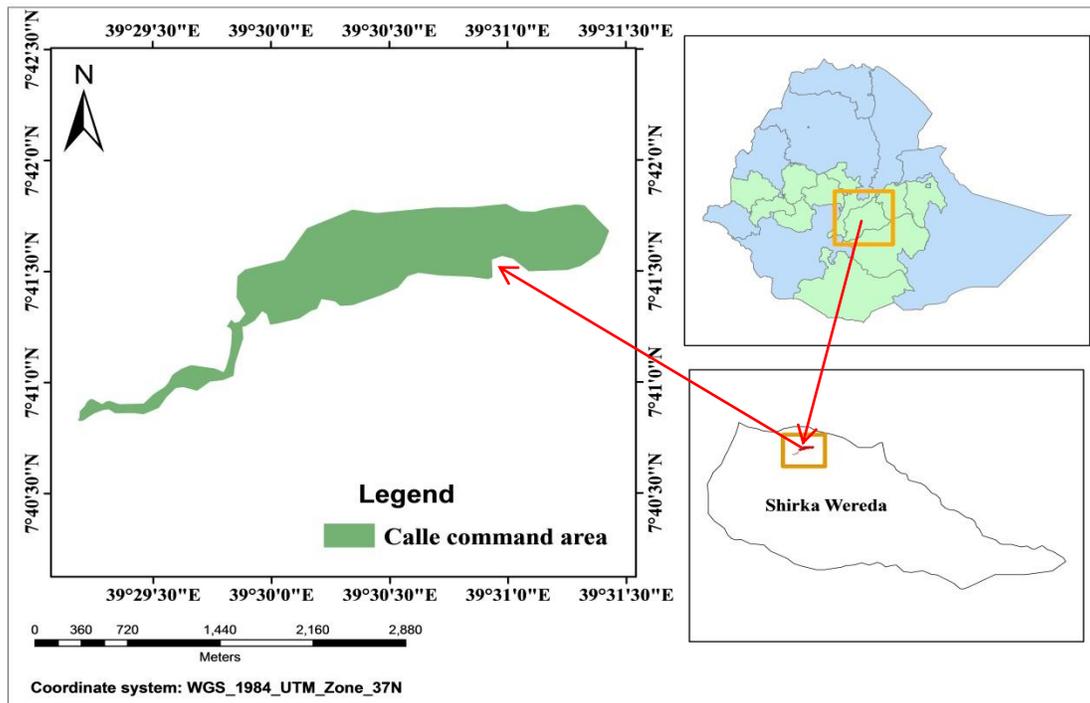


Figure 1-1 Location of project area

2.2 Climate

Climate is the important factor determining the success or failure of agriculture. It influences agricultural operations from sowing of a crop to the harvest and particularly rain fed agriculture depends on the mercy of the weather. The crops are to be sown at the optimum period for maximum yield. In dry lands, the time of receipt of rainfall decides the sowing date. The study of climate helps to minimize the crop losses due to excess rainfall, cold/heat etc. It helps in forecasting pests and diseases, choice of crops, irrigation and other intercultural operations through short, medium and long-range forecasts. It helps to identify places with same climatic conditions (Agro climatic zones). This will enable to adopt suitable crop production practices based on the local climatic conditions. It also helps in the introduction of new crops and varieties. Ticho meteorological Station is the nearest station from which the climatic data were inferred.

2.2.1 Rainfall

Precipitation refers to the water (moisture) received in the form of rain, snow, hail, fog, dew or a combination of them. However, rainfall is the most important form of precipitation in the tropics and subtropics in which its efficiency is measured by its yearly amount, distribution and duration.

The area is characterized by bi-modal rainfall pattern that extends from April to Mid-November with dry spell period in mid-November to mid-march. However, as it was described by the farmers, the rainfall of the area is characterized by late onset and early offset as well as inadequate in its amount. Even though the area is characterized by bimodal rainfall pattern, the moisture obtained during the short rainy season is not enough for crop production. Therefore, the total average annual rain fall is calculated to be **1265mm**. Maximum rainfall occurred in the month of August which is 165mm as shown in Table 2-1.

Table 2-1: Monthly rain and Effective rain fall of project area

Month	Rain, mm	Eff Rain, mm
January	46	42.6
February	87	74.9
March	135	105.8
April	155	116.6
May	101	84.7
June	95	80.6
July	157	117.6
August	165	121.4
September	144	110.8
October	103	86
November	54	49.3
December	23	22.2
Total	1265	1012.5

2.2.2 Temperature

The prevailing temperature considerably influences selection of crops and their growing periods. Optimum temperature plays an important role on the growth period and the production of crops. The mean maximum annual temperature of the area is 20.2^oc and the mean minimum annual temperature is 5^oc, in which the highest mean maximum temperature and a mean minimum temperature were recorded in February and July months respectively as illustrated in Table 2-2. Thus, in command area mostly low to moderate temperature ranges are occurred which is favorable for the growth of various crops in the area.

Table 2-2: Minimum, Maximum and monthly average temperature project area

Months	Min Tem(°c)	Max Tem(°c)	Average Temp(°c)
January	6.2	20.9	13.55
February	7.2	21.6	14.4
March	8	21.2	14.6
April	8.9	20.2	14.55
May	9	20.7	14.85
June	8.1	20.8	14.45
July	8.4	19.5	13.95
August	8.1	19.1	13.6
September	8.1	19.3	13.7
October	7.5	18.7	13.1
November	5.9	19.2	12.55
December	5	20.2	12.6

2.2.3 Soil

The texture of the sampled soil layer (0-35cm) ranges from clay to clay loam while the deeper one belongs to clay type of soil. The command area soil pH value is recorded between the ranges of 7.0 to 7.9 which are moderately alkaline and the amount of available phosphorus (P) also recorded in the ranges of 0 to 4.26 ppm which is found in very low to low. Hence, phosphorus fertilizer response is most likely. Moreover, results obtained from the laboratory showed 0.05 to 0.15% which is showed in medium to high ranges of organic matter content (1.08 to 3.29%), and the C.E.C of the command area soils is found in the high range (51.7 to 74.1meq/100g) of soil. Thus, soils of the command area are good for irrigation agriculture. Therefore, detailed information about the soil of the study area can easily be obtained from the soil report of this study.

2.2.4 Length of Growing Period

The concept of growing period is essential to agro-ecological zoning, and provides a way of including seasonality in land resource appraisal. In many tropical areas, conditions are dry during part of the year for crop growth to occur without irrigation, while in some seasons of the year the temperature condition limits crop growth and development. The growing periods defines the period of the year when both moisture and temperature conditions are suitable for crop production.

The growing period provides a framework for summarizing temporally variable elements of climate, which can then be compared with the requirements and estimated response of the plant. Such parameters as temperature regime, total rainfall, and evapo- transpiration and the incidence of climatic hazards are more relevant when calculated for the growing period, when they may influence crop growth rather than averaged over the whole year. The estimation of growing period is based on a water balance model which compares rainfall (P) with potential evapo-transpiration (PET). If the growing period is not limited by temperature, the ratio of P/PET determines the start, end and type of growing period.

The determination of the beginning of the growing period is based on the start of the rainy season. The first rains fall on soil which is generally dry at the surface and which has a large soil moisture deficit in the soil profile. In the absence of soil moisture reserves seedbed preparation, seed germination and the initial growth of crops are therefore entirely dependent on the amount and frequency distribution of these early rains. Experimental work indicates that the effectiveness of early rains increases considerably once P is equal to, or exceeds half. The growing period continues beyond the rainy season, when crops often mature on moisture reserves stored in the soil profile. Soil moisture storage must therefore be considered in defining the length of the growing period.

The LGP is classified based on the number of day in the year that the area gets moisture important for plant growth. The table 2-3 below shows the general LGP classification systems.

Table 2-3: Length of Growing Period Classes

LGP Days	Universal Terminology
A growing period of below 45 days	Arid
A growing period of 46-60 days	Semi-arid
A growing period of 61-120 days	Sub-moist
A growing period of 121-180 days	Moist
A growing period of 181-240 days	Sub-humid
A growing period of 241-300 days	Humid

Source: *Revised Agro-Ecological Classification, 2005*

The length of growing period could give a highlight about the potential crops and varieties to be considered to develop crop basket for the given area. Further the main constraints related to the agricultural development could be identified that can indicate the area that need more attention and intensive data assessments. Therefore, the proposed irrigation project area failed under **121-180** LGP which is moist nature.

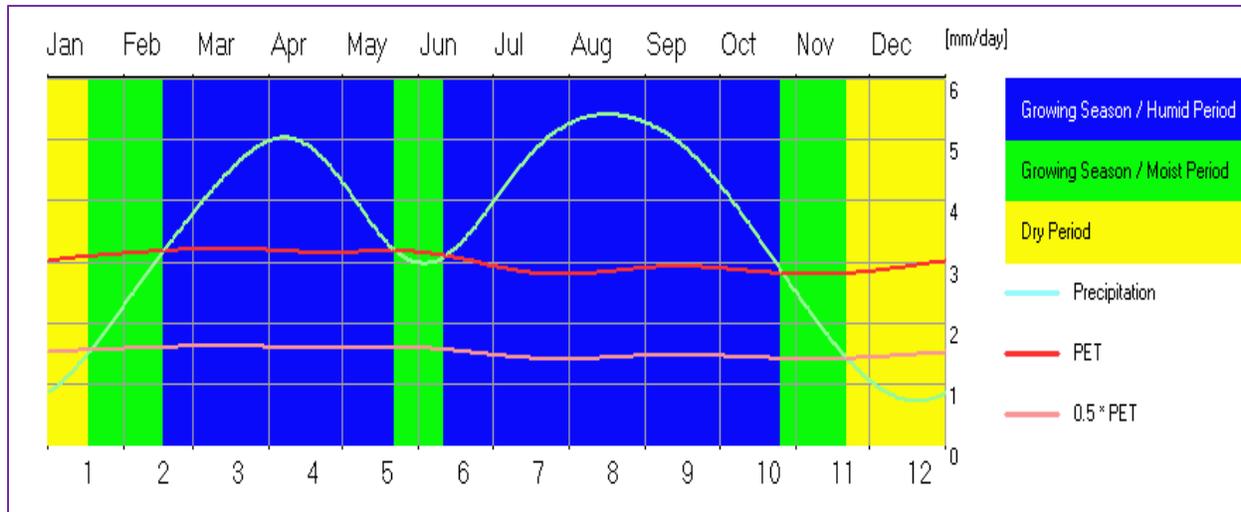


Figure 2-1: Local growing season of the project area

3. EXISTING FARMING SYSTEM

The existing farming system in the area is mixed farming where production of crops and livestock for the market and own production is commonly practiced. The livelihood system in the project area is integrated in such a way that the oxen are used as traction power, the livestock as a whole contribute farmyard manures by feeding on the crop residues and free grazing. Plowing of land in the project area takes place by use of oxen power. Harvesting and threshing of crops also practiced by man power (cutting by sickle) and by draft animals, respectively. This is due to the undulating form of land which makes the use of farm machineries difficult. Major crops grown in the study area are sorghum, maize, beans and tef, crops are major crops cultivated by local peoples during the main rainy season.

3.1 Land Tenure System

Land tenure system is a relationship between individuals and groups of individuals by which rights and use of land resource are determined. The traditional land use and land management practices that used to sustain the welfare of human population under low population pressure with little or no technical inputs is no longer able to support the growing population due to increasing population density and degradation of natural resource base, declining per capital food production results in deteriorating human welfare conditions. In and around the command area, land tenure system is privately owned and the farmers have the right to use the land under the administration of government.

Significantly large areas of lands are also covered by natural forest with forest coffee production. According to the present study, most of the farmers (about 40%) hold more than two hectares while the majorities hold less than of 0.5 ha in the district as well as in the command area. Nevertheless, in the study area there are many number of farmers those are have farm land and oxen. These problems may create due to the presence of high population pressure in and around the command area. Hence, their livelihood also depends on land rent, production of timber and charcoal.

3.1.1 Land Use Pattern

The land use pattern of Shirka district and study area (PA) has exhaustively utilized the arable land mainly for rain fed agriculture. According to the data collected from the district agricultural office the area is allocated for crop production in which rain fed cultivated land contribute 74.77% of the total the kebele area.

Table 3-1: Land use type in district and study kebele

S.N	Land use	District Area in (ha)	Area (%)	Kebele Area in (ha)	Area (%)
1	Arable land	27244	40.4	0	0
2	Cultivated land	21566	32.0	686	86.4
3	Grazing land	1472	2.2	2	0.3
4	Forest land	12622	18.6	100.7	12.7
5	Settlement	3937	5.8	0	0
6	Other uses	648	1.0	5	0.6
		67489	100	793.7	100

Source:- Shirka District Agricultural Development Office

3.2 Existing Crop Production System

3.2.1 Rain fed Agriculture

The rain fall pattern around project area is bi-modal, mid-February- mid-May (short) and mid-June-mid-October (long) rainy seasons. At present, the short rainy season is not effective for agricultural production because of the climatic disturbance. The study area is endowed with favourable climate, soil and topography for cultivation of diverse crops. Maize is the most widely grown crops in the study area mainly maize, sorghum, wheat, barley, beans and small vegetables which are commonly cultivated crops and used for food purpose and Chat also grown in the district and it serve as a cash crop.

Table 3-2: Crop type and yield of rain fed agriculture in the district 2009/2010

S.N	Crop type/input type	Unit	Yield/ha	Price/Qt)	Remarks
1	Cereals/Grain				
	Maize	Kun	45	650.00	Used selected and local seeds
	Wheat	Kun	30	1200.00	Used selected and local seeds
	Barely	Kun	18	1100.00	Used local seeds
	Sorghum	Kun	22	700.00	Used local seeds
2	Pulses				
	Horse bean	Kun	8	1700.00	Used local seeds
	Pea	Kun	7	1700.00	Used local seeds
3	Root crops				
	Potato	Kun	80	350.00	Used selected and local seeds
4	Vegetables				
	Cabbage	Kun	120	1200.00	Used selected seeds
	Pepper	Kun	20	4000.00	Used selected seeds
	Carrot	Kun	80	1600.00	Used selected seeds
	Onion	Kun	60	1500.00	Used selected and local seeds
	Garlic	Kun	35	3000.00	Used local seeds
	Tomato	Kun	85	1000.00	Used selected seeds
5	Cash crops				
	Sugar cane	Pcs	-	16.00	Used local seeds
	Chat	kg	-	100.00	Used local seeds

Source: District agricultural development office

Table 3-3: Existing Cropping Calendar

SN	Crop type	Land preparation (months)	Sowing (month)	Harvesting (month)	LGP
1	Cereals				
	Maize	March	April	November	145
	Wheat	May	June	November	150
	Barely	May	June	November	150
	Sorghum	March	April	December	180
2	Pulses				
	Horse bean	June	June	November	140
	Pea	June	June	November	140
3	Vegetables				
	Potato	June	June	October	120
	Cabbage	June	June	September	115
	Pepper	June	June	November	160
	Carrot	June	June	September	105
	Onion	June	June	October	130
	Garlic	June	June	October	135
4	Cash crops				
	Sugar cane	Perennial			
	Chat	Perennial			

3.2.2 Current Traditional Irrigation Practice

Farmers have built small-scale schemes on their own initiative, sometimes with government technical and material support. However, the diversion sites of these traditional small-scale irrigation schemes are not built on permanent basis and they are forced to rebuild the structures after every flood season. These schemes are being managed by the beneficiary farmers through their own water users' association' or committees. The farm size for irrigated plots per household is usually in the range of 0.25 ha - 0.5 ha. In some cases, the size is as low as few tens or hundreds of squaremeters. Water users' associations have long existed to manage traditional schemes.

The traditional water users' associations in the form of water committees are generally well organized and are effectively operating by farmers who know each other and are committed to cooperate closely to achieve common goals. A typical association comprises up to **35** users who share a common main canal or its branches. Such associations handle construction, water allocation, operation and maintenance functions. Interventions in the area of traditional irrigations is upgrading which usually consists of improving head works, which often get washed away by flood, and lining of main canals.

Table 3-4: Crop type commonly cultivated in the project area

SN	Crop type/input type	Unit	Yield/ha)	Remarks
1	Cabbage	Kun	150	Used selected seeds
2	Pepper	Kun	20	Used selected seeds
3	Carrot	Kun	90	Used selected seeds
4	Onion	Kun	80	Used selected and local seeds
5	Garlic	Kun	25	Used local seeds
6	Maize	Kun	40	Used selected seeds

Source: District agricultural development office

Table 3-5: Cropping calendar for traditional irrigation in & around project area

Crops type	Operational calendar					
	Time of seed bed preparation		Sowing	Time of weeding		Time of harvesting
	ploughing	Freq		Weeding	Freq	
Potato	Nov	3	Nov	Dec	2	Feb
Cabbage	Dec	3	Jan	Feb	3	Apr
Onion	Jan	3	Feb	Mar	2	Jul
Garlic	Dec	3	Feb	Mar	2	Jun-Jul
Carrot	Jan	3	Feb	Mar	2	May-Jun
Beetroot	Jan	3	Feb	Mar	2	May
Pepper	Nov	3	Dec	Jan	3	Mar
Maize	Dec	2	Jan	Jan	3	May

Source: District Agricultural Office

3.3 Agricultural Techniques

Depending on our field assessment and information that obtained from the concerned development sectors, the existing rain fed farming system also follows traditional method of crop production. In the project area, even if there is suitable agro ecology for the production of many crops, most farmers relatively produce limited range of crop types which are mainly used for their subsistence consumption and few for additional household income generation. On the other hand, the supplying of agricultural inputs such as improved seeds and fertilizers for existing traditional rain-fed agriculture is not adequate for full potential use of the available resources. As information collected from the local farmers the price of these agricultural inputs is increasing from time to time and get not affordable.

As a result, they use few inputs, especially, fertilizers on large area of land, which is not followed proper recommendation. The basic agricultural techniques like, crop rotation, intercropping, crop diversification, double cropping, row planting, soil and water conservation and other related activities are not yet well practiced in the area.

The farmer's use oxen draft power for ploughing of farmland, and traditional ploughing system can cause the formation of a hard pan beneath the top soil. This lowers the water retention capacity of the soil and exposes the upper agricultural soil to water erosion. There are great variations among the farmers, depending on the different biographical conditions, skills, the availability of labor and access to resources outside the farm. Most are marginal subsistence farmers, cultivating basic food crops only. But the production of such crops is low, not enough to meet their requirements in most years.

The livestock productivity and productivity is very low due to the poor feeding system, poor management and lack of improved breeds. The prevalence of livestock diseases, feed shortage and low awareness of improved management practices has their own impact to low productivity.

3.4 Major Constraints

Over 90% of agricultural production depends on rain fed agriculture, which is also facing serious challenges and constraints that unable to produce sufficient production to fulfill the food requirements of the whole nation. This indeed, the importance of irrigation in the overall economic development of the country and practical demonstrations have been observed that through irrigation there is a possibility to attain agricultural surpluses enough to satisfy the need for domestic consumption and for external markets, of course with the required quality of produce. The following are among the major challenges and constraints:

- ❑ Inadequate emphasis given for setting up of appropriate institutional arrangements at all levels to provide more effective and efficient services to the users in irrigated agriculture
- ❑ Inadequate support in input supply and distribution systems and credit facilities,
- ❑ Increased input prices that are not affordable to subsistence farmers’;
- ❑ Shortage of agricultural inputs and limited availability of improved irrigation technologies,
- ❑ Low level of know- how and limited practical skills of farmers in irrigated agriculture with predominated traditional and inefficient water management practices,
- ❑ Availability of limited trained manpower and inadequate capacity in providing effective and efficient extension services in irrigated agriculture;
- ❑ Increased degradation rate of natural resources- soils and vegetation cover and consequently lead to build up of siltation that would significantly affect the irrigation infrastructure;
- ❑ Limited or lack of community consultation during planning and developing of irrigation schemes;
- ❑ Limitations in skill transfer and improved irrigation agronomic practices and
- ❑ Low-level of linkage between research- extension – farmers in promoting irrigation technologies.
- ❑ The occurrence of different pests (weeds, insects, diseases, birds and others) is among the major production constraints adversely affecting the level of crop production in the area. With the intensification of crop production using irrigation water the infestation level of these pests could be more pronounced in future and this has to be realized in advance.

3.5 Livestock production

Livestock production is a major component of the farming system. It is also one of the economic activities for traction powers, provision of dairy products, transportation and for household income generation. Oxen are selected for speed and endurance in pulling traditional ploughs. Small ruminants and chickens are generating additional incomes for the community. Traditional beekeeping is also normally known in the area. Modern beekeeping is not as such significantly practiced, but small scale activities are there in few pocket areas. Equines serve as means of transport for human and agricultural products. The major type and quantities of livestock in where the proposed project is located) are indicated in Table 9.

Table 3-6 Livestock population in district and project Kebele

S.N	Livestock type	Livestock population		Common diseases	Methods of diseases control
		District (qty)	Sole Chisa (qty)		
1	Cattle	218588	2413	Foot & Mouth disease Newcastle, Pasturollosis, Anthrax, Black legs, endo parasites African Horse Sickness Coccidiosis, etc.	Except poultry, vaccination and treatments are the used methods in and around project area
2	Sheep	60368	267		
3	Goat	49937	950		
4	Donkey	21763	443		
5	Horse	16234	4		
6	Mule	7380	237		
7	Poultry	102539	3789		

Source: District Agriculture Development Office

According to the information that obtained from district livestock health clinic and the community, FMD, AHS, Newcastle and Coccidiosis are the most prevalent diseases in the area. Vaccination is the major means of preventing these diseases and farmers use their own traditional healing mechanisms practiced from generation. In the area natural grazing is the major sources of feed for livestock. In addition some improved forage grasses, multipurpose legume trees and few industrial by products are used for livestock feed in the area. Crop residues are largely consumed on the field and also collected, stored and fed during the season of feed shortage. Hay and silage making is not common in the area.

Communal grazing land is the major grazing arrangement among the farmers of the area. Farmers allocate common grazing land at the bottom of the hill around river banks wetland and natural forest to feed their animals in common. Individually, farmers allocate and fallow some part of their crop land for animal grazing. Zero grazing is also practiced by few farmers exercising for animal fattening around homesteads.

4. CONSTRAINTS AND OPPORTUNITIES OF IRRIGATION AGRICULTURE DEVELOPMENT

4.1 Agricultural development constraints

It is a great task to identify and analyze the constraints of the agricultural production system in the project area to come-up with tangible and effective recommendations. The constraints intend to be either of agronomic, social, institutional and environmental. The typical constraints of crop production system in the project area were identified through consultation of experts and local farmers and valuable data was collected. Most common crop production constraints of the smallholder farming are listed as follows: -

4.1.1 Social Constraints

- Population pressure causes land fragmentation
- Resistance of the community to new technologies
- Lack of adequate knowledge on irrigation technology
- Uneven level of commitment among the local leaders and committee members

4.1.2 Institutional Constraints

- Lack of managerial skills in community based organization
- Inadequate commitment and lack of institutional capacity at kebele level to organize the beneficiaries to involve in irrigation agriculture,
- Weak capacity of research centers to address the irrigation agriculture constraints,
- Weak institutional capacity of service and marketing cooperatives to manage with crop outputs
- Imperfect operation of agricultural marketing system
- Weak institutional linkage between agricultural support service providers
- Farmers' training centers give less attention to irrigation agronomy
- Poor linkage between the farmers and potential agricultural enterprise to exchange their experience and being reliable partner in the marketing system; and others

4.1.3 Agronomic Constraints

- Depletion of soil fertility due to improper tillage practices and inadequate soil conservation measures,
- Inadequate supply of basic agricultural inputs such as improved seeds, fertilizers, animal breeds and animal feeds.
- The prevalence of crop and livestock diseases and weeds and poor cropping pattern utilization,

- Continuous price increase of important agricultural inputs, especially fertilizers.
- Improper utilization of natural resources leading to soil and forest degradation in the area.
- Poor access to markets, inadequate infrastructures, absence of modern irrigation practices,
- Weak extension activities from the concerned stakeholders

4.2 Opportunities for Irrigated Agriculture Development

The main purpose of identifying the potentials and opportunities of the project area is to support the process of determining the type of crops to be proposed for irrigated agriculture. The selection of the crops should be based on agronomic, social and institutional potentials of the area, besides the existing and future opportunities need to be taken into consideration for the success of the project.

The agricultural opportunities are differing from place to place based on the natural resource availability, social, economic and infrastructure conditions of the area. Therefore, the assessment should gear specific to irrigated agriculture to identify reliable opportunities for anticipated project. The following opportunity areas are identified and recommended: -

- Strong political will from to senior government leadership
- Conducive SSI sub-sector policy environment;
- Abundant water resources that can be tapped for irrigation use
- Good marketing opportunity for irrigated crops
- Favorable climate and land suitability,
- Irrigation is getting emphasis in research and higher learning institutions,
- Availability of irrigation technologies, even though limited.

4.3 Government Development Policies and Strategies

The overall objective of irrigation policy is to develop the huge irrigated agriculture potential for the production of food crops and raw materials needed for agro industries, on efficient and sustainable basis and without degrading the fertility of the production fields and water resources base.

Detail Objectives

- ❑ Development and enhancement of small scale irrigated agriculture and grazing lands for food self-sufficiency at the household level.
- ❑ Development and enhancement of small-, medium- and large - scale irrigated agriculture for food security and food self sufficiency at national level including export earnings and to satisfy local agro-industrial demands.
- ❑ Promotion of irrigation study, planning and implementation on economically viable, socially equitable, technically efficient, environmentally sound basis as well as development of sustainable, productive and affordable irrigation farms.
- ❑ Promotion of water use efficiency, control of wastage, protection of irrigation structures and appropriate drainage systems.
- ❑ Ensuring that small-, medium- and large-scale irrigation potential projects are studied and designed to a stage ready for immediate implementation by private and/or the government at any time.

5. IRRIGATION AGRICULTURAL DEVELOPMENT PLAN

5.1 Selection of Crops

5.1.1 Crop Basket Determination

Before the start of the selection of potential crops for the irrigated agriculture, list of a range of crops growing in the project area should be prepared. The crop basket not necessarily include only the list of crops currently growing in the project area rather based on the agro-climatic and soil conditions all possible crops could be incorporated in the crop lists as shown in Table 5-1. Because there are potential and suitable crops which might not currently found in the cropping patterns of the project area need to be considered in new development intervention.

Table 5-1: Possible List of crops basket in project area

Crop Group	Type of crops
Cereals	,maize, barley, oats, , wheat, ... etc.
Pulses	Chickpea, faba bean, soybean. lentil, haricot bean, filed pea, grass pea, cowpea etc
Oil crops	Flax
Vegetables	Shallot, onion, beetroot, cabbage, pepper, potato, carrot, cucumber, lettuce, green- bean, etc.
Fruits	Apple
Stimulant crop	Chatand tobacco, etc.

After the identification of suitable crops those could be grown in the given agro-ecology and farming systems, the next step is screening the most appropriate crops meet the objective of the projects. The selection criteria should be set to make more appropriate list of crops, further briefing is required why the crops are incorporated in the cropping pattern. This information will give a highlight for implementers to use the products accordingly for desirable purposes.

During community consultation and household survey, the preferences of the respondents should be addressed to capture the need of the beneficiaries. It must be clear that the expertise should not apply all the proposed crops from the community. The proposal further should analyze from different perspectives to meet the project goals and realize irrigation development.

5.1.2 Crop Selection Criteria and Selection Process

The smallholders would have two major objectives to carry out irrigation agriculture on their plots of land; attaining the food demand of the family members is the primary objective, while growing cash crops to generate household income is the second important objective. In some cases, irrigation projects planned to attain maximum return by growing only cash crops in both supplementary and full irrigation cropping seasons. Under small-scale irrigation the crops selection should taking into account the optimum utilization of water, land and labour to attain the objective of the project.

Crop selection is a main and determinant process to ensure the sustainable development of irrigation projects, because the overall goals of the irrigation project are screwing to improvement crop outputs. Besides these all other sector studies are relying on the recommendations of this process.

Therefore, adequate emphasis and time should be given to crop selection process and in some cases that might need consultation with the study team members for optimum output. During community consultation and household survey, the preferences of the respondents should be addressed to capture the need of the beneficiaries it must be clear that the expertise should not apply all the proposed crops from the community. The proposal was further analysed from different perspectives to meet the project goals and realize irrigation development.

5.1.3 Selection Criteria

The criteria for selecting the potential crops should follow multidimensional approach to cover various issues. The criteria could categorize into agronomic, social, environmental, cultural, and business sectors to simplify the determination of the selection criteria. Most importantly, the criteria should not be complex to exercise rather need to be simple and sensitive to the desired project objectives. Three major targets of the criteria are increased crop production, high income generation and restoration of soil fertility.

Accordingly, hereby briefed possible criteria are listed and apply where appropriate. Brief explanation is stated to describe the selection factors for better understanding. It is believed that there could be other factors to be considering for better crop identification for specific project areas.

Agro-climate

it is one of the major environmental factors that determine the growth and productivity of the crops, thus in reference to the temperature, rainfall, humidity, and day-length requirements of the crops, more appropriate crops from climatic factor point of view could be screened. The range of climatic requirements for each proposed crop can be referred from different literatures and area specific research findings.

Length of growing period

Suitable for the proposed crop intensity: crop varieties characterized by short length of growing period are preferred for double cropping. It should keep in mind that short-cycle varieties preferably to be considered during crop selection, so that the LGP of a given crop includes short and long-cycle varieties those can grow in different growing period. It gives opportunities to include more crops in the cropping pattern.

Potential of the irrigation water source

The accessibility of irrigation water varies across the country and currently it becomes a scarce natural resource. The potential of the Calle river water source has a base flow of 150l/s discharge capacity during peak dry season therefore, based on the obtained information from hydrologists the potential crops were selected that can able to irrigate up to 103 hectares of net command area.

Soil condition of the command area

Most of the command area soils is dominated by Vertisols and livisols. Vertisols, because of their high water-holding capacity, are suited to dry land crop production in semi-arid environments with uncertain and heavy rainfall, Selected physical and chemical properties of Vertisols that affect their' management for crop production are discussed. Due to their high clay content, the physical properties of Vertisols are greatly influenced by moisture content; usually, these soils are too sticky and unworkable when wet, and very hard when dry. The soil moisture range in which the physical condition of Vertisols is suitable for tillage and planting operations is quite narrow. Deep Vertisols have impeded drainage in the rainy season with consequent loss of traffic ability; poor air-water relations are suspected. Land management practices that facilitate drainage and improve aeration, water intake and permeability of these soils need to. be evolved. Though generally of low fertility status, Vertisols offer opportunities for better crop production in semi-arid areas with erratic rainfall compared with other soil orders found in these regions; this is mainly due to their high moisture-holding capacity which allows crops to grow or survive for longer periods.

On the other hand along the river bank the command area soils have Luvisols nature. Luvisols are technically characterized by a surface accumulation of humus overlying an extensively leached layer that is nearly devoid of clay and iron-bearing minerals..

5.2 Proposed Crops

Based on the above selection criteria crop like **maize, onion, carrot and potato** are proposed for the dry season and **maize, tef and wheat** are proposed for the wet season. Although some of the crops proposed in the project may not have been grown in the project area, most of them have been successfully grown in similar agro-climatic regions. Many different crops were initially considered as adaptable in the project area. But for the reason of estimation of water requirement and financial analysis most of them are not considered and only 3 of them have been selected.

5.2.1 Details of Selected Crops

The essential climatic and soil needs, length of growing period, and their appropriate agronomic and other related requirements of the selected crops are identified below.

Onion

- It grows under a wide range of climates from temperate to tropics (especially from 700 to 2200m.a.s.l).
- It is a high value and demanded crop in the project area and surroundings.
- For a high yield of good quality, the crop needs controlled and frequent supply of water throughout the total growing period.
- Although the crop can be grown on various types of soils, it grows best on light soils, with a pH of 5.5 to 7.5
- Optimum temperatures are ranging between 15⁰c to 23⁰c and low temperatures cause slow growth, poor bulbs and the likes. So planting time adjustment is very much important.
- Irrigation should be discontinued as the crop approaches maturity to allow the tops to desiccate, and also to prevent a second flush of root growth.
- Has a good place in crop rotation practices

Maize

- It is a food and cash crop at green harvest for the community
- Workable and relatively easy for management.
- Its crop residue is used for animal feeding and other economic purposes.
- It is a high potential crop among cereals
- It is a warm –weather crop and grows from the sea level up to altitudes 2500m.a.s.l.
- It is tolerant to wind range of environmental conditions but should be free from frost.
- Optimum temperature for germination is 18⁰c to 25⁰c and for optimum growth 18⁰c to 31⁰c are preferable.
- It requires 800 to 1500 mm of water for optimum production.
- It grows on many type of soils, well drained and aerated
- Its pH ranges from 5.8 to 8.5
- Particularly in the seedling stages, the crop is susceptible to salinity and proper drainage is essential.

Carrot

- Like onion it grows under a wide range of climates from temperate to tropical, especially from 700 to 2200m.a.s. l.
- It is a high value and demanded crop in the project area and surroundings.
- Preferable soil pH is 6.5 to 7.5 and it grows in all soil types.
- For optimum growth, a temperature of 16⁰c to 28⁰c is preferred.
- It has an economic demand in the project area.
- I t has a good place in crop rotation

Potato

- It is a food and cash crop for the poor community
- Workable and relatively easy for management.
- It is a high potential crop among root crops
- It is a cool weather crop and grows from altitudes 1800 up to 3000m.a.s.l.
- It is tolerant to wind range of environmental conditions, but be free from frost & hail.
- Optimum temperature for germination and growth is 15⁰c to 25⁰c.
- It requires 800 to 1500 mm of water for optimum production.
- It grows on many types of soils, well drained and aerated
- It is susceptible to disease and proper management is essential.

5.3 Irrigation Seasons

Irrigation seasons are decided based on the existing climate condition, length of growing period (LGP) of the proposed crops and capacity (efficiency) of the beneficiaries of the project. As to the proposed project condition, two times irrigation seasons as a “Dry-season & Wet -Season” irrigation development are possible, but the latter, (Wet-Season) will be considered as a supplementary and the former (Dry-Season) is considered as “Full-Time” irrigation season. The full-time irrigation season is proposed immediately when most rain-fed crops are harvested. The month of November is assumed to be a starting Month. Even though all crops will not completely be harvested, this period is a must considering the (LGP) of crops, appropriate marketing time of the produce, and the time for second irrigation practices. For the wet season irrigation schedule, it could either be before the onset or after the offset of rainfall according to farmer’s preferences. Accordingly, the following time schedule for both dry and wet seasons is performed in Table 5-2.

Table 5-2: Cropping calendar for dry and wet season

No	Dry Season					LGP
	Crop	Area (ha)	Area (%)	Planting	Harvesting	
1	Onion	30	29.13	1-November	End-April	125 Days
2	Maize	25	24.27	1-November	End-March	140 Days
3	Carrot	13	12.62	1-November	End -March	115 Days
4	Potato	35	33.98	1-November	End-April	120 Days
	Total	103	100	-----	-----	-----
	Wet season					
1	Wheat	45	43.69	Early-June	Late-Dec	150 days
2	Maize	13	12.62	Early-June	Late-Nov	150 days
3	Barley	45	43.69	Early-may	Late -Dec	150 days
	Total	103	100.00	-----	-----	-----

5.4 Proposed Cropping Pattern and Intensity

Multiple cropping is practiced when supply of water is assured during the scarcity periods and the intensity of cropping depends on the quantity of water made available during the irrigation season. The area under single or multiple cropping is mainly decided according to intensity of irrigation and the types of crop varieties to be grown. The areas to be brought under different crops in different seasons are decided according to the agro- climatic situations of the tract. Where possible the cropping intensity is desirable to approach 200%. But from practical point of view under Ethiopian condition, even it is preferable to aim at a cropping intensity of around 100-120% under minimum management input, 120-150 % for medium input, 150-180 % for higher management input and 180-200 % under intensive commercial management.

Therefore, in practice it is preferable to aim at a lower cropping intensity. Hence, the cropping intensity of **180-200%** is proposed for the project in two cropping patterns over one calendar year and it is shown in the Table 5-3.

Table 5-3: Cropping Patterns and Intensity

Crop	Area (ha)	Wet season			Dry season			
		Area (%)	Sowing date	Harvesting date	Area (ha)	Area (%)	Sowing date	Harvesting date
Onion	--	--	--	--	30	29.13	1-Nov	End March
Maize	13	35	End April	November	25	24.27	1-Nov	End March
Carrot	-	-	-	-	13	12.62	1-Nov	March
Potato	-	-	-	-	35	33.98	1-Nov	March
Wheat	45	43.69	Mid Jun	Nov	--	---	---	-----
Barley	45	43.69	Mid Jun	Nov	---	----	---	----
Total	103	100			103	100	---	-----

Hence, the cropping intensity of 180-200% is proposed for the project in two cropping patterns over one calendar year. Generally, the period early March to end of April is the relatively moist season when supplementary irrigation may be required only in the event of dry spells for normal growth of crops. Likewise, the period early November to mid-March is the relatively Dry season when full irrigation will be required.

5.5 Agricultural Inputs

Ethiopian farmers are known for their low rate of application of modern inputs. Use of improved seed is limited to only 2% of the peasants and the number for herbicides and pesticides usage is less than 5%. Agricultural input utilization in smallholder farms constrained with technical, economic and social factors. Potential adopters may be confronted with constraints such as lack of purchasing power, credit, information, and communication links with product and input markets. Despite these and other input use constraints the farmers' experience and exposure to new technologies have been improved due to intensive extension work and attractive crop market prices.

The need of essential agricultural inputs ever increasing in irrigated agriculture. Thus in planning of modern irrigated agriculture the required inputs for the project must be quantified and included in the project document. It helps to plan the financial requirement for each season; to quantify the amount of input to be supplied by potential supplier and to design relevant supportive interventions for improvement of input application.

Therefore, for the project study four essential agricultural inputs including the labor, irrigation water, fertilizer, agro-chemicals and improved seeds expected to analyze their availability and requirement.

5.6 Seeds Requirement

5.6.1 Determining Crop Seeds

As indicated in crop selection criteria section, the availability of potential improved seed is one of the criteria to nominate the crops for the project. In line with this, by referring different literatures from research centers and Ministry of Agriculture annual booklets potential seeds could be screened for recommendation.

The following issues are suggested to take into consideration in identification of the improved seeds for given project area are:

- Length of growing period of potential varieties should be compatible with recommended cropping pattern in which in most cases short-cycle seeds are preferable
- Suitable altitude ranges;
- Level of acceptance of given varieties in the project area, for instance there could be some varieties which have rejected due to different reasons. Therefore, this information need to gather during community consultation
- Susceptibility to insect pests and diseases
- Proximity to market and potential customers in particular for perishable products.

Table 5-4: Seed Requirements for Dry and Wet Season Crops

No	Crops	Seed rate (Kg/ha)	Varieties	Estimated Cost (Birr)
Dry Season				
1	Onion	0.5	Adama red and Bomby	1000 Birr/250g
2	Maize	25-30	BH-660, HB-661	250 Birr/12.5kg
2	Carrot	0.5	Scharwoode	600 Birr/250g
3	Potato	1800	Gudene and Jalene	1000 Birr/Qun
Wet season				
1	Wheat	100-150	Degelu and Kekeba	1350 Birr/100kg
2	Maize	25-30	BH-660, HB-661	250 Birr/12.5kg
3	Barley	200	Kuncho	500/25kg

Table 5-5: Summary of Seed Requirement

Crop	Seed rate (kg/ha)	Dry season Requirement		Wet season requirement(kg)		Annual total seed requirement (kg)
		Area(ha)	(qt/kg)	Area(ha)	(qt/kg)	
Onion	0.5	30	15	--		15
Maize	25	25	625	13	325	950
Carrot	0.5	13	6.5	-		6.5
Potato	1800	35	63000	-		63000
Wheat	150	--		45	6750	6750
Tef	25	--		45	1125	1125

5.6.2 Potential Source of Improved Seeds

Under existing improved seed production, supply and marketing systems the following sources could be considered:

- National Seeds agency
- Regional Seeds agencies
- Certified private commercial farms
- Ethiopian agricultural research centers
- Small holder farmers
- Imported seeds from traders

5.7 Fertilizer Requirements

There is an intimate relationship between soil moisture and nutrient availability, the greatest benefits from fertilizer application can be obtained under irrigated conditions. Literatures, noted that there is a significant correlation between soil moisture regime, fertilizer requirement and availability of fertilizer for plants use. The experiments revealed that the mineralization of nitrogen increases as the water content of the soil increases from permanent wilting percentage to field capacity. As the fertilizer nitrogen is applied to the surface soil, its uptake is inhibited when the soil dries. Water use efficiency is raised by fertilizer which increases dry matter production.

In case of phosphorous element, under optimum moisture level the availability of phosphorous to plants is increasing, however, excessive soil moisture may reduce P absorption possible because of reduced aeration and root penetration. It is believed that application of appropriate and required quantity of fertilizer has remarkable contribution to the plant water use efficiency and ultimately increase the productivity of the crops. Therefore, determining the type of fertilizer and its requirement would be a critical task for the agronomist as well as to the beneficiaries.

The rate of fertilizers for the proposed crops can be available from the research proceedings and other sources. Full package recommendations are mostly available for the released varieties and this data could be used to calculate the fertilizer requirements.

Table 5-6: Fertilizers Requirements for Proposed Crops

No	Crops	Fertilizers(Kg/ha)		Remarks
		DAP/NPS	Urea	
Dry Season				
1	Onion	100	200	DP/NPS estimated cost 1500 Birr/100kg
2	Maize	100	200	DAPNPS estimated cost 1500 Birr/100kg
3	Carrot	100	100	DAP/NPS
4	Potato	200	100	DAP/NPS
Wet season				
1	Wheat	100	100	NPS estimated cost 1400 Birr/100kg
2	Maize	100	200	Urea estimated 1300 Birr/100kg
3	Tef	46	41	

Table 5-7 Summary of seasonal and annual fertilizer recommendation

Crop	Dry season				Wet season				Total requirement, (qt)
	Area (ha)	DAP (qt)	Urea (qt)	Subtotal	Area (ha)	NPS (qt)	Urea (qt)	Subtotal	
Onion	30	60	30	90	--	--	--	--	90
Maize	25	25	25	50	13	13	13		63
Carrot	13	13	13	26	-	-	-	-	26
Potato	35	70	35	105	-	-	-	-	105
Wheat	--	--	--	--	45	45	45	90	90
Teff	--	--	--	--	45	23	20	43	43

5.7.1 Fertilizer Application

There are a number of fertilizer application methods, based on the crop and its cultivation system. Among these, Deep-banding, Side/basal dressing, foliar application and others are known. However, as to the level of irrigation and farmer's awareness, banding, basal and top dressing are the most important application methods in small scale irrigation development. The time of application is also influenced by the type of crop and fertilizer to be used. Accordingly, the following application experiences are designed for the proposed project.

5.8 Agro-chemicals

Similar to other inputs, agro-chemicals should be quantified and costs for further analysis and to provide relevant information for planners and implementers. Unlike to above mentioned inputs the agro-chemical requirement computation need slight modification in approach to avoid exaggerated figures which could not practically applied during the cropping seasons. The unique characteristics of this input requirement calculation compare to others? These are

- Agro-chemicals requirements should not be calculated for the whole cropland unless in some cases like if the crop filed needs a prophylactic measure then the calculation could cover the whole area for specific crop. Otherwise the expert effort is valuable to fix the quantity of the agro-chemicals to plan for the cropping year.
- The frequency of pest occurrence is unpredictable
- Storage capacity and toxicity nature to human and animals of agro-chemicals
- High investment requirement for purchasing

In order to avoid risks on project feasibility and to compromise with the actual experiences, the percent of the area to be considered for requirement estimation was fixed for each crop. The judgment was fixed based on the actual pest prevalence conditions of the project area, suggested to be not more than 20-30%.of the crop area.

Steps to compute agro-chemicals requirements and costs

- Calculate the crop area determined for calculation in reference to the above percentage
- Identifying most common and potential pests and diseases for the proposed crops
- Identifying agro-chemicals for the identified pests with their rate of application
- Data was Collected on price for identified pesticides

Then we can estimate the required pesticides and costs for the project as illustrated in Table 5-8.

Table 5-8: Estimation of agro-chemicals requirements

No	Crop	Insecticides	Fungicides	Herbicides	Remarks
Dry season					
1	Onion	Cypermethrin, at 1.0 l/ha	Ridomill at 2.0 kg/ha.		1. Pesticides estimated cost 300 Birr/liter 2. Fungicides estimated cost 1000 Birr/kg 3. Herbicides estimated cost 200 Birr/liter
2	Maize	Cypermethrin, at 1.0 l/ha	Tilt 250 EC at 2.0 l/ha	---	
3	Carrot	Cypermethrin, at 1.0 l/ha	Ridomil, at 2.0 kg/ha		
4	Potato	Cypermethrin, at 1.0 l/ha	Ridomill at 2.0 kg/ha.	-	
Wet season					
1	Wheat	Carbaryl 85% at 1.0 l/ha	Ridomil, at 1.0 kg/ha	2,4-D at 1.0 l/ha	
2	Maize	Cypermethrin, at 1.0 l/ha	Tilt 250 EC at 1.0 l/ha	Atrazin at 1.0 l/ha	
3	Tef	Carbaryl 85% at 1.0 l/ha	-	-	

Table 5-9: Summary of seasonal and annual agro-chemical requirements and costs

Crop	Dry season requirement			Wet season requirement			Annual requirement	
	Area/ha	Qty (Kg/lt/h)	Total Cost (birr)	Area/ha	Qty (Kg/lt/h)	Total Costs (birr)	Qty (kg/lt/h)	Total Cost (birr)
Onion	30	3	45000	---	---	---	3	45000.00
Maize	25	3	37500	---	---	---	3	37500.00
Carrot	13	3	19500	---	---	---	3	19500.00
Potato	35	3	52500	---	---	---	3	52500.00
Wheat	-	--	---	45	3	67500	3	67500.00
Tef	--	--	--	45	3	13500	1	13500.00

5.9 Human Labor Requirements

Under traditional and smallholder farming system human labor is a major and determinant input for agriculture, out of total labor requirements family labor taking major share while extra labor covers the remaining labor demand. In order to estimate the available family, labor the demographic data of the households is very important. The available active labor in man-days can be estimated by considering the age-group distribution for the average family size. Then multiply the man-days by number of working days in one year. The result indicates the potential available labor in the household. For example, the average size of a farm household within the project area is 6.0 persons and the potential available labor is estimated at 3.0 man-days per household. Assuming 250 working days in a year for crop production activities, an average household could therefore mobilize about 750 man days in a year.

For further comparison and to calculate the need of extra labor, average labor requirement per hectare should be referred for each crop and add up the requirement in annual base. Then by subtracting the required man-days from the potential available labor the planner could find out the need of extra labor either to be covered from mutual labor arrangement or hired labor.

The labor requirement for irrigated crop production was estimated in consultation with the communities or beneficiaries in the project area because of variability of labor utilization in different areas of the country.

Draught Power: usually oxen power is an essential source of power to undertake major land preparation operations under smallholder mixed farming system. To compute the requirement of the draught or oxen power, frequency of the activity and oxen-days required for single round per hectare are important. By multiplying the number of frequency by oxen-days required per hectare we can get the total required oxen-days for given crop and activity depicted in Table 5-10.

Table 5-10 Labor requirement estimation per hectare “with-project” condition

Activity	Unit	Crops			
		Onion	Maize	Carrot	Potato
Nursery	MD	30	0	30	0
Pre planting operation	MD	16	16	16	16
Planting	MD	20	2	10	20
Fertilizer application	MD	2	2	2	2
Irrigation	MD	20	20	20	20
Weeding	MD	40	40	40	40
Crop protection	MD	2	2	2	2
Harvesting	MD	20	10	15	10
Postharvest operation	MD	8	8	8	8
Total	MD	158	100	143	118
Unit cost (Birr/man day)	Birr	75.00	75.00	75.00	75.00
S. Total Cost (A)	Birr	11,850.00	7,500.00	10,725.00	8,850.00
Oxen Days	OD	16	16	16	16
Unit Cost (Birr/Oxen Day)	Birr	150	150	150	150
S. Total Cost (B)	Birr	2400.00	2400.00	2400.00	2400.00
Grand Total (A)+(B)	Birr	14,250.00	9,900.00	13,125.00	11,250.00

* MD= Man day

Table 5-11 Labor requirement estimation per hectare “without-project” condition

Activity	Unit	Crops		
		Maize	Tef	Wheat
Nursery	MD	0	0	0
Pre planting operation	MD	16	16	16
Planting	MD	2	1	1
Fertilizer application	MD	2	1	1
Irrigation	MD	0	0	0
Weeding	MD	40	60	40
Crop protection	MD	2	2	2
Harvesting	MD	8	8	8
Post harvest operation	MD	4	4	4
Total	MD	74	92	72
Unit cost (Birr/man day)	Birr	75.00	75.00	75.00
S. Total Cost (A)	Birr	5,550.00	6,900.00	5,400.00
Oxen Days	OD	16	16	16
Unit Cost (Birr/Oxen Day)	Birr	150	150	150
S. Total Cost (B)	Birr	2400.00	2400.00	2400.00
Grand Total (A)+(B)	Birr	7,950.00	9,300.00	7,800.00

Table 5-12 Crop budget estimation per hectare "with project" condition

Descriptions	Crops												
	Unit	Onion			Maize			Carrot			Potato		
		Qty/ha	Unit Rate (Birr)	Total Cost (Birr)	Qty/ha	Unit Rate (Birr)	Total Cost (Birr)	Qty/ha	Unit Rate (Birr)	Total Cost (Birr)	Qty/ha	Unit Rate (Birr)	Total Cost (Birr)
Human Labor	MD	188	75.0	14100	100	75.00	7500.00	143	75.00	10725.0	118	75.00	8850.00
Land preparation	OD	16	150.0	2400.00	16	150.00	2400.00	16	150.00	2400.00	16	150.00	2400.00
Seeds	Kg	0.5	1000.0	1000.00	25	21.60	540.00	0.6	600.00	600.00	18	1000.00	18000.0
Urea	Quintal	1	1070.0	1070.00	1	1070.00	1070.00	1.0	1070.00	1070.00	1.0	1070.00	1070.00
DAP/NPS	Quintal	2	1350.0	2700.00	1	1350.00	1350.00	2.0	1350.00	2700.00	1.0	1350.00	1350.00
Pesticide	Liter	3	500.0	1500.00	3	500.00	1500.00	3.0	500.00	1500.00	3.0	500.00	1500.00
Sacks	Number	80	10.0	800.00	65	10.00	650.00	90	10.00	900.00	180	10.00	1800.00
Land Tax	Birr		0	500.00	0	0	500.00	0	0	500.00	0	0	500.00
Miscellaneous	Birr			1000.0			1000.00			1000.00		0	1000.00
Total Expense	Birr			25070.0	211.00	0	16510.00	0	3755.00	21395.00		0.00	36470.00
Yields	Quintal	80	1000.0	80000.0	65	700	45500.0	90	900	81000.0	180	700	126000.0
Gross income	Birr			80000.0			45500.00		900.0	81000.00			126000.00
Net income	Birr			54930.0			28990.00			59605.00			89530.00

Table 5-13 Crop budget estimation per hectare “without project” condition

Descriptions	Crops									
	Unit	Wheat			Maize			Tef		
		Qty/ha	Unit Rate (Birr)	Total Cost (Birr)	Qty/ha	Unit Rate (Birr)	Total Cost (Birr)	Qty/ha	Unit Rate (Birr)	Total Cost (Birr)
Human Labor	MD	72	75.00	5400.00	74	75.00	5550.00	92	75.00	6900.00
Land preparation	OD	16	150.00	2400.00	16	150.00	2400.00	16	150.00	2400.00
Seeds	Kg	150	12.50	1875.00	25	21.60	540.00	200.00	9.00	1800.00
Urea	Quintal	1	1070.00	1070.00	1	1070.00	1070.00	1.0	1070.00	1070.00
DAP/NPS	Quintal	1	1350.00	1350.00	1	1350.00	1350.00	1.0	1350.00	1350.00
Pesticide	Liter	3	500.00	1500.00	3	500.00	1500.00	2.0	500.00	1000.00
Sacks	Number	35	10.00	350.00	45	10.00	450.00	25	10.00	250.00
Land Tax	Birr		0	500.00	0	0	500.00	0	0	500.00
Miscellaneous	Birr			1000.00			1000.00			1000.00
Total Expense	Birr			15445.00		0	14360.00	0		16270.00
Yields	Quintal	35	1200.00	42000.00	45	700	31500.0	25	2000.00	50000.00
Gross income	Birr			42000.00			31500.00			50000.00
Net income	Birr			26555.00			17140.00			33730.00

5.10 Crop Yield and Projection Estimates

Agricultural production and estimate and projection are crucial output of agronomic study to explain the potential of the project to contribute to household food security and increased income. As observed in some of the small-scale irrigation projects, the total output of the crop production did not indicate rather than demonstrating the yield or per hectare change due to intervention. Incorporating the total production gain from the intervention is vital indicator of development which needs to be estimated to demonstrate the project potential in crop production. The other issue which undermined during most of the agronomic studies is excluding of the contribution of crop by-products in household economy. In this training material, the conversion factor based on the yield of given crop is presented to apply to calculate partial crop margin at farm level.

5.10.1 Yield Projection Estimates

Yield projection of the project shows the trends of the crop productivity over the project period. The estimation is based on multiple growing factors that determine the crop productivity of the project. Yield estimate could be determined by considering the proposed interventions and improved growing factors which vary between projects. The initial step is identifying major assumptions to be considered to set the yield at the first cropping year and for further projections. Some of common assumptions are listed but not exhaustive:

- Current yield under existing cropping system in the project area or similar ecologies to set the first-year yield
- Yield potential of suggested crop varieties from research outputs proven on farmer's plot
- Yield obtained by model and progressive farmers.
- Regional and National average yields (can be from CSA agricultural reports)
- Farmers' experience in irrigated agriculture and their potential to use the proposed agricultural inputs
- The anticipated commitment of the technical support from district and kebele agricultural development offices
- Comparative advantage of the project area for input distribution and marketing
- Intensive follow up and adequate extension service to be undertaken

Once the assumptions are set then yield could project to the life span of the project. During the yield projection, the agronomist must determine the production year where each crop reaches at full development stage and for the subsequent year the yield will be constant throughout the project life. Some of the above-mentioned assumptions will be applicable for determination of this cropping year. In most cases, in the project where there is good irrigation farming system experience, high level of beneficiary involvement and level of improved technology application the optimum yield could be achievable at shorter period. It's suggested to consider maximum of 3 years for small-scale irrigation project.

The yield incremental rate per year could vary depend on the potential yield increment margin of the proposed crops. There is a possibility to take constant rate of increment for all crops with certain percentage were fixed as shown in Table 5-14.

Table 5-14: Yield Projection for five (5) Years

No	Crops	Yield (qt/ha)				
		1 st -Year	2 nd -year	3 rd Year	4 th -year	5 th -20year
<i>Dry Season</i>						
1	Onion	80	90	110	120	120
2	Maize	50	60	65	80	95
3	Carrot	90	100	110	115	120
4	Potato	140	160	180	200	220
<i>Wet Season</i>						
1	Maize	50	60	65	80	95
2	Wheat	25	30	35	35	40
3	Tef	20	22	23	24	25

6. CROP WATER REQUIREMENT

Crop water requirement is the water required by the plants for its survival, growth, development and to produce economic parts. This requirement is applied either naturally by precipitation or artificially by irrigation. The crop water requirement varies from place to place, from crop to crop and depends on agro-ecological variation and crop characters.

Crop water requirement is the depth of water needed to meet the loss through evapo-transpiration of diseases free growing in large fields under non restricting soil conditions including soil water and fertility and achieving full production potential under the given growing environment.

$$ET_{Cr} = ET_o \times K.C$$

6.1 Reference Crop Evapo-Transpiration (ET_o)

Reference crop evapo-transpiration is the rate of evaporation from an extensive surface of 8 to 15cm tall green grass cover of uniform height, actively growing, completely shading the ground the with no shortage of water. The Reference crop evapo-transpiration (ET_o) for the project is calculated by modified Pen man-Monteith method using CROPWAT 8.0 software. The climatic factors used for the calculation are temperature (minimum and maximum), humidity, wind and sun shine hour. The monthly ET_o calculated is depicted in Table 6-1.

Table 6-1: Climate data of project area

Month	Min Temp, °C	Max Temp, °C	Humidity %	Wind, km/day	Sun, Hrs	Rad, MJ/m ² /day	ET _o , mm/day
January	5.1	22.6	45	78	7.5	19.1	3.46
February	6.7	22.9	48	78	7.9	20.7	3.77
March	8.2	22.9	54	86	7.1	20.3	3.88
April	9.3	21	65	86	7.3	20.7	3.76
May	8.9	21.5	55	104	7.9	21	3.93
June	8.3	22.5	54	130	6.8	18.9	3.87
July	8.5	22	60	112	4.5	15.7	3.32
August	8.3	21.6	61	86	6.2	18.6	3.54
September	8.2	21.1	55	69	6.4	19.2	3.55
October	7.8	19.7	60	78	8	21	3.62
November	5.7	20.3	58	78	8.6	20.7	3.47
December	5.4	21.5	49	86	7.8	19	3.39
Average	7.5	21.6	55	89	7.2	19.6	3.63

6.2 Length of Crop Growth Stage

As the crop develops, the ground cover, crop height and the leaf area change. Due to differences in evapo-transpiration during the various growth stages, the Kc for a given crop will vary over the growing period. The growing period can be divided into four distinct growth stages: initial, crop development, mid-season and late season.

- **Initial stage:** The initial stage runs from planting date to approximately 10% ground cover. The length of the initial period is highly dependent on the crop, the crop variety, the planting date and the climate. The end of the initial period is determined as the time when approximately 10% of the ground surface is covered by green vegetation. Moreover, during the initial period, the leaf area is small, and evapo-transpiration is predominately in the form of soil evaporation. Therefore, the Kc during the initial period ($K_c \text{ ini}$) is large when the soil is wet from irrigation and rainfall and is low when the soil surface is dry
- **Crop development stage:** The crop development stage runs from 10% ground cover to effective full cover. Effective full cover for many crops occurs at the initiation of flowering. For row crops where rows commonly interlock leaves such as beans, sugar beets, potatoes and corn, effective cover can be defined as the time when some leaves of plants in adjacent rows begin to intermingle so that soil shading becomes nearly complete, or when plants reach nearly full size if no intermingling occurs. As the crop develops and shades more and more of the ground, evaporation becomes more restricted and transpiration gradually becomes the major process. During the crop development stage, the Kc value corresponds to amounts of ground cover and plant development. Typically, if the soil surface is dry, $K_c = 0.5$ corresponds to about 25-40% of the ground surface covered by vegetation. A $K_c = 0.7$ often corresponds to about 40-60% ground cover.
- **Mid-season stage:** -The mid-season stage runs from effective full cover to the start of maturity. The start of maturity is often indicated by the beginning of the ageing, yellowing or senescence of leaves, leaf drop, or the browning of fruit to the degree that the crop evapotranspiration is reduced relative to the reference ETo. Although, the mid-season stage is the longest stage for perennials and for many annuals, but it may be relatively short for vegetable crops that are harvested fresh for their green vegetation. At the mid-season stage the Kc reaches its maximum value. The value for Kc ($K_c \text{ mid}$) is relatively constant for most growing and cultural conditions.

- **Late season stage:**The late season stage runs from the start of maturity to harvest or full senescence. The calculation for Kc and ETc is presumed to end when the crop is harvested, dries out naturally, or experiences leaf drop. The Kc end value is high if the crop is frequently irrigated until harvested fresh. If the crop is allowed to senesce and to dry out in the field before harvest, the Kc end value will be small. Senescence is usually associated with less efficient stomata conductance of leaf surfaces due to the effects of ageing, thereby causing a reduction in Kc.

Table 6-2: length of growing stages and kc of proposed crops

S N	Crops	Initial	Crop dev't	Mid-season	Late season	At harvest	Total growing period	Seasonal ET (mm)	Total growing period
1	Onion	0.60	0.80	1.1	0.9	0.85	0.90	550	130
2	Maize	0.50	0.85	1.2	0.95	0.60	0.90	800	150
3	Carrot	0.60	0.90	1.2	1.1	0.96	0.90	501	115
4	Potato	0.50	0.80	1.2	0.95	0.75	0.90	700	130

6.3 Crop Coefficient (Kc)

The effect of crop characteristics on crop water requirement is given by the crop coefficient. It represents the relationship between reference (ET_o) and crop evapo-transpiration (ET_{cr}) or $ET_{cr} = K_c \times ET_o$. Values of crop coefficient given are shown to vary with the crop, its stage of growth, growing season and the prevailing weather conditions. Though, the crop coefficients used are taken from yield responses to water, FAO irrigation and drainage paper 33, the table of crop coefficient (kc) of different growth stages.

6.4 Effective Rainfall

Effective rainfall is the part of the rainfall that satisfies the evapotranspiration demand of the crops. The area receives rainfalls throughout the year ranging from a min of 14 mm/month to a maximum of 129 mm per month. The annual rainfall is 823mm. It is established that rainfall exceeding 5mm can meet part of the plant evapotranspiration needs. The effective rainfall is determined based on the empirical formula. The effective rainfall has been distributed on decadal basis for computing the net crop water requirement.

Table 6-3: Effective Rain Fall for the Project Area

Month	ETo mm/day	ETo mm/month	Rain (mm)/month	Eff rain (mm)
January	3.46	103.8	22	21.2
February	3.77	113.1	41	38.3
March	3.88	116.4	67	59.8
April	3.76	112.8	129	102.4
May	3.93	117.9	72	63.7
June	3.87	116.1	59	53.4
July	3.32	99.6	88	75.6
August	3.54	106.2	109	90
September	3.55	106.5	119	96.3
October	3.62	108.6	67	59.8
November	3.47	104.1	36	33.9
December	3.39	101.7	14	13.7
Total	43.56	1306.8	823	708.2

Rainfall Characteristics - Large quantity as well as high intensity will reduce effectiveness because of excess run off and less infiltration rate. A well-distributed rainfall with some frequent light showers is more conducive to crop growth than downpour.

- ❑ **Land slope** - Here, because of the slope very less infiltration opportunity time is available which results in rapid run off loss and less effective.
- ❑ **Soil properties** - Properties like infiltration rate, retention capacity, releasing capability and movement of water influence the degree of effectiveness. High infiltration, high water holding capacity etc., increase effectiveness by avoiding run of losses. High moisture content, low infiltration rate, low water holding capacity reduces effectiveness.
- ❑ **Ground water characteristics:** -Shallow water table causes more run off and effectiveness is low. Deep water table causes more infiltration and percolation and effectiveness of rainfall is more.
- ❑ **Management practices:-** Bunding, terracing, contour tillage, ridging, mulching, etc., reduce the runoff and increases the effectiveness of rainfall.
- ❑ **Crop characteristics:-** Crop with high water consumption creates greater deficits of moisture in the soil. The effective rainfall is directly proportional to the rate of water uptake by the plant.
- ❑ **Carry over soil Moisture:-** It is the moisture stored in the crop root zone depth between cropping seasons or before the crop is planted. This moisture is available to meet the consumptive water needs of the succeeding crop. The contribution of rain occurring just prior to sowing may be equivalent to full irrigation.

- **Seepage and percolation:-** Surface and sub surface seepage and deep percolation below root zone will also influence effectiveness of rainfall.

6.5 Irrigation Efficiency

In the determination of irrigation water requirement, losses of water incurred during conveyance, distribution and application to the field should be accounted for. Irrigation efficiency expresses the percentage of the quantity of water used efficiently for the growth of the crop in the field in the quantity of intake water from the water source, and is a value which can only be estimated in the design stage. The irrigation efficiency is calculated by the following formula.

$$E = E_c * E_a / 100$$

E: Overall Irrigation efficiency (%)

E_c: Conveyance efficiency (%)

E_a: Field application efficiency (%)

The conveyance efficiency is the ratio of the quantity of water supplied to the fields out of the quantity of intake water from the water source, and represents the efficiency of water transport in the canals. The field application efficiency is the ratio of the quantity of water used for the growth of the crop out of the quantity of water supplied to the fields.

The irrigation efficiency of the potential irrigable areas of each target river sub-basin is shown below based on “Irrigation Water Management: Irrigation Scheduling” (1989, FAO). The conveyance efficiency is selected in the setting that the soil type is clay because the soil of the potential irrigable area is vertisols and the canal length is more than 2000m. Besides, regarding the field application efficiency, the surface irrigation is adopted.

- Irrigation Hour per day: 10hr
- Conveyance Efficiency (E_c): 80%
- Field Application efficiency (E_a): 60%
- Overall Irrigation efficiency (E): 48%

6.6 Result of Irrigation Water Requirement Analysis

Monthly irrigation water requirement is calculated using the mean monthly rainfall data shown in the above table. This calculated irrigation water requirement is the basis for the determination of the system capacity. Hence, the crop water requirement/ ***design supply for the project is 1.56 lit/sec/ha*** in the month of January is required with the assumption of a daily irrigation cycle of 10 hours and rotational flow in the main canals.

Therefore, the total irrigation water required to satisfy net irrigation command area 103 ha of land will be calculated from the formula,

$$Q = \text{Duty} \times \text{area}$$

Where Q is discharge in lit/sec

$$\text{Duty} = \text{flow in lit.sec/ha} = 1.56 \text{ lit/sec/ha} \times 103 \text{ha}$$

$$A = \text{area in ha} = 103 \text{ha}$$

$$Q = 1.57 \text{ lit/sec/ha} \times 103 \text{ha} = 161.71 \text{ lit/sec}$$

6.7 Irrigation Scheduling

Irrigation scheduling is a systematic method by which a producer can decide on when to irrigate and how much water to apply. The goal of an effective scheduling program is to supply the plants with sufficient water while minimizing loss to deep percolation or runoff. Irrigation scheduling depends on soil, crop, atmospheric temperature, irrigation system and operational factors. Proper irrigation scheduling requires a sound basis for making irrigation decisions. Accordingly, for all crops fixed interval at various stages of the crop development is selected yielding minimum yield reduction.

Two factors are important when considering the influence of the irrigation schedule on the choice of intake method: what is the duration and frequency of water supply to the field, and is only one field supplied or are two or more supplied simultaneously. If the duration of water delivery to a field is short, then the use of a gated intake is the most practical because it can be opened and closed easily as many times as needed. The opening and closing of a breach in a canal embankment will take some time, and when a canal bank is opened and closed frequently, the cross-section of the field channel will be eventually become badly degraded. For effective use of siphons, the duration of water delivery should be long in relation to the time it takes to get them all started.

For furrow irrigation, the use of spills should be considered when the duration of water delivery is short. When several farmers are taking water at the same time, each should have an equal share. The use of breaches in such a case is bad, since the discharges are not easy to control. The same applies to gated intake structures because, although gates may be equal in size, the water level in the channel in relation to the respective field levels may not be the same. To ensure equal water intake, siphons or spills are recommended because the total discharge is determined by the number and diameter of tubes, and so is easier to control than when breaches or gated intakes are used. Therefore, field irrigation schedules are based on field water balance and are expressed in depth (d in mm) and interval of irrigation (i in days).

6.7.1 Depth of Irrigation Application (d)

Depth of irrigation application is the depth of water that can be stored within the root zone between the so-called field capacity (sfc) and the allowable level the soil water can be depleted for the given crop, soil and climate. Some crops, such as, vegetables, potatoes, onions and straw berries, require relatively wet soils to produce acceptable yields; others such as cotton, wheat and safflowers will tolerate higher soil water depletion level. However, the tolerated depletion varies greatly with crop development stages; for most crops a reduced level of depletion should be allowed during changes from vegetative to reproductive growth or during heading and flowering to fruit setting.

Depth of irrigation application (d) is equal to the readily available soil water (p.sa) over the root zone (D). An application efficiency factor (Ea) is always added to account for the uneven application over the field or

$$d = \frac{(p.sa) \cdot D}{Ea} = \text{mm}$$

Where

d= depth of application in mm

P= fraction of available soil water

Sa= available soil water in mm/m soil depth

D= Rooting depth of crops in m.

Ea= application efficiency

Table 6-4: Depth of Application during peak water requirement

Description	Unit	Onion	Maize	Carrot	Potato
Available soil water in soil depth(Sa)	mm/m	140	140	140	140
Fraction of available soil water(p)	---	0.25	0.60	0.45	0.25
Readily available soil water (p.sa)	mm/m	35.00	84.00	63.00	35.00
Correction for ET crop		0.95	1.05	0.95	1.05
Rooting depth	m	0.30	1.00	0.40	0.50
Readily available soil water (p.sa).D	mm	10.00	88.20	23.94	18.35
Application Efficiency		0.60	0.60	0.60	0.60
Depth of irrigation	mm	16.6	147	39.90	30.60

6.7.2 Irrigation Application Interval (i)

Correct time of irrigation application is over-riding importance. Delayed irrigation, particularly when the crop is sensitive to water stress, could affect yields, which cannot be compensated for by subsequent over watering. Timing of irrigation should confirm to soil water depletion requirement of the crops which are shown to vary considerably with evaporative demand, rooting depth and soil type as well as with stage of crop growth, therefore rather than basin irrigation interval on calendar or fixed schedules, considerably flexibility in time and depth of irrigation should be maintained to accommodate distinct difference needs during in crop's growth cycle water. These detailed considerations are often not cover at design stage. Normally the irrigation interval given in FAO Irrigation and drainage paper number 24 is for dry irrigation season which is. The irrigation interval can be obtained from:

$$i = \frac{(p.sa).D}{ET \text{ crop}}$$

As we seen from the following table that for proposed crops irrigation interval is different for different crops. Although for maize 21days, onion 3 days, carrot 6 days and for potato 5 days recommended during peak water requirement (Table 6-5).

Table 6-5: Irrigation Interval during peak water requirement

Description	Unit	Selected Crops			
		Onion	Maize	Carrot	Potato
Readily available soil water (p.sa.). D	mm	10.00	88.20	23.94	18.35
Maximum ET _{crop}	mm/day	3.61	4.1	3.96	3.95
Irrigation Application Interval (i)	days	3.0	21.0	6.0	4.6

6.8 Determination of water stress period of selected crops

Each crop has a different water stress period depending mainly on the climate and soil type. Some crops are sensitive to the water stress in germination period while other is at development or flowering period. The water stress period for each crop has to be obtained through research. At the absence of research data an agronomist has been advised to use cautiously water stress periods of crops given in FAO Irrigation and Drainage papers No. 24 and 33.

Table 6-6 Critical growth stages of some common crops

No	Crop	Critical growth stages /periods to water deficit
1	Onion	Bulb enlargement, during rapid bulb growth > vegetative period /and for seed production at flowering/
2	Maize	Flowering > grain filling > vegetative period; flowering is very sensitive if no prior water deficit
3	Carrot	Throughout the growing season
4	Potato	Period of stolonization and tuber initiation > yield formation > early vegetative and ripening

7. AGRONOMIC PRACTICES FOR PROPOSED IRRIGATION CROPS

7.1 Onion - (*Alium spp.*)

Onion is among the bulb crops, which are economically important in human diet. In particular, it has considerable importance in the daily Ethiopian diet and has the potential for domestic use and local processing industries as well. Of course, the traditional shallot was widely used in the past, but currently the onion is substituting it. However, onion at large-scale level is being produced mainly for export purpose. Practically, all plant parts are edible, but the bulbs and the lower stem sections are the most popular as seasonings or as vegetables. The onion is probably native to the Middle East region. The edible onion bulb averages 85 to 87 % water, 1.4 % protein, 10 % carbohydrates, 0.2 % fat, and about 0.6 % ash. It is rich in calcium and moderately supplied with phosphate and iron. It is classed as an energy food, because the calories are supplied largely from carbohydrates /mostly sugars/, but vegetable is well known most for their flavouring. All parts of the plant contain the pungent principle that makes onions desirable as seasoning herbs. The pungent principle is, due to volatile sulfur compounds.

In most cases, it is being produced for marketing and for earning cash. Onion production in Ethiopia among the subsistence farmers is mainly considered for the market and cash earning. However, it is also being produced partially for home consumption. The preference of onion in Ethiopian diet is for a very pungent onion with red skin, high solids and good storage quality.

Varieties

Onions are strongly influenced by day length to produce bulbs and only short-day varieties are adapted to Ethiopian condition that is to say, a day length of approximately 12 hours. Varieties that are either long or intermediate are not adapted to Ethiopian condition, since they are not producing bulb, grown in region having 12 hours day. Varieties adapted to specific areas must be resistant to diseases, and have good size and yielding capacity, long storage properties and the pungency or flavor desired of the onions. The recommended varieties under irrigation are, therefore, Adama Red, Red Creole, Bombay Red and Melkam Red (Pusa red). However, Red Creole is not widely adapted and usually imported seeds of this variety have low quality standards. However, it has some resistance to leaf diseases such as powdery mildew and purple blotch. Experience of some farmers, in some parts of the country revealed that Bombay Red is more preferred by the farmers, mainly due to better market demand and of course, its productivity level has also significant role for its acceptance. However, the problem is that it produces split bulbs and inferior quality for storage.

Adama Red has more pungent property than the others and keeps well and widely used for local consumption and for export. These improved varieties of onion have low resistant to diseases, particularly susceptible to purple blotch disease and onion trips attack. The Ethiopian shallot is resistance to leaf diseases and for this reason, rain fed production by the subsistence farmers is then recommended.

Soil and climatic requirements

Soil

Onion can be grown on different soil types but well- drained medium textured soils rich in organic matter content are more preferred. Optimum pH is in the range of 6 to 7. The crop is sensitive to soil salinity and yield decrease varies at different levels of salinity /ECe/. In particular, young seedlings are susceptible to salt injury so direct seeding on saline soils should be avoided. Heavy black soil is not suitable for onion bulb development. Altitude The length of the growing period varies with climate but in general, 130 to 175 days are required from sowing to harvest. In most cases onion widely grown in the mid and high altitude areas of 700 to 2400 m.a.s.l, but altitudes from 1200 to 1800 m a.s.l are very suitable for onion production. Onion is moderately resistant to frost. Cool weather in higher altitudes, slows down the normal growth of the plant and instead it encourages the plant to initiate flowering

Temperature

For the initial growth period, cool weather and adequate water is advantageous for proper crop establishment, whereas during ripening warm, dry weather is beneficial for high yield of good quality. The optimum mean daily temperature is from 15°C to 20°C (18°C- 23°C day and 10°C- 12°C night). Proper crop variety selection is essential, particularly in relation to the day length requirements in order to produce the bulb.

Rainfall

For optimum yields onion requires 350mm-550mm water throughout its growing period. Onion, as most vegetable crops, is sensitive to water stress and yield is significantly affected. Therefore, for successful onion production the availability of irrigation water, particularly for dry season production is important. Onion is shallow rooted crop and it could not extract water from deep soil layers. This requires the application of irrigation water more frequently but light irrigations should be applied.

Land preparation

Onions develop the end of their stems underground or at a certain depth below the surface of the soil. This part of the stem, which further enlarged within the soil, is called the bulb. The bulb grows quickly and becomes large if the soil is light, not too moist, rich in humus and free from weeds. If the soil is very moist, the bulb may rot. In a well-tilled soil, the water goes down deep and air can get in. So it is important to till the soil deeply. Depending on the specific environmental conditions the land should be ploughed and leveled accordingly. After the field is well levelled furrows at a spacing of 0.40 m for irrigation water application should be prepared. Then the field preferably pre-irrigated one or two days before transplanting.

Planting

The crop is usually sown in the nursery and transplanted after 40 to 45 days. Direct sowing in the permanent field is also practiced but requires high capital investment. However, transplanting after 40 to 45 days of sowing in the nursery is more advantageous in Ethiopian condition, since labour is not so expensive. Because transplanting gives a possibility to select healthy seedlings for planting, it shortened the overall maturity period of the crop, easy to eliminate weak and diseased plants in order to obtain an even stand on the field and in most cases it avoids re-sowing /replanting activities to replace the missed plants, due to germination problem. The crop is usually planted in rows or on raised beds, very often with two rows in a bed, with a spacing of 0.3m between rows and 0.1 m between plants.

Nursery site selection

Appropriate nursery site selection should be given prime importance in onion seedling raising activities in order to raise healthy seedlings. The points to be considered in nursery site selection for onion is the same as for other transplanted vegetable crops discussed under the “General considerations”.

Nursery management practice

The nursery management practices for onion is the same as for other transplanted vegetable crops (refer to the “General considerations for vegetable growing under nursery management practice”). The recommended seeding rate is 3.5 kg/ha and 50 g of seeds for a size of 1 m X 5 m plot nursery is sufficient, 100 g for the size of 1 m X 10 m. But for direct seeding in the permanent field 7 kg/ha is required. For uniform distribution of seeds it is preferable to mix the seed with sand.

Transplanting

- Seedlings will be ready for transplanting to the permanent field after 40 - 50 days of stay in the nursery site, or when the seedlings develop 2 to 3 true leaves /at 12 to 15 cm height/;
- Transplanting of seedlings preferably be done in the morning and late in the afternoon hours in order to avoid wilting of seedlings;
- It is necessary to irrigate the seedbed two days before transplanting for ease of uprooting seedlings and to minimize damage to roots;
- Uprooting of seedlings should be done very carefully in order not to damage the roots;
- The recommended planting system for hand cultivation is by making flat top ridges with furrows between the ridges;
- Plant double rows on the flat ridges 20 cm apart and the spacing between double rows is 30 to 40 cm and spacing within the row is 10 to 15 cm;
- Leaves and roots of seedlings should not be trimmed;
- Seedlings must be planted in the soil below the surface but the base of the seedlings should not be more than 2 to 3 cm deep in the soil;
- Irrigate the newly planted seedlings immediately after transplanting;
- After 7 days of transplanting it is necessary to carry out replanting in places of missed seedlings;
- Do not earth up the onion plants when you cultivate; if you cover the bulb, it won't grow well.

Weed control

Weed control is highly essential for successful onion production. The slow growth- rate of the onion in its initial stages, combined with its open growth habit of the crop and due to the shallow root system of the crop, competent from weeds can be very severe. Therefore, the crop needs to be inter- row cultivated and weeded at least 3 times throughout the growth periods. Depending on the weed situation, particularly at early growth stages the crop should be weeded frequently and kept free of weeds. The first cultivation and weeding should be done after 15 days of transplanting, the second and third on the 30 and 50 days after transplanting. It is very important to avoid excess soiling up on the tops and stems of the plant in order to prevent sharpened bulbs formation and thin skin development that can elongated maturity period and reduced storability of the produce.

Fertilizer application

It is best to grow onions after salad plants such as lettuce and the like. Salad plants do not use all the mineral salts in the soil. Onions use up the salts that remain from the manure you put down for the first crop. Applying fertilizers, is therefore, very important under onion crop. Onions need above all potassium and phosphorus. Sulfur is often very useful too. The amount of fertilizers in the form of DAP and Urea should be mixed together and applied during the seedbed preparation.

Nitrogen fertilizer should be given gradually and moderately, since an excess application causes the formation of thick collars to the bulbs and reduces keeping quality. As a result of excess nitrogen application, the plant may also develop more leaves than the bulbs and consequently the yield will be reduced. The recommended amount for the seedbed size of 1 X 5 m is 52 g of DAP and 33 g of Urea and for the seedbed size of 1 X 10 m is 104 and 66 g of DAP and Urea are required respectively. But in the permanent field under onion crop 200 and 100 kg/ha of DAP and Urea are required respectively. However, in some areas of the Upper Awash and Melkasa 92 kg/ ha of nitrogen is recommended to use, where the first half is applied as a basal application and the second half one month of after transplanting. DAP is applied fully as a basal application in the form of band placement in order to avoid loss through fixation. Application of irrigation water is essential immediately after fertilizers are applied.

Water requirements

For optimum yields onion requires 350 - 550 mm water throughout its growing period. Onion, as most vegetable crops, is sensitive to water stress. Onion is shallow rooted crop not more than 30 cm deep and it needs frequent but light irrigations. For optimum yields the soil water depletion should not exceed 25 % of the available soil water. When the soil is kept relatively wet, root growth is reduced and this favours bulb enlargement. Irrigation should be discontinued as the crop approaches maturity to allow the tops to dry out and also to prevent a second flush of root growth and avoid problems of curing.

The crop is very sensitive to water deficit during the yield formation period, particularly during the period of rapid bulb growth, which occurs about 60 days after transplanting. The crop is equally very sensitive during transplanting from the nursery to the permanent field. For a seed crop, the flowering period is very sensitive to water deficit.

During the vegetative period the crop appears to be relatively less sensitive to water deficit. For high yield of good quality the crop needs a controlled and frequent supply of water throughout its growing periods. However, over-irrigation increases disease susceptibility of the crop and reduces growth as a result the final yield will be reduced. Therefore, in order to achieve large bulb size and high bulb weight, water deficit during the yield formation period /bulb enlargement/ should be avoided. Under limited water supply condition water saving can be made during the vegetative and ripening periods. However, onion production under such conditions water supply should be preferably be directed toward maximizing production per hectare rather than extending the cultivated area with limited water supply.

The crop as indicated above has a shallow root system with roots concentrated in the upper 0.3 m soil depth. In general, 100 % of the water uptake takes place in the first of 0.3 to 0.5 m soil depth. It is essential to schedule irrigations of onion to maintain a continuous high soil moisture levels. In this regard the crop requires frequent but light irrigations, which should be planned to irrigate when the 25 % available soil water in the first 0.3 m soil layer has been depleted by the crop. Irrigation should be scheduled by observing soil moisture level and not by observation of the crop. In the initial growth stages up to four weeks period of time after transplanting it will be necessary to apply irrigation water at every 4- 5 days interval and every 5 to 7 days is commonly practiced then after. Over- irrigation sometimes causes spreading of disease such as downy mildew and white root rot. Irrigation should be discontinued 15 to 25 days before, harvest. The most common irrigation methods applied under onion crop are furrow and basin

Crop Pest Control

Disease control

Various diseases may attack onions. However, downy mildew [*Peronospora destructor*] and purple blotch [*Alternaria porri*] are the major diseases that attack onion severely, particularly during the rainy season and when the humidity is high.

Symptoms of purple blotch

Sunken spots at first water- soaked but rapidly becoming violet/brown, and often zoned and with a yellow hollow, appear on leaves and seed- stalks. Under wet conditions these spots enlarge and elongate, destroying the leaf and stalk tissue. The fungus can also cause a rot of the bulb. Usually, the infected leaves turn yellow and die within 3 to 4 weeks. However, stalks are often girdled and fall over before the seeds mature. The fungus gradually grown down from the leaves and affected the bulb.

Downy mildew

The onion mildew is caused by *Peronospora destructor*. The disease is so destructive under moist conditions. The pathogen over-winters as mycelium in the onion bulbs and sometimes in the seeds as well.

Symptoms:- White to purplish fruiting in elongated white or tan unless the *Peronospora* is followed by other fungi that cause a black mold covering. Usually, the fungus coats the outer surface of old outer leaves first, and when the disease has progressed downward to the leaf sheath, the leaf drops over and then the whole plant becomes yellowish and dies. Recommended measures for the control of the aforementioned diseases are: (1) Never grow two crops of onions one after the other and keeping a four year crop rotation cycle with cereals and pulses is highly important; (2) Make the field free of weed /weeding at least 2 times in the growing period/; (3) Whenever necessary weekly spray with 3.5 kg/ha rate of mancozeb and zineb or 3 kg of ridomil for 3 to 4 times by mixing up with 600 liters of water; (4) For rainy season production, preferably it is advised to use shallot under supplementary irrigation and not onion; (5) Onion is recommended to be cultivated during the dry season under irrigation; (6) Under rain fed condition it is important to make sure that the crop maturity should overlay with dry weather condition.

Onions are also very susceptible to white rot *Fusarium*, Pink rot, even though they are not serious in Ethiopia and several other types of nematodes. Root rots are due to fungus, which attack onion seeds, destroy the roots and bulbs of seedlings, then further cause the leaves to wither and kill the onion plant. Control rots by disinfecting the soil with boiling water, or with Formol.

Crop rotation

In order to avoid the build up of soil borne insect pests and plant diseases crop rotation is recommended under onion crop. Onion could be rotated with crops such as cabbage, tomato, Swiss chard, lettuce and green means.

Insect pest control

Onion thrips, leaf miners and cutworms and wireworms are some of the common insect-pests that attack onion. Onion thrips /*Thrips tabaci*/ are one of the most common insect pests that attack onion in the dry season, particularly in hot, dry climates. These tiny, yellowish sucking insects attack the onions leaves, giving them a blanched appearance.

Damage: Both nymph and the adults rasp the surface tissue of the leaves, causing wounds from which flows the sap on which the insect feeds. The leaf surface of attacked plants bears fine, silvery- white mottling and flecks; the leaves may shrivel and the leaf-tips become dried- out and papery. In the case of a heavy attack, yield losses can be serious, with stunted leaf- growth, reduced bulb size and in extreme cases, death of the plants.

Control: When 5 to 10 insects are observed per plant it is possible to control the pest by using one of the following insecticides. These are: (1) Spraying with 0.5 l/ha of cypermethrin 10 % E.C mixing with 200 liters of water and spray every two weeks for 3 to 4 times; (2) Spray with 3 l/ha of thiodan by mixing with 600 litres of water and spray every 1 to 3 times; (3) Dipping onion seedling in the solution of one spoon of diazinon 60 % E.C and 5 liters of water that can protect onion from trips attack.

Harvesting

- Onion can be harvested within 80 to 100 days after transplanting;
- Bulbs are ready for harvesting when 75 % of the tops are dry and falls on the ground, but before the foliage has dried down completely. If it is harvested before it does not keep well;
- When the crop is matured for harvesting it is advisable to harvest using appropriate hand tools such as forks and care should be taken not to damage the skin;
- Bulbs should be harvested before the tops are completely dried up, otherwise the bulb will decay on the root;
- It is best to lift onion bulbs, when it is not raining, so that they will not rot;
- In the dry season it is possible to leave the fresh harvest bulbs on the field for at least a week period so as to dry them well, covering them with a little grass or straw or with its own leaves in order to protect them from strong sunlight and to protect from cold weather;
- When it is dried detached the bulbs from the tops leaving at least 1- 2 cm of top is usually left on the bulb to prevent disease entrance;
- Roots should be trimmed as close as possible to the bulb, but tops should be trimmed at least to a length of about 1 to 2 cm; Put bulbs in an open mesh bags to complete curing. If it rains, dry the onions under shelter;
- Transport dried onions to the packing and grading centre; sorting disease affected, damaged or decayed bulbs and grading is important and store in cleaned and ventilated storage facilities.

Storage

Only onions, which have been properly dried or cured, are suitable for storage. Rapid development of rot diseases and premature sprouting of can be expected if improperly cured. Onions are best stored in loose stacks up to 50cm deep with good ventilation. Onions should not be bagged until required for marketing. Size grading and eliminating defective bulbs should be done before storage. Large sized bulbs may be expected to have shorter storage life than smaller ones and should be, therefore, be stacked separately. The onion store should be sited where there is good air movement for ventilation.

7.2 Maize- (*Zea mays*)

Maize is one of the most important long- cycle cereal crops originated in the Andes of Central America. It is the most widely distributed and the most important cereal crop worldwide next to wheat and rice. Maize is a principal food crop reached in starch or carbohydrates, averaging about 71% on a worldwide basis but comparatively mature, dry maize kernels contain low levels of high quality protein (9.5%) and some minerals. However, yellow varieties of maize contain significant amounts of carotene, which humans and animals can convert it into vitamin A. The germ protein is of good nutritional quality whereas the endosperm protein is deficient in two essential aminoacids, lysine and tryptophan. Since maize is an energy giving food, particularly in areas where maize is considered as staple food should be supplemented with protein foods such as animal products and grain legumes or oil seeds and with foodstuffs to supply vitamins and minerals to produce a balanced human diet.

Varieties

Maize in general, has the highest yield potential of all cereal crops. However, in order to grow the crop successfully it is very important to take into consideration the selection of more appropriate varieties adaptable to the existing growing seasons and to the specific growing areas. Under irrigation condition, high yielding varieties of maize are recommended to use, unless and otherwise shortage of irrigation water is a concern to raise high yielding varieties of maize with high demand of water.

The variety should be selected according to its suitability to the specific area and the intended use of the crop. The seed should be clean, disease- free and with a good germination capacity. The recommended maize varieties under production are grouped as hybrid and composite varieties. Among hybrid maize varieties BH- 140, BH- 540, BH- 660 and Phb- 3253 are recommended for use, while A- 511, Kuleni, Katumani, Gutto, and Melkassa- I (yellow maize) are among the open pollinated /composite/ varieties that have different adaptability ranges in different agro- ecological zones /for varietal characteristics refer Table 25/. However, in the absence of well- adapted improved varieties to the specific locality, it is also possible to use local cultivars that have wide range of adaptability with promising yield potential. In addition to the specific agro- ecological variability the irrigation water availability should be taken into consideration for appropriate maize variety selection. In this regard, short- maturing and composite varieties are preferable in areas with limited supply of irrigation water, while the long- maturing hybrid varieties that require adequate supply of irrigation water need to be cultivated in areas where there is a promising available water resource.

Soil and climatic requirements

Soil

The crop grows on different soil types, but performs less on very heavy clay and very sandy soils. The crop grows best and gives optimum yield on well-aerated and well-drained loamy soils with pH value of 5 - 7. The crop is susceptible to water logging. The roots cannot perform their normal function or survive in waterlogged soils. Maize is moderately sensitive to salinity. The fertility demand of the crop is relatively high, particularly the high yielding hybrid varieties. The crop is deep-rooted up to 3 m and 80 % of the roots are located in the upper layer of 0.8 to 1.0 m. In general, the crop can be grown continuously as long as the soil fertility is maintained at the optimum level. However, crop rotation with legumes and other short-cycle cereals is advantageous in order to maintain soil fertility and reduce the build up of soil-borne insect pests and plant diseases and minimize crop yield losses that could be incurred, due to pest attack.

Temperature

The crop is grown over a wide range of climates ranging from the temperate to the tropics during the period when mean daily temperatures are below 15°C and frost-free period. However, maize thrives best in warm tropical climates provided that moisture supply is adequate during the growing season. Maize requires a fairly high temperature in order to germinate and germination is impossible below 10°C, while that of wheat and barley, can grow at much lower temperatures. But many varieties of maize at higher temperatures require sufficient moisture to germinate and for normal growth and development. Therefore, for germination the lowest mean daily temperature is about 10°C, while 18 to 20°C are considered as optimum.

As it is indicated above, the crop is very sensitive to frost, particularly in the seedling stage but it tolerates hot and dry atmospheric conditions as long as sufficient water is available to the plant and temperatures are below 45°C. However, the more optimum temperature range is 24 to 30°C. At temperatures above 30-35°C and a relative humidity of 30%, pollination is significantly affected and resulted in poor ear fill. The influence of temperature on the length of the growth cycle is considerable. The variety sown at an altitude of 1,500 m in the tropics will have a much longer growth cycle than the same variety sown at sea level. The growing season is most markedly affected by temperature, when daily mean temperatures are greater than 20°C, early maturing varieties such as Katumani take up to 80 to 110 days and medium maturing varieties take up to 120 to 150 days to mature, whereas long maturing varieties take up to 165 to 180 days.

Altitude

Maize grows at a wide range of altitudes from 0 to 2400 m above seas level, but best perform at altitudes of 1000 - 2000 m above sea level and depending on temperature and the variety it reaches physiological maturity in about 90- 130 days. Obviously at higher altitudes, particularly above 2 200 m the growing season becomes extended up to 8-12 months as mean daily temperature is lowered and at the same time seed setting will be critical instead the crop can be grown efficiently as a forage crop. The main maize growing season in Ethiopia is from April through October- November under rain fed condition. However, under irrigation condition in frost free areas maize can be grown at any time of the year.

Rainfall

Maize is an efficient user of water in terms of total dry matter production and it is potentially the highest yielding grain crop of all cereals group. Therefore, for maximum production a medium maturing variety grown for grain requires between 500- 800 mm of water depending on specific climatic conditions of the area. High yielding varieties usually have high water requirements as compared with the short maturing varieties. Maize is a cross-pollinated crop (i.e. 95 %). Therefore, maintaining the moisture regime of the soil and the nutrient status at the optimum, particularly during flowering and grain filling stages is very crucial. Maximum nutrient and water uptake occurs during the periods of flowering and pollination. Pollination is a very critical time and is readily affected by stress. Wilting of maize during this period will cut yields very significantly (20- 50 %).

Land preparation

Maize is customarily planted on the land that has been cleared and tilled to incorporate crop residues of the preceding crops, and loosened to an adequate depth (20 to 25 cm). Seedbed preparation further assists to incorporate the applied manures with the soil and to destroy perennial weeds as well. The tillage should leave the soil surface somewhat roughened to facilitate penetration of rainfall and to minimize runoff and erosion losses. On the other hand, tillage has minimal effect on crop yields.

Planting /sowing

In the traditional system of maize cultivation, farmers plant maize behind the plough without using exact plant spacing. They use a high seed rate (30- 40 kg/ha) for security reasons such as against emergence- insect- wind- hail and drought- damage and to provide fodder for their livestock. Generally, plant stand at emergence is as high as 75,000 plants /ha. Farmers gradually thin out the plants between first and second weeding and the resultant stand at harvest is usually 30,000- 45,000plants /ha. However, under irrigation conditions, planting density is an important consideration to maintain the optimum plant population per hectare. Plant stand per unit area varies from farm to farm, variety to variety, location to location, and according to cropping patterns. Genotypes with less leaf area per plant require more plants per unit area; shorter plants require narrower rows than taller varieties. As a general rule, plant stand should be higher under high fertility conditions and similarly, under irrigation and slightly lower stands are to be maintained on soils with low fertility and rain fed conditions in order to maintain the required plant population as per the moisture content and fertility status of the soil.

Depending on the type of varieties and seed size the recommended seed rate of maize is in a range of 25 - 30 kg/ha. For large seed sized varieties the seed rate can be taken as 30 kg/ha. Plantings should be made in rows for convenience of weeding and pest control, for ease of irrigation water application and harvesting operations. Therefore, the crop should be planted in rows 0.75 m apart and 0.25- 0.30 m between plants and with this planting distance the estimated plant population will be 48, 000 to 57, 000. On average with this planting distance more than 53, 000 plant population per hectare could be maintained. The depth of sowing varies depending on the soil type and season of cultivation. In this regard, on heavy soils the planting depth is around 5 cm and on well- drained light sandy soils it can be sown as deep as 10 cm. However, under irrigation condition without water stress- planting depth should be kept at minimum in order to initiate early germination and develop further more healthy and stronger plant. Two seeds should be planted in a hole and thinned out later leaving the most vigorous one in each hole.

Weeding /cultivation

In the traditional system of maize cultivation, farmers plant maize behind the plough without using exact plant spacing. They use a high seed rate (30- 40 kg/ha) for security reasons such as against emergence- insect- wind- hail and drought- damage and to provide fodder for their livestock. Generally, plant stand at emergence is as high as 75,000 plants /ha. Farmers gradually thin out the plants between first and second weeding and the resultant stand at harvest is usually 30,000- 45,000 plants /ha. However, under irrigation conditions, planting density is an important consideration to maintain the optimum plant population per hectare. Plant stand per unit area varies from farm to farm, variety to variety, location to location, and according to cropping patterns. Genotypes with less leaf area per plant require more plants per unit area; shorter plants require narrower rows than taller varieties. As a general rule, plant stand should be higher under high fertility conditions and similarly, under irrigation and slightly lower stands are to be maintained on soils with low fertility and rain fed conditions in order to maintain the required plant population as per the moisture content and fertility status of the soil.

Fertilizer application

High yielding potential in maize is closely associated with the responsive nature of the crop to nitrogen and phosphorus fertilizers in combination with the high level of photosynthetic activity in the leaf, due to abundant leaf growth, provided that other inputs and management practices are applied accordingly. Nitrogen interacts positively with plant population, with earliness of sowing, with potential of the variety, with good practice of weed control and moisture supply. It should be remembered that weeds also use fertilizers. Therefore, maize field must be weeded 30-40 days after planting to avoid wasting of fertilizer on growing weeds. If weeds cannot be controlled, then fertilizers should not be applied. It is strongly recommended that apply fertilizers after weeding in order to avoid nutrient loss, being used up by the growing weeds and drainage should also be maintained under waterlogged conditions to improve nutrient uptake by the crop.

The fertilizer recommendation varies with the soil type and agro- ecological zones. The recommended rates of fertilizer under maize as per the recommendation made by the previous National Fertilizer and Inputs Unit of the former MoA based on the soil color are 50-100 kg/ha and 100-175 kg/ha of commercial fertilizers in the form of Urea and DAP respectively. It is also advisable to use the recommendation given by EARO for different maize growing areas as 50 - 200kg/ha and 50 - 225 kg/ha of Urea and DAP respectively in the form of commercial fertilizers.

In order to get efficient use of minimal fertilizers, it should either be drilled near the plants or band placed /side dressed along the rows of the crop. Broadcasting of fertilizer should be discouraged. The fertilizer should be covered with the soil as soon as after it has been applied; otherwise more than half of the nitrogen applied will be lost by volatilization.

Water requirements

Maize is an efficient user of water in terms of total dry matter production and it is potentially the highest yielding grain crop of all cereals group. For maximum production a medium maturing varieties grown for grain requires between 500 - 800 mm of water depending on specific climatic conditions of the area. The crop is fairly tolerant to mild water stress during its vegetative period and also during the ripening of the grain. However, it is both very sensitive to water deficit and excess watering during flowering, i.e. tasseling and silking. Indeed, severe water stress during silking may result in almost no grain yield, due to silk drying and ineffective pollination. Water deficit during the yield formation period may lead to reduced yield, due to a reduction in grain size, whereas the water deficit during the ripening period has little effect on grain yield. The crop factor (kc) relating water requirements (ET_m) to reference evapotranspiration (ET_o) for different crop growth stages of grain maize is for the initial stage 0.3- 0.5 (15 to 30 days), the development stage 0.7- 0.85 (30 to 45 days), the mid-season stage 1.05- 1.2 (30 to 45 days), during the late season stage 0.8- 0.9 (10 to 30 days), and at harvest 0.55 0.6. But this should be determined locally.

Irrigation scheduling

In the case of maize, where water supply is limited it is advantageous to meet as far as possible, full water requirements so as to achieve maximum yield from limited area rather than to spread the limited water supply over large area. Soil water depletion up to about 55 % of available soil water has a small effect on yield. Indeed, it is beneficial to allow somewhat greater depletions during the early stages of growth in order to enhance deep rooting. However, depletion of 80 % or more is allowable during the ripening period. If there is adequate supply of irrigation water, intervals of 21 days will be sufficient to ensure good yields. The depth of water that could be applied per irrigation is about 5 cm. In areas, where rainfall is low and irrigation water supply is restricted, then irrigation scheduling should be based on avoiding water deficits during flowering and yield formation periods respectively. When severe water deficit is unavoidable, then it is recommended to save water during vegetative and yield formation periods and be supplied for the crop during flowering period without incurring additional yield loss.

Crop pest control

Major diseases of maize and their control

The major diseases that attack maize are rust/*Puccinia sorghi*/, leaf blight / *Helminthosporium turcicum*/, head smut / *Sphacelotheca reiliana*/ and downy mildew. The recommended methods of control for the aforementioned diseases are: (1) Using disease free and clean seeds as a seeding materials; (2) Avoiding excess water from the field; (3) Controlling of weed species that can serve as a host plant around the field edges- field sanitation; (4) Using disease resistant varieties for production; (5) Keeping appropriate crop rotation cycles and (6) Applying appropriate rate of fertilizers.

Insect pest control

Maize stalk borer, armyworms, cutworm, aphids and African bollworm are the major insect pests that cause damage to maize crop. Control methods for each insect-pest are discussed.

Stalk borer

- Destroying of crop residues of maize from previous season.
- Removal and destruction of plants with dead heart symptoms during the first six weeks period.
- Destroying of alternative food sources around the field.
- Applying chemical control when the damage extent level is reached at 5% and putting a pinch of cypermethrin 1 % granule or diazinon 10% inside each leaf funnel of plants, with windowing leaves.

Aphids

- Spray with roger 40 % E.C 1 liter per hectare by mixing with 200 litres of water.
- Spray perimicarp 50 % W.P 1 kg per hectare by mixing with water.
- Endosulphan 35 % E.C from 1 - 2 lit/hectare by mixing with water.
- Perimiphos methyl 50 % W.P 1 kg/ ha by mixing with water.

African bollworm

- Deep ploughing and exposing the eggs and pupae to their natural enemies and unfavorable weather conditions.
- Destroying plants that serve as alternative food sources.
- Spraying with 2 litres per hectare of endosulphan 35 % E.C by mixing with water.
- Endosulphan 25 % U.L.V 3 liters per hectare directly without mixing with water.

Armyworm

The control of armyworm should start immediately when two larvae per plant are observed. The following are the recommended control methods: (1) Applying 2 litres per hectare of malathion 50 % E.C; (2) Spraying 85 % W.P 1.5 kg/ha by mixing with water; (3) Spraying malathion 95 % U.L.V 1.25 or Sumathion / Fenitrothion/ 95 % U.L.V 1.5 l liters per hectare directly without mixing with water; (4) Diazinon 60 % E.C or Fenitrothion 50 % E.C 1 liter per hectare by mixing with water

Cutworm

- Baiting using trichlorophone 95 % W.P 250g with 25 kg of wheat straw damped with water.
- 2 litres per hectare of endosulphan 35 % E.C by mixing with 200 liters of water.
- Fenitrothion 50 % E.C 1 liter per hectare by mixing with water and spraying in the afternoon hours.

Maturation and harvest

The maize grain is considered physiologically matured when the kernels reach the “hard dough” stage. The time of physiological maturity is accurately determined by the development of the “black layer” at the point of attachment. Translocation ceases when this black layer forms. At physiological maturity, the kernels still contain about 30- 35 % moisture, which is too wet for spoilage-free storage /except in the form of de-husked ears stored in a crib/. From this stage onward, ripening consists of moisture loss, which may be quite rapid if the weather is dry. If you want to roast the maize cobs, harvest the cobs when the grains are not too ripe. If you want to make flour, harvest the cobs when the grains are quite ripe. Maize kernels should have 10 to 12 % moisture, as the grain will store without molding at this moisture content. If birds or other pests cause serious field damage to ripening maize, the crop may be harvested at the hard dough stage and dried under protected conditions. Subsistence farmers allow maize drying in the field on the stalk before harvesting.

In general, maize yield potential mainly depends on the characteristic of the variety, favorable climatic condition and other management practices. A large ear of maize may have 1000 kernels, but 500- 600 is normal. Any shortage of water, nutrients, or sunlight during the first few weeks of kernel development usually affects the kernels at ear’s tip first, making them shrivel or abort. Most tropical and subtropical maize varieties commonly produce 2- 3 useful ears per plant under good conditions and the most important is the ear and grain size and properly filled up of grains.

Storing maize

Maize cobs can be stored in their husks. That way, the cobs keep better. They can also be stored without their husks, but then insects such as moth weevil may attack the cobs. The greatest hazards to stored maize are: (1) Molding when moisture content is too high; (2) Insect damage- grain weevils, grain moth larvae, and (3) Rodent damage. Grain infesting insects are often brought in from the field at harvest, or they may remain in storage areas from season to season. Storage losses are heavy in warm climates and damage may be serious in relatively short periods Treatment of the empty storage areas, and treatment of all grain as it enters storage irrespective of apparent infestation, is necessary and relatively inexpensive. Infested empty storage areas and empty containers may be disinfected with a weak solution of Malathion, an insecticide that is rapidly degraded and leaves no toxic residue.

7.3 Carrot (*Daucus carota* L.)

The carrot belongs to the family Apiaceae. It is related to celery, celeriac, coriander, fennel, parsnip and parsley, which are all members of this family. The carrot originated in Asia. Initially the roots were long and thin, and either purple or yellow in color. These colors, as well as white and orange, still exist, with the orange or orange-red colors being by far the most popular today. Many shapes of roots also exist, from rather long and thin roots to shorter and thick. Roots may be cylindrical, conical, or even spherical in shape. Carrots are particularly rich in carotene (pro-vitamin A). They are consumed either fresh, as a salad crop, or cooked. Large quantities are also processed, either alone or in mixtures with other vegetables, by canning, freezing or dehydration.

Climate

Carrots belong to the moderately hardy group of plants that are not particularly sensitive to winter cold and frost. Heavy frost just before harvesting can scorch leaves. Carrots do best under cool conditions (10° to 25°C), and their seeds also germinate quite well, though slowly, under cool conditions. Crop development is much slower during colder weather than when temperatures are higher. While carrots can tolerate low temperatures, they can also endure a considerable amount of heat. Carrot crops can thus be grown throughout the year, except in very cold areas, where there is virtually no growth during winter. In very hot areas, summer production is not easy, because it is difficult to establish a good stand. Diseases such as *Alternaria* leaf blight also cause more problems, usually in late summer and autumn, with warm temperatures, high humidity and heavy dew.

Soil

The objective in growing carrots is a high yield of straight, smooth roots. The first requirement is a deep, well-drained, well-prepared soil of a loose, friable structure. Sandy loam or loam soils are most suitable. Heavy, stony, compacted or poorly-drained soils interfere with good root development and are less suitable. In fairly heavy, humus-rich soils, carrots tend to develop excessive leaf growth, and to form forked, hairy roots; they also tend to be rougher and coarser on the outside. Very light soils subject to wind erosion should be avoided. However, the lighter-textured soils are frequently preferred, if well-fertilized and irrigated, because roots then tend to be smoother, straight and have a better appearance; roots are also easier to wash clean at harvest. Carrots grow poorly in very acid soil with a pH of 5 and lower. Carrots are also very sensitive to soil salinity, and brackish soils should be avoided.

Seeding rates

The size of the end product desired affects seeding rate - the denser one plants, the smaller the individual roots produced. For example, one may use a variety such as Red Core Chantenay to produce large, blocky roots (up to 60 mm in diameter and 160 mm in length) if the product is to be delivered to a factory for dicing, by having only 100 to 150 plants per m², using say 3 kg seed per hectare. However, one can plant the same variety for producing whole baby carrots (15 to 27 mm in diameter and less than 80 mm in length) by having 700 to 1000 plants/m², using 20 kg or more seed per hectare.

Fertilizer

Carrots require a fertile soil which allows rapid, uninterrupted growth. In many of the moister areas of KwaZulu-Natal, the soil is naturally acid and leached. Heavy fertilizer dressings may then be necessary, but the use of compost or organic manures is not recommended, as they often cause unattractive, hairy roots, with a coarser texture. Organic manures should preferably be used on preceding crops in the rotation. Suitable liming and fertilizer programmes, based on reliable soil analyses, should be developed for each field.

Nitrogen (N)

Nitrogen requirements of carrots are relatively low. Good yields are possible with applications of as little as 80 kg N per hectare. However, up to 130 kg nitrogen may be applied, particularly where the soil phosphorus and potassium status is high and where excessive leaching on sandy soils occurs. High rates of nitrogen should be avoided, as this stimulates leaf growth at the expense of root development and yield, and also delays harvesting. It is generally better to under- rather than over-apply nitrogen. Very lush leaf growth may also promote the development of diseases, such as Sclerotinia white mould, especially in the dense plantings used for baby carrot production. Most of the nitrogen is applied at planting, except on the sandier soil types, where leaching is likely. The remainder is applied, usually at 4 to 8 weeks, when more rapid leaf growth starts. Due to the high potassium requirement of the crop, potassium nitrate is often favored for top-dressing.

Phosphorus (P)

Phosphorus promotes root development and thus ensures more vigorous growth. It is a very important element for all root crops. Where the phosphorus status of the soil has been built up, 40 kg of applied phosphorus per hectare should be adequate for a good crop.

Irrigation

The soil should never be allowed to dry out. This is of critical importance from planting until the plants have emerged and become well-established, in order to achieve a good stand. The top 30 or 40 mm of the soil, in which the seeds are planted and the early root development occurs, may dry out rapidly under hot conditions, especially if ridge-planting is used, unless frequent light irrigations (only 5 to 10 mm may be necessary) are applied - the lower soil layers may still be moist. In summer it may be necessary to apply water once or even twice a day; during early growth a solid-set sprinkler system would be ideal under such conditions. The soil moisture should be maintained at above 50% of available moisture throughout growth. Generally 25 mm of water per week should be adequate, but under warm, dry, summer conditions, especially if accompanied by hot, dry winds, up to 50 mm may be necessary. Dry conditions when the roots start bulking up can severely reduce yields and quality. Under dry conditions long, thin roots are produced, while excess moisture will result in a larger diameter but excessively short roots.

Rotation

A three-year rotation is advisable, mainly to reduce the risk of pest and disease build-up. By including deeper-rooted crops in rotation with the shallow rooted carrot, nutrients and moisture from the deeper soil layers can be utilized.

Weed control

Carrots are small, rather vulnerable plants during the early stages of growth. Many weeds, on the other hand, grow rapidly and vigorously, and are efficient competitors for available nutrients, water and sunlight. It is very important that weeds be controlled in the early stages of crop development, because early competition can adversely affect plant growth and result in the lowering of crop yields. Weed control can be achieved mechanically, by hand, chemically or by a combination of these methods. In carrot production, chemical control of weeds, supplemented with mechanical and/or hand weeding, is the general practice.

Harvesting and marketing

Although there are some varietal differences, the crop is usually ready for market within 3 to 3½ months, although it may take about a month longer during cold conditions. The roots are harvested when they reach the desired size but are still tender and succulent. For the normal markets, this is when the roots have reached a diameter of 20 mm or more, but is obviously earlier where very slender carrots are needed for pre-packs for specific markets, or for "baby" carrots. Where carrots have grown poorly, or in very dense stands, the criteria for lifting should not be size, but rather maturity and quality.

Carrot roots tend to color up later at their swollen tips than higher up. When the tips have colored up properly, the carrot is "ripe" and should be lifted without further delay, as further size increase is slow, cracking of roots becomes more common, and quality deteriorates. At this stage, root size is no longer the criterion for harvesting. On loose, open, sandy soils it is possible to pull the carrots by hand. Successive harvesting is possible, taking the largest roots at any single harvest. Generally, however, a single harvest of assorted root sizes is practiced by large-scale producers.

Where carrots are planted on ridges or raised beds, they can be loosened by drawing an implement with a horizontal blade through the soil beneath the roots. If planted on level ground, the same implement can sometimes be successful; otherwise roots are ploughed up or lifted with forks. The carrots are then gathered by hand, washed and graded. A proportion of carrots are marketed by being bunched, with leaves attached. Bunches vary in size from about 5 to 10 or more roots. They are then packed in crates or even mesh pockets.

The freshness and quality of leaf is often important to buyers, as it gives an indication of the freshness of the product, especially at the retail outlet. Packing to create the impression of uniform root size enhances the presentation. The use of pre-packs without leaves is also popular, particularly for very fine roots or baby carrots. Other packing's commonly used are one and two kg perforated plastic bags, or even cardboard boxes with carrots bulk-packed in an inner plastic covering.

Commercial yields for large carrots average between 20 and 40 ton per hectare, although 60 ton or more are sometimes obtained by successful farmers. Baby carrot yields are generally about half those of large carrots.

7.4 Potato /*Solanum tuberosum* -L./

Potato is thought to have originated in the highlands of tropical and subtropical regions of South America /currently known as Bolivia and Peru/. Potato is one of the most important agricultural crops and it is being grown worldwide as a main source of carbohydrate next to rice, wheat and maize. The average composition of the potato tuber is about 75 to 78 % water, 1.8 to 2.0 % of high quality protein, 17 to 20 % carbohydrates, 1.2 % fibre, 1.0 % ash, and less than 1.7 % fat. It is low in calcium but fairly high in phosphorus. Of the vitamins, it has substantial content of ascorbic acid, riboflavin, niacin and thiamin. Nutritionally, potato is perhaps the most balanced of the major food crops and it provides calories and protein in proportion to adult human requirements. Potato proteins are somewhat deficient in the amino acids of methionine and cystine. However, it ranks next to soybeans and are superior to the cereals in total protein production per hectare.

In Ethiopia potato is being cultivated in different parts of the country, since the 19th century, mainly in mid and high altitudes, initially as a garden crop but currently, it is also considered as the main field crop. It is being growing mainly for home consumption and the main source of cash for the highlanders as well. In most parts of potato growing areas, potato is being growing mainly by rain fed agriculture. In this relation excess production supply is evident during the main season that leads to low crop price and as a result the farmers are not getting attractive market prices for their produce. In areas, where there is irrigation water, potato is, therefore, advised to be cultivated during the dry season and then the farmers may have the opportunity to get better market price.

Potato is a crop that has different uses. It is in particular, an important product for food purpose to the people and even sometimes it is called as the second bread. Potatoes have a high degree of acceptance as food in all countries where the crop is grown. Potato tuber is used for meals in so many different ways. It is very common in the European kitchen to prepare more than 200 different types of food items from potato. Even in Ethiopia it can be utilized as a food in different ways. Potato tuber is an excellent raw material for production of different kinds of high value industrial products such as for the preparation of alcohol, glucose and in Ethiopia; in particular it is used even for preparation of some local drinks, such as distilled liquor, which is locally called "Areki". Furthermore, potato plays an important role in food processing industries. The leftover from potato is a good source of fodder for cattle. From agronomic point of view, potato is considered as an important preceding crop in crop rotation for wheat, maize and grain pulses that reduces the problem of weed and incidence of diseases.

Soil and climatic requirements**Altitude**

Usually potato is growing in mid and high altitude areas, particularly in high altitudes it is considered as the main stable crop of the highlanders. Potato can be grown successfully in lowland areas as well under irrigation and promising results can be achieved. Best-suited altitudes ranged between 1500- 2800 m. However, for healthy tubers production, particularly for planting purpose, it should strictly be cultivated in high altitude areas. Potato is susceptible to frost damage and it should be grown at frost free periods.

Temperature

For normal tubers development and to obtain high tubers yield temperatures from 5 to 25 °C are more suitable. But optimum soil temperatures for normal tuber growth are from 15 to 18 °C during the growing period. In general, a night temperature of below 15 °C is required for tuber initiation and tuber growth is sharply inhibited when the temperatures are below 10 °C and above 30 °C. Temperatures from 20 to 29 °C lead to the development of small tubers.

Soil

Potato requires a well- drained, aerated and porous sandy loam or loamy sand soils with pH value of 4.5 to 7.5. Not recommended heavy clays and waterlogged soils. Potato is grown in 3 or more year rotation cycle with other crops such as maize, beans and fodder crops, in order to maintain soil productivity, control weeds and reduce crop losses, due to insect pest damage and diseases, particularly soil- borne diseases.

Rainfall/moisture

For high yields, the total crop water requirements for a 120 to 150 days crop are about 500 to 700 mm, depending on the climate of the area. Potato is relatively sensitive to soil water deficit. To optimize yields the total available soil water should not be depleted by more than 30 to 50 per cent.

Production constraints

Major constraints to increased and extended production are the high cost of production, lack of cultivars adapted to specific conditions, diseases and pests damages and the need for improved post- harvest technologies for the diverse environments where potato is grown. The following are recommended improved irrigation agronomic practices to increase production and productivity.

Land preparation

One of the main conditions that allowed obtaining high yields of potato is formation of well prepared, aerated and with adequate moisture of soil. Land preparation, in addition to improving chemical and physical conditions of soil, it is useful to control weeds and expose eggs and pupae of insects and soil borne disease pathogens to sunshine and to their natural enemies. It is also useful to incorporate organic and inorganic fertilizers with the soil. Generally, the following land preparation practices are recommended for potato crop:

- In the first place appropriate sites should be selected for the cultivation of potato;
- It is important that the site should not be previously occupied by potato or related crop species such as cucumber, tomato, pepper, eggplant and tobacco during the preceding four consecutive seasons to avoid the build up of diseases, insect pests and nematodes;
- Prepare the land immediately after harvest of the preceding crop and before the soil is losing its moisture for ease of ploughing;
- Plough the land 2 to 3 times following the germination of weeds at a depth of 25 to 30cm;
- Frequent ploughing can help to loosen the soil to enhance rapid germination and further uniform crop development;
- Then maintain a furrow keeping a distance of 60- 75cm between rows and make ridges of different sizes depending on the soil type and topography of the area;
- Apply pre- planting irrigation a day or two days before planting in order to maintain available soil moisture germination and to maintain the permanent shape of furrows.

Preparation of tubers for planting

In general, for obtaining high production of potato, it is important to pay special attention

to use quality planting materials and its prior preparation for planting. The following areas need special consideration:

- Potatoes are usually propagated by planting seed tubers that are locally produced;
- Separate potato tubers in their size and store them to sprout;
- For rapid germination and uniform plant development only sprouted tubers should be used;
- For dry season planting tubers should be stored in a cool ventilated store for about 2 to 3 months to develop appropriate sizes of sprouts;

- ❑ Tubers stored for seed purpose should have three and more sprouts that are well developed and approximately 1cm long can be used as a criteria for planting;
- ❑ Do not use large or small size tubers for planting, instead medium sized tubers with about 40- 60 g weight, not affected by insect and disease as well as not peeled skin are more appropriate tubers for planting purpose;
- ❑ Care should be taken during transportation in order not to damage sprouted tubers.

Planting

- ❑ Under irrigation the crop is mainly grown on ridges. If the planting is for seed purpose, then potato can be planted on both sides of the ridge with the ultimate objective of obtaining high production of medium sized tubers, whereas if it is being cultivated for consumption the planting method is just in one side of the ridge with the ultimate objective of obtaining large sized tubers that have better market value, with less tuber in numbers, but with increased production;
- ❑ The crop is frost sensitive, therefore, it is recommended to plant in frost-free periods, usually under irrigation the more appropriate time for potato planting is starting from first week to end of January, but in low land or frost free areas it can be planted starting from September onwards;
- ❑ For planting 1 ha of land 15 to 20 quintals of sprouted tubers or 1, 500-20, 000 kg/ha, depending on the size of tubers, are required;
- ❑ The sowing depth is generally, 8-10 cm, while plant spacing for production purpose is 0.75 X 0.3 m under irrigation, whereas for rainfed planting the distance can be increased to ensure sufficient soil moisture (80 – 100 cm). For seed purpose the planting distance should be reduced and maintained as 20 cm between plants and 60 cm between rows;
- ❑ If the sprout is only one per tuber the sprouted part should be put upright and covered with the soil;
- ❑ Attention should be given to irrigate immediately the newly planted field.

Cultivation /weed control

Inter- cultivation and timely weeding are important operations that should be undertaken in order to improve the soil aeration and water infiltration and reducing weed competition for water, nutrients, sun light radiation and space. These operations can be handled simultaneously or as independent activities. Potatoes are not strongly competitive with weeds. Prompt removal of weeds by pulling, hoeing or tillage is essential to avoid competition with the potato plant for nutrients and moisture.

Delayed weed control is very serious because of the interference with tuber formation and development. Particularly, weed competition is most damaging to potato in the early growth stages, until canopy formation; therefore, thorough weed control at these early stages is essential from 7- 12 weeks depending upon the variety and growth conditions. Generally, minimum of two to three weeding are necessary, depending upon the competitiveness of the variety, the type and intensity of weeds and the growing conditions, till full canopy closure. Therefore, the recommended weed control practices under potato are:

1. Potato field should be free of weeds, then cultivation and weeding is important;
2. 2-3 times cultivation and earthing up is important till the canopy is well established;
3. Shallow cultivation and earthing up is also important to perform when the crop is at 15 to 30cm height, particularly to avoid greening of tubers when exposed to sunshine and to maintain its food value and to kill weeds and to control potato tuber moth.

Fertilizer application

Potato is a high nutrient requiring crop and responds positively on fertilizer application. In this regard, poor soil management is perhaps one of the most important constraints for low productivity. Although improved cultivars are important components of production, they require proper soil management in order to realize their yield potential. Nutrition of potato is dominated by its shallow rooting habit and rapid growth rate. So that high yields necessitate a good supply of nutrients throughout the growth period. Application of organic and also inorganic fertilizers increased yield of potato significantly up to 50 % and above. As the same thing is true for other field crops, before fertilizer application it is important to consider soil properties and fertility status, chemical properties of the fertilizer and their nutrient uptake behaviour of the variety of potato planned to be cultivated.

Manure is one of the most important organic fertilizer sources applied under potato, even though its effectiveness is different depending on different soil and climatic conditions of the area. Therefore, it is highly recommended to apply manure under potato considering the soil and climatic factors. In Ethiopian condition, it is recommended to apply manure at a rate of 20 t/ha if it is available.

The recommended amount of manure has to be applied 2 to 3 months prior to planting and incorporate with the soil thoroughly in order to give time for decomposition and make available the nutrients required by the crop. Nitrogen results in early development of the foliage and, therefore, of photosynthetic capacity and maintains active photosynthesis for the required growth period. However, an excess supply may delay tuber initiation and therefore, reduce yield. Nitrogen requirement depends on many factors including soil types and previous cropping practices. In high rainfall areas or under irrigation conditions, a split application of nitrogen fertilizer is recommended, to reduce losses of nitrogen, due to leaching. However, application of nitrogen after tuber development will prolong vegetative growth and delay crop maturity.

Potato needs a good supply of readily available phosphorus, since the root system is not extensive and does not readily utilize less available forms. Because of low efficiency of uptake by potato, phosphorus fertilizer application needs to be considerably higher than the 30 - 80 kg/ha of P₂O₅ taken up by the crop. Phosphorus fertilizer recommendations are, therefore, high in most tropical situations, ranging from 100- 200 kg/ha of P₂O₅ for most tropical potato crops. Phosphorus fertilizer is used more efficiently by potatoes if side dressed and this is especially so at low or moderate application rates. Water-soluble Phosphorus fertilizer is the most efficient source for application under potato crop. Potassium also plays key role in photosynthesis and starch production in potato crop. High yielding varieties can remove 300 kg/ha or more of K₂O in the tuber alone. Potassium fertilizer requirement depends on soil supply and organic manure application. Irrigation can improve availability of soil potassium and there can be varietal differences in susceptibility to potassium deficiency.

In Ethiopia, however, recommendations of potassium fertilizers are not available, of not only for potato but also for other crops. Potato quality is also influenced by nutritional imbalance. Excess nitrogen fertilizers can reduce tuber dry matter and cooking quality, while deficiency of potassium can cause blackening of tubers. The following are recommended for potatoes for most potato growing areas of Ethiopia:

- ❑ Recommended to use 200 kg/ha of DAP before planting or during planting;
- ❑ 150 kg/ha of Urea should be added in split application;
- ❑ For Chiro variety in West Hararghe potato growing areas recommended to use 100 and 150 kg/ha of DAP and Urea respectively;
- ❑ Similarly, for West Amhara potato growing areas 100 and 150 kg/ha of DAP and Urea are recommended respectively;

- ❑ The first half urea is applied when the plant height is at 15 to 20 cm or after 30 to 40 days after planting just at the time of first cultivation and earthen up. The second will be given at the second cultivation and earthen up or at the starting of flowering and covered with soils; Irrigation water should be applied to the field immediately after fertilizer application;
- ❑ Application of organic manure or compost under potato is highly recommended if it is available to supplement the high nutrient requirements of the crop /200- 400 qt/ha well decomposed manure before land preparation/.

Water Requirements

The total crop water requirement for 120-150 days of potato is about 500 to 700 mm, depending on the climate. Potato is relatively sensitive to soil water deficit. To optimize yields the total available soil water should not be depleted by more than 30- 50 %. Depletion of the total available soil water during the growing period of more than 50 per cent results in lower yields. Water deficit during the period of stolonization and tuber initiation and yield formation have the greatest adverse effect on yield, whereas ripening and the early vegetative periods are less sensitive.

Irrigation scheduling

Potato being a shallow rooted crop requires frequent irrigations of shallower depths rather than a few heavy irrigations. In this regard, on average 7 - 10 irrigations are applied during the growing period. The interval between irrigations depends mainly on soil types and the crop growth stages and a range of 7 to 10 days interval is used depending on soil type and temperature of the area. Therefore, irrigation intervals for sandy loam soils may be from 6 to 7 and 9 to 10 days for loam soils. However, the irrigation intervals might be longer in the early crop development stages and shorter with increased vegetative growth and stolonization and a little bite longer up to 15 days before harvesting.

The potato field should be kept moist but not wet throughout the duration of the crop-growing period. The field may be pre- irrigated before planting with aim of enhancing rapid germination and uniform crop development. Irrigation should be discontinued 2 to 3 weeks before harvesting in order to enforce uniform maturity and to develop stronger skin of tubers that increase the keeping quality of tubers. When rainfall is low and irrigation water supply is restricted irrigation scheduling should be based on avoiding water deficits during the period of stolonization, tuber initiation and yield formation.

In order to save water for these critical stages supply of water can be restricted during the early vegetative and ripening periods. If water supply is deficit during the critical periods of water demand of the crop, due to water scarcity, subsequent irrigation produces a set of small sized tubers and as a result leading to a reduction in yield and the market value of tubers, due to price is low. Water supply and scheduling are important in terms of tuber quality. Water stress in the early part of the yield formation period increases the occurrence of spindle tubers. Water deficits during this period followed by irrigation may result in tuber cracking or tubers with black hearts.

Irrigation methods

The most commonly used method for potato in Ethiopia is furrow irrigation.

Crop pest control

Disease control

Potato is susceptible to a wide range of diseases, of which potato late blight /*Phytophthora infestant*/ is the most important fungus disease because no varietal immunity has been found in Ethiopiaso far. In lowland areas, early blight /*Alternaria solani*/ is frequently found and it is also a fungusdisease that attacks the leaves. The fungus can survive in the soil on plant refuse. Bacterial wilt /*Pseudomonas solanacearum*/ is endemic and affects potato in warmer areas. The organism thatcauses the disease is a soil- borne bacterium that may survive in the soil on crop residues for manyyears. It has a wide host range including tomato, pepper, tobacco, eggplant and different weedspecies. Invasion of potato by bacterial wilt is acute and destructive. The disease is soil-borne andmay be transmitted by infected planting material and restricted to use planting materials wherebacterial wilt is reported such as the Shashamane area. In addition, potato is exposed to viraldisease attack such as leaf roll.The most important aspect of disease control is to fully exploit preventive measures. Then the following are the recommended practices for the control of major diseases on potato:

1. Use of disease free planting materials or tubers;
2. Use of disease resistant varieties;
3. Keep strictly a 4 year cycle of crop rotation with cereals, pulses and fodder crops;
4. Rough out infested plants and buried them;
5. For the control of viral disease it is important to control aphids /the carriers/ by spraying 1.5 lit parathin per ha in every week;

6. For the control of early and late blights use 3 kg/ha of mancozeb mixing with 600 lit of water and spray every week or ridomyl M.Z 63.5 % W.P at a rate of 2 kg/ha mixing with 400-600 litre of water spray every week from 2 to 3 times repetitively. Actually availability and affordability of the chemicals mentioned above is the very crucial issue in the Ethiopian condition, particularly at subsistence farmers' level. Therefore, as an alternative, particularly in areas where there is irrigation potential it is recommended to cultivate potato in dry season under irrigation in order to minimize disease infestation and extent of damage.

Insect pest control

Aphids, potato tuber moth /PTM/ and red ants are the major insect pests that attack potato. Red ants attack the stem and tubers by boring. Aphids are tiny insects green, white or black in colour and have shiny body that attached with to the plant parts. It attacks and damages the plant by sucking lower parts of the leaves or young growing tissues of the potato plant. In addition, aphids serve as carriers for the transmission of viral diseases. Aphids can also attack the newly sprouted eyes of potato. PTM is a common insect pest in the lowlands that attack severely the stem and potato tubers in the field and attacks tubers in the store. The following are the recommended practices for the control of these insect pests: Keeping strictly the recommended crop rotation practices, earthen up tubers in order to avoid insect pest attack, cleaning of storage areas before storing the new harvest, use the leaves of Lantana camara and neem tree with the stored products is effective, particularly against the control of PTM/, care should be taken not to damage the skin of tubers during harvesting to avoid further pest attack, field sanitation is also important, it is also recommended to use chemical means of protection as well, such as endosulfan 2 lit/ha or malathion 1.5 lit/ha mixed with 600 lit of water.

Harvesting and storage

Potato from planting to full maturity will take about 90 to 120 days on average depending on the specific environmental conditions and the variety. When the potatoes leaves are just turning to yellowish in colour, it is then the typical sign of maturity. Potato can be harvested at any size but usually best to let them grow to full size (until the vines die off), bearing market considerations. The vines should be dead before harvest for 2 reasons: (1) So the skins will set (harden); (2) To prevent transfer of late blight spores from the vines to tubers which can cause them to rot; vines can be killed topping or with gramoxone. Handle carefully to avoid bruising.

During harvesting in order the skin of tubers to become stronger and to harvest easily it is recommended to cut down the shoot or vegetative parts above the ground and leave for about 10- 15 days before harvest, particularly in hot climates. After the skin of tubers has become stronger it is then possible to dig out tubers using appropriate tools. Then afterwards it will be important to separate the tubers for seed purpose and for marketing or consumption and should be kept safely in appropriate areas not exposed to insect pests attack. But tubers isolated for seed purpose should be kept in diffused light store. Prompt harvest will reduce the possible damage by soil infesting insects that attack tubers. The tubers should be stored temporarily in a shaded, dry, well-ventilated place for seven to ten days to allow time for the skin to become well suberized, and for any cuts or bruises from digging to heal. Thereafter, they may be stored most satisfactorily in a well- aerated, cool, dry place until sold or converted into food. Potato gives yield between 200 and 350 quintals per hectare with adapted varieties under good management.

8. POST-HARVEST MANAGEMENT ACTIVITIES

The three main objectives of applying postharvest technology to harvested fruits and vegetables are:

- To maintain quality (appearance, texture, flavor and nutritive value)
- To protect food safety, and
- To reduce losses between harvest and consumption.

Effective management during the postharvest period, rather than the level of sophistication of any given technology, is the key in reaching the desired objectives. While large scale operations may benefit from investing in costly handling machinery and high-tech postharvest treatments, often these options are not practical for small scale handlers. Instead, simple, low cost technologies often can be more appropriate for small volume, limited resource commercial operations, farmers involved in direct marketing, as well as for suppliers to exporters in developing countries.

Many recent innovations in postharvest technology in developed countries have been in response to the desire to avoid the use of costly labor and the desire for cosmetically "perfect" produce. These methods may not be sustainable over the long term, due to socioeconomic, cultural and/or environmental concerns. For example, the use of postharvest pesticides may reduce the incidence of surface defects but can be costly both in terms of money and environmental consequences. In addition, the growing demand for organically produced fruits and vegetables offers new opportunities for small-scale producers and marketers.

Local conditions for small-scale handlers may include labor surpluses, lack of credit for investments in postharvest technology, unreliable electric power supply, lack of transport options, storage facilities and/or packaging materials, as well as a host of other constraints. Fortunately, there is a wide range of simple postharvest technologies from which to choose, and many practices have the potential of meeting the special needs of small-scale food handlers and marketers.

Post-harvest activities are critical to ensuring the botanical material meets appropriate quality specifications. Temporary storage, sorting and inspection, washing and cleaning, and dehydration are steps commonly applied to the harvested material; these require proper attention in order to prevent degradation and contamination.

8.1 Post-harvest handling

8.1.1 Handling immediately after harvest

- ❑ The harvested crop should be handled, stored, and consolidated in a manner that ensures that the harvested material does not degrade.
- ❑ Avoidance of compaction In general, do not fill or stack sacks or other harvest containers to levels that will result in compacting of harvested materials, as this may cause physical damage as well as temperature build-up and overheating.
- ❑ Protection from external sources of contamination, Protect the harvested material from contact with birds, rodents, insects, and other animals, as well as dirt, dung, smoke, and exhaust.
- ❑ Protection from the elements:-Protect the harvested material from exposure to the elements as appropriate. In most cases the material should be protected from direct sunlight, rainfall, freezing, etc., except where such exposure is required for a specific purpose such as sun-drying.
- ❑ Timing:-Where applicable, minimize the transit time from the point of harvest to the location used for consolidation and cleaning. (However, this may not apply where additional steps are required to prepare the crop for use, such as sun-drying.) Plant materials should be promptly unloaded and unpacked upon arrival.
- ❑ Examination:-If harvested materials are brought from diverse locations or collectors to one location for consolidation and cleaning, examine the harvested material upon arrival to determine whether the material appears to be generally uniform and acceptable.
- ❑ Consolidation:-If multiple harvest lots are consolidated together, assign a new lot number to the combined harvest. Maintain records of the individual lot numbers and quantities combined together.
- ❑ Temperature and moisture control:--Ensure that both the temperature and moisture of the harvested material are controlled throughout post-harvest handling as appropriate to prevent degradation. Use of refrigeration, packing in dry ice, or other cooling steps may be used when needed and appropriate

8.1.2 Separating the desired plant part

- ❑ For certain materials, additional steps are required to separate the target plant part. For example, in some species the outer bark of the trunk, branches, or roots is removed.
- ❑ Such steps that serve to isolate the desired plant part are generally defined by as farm activities (rather than food processing activities).

8.1.3 Washing and cleaning

Many harvested materials, especially roots, need to be washed after harvest to remove dirt and soil. Cleaning is also needed to remove any foreign matter that may have been inadvertently mixed in with the harvest.

1. Washing may be performed under running water, with spray nozzles (where this will not damage the plant material), or by soaking. It may be advantageous to use separate containers for different stages of washing and rinsing.
2. The following recommendations apply to washing and cleaning operations on a farm.
 - ◆ Water quality. Use only potable water for washing the harvested plant material.
 - ◆ Building design. Carry out washing operations in a building or room designed to prevent build-up of mud and other possible sources of contamination. Washing areas should be isolated from areas where other steps are performed.
 - ◆ Drainage. Provide adequate drainage from the washing site, sufficient to dispose of peak water usage. The drainage system should be designed to avoid contamination of potable water supplies.
 - ◆ Drying. Arrange and handle washed crop material in a manner that ensures wash water is adequately removed from the cleaned material.
 - ◆ Removal of foreign matter. Either before or after washing, inspect for or remove all visible foreign matter and sub-standard material. Ensure the botanical material is sufficiently well displayed for ready visibility (e.g., on a conveyor, or spread out on tables, screens, or tarps). Foreign matter includes plant material from other species or from other parts of the harvested species; soil and rocks; insects and other animals; and wire, glass, paper, tools or tool parts, and other man-made objects. Sub-standard material includes, for example, discolored leaves or flowers; immature, overripe, or badly bruised fruits; or any other material that would cause the botanical material not to meet its specifications

8.1.4 Dehydration

Many of the plants that are grown or collected for use in food must be properly dried prior to use, and drying of plant materials is often performed by the same individuals and companies that harvest the plants. Drying conditions can either preserve or degrade naturally occurring botanical constituents and can greatly affect the quality of the material. Insufficient drying can result in microbial or mold growth, while either insufficient or excessive drying can result in degradation of organoleptic characteristics and botanical constituents. Adherence to proper dehydration conditions is therefore essential when drying is performed.

1. Irrespective of its regulatory status and whether the material being dried will be used for food or for a non-food purpose, drying processes should meet the following guidelines.
 - a. Timing. Conduct the dehydration process as quickly as possible after the harvested crop is ready for drying. This is often immediately after harvest, but in some cases, such as where blotting is required, a delay may be necessary.
 - b. Sunlight and shade. As a general rule, flowers and leaves in which color preservation is important should be dried in the shade, unless otherwise specified. Direct sunlight may be utilized for drying when appropriate.
 - c. Temperature control. The optimal drying temperature differs for various plants and plant parts; however, an air temperature of 110° F or 45° C is appropriate for a wide range of botanical materials. Drying should be completed quickly enough to minimize growth of spoilage organisms or (where relevant) pathogens. Some plants, however, are particularly susceptible to excessive temperatures and may require use of a lower temperature. Establish and maintain a temperature that is appropriate for the specific crop and do not allow the temperature in the drying facility or in the botanical material itself to exceed the range at which damage to the quality of the crop may occur.
 - d. Cutting before drying. When the harvested crop consists of items that are large or contain a high level of moisture (e.g., fruit), slice, chop or split these into relatively uniform pieces to ensure they dry quickly, thoroughly, and consistently.

2. Air drying, many operations conduct drying processes in open air, either outdoors or in enclosed areas. On farms drying may be performed in the field or in barns or sheds, while food drying that is outside the “farm” definition must occur in a building that meets the requirements of the applicable food processing regulations. Drying may rely entirely on ambient heat or may also use artificial heat. The following practices are essential to all such operations.
 - a. Design outdoor drying operations with sufficient covering over the dehydrating botanical material (e.g., a net, tarp or roof) to protect against contamination from birds and other flying animals. Also, establish procedures to rapidly provide cover in case of rain or other events that could interrupt the drying process or contaminate the in-process material.
 - b. Design indoor drying operations to ensure that there is sufficient ventilation for airborne moisture to escape.
 - c. In both outdoor and indoor settings, provide adequate air circulation throughout the drying area, for example by installing fans as needed or by monitoring natural air circulation.
 - d. Place material to be dried in thin layers on clean surfaces that afford adequate air circulation. Use food-grade surfaces if the crop is a food crop.
 - e. Carefully turn the dehydrating material as needed to facilitate rapid and complete drying.
 - f. If heaters or other sources of artificially generated heat are used in the drying operation, provide adequate ventilation of the heating equipment, and use only fuels that will not result in smoke or other combustion products coming into contact with the crop and thereby contaminating the material.

8.1.5 Crop rotation

The place occupied by the different crops during consecutive years makes up the crop rotation. In order to reduce the risk of pests and diseases and to maintain soil fertility, crops are rotated within the field in such a way that crops belonging to the same family do not occupy the same area during consecutive years as they share same pests and diseases. Of special concern are crops susceptible to nematodes. In this case, a rotation cycle of minimum four years is required. Moreover, crop rotation is used to avoid the build-up of diseases and pests and to avoid or minimize loss of soil fertility. The possible arrangements in crop rotations can be the following:-

- Cereals/vegetables/or Pulses which help for avoidance especially of stalk borer and rust
- Pulses/cereals/or the other listed.
- Legumes-Possibly advantageous for soil nitrogen fixation if nodulation occurs, and facilitate for avoidance of root borne diseases.
- Pepper/Other crops not the same family to pepper avoidance especially of nematode build up, blight and bacterial wilt only solanaceous crops should be avoided in the rotation system.
- Maize/with vegetables and other cereals is possible

Shallow rooted crops alternatively with deep rooted crops for efficient utilization of resources is also one of the rotational possibilities

9. AGRICULTURAL SUPPORTING SERVICES

9.1 Agricultural extension

The measure of success of irrigation will be its ability to meet its objectives and targets. Extension supports to achieve it, by.

- ❑ Increasing the agricultural returns from irrigated agriculture and thereby increase living standard and alleviate poverty.
- ❑ Improving the farmers' capacity to develop agricultural production so that schemes achieve their economic potential.

The achievement of successful schemes and viable project therefore achieved with the beneficiaries and should not end on completion of the irrigation infrastructure. For the farmers to be able to increase the total value of their input, they need not only regular access to markets, credit and on farm inputs but also exposure to technological improvements and an opportunity to learn new skills. It is necessary to ensure that, the intensity of the extension input developed remains especially high during the first years of cropping as this the time when farmers will need to adapt to the considerable changes in the cropping pattern, increasing intensity and agricultural practices that can be expected with the introduction of irrigated agriculture for the first time.

Therefore, it is important that the extension services are in place and prepared prior to the onset of the irrigation. Agricultural extension is the transfer of new/ improved technologies from the research canters to the users or farmers to make them benefited of the disseminated technologies. The extension package plots on farmers' field performed around the project area on cereal crops are serving as demonstration sites to make the farmers familiarize with the use of improved agronomic/ cultural practices(such as good seed bed preparation, timely sowing, timely weeding, etc), improved seeds, fertilizers, herbicides and pesticides. These helped the farmers to get an optimum yield per unit area of land and to get know how about the agricultural inputs and their utilization. But concerning the vegetable crops production by irrigation, it is not widely experienced and it is at its infant stage and almost no inputs are used Thus, strengthening the irrigation extension with qualified development agents to give technical advices for the farmers on the use of irrigation water and the proposed improved technologies of production are very essential.

9.2 Supply of agricultural inputs

To get a successful crop, it becomes essential to make effective use of fertilizers along with other important soil and water management practices. The use of chemical fertilizers is essential for obtaining high crop yields. Full benefit of fertilizers can be obtained only when the recommended doses of nitrogenous, phosphate/NPS fertilizers are applied. However, many small landholders and resource-poor farmers cannot offer costly fertilizers. This pushes them to use under dose to apply little fertilizers over a large area of their farm land without the recommended rate. As a result, the fertilizers may have no effect on yield.

Water and fertilizer are both high-cost inputs in crop production. However, they are also the highest-return input. When water is readily available to plants, nutrients may move towards roots easily for their absorption or uptake. This is the reason why under dry land conditions, the applied fertilizers have a very limited response to the growing crops. The fertilizer use efficiency in irrigated and rain fed areas can be enhanced through better water management and conservation practices.

The movement of nutrients in the soil is primarily related to the soil moisture and secondarily by the extent of root distribution. In fact, the root distribution affects the availability of both the soil water and the nutrients from the soil profile. A deeper and extensive ramification of the root system assists in exploration of moisture and nutrients from deeper layers of soil. This together with improved top growth due to balanced fertilizers improves the water use efficiency as the effective depth of the reservoir increases according to which plants can absorb water.

There are different agricultural inputs proposed for the project to be used by the farmers. As it is well known in the region, different agricultural inputs are not available and widely used on irrigated agriculture but rain fed agriculture. Thus, these inputs should be made available to the farmers/ beneficiaries of the project to use as proposed and to get the optimum proposed output. The inputs should be available to the farmers at their vicinity at time of irrigation operation with the required amount. This supply of inputs mainly expected from the district co-operatives' office by doing with the district agricultural development office based on the felt need of the farmers requested by the extension worker working with the farmers.

9.3 Credits and marketing

Credit services- Provision of credit to the small holding farmers helps them to buy the required amount of inputs and use as per the recommendation and thereby boosting crop production. Even though there are interest and initiation of the farmers for irrigation development, but there is a problem of lack of money for purchases of inputs. To solve the problem of the initial capital for purchase of inputs, it needs an intervention of both governmental and non-governmental organizations. The existing micro-finance institutions are the dominant sources of credit supply to small holder farmers. Cooperatives have great role in the area of saving and loan giving services for their member farmers.

Marketing-Marketing is the process by which a product or service originates and is then priced, promoted, and distributed to consumers. To initiate the farmers and to make the production sustainable and reliable, the products produced should be of good quality to sell for good prices to generate income for the beneficiaries. Thus, the farmers should plan as proposed cropping pattern from the beginning and should consider the market need and its accessibility. Agricultural cooperatives and unions can fundamentally and reliably solve the individual farmer's problems in the area of input supply and products marketing

10. ESTABLISHMENT OF WATER USERS ASSOCIATION

Peasant farmers who will join the proposed irrigation scheme will be identified and selected right the beginning period of the project. Peasant associations, community leaders, the project, Woreda and Zonal Agricultural Offices and Wereda and Zonal administrative councils will participate jointly in undertaking the duty of farmer's selection. During selection of farmers, the willingness of each farmer, priority to farmers in the command area and additional farmers from outside the command area will be used as possible parameters to select potential beneficiaries. Particular attention could be given to adequately participate female farmers in the project scheme.

Objective

The WUA being the management structure at site (scheme) level and being the owner of the irrigation scheme, it has various objectives, responsibilities and functions in the development process of the schemes. Among the various objectives, the main ones are:

- Coordinate the participation and involvement of the beneficiary communities for equitable irrigation water distribution among the farmers on outlet command basis
- Process and carryout resource mobilization (irrigation O & M fee, labour contribution, material resolve disputes and conflicts among the beneficiaries that may arise due to improper water utilization.
- Provide support and assistance in the form of labour, cash and construction materials during scheme construction.
- Prepare operations and maintenance plans and ensure their implementation.
- Facilitate irrigation extension, micro-watershed, drainage and pollution control work in the service area or canal network.
- Enlist members and update the list of water user farmers.
- Maintain records
- Propose changes in scheme during planning and construction.
- Prepare and execute irrigation management plans etc.

In view of the critical need to get equitable distribution of irrigation land to the existing farmers in the area and in view of the fact that each and every selected farmer is getting technically manageable and feasible holding of the irrigable land it is proposed that about **0.5** hectare irrigable land will be distributed to each selected house hold farmers. Accordingly, the total number of beneficiaries from the intended project will eventually be about **206** house hold.

10.1 The management committee

- ❑ The beneficiary communities (general assembly) shall establish then project management committee, control committee and other subcommittees members.
- ❑ The beneficiary communities (general assembly) shall elect the management committee members. The service period for the executive committee members shall be two years but re-election of members is possible for period of two consecutive terms only.
- ❑ The management committee members shall consist of minimum seven members, but depending to the scale or size of the irrigation scheme the committee member can be more than seven, out of which at least two to three shall be women.
- ❑ Legal binding decisions may only be taken if the Chairperson in accordance with the by-law has invited the management committee members and if more than half of the members are present.

The water user association management committee shall consist at least:

1. Chairperson
2. Vice chairperson
3. Secretary
4. Treasurer /Cashier
5. Accountant,
6. Member/Purchaser/
7. Member/ Store keeper /Scheme Operator/

In addition to the main management committee, the general assembly will also elect the control committee, Irrigation Water Scheduling and Distributing Committee, Input Supply and Marketing Committees. Moreover, the farmers in tertiary unit (TU) constitute water users teams (WUT), who organize the water rotation in their tertiary unit (TU) and these TU-Team Leader also elected by the Management Committees through discussion of the project beneficiaries.

10.2 Rights and obligation of water user association members

Rights

The beneficiary community has the following right:

- a) To get the irrigation water supply service without any discrimination.
- b) To be elected for or elect the water user association committee.
- c) To elect caretaker for the scheme.
- d) To decide on the type of payment amount to cover running and maintenance cost and the like.
- e) To decide upon the expansion and choice of technology.
- f) To decide upon the type and amount of contribution whenever the need arises.
- g) To attend the general meeting and provide constructive idea
- h) To decide the type and the amount of allowance and incentive that shall be given for the committee members based on the financial capacity of the scheme.

Obligation

The beneficiary community has the following obligation:

- a) To use the irrigation scheme properly.
- b) To safe guard the scheme from damage or abuse.
- c) To be involved actively in every activity that shall be significant and required for the scheme, e.g. construction of access road, canal clearing, clearing the surrounding areas of water source
- d) To attend the general meeting that shall be arranged by the committee.
- e) To pay on time users fee that shall be decided on the general meeting.
- f) To report on time any break down or unusual conditions of the scheme to the concerned body.
- g) To safe guard the irrigation water source and related water diversion structure and keep the scheme under good condition.
- h) To co-operate with the WUA committee and scheme caretakers.
- i) To perform every activity but only significant for the scheme that shall be assigned by the committee chairperson, for instance conveying message to the concerned bodies.
- j) To adhere to the regulation set to manage the scheme.

10.3 The by-laws of water user association

The by-law is the guiding rules and regulation of water user association benchmark for the operation and management of the scheme. Bylaws should be prepared, discussed on and approved by the general assembly. Every water user association shall have its own by-laws: The contents of the by-laws shall include the following particulars.

- ◆ Name, location, address and working place (area) of the association
- ◆ Objectives and activities of the association
- ◆ Requirements necessary for membership of the association
- ◆ The right and duties of members of the association
- ◆ The power, responsibilities and duties of management committee, control committee, conflict management committee and credit and input supply committees
- ◆ Conditions, rules, regulations and requirements for irrigation water acquiring, allocation, distribution and drains
- ◆ Conditions for withdrawal and dismissal from membership
- ◆ Conditions for re-election, appointment, terms of office and suspension or dismissal of the members of the management committee or other committees.
- ◆ Conditions for calling of meeting and voting
- ◆ Conditions for fixations of water rates, recovery and other resource mobilization
- ◆ Conditions for land utilization and reallocation
- ◆ Conditions for conflict management
- ◆ Conditions for amendments of the by-laws
- ◆ Other particulars not contrary to objectives of WUA.

11. CONCLUSION AND RECOMMENDATION

11.1 Conclusion

The increasing population and land pressure has worsened the status of poverty and household security in the farming community of the locality. The potential for increasing crop production and income from traditional rain fed cropping is very limited, exacerbated by the erratic nature of the rainfall pattern and land degradation.

The proposed project conforms to the objectives of improving the household economy by addition of improved technology to increase agricultural productivity. It addresses the pressing needs of the area by adequately responding to food security problem of the local population. It will widen social and economic benefits including employment and better living standards.

Farmers are well aware of the prevailing problems of the area (drought, low crop productivity, etc.) and their attitudes are favourable towards the implementation of the project.

11.2 Recommendation

The sustainability of the project is very much dependent on the full participation of the beneficiaries in all aspects of the project implementation. The participatory approach will create a sense of responsibility and ownership and greatly contributes to the success of the project. The objectives of the scheme will only be achievable when:

- The beneficiaries are encouraged to organize themselves for operation, input provision and marketing of products,
- Provision of credit for inputs and other needs is effected,
- The extension service is effectively established, and
- Periodical training should be provided to both extension field staff and beneficiary farmers.

The cropping pattern proposed for the scheme is based on the current knowledge of the beneficiaries and as such does not pose any problem of adoption. However, the production of vegetables and other cash crops in most part is dictated by the prevailing market demands. Planning of vegetable crop production, therefore, requires adequate market information to be parted to the farmers.

12. REFERENCES

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Annex 1: Crop Water Requirement Calculation for Onion

Project **Calle** Zone: **Arsi** District **Shirka** Crop **Onion**

No	Designation	Symbol	Opertation	Unit	MONTHS												Total
					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1	ETO	ETO	Penman	mm/month	103.2	104.7	105.9	100.5	103.2	101.1	89.7	91.8	95.7	90.6	91.8	98.7	1177
2	Crop factor	Kc			1.1	0.9	0.85	0.90							0.60	0.80	
3	Crop Eap	Et crop	(1 x2)	mm/month	113.5	94.23	90.02	90.45	0	0	0	0	0	0	55.08	78.96	
4	Rain fall	P	metro	mm/month	46	87	135	155	101	95	157	165	144	103	54	23	1265
5	Effective rain fall	Pe	*	mm/month	42.6	74.9	105.8	116.6	84.7	80.6	117.6	121.4	110.8	86	49.3	22.2	1013
6	TNT requirement	INT	(3- 5)	mm/month	70.92	19.33	-15.8	-26.2	-84.7	-80.6	-118	-121	-111	-86	5.78	56.76	
7	Project efficiency	Ep	**		0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	
8	TGI reqt	It	(6/ 7)	mm/month	141.8	38.66	-31.6	-52.3							11.56	113.5	
9	Suup.Reqt/ha	Qt	(8/ 259.2)	l/s	0.547	0.149	-0.12	-0.2	0	0	0	0	0	0	0.045	0.438	
10	Irrigation area	A	Crop pattern	ha	30	30	30	30	30	30	30	30	30	30	30	30	
11	Supply Req	Qt	(9 x 10)	l/s	16.42	4.475	-3.65	-6.05	0	0	0	0	0	0	1.338	13.14	
12	Hr appl/day	hr	Given	hour	10	10	10	10							10	10	
13	Supply reqt/day	q/d	(11 x 24/12)	l/s	39.4	10.74	-8.77	-14.5							3.211	31.53	
14	supply reqt/ha	Q/d	(12 x 24/12/A)	l/s/ha	1.313	0.358	-0.29	-0.48	0	0	0	0	0	0	0.107	1.051	
15	design supply	q	Max (14/A)	l/s/ha													1.368

Annex 2: Crop Water Requirement Calculation for Maize

Project: Calle Zone: Arsi District Shirka Crop: Maize (Green cobe)

SN	Designation	Symbol	Operation	Unit	MONTHS												Total
					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1	ETO	ETO	Penman	mm/month	103.2	104.7	105.9	100.5	103.2	101.1	89.7	91.8	95.7	90.6	91.8	98.7	1177
2	Crop factor	Kc			1.2	0.95	0.60								0.50	0.85	
3	Crop Eap	Et crop	(1 x2)	mm/month	123.8	99.47	63.54	0	0	0	0	0	0	0	45.9	83.9	
4	Rain fall	P	metro	mm/month	46	87	135	155	101	95	157	165	144	103	54	23	1265
5	Effective rain fall	Pe	*	mm/month	42.6	74.9	105.8	116.6	84.7	80.6	117.6	121.4	110.8	86	49.3	22.2	1013
6	TNT requirement	INT	(3- 5)	mm/month	81.24	24.57	-42.3								-3.4	61.7	-1013
7	Project efficiency	Ep	**		0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	
8	TGI reqt	It	(6/ 7)	mm/month	162.5	49.13	-84.5	0	0	0	0	0	0	0	-6.8	123.4	
9	Suup.Reqt/ha	Qt	(8/ 259.2)	l/s	0.627	0.19	-0.33	0	0	0	0	0	0	0	-0.03	0.476	
10	Irrigation area	A	Crop pattern	ha	25	25	25								25	25	
11	Supply Req	Qt	(9 x 10)	l/s	15.67	4.739	-8.15	0	0	0	0	0	0	0	-0.66	11.9	
12	Hr appl/day	hr	Given	hour	10	10	10								10	10	
13	Supply reqt/day	q/d	(11 x 24/12)	l/s	37.61	11.37	-19.6								-1.57	28.56	
14	supply reqt/ha	Q/d	(12 x 24/12/A)	l/s/ha	1.504	0.455	-0.78	0	0	0	0	0	0	0	-0.06	1.143	
15	design supply	q	Max (14/A)	l/s/ha							1.567						

Annex 3: Crop Water Requirement Calculation for Pepper Fresh

Project Calle Zone: Arsi District: Shirka Crop: Pepper (Fresh)

No	Designation	Symbol	Operation	Unit	MONTHS												Total
					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1	ETO	ETO	Penman	mm/month	103.2	104.7	105.9	100.5	103.2	101.1	89.7	91.8	95.7	90.6	91.8	98.7	1177
2	Crop factor	Kc			1.1	1.0	0.90								0.40	0.75	
3	Crop Eap	Et crop	(1 x2)	mm/month	113.5	104.7	95.31	0	0	0	0	0	0	0	36.72	74.03	
4	Rain fall	P	metro	mm/month	46	87	135	155	101	95	157	165	144	103	54	23	1265
5	Effective rain fall	Pe	*	mm/month	42.6	74.9	105.8	116.6	84.7	80.6	117.6	121.4	110.8	86	49.3	22.2	1013
6	TNT requirement	INT	(3- 5)	mm/month	70.92	29.8	-10.5								-12.6	51.83	
7	Project efficiency	Ep	**		0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	
8	TGI reqt	It	(6/ 7)	mm/month	141.8	59.6	-21	0	0	0	0	0	0	0	-25.2	103.7	
9	Suup.Reqt/ha	Qt	(8/ 259.2)	l/s	0.547	0.23	-0.08	0	0	0	0	0	0	0	-0.1	0.4	
10	Irrigation area	A	Crop pattern	ha	13	13	13								13	13	
11	Supply Req	Qt	(9 x 10)	l/s	5.472	2.299	-0.81	0	0	0	0	0	0	0	-0.97	3.999	
12	Hr appl/day	hr	Given	hour	10	10	10								10	10	10
13	Supply reqt/day	q/d	(11 x 24/12)	l/s	13.13	5.519	-1.94								-2.33	9.597	
14	supply reqt/ha	Q/d	(12 x 24/12/A)	l/s/ha	1.01	0.425	-0.15	0	0	0	0	0	0	0	-0.18	0.738	
15	design supply	q	Max (14/A)	l/s/ha							1.05						

Annex 4: Crop Water Requirement Calculation for Potato

Project: Calle Zone: Arsi District Shirka Crop Potato

No	Designation	Symbol	Opertation	Unit	MONTHS												Total
					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1	ETO	ETO	Penman	mm/month	103.2	104.7	105.9	100.5	103.2	101.1	89.7	91.8	95.7	90.6	91.8	98.7	1177
2	Crop factor	Kc			1.2	0.95	0.75								0.50	0.80	
3	Crop Eap	Et crop	(1 x2)	mm/month	123.8	99.47	79.43	0	0	0	0	0	0	0	45.9	78.96	
4	Rain fall	P	metro	mm/month	46	87	135	155	101	95	157	165	144	103	54	23	1265
5	Effective rain fall	Pe	*	mm/month	42.6	74.9	105.8	116.6	84.7	80.6	117.6	121.4	110.8	86	49.3	22.2	1013
6	TNT requirement	INT	(3- 5)	mm/month	81.24	24.57	-26.4	-117	-84.7	-80.6	-118	-121	-111	-86	-3.4	56.76	
7	Project efficiency	Ep	**		0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	
8	TGI reqt	It	(6/ 7)	mm/month	162.5	49.13	-52.8	-233	-169	-161	-235	-243	-222	-172	-6.8	113.5	
9	Suup.Reqt/ha	Qt	(8/ 259.2)	l/s	0.627	0.19	-0.2	-0.9	-0.65	-0.62	-0.91	-0.94	-0.85	-0.66	-0.03	0.438	
10	Irrigation area	A	Crop pattern	ha	35	35	35								35	35	
11	Supply Req	Qt	(9 x 10)	l/s	21.94	6.634	-7.12	0	0	0	0	0	0	0	-0.92	15.33	
12	Hr appl/day	hr	Given	hour	10	10	10								10	10	
13	Supply reqt/day	q/d	(11 x 24/12)	l/s	52.66	15.92	-17.1								-2.2	36.79	
14	supply reqt/ha	Q/d	(12 x 24/12/A)	l/s/ha	1.504	0.455	-0.49	0	0	0	0	0	0	0	-0.06	1.051	
15	design supply	q	Max (14/A)	l/s/ha							1.57						