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ACRONYMS

m.a.s.l	Meters above Sea Level
Br	Birr
CROPWAT	Crop Water Requirement
d	irrigation depth
D	root depth
DA	Development Agent
Ea	Application Efficiency
Ec	Conveyance Efficiency
Ed	Field canal Efficiency
ETcr	Crop Evapotranspiration
ETo	Reference Crop Evapotranspiration
Ha	hectare
H.H	House Holds
i	irrigation interval
IRn	Net Irrigation Requirement
IRg	Gross Irrigation Requirement
Kc	Crop coefficient
l	liter
LGP	Length of Growing Period
MD	Man Day
mm	millimeter
NPS	Nitrogen Phosphorus Sulfur
^oC	Degree centigrade
OD	Oxen day
P	allowable depletion
p	Total rainfall
p eff	Effective rainfall
OWWDSE	Oromia Water Works Design and Supervision Enterprise
Qt	Quintal
s	Second
Sa	Total available moisture
UTM	Universal Traverse Meridian

EXECUTIVE SUMMARY

Irrigation is the key input in crop production. Full benefit of crop production technologies such as high yielding varieties, fertilizer use, multiple cropping, crop culture and plant protection measures can be derived only when adequate supply of water is assured. On the other hand optimum benefit from irrigation is obtained only when other crop production inputs are provided and technologies applied. It is through irrigation and integrated crop development that sustainable crop production can be ensured.

In this view, the feasibility study of Worbate Small Scale Irrigation Development Project was carried out in Gomole woreda, Abunu kebele to develop a net command area of 205.54 ha.

The general objective of the agronomy study is to investigate the existing agriculture and identify crops that are adaptable to the area and recommend the improved agronomic practices to increase the productivity and production of the crops on the proposed command area through introduction of modern irrigated agriculture and by using modern farming technologies and thereby attain food self sufficiency and food security of the community of the area.

The selection of potential crops during the feasibility study of the project has given due emphasis to the critical conditions such as climatic conditions and adaptation of the crops to the growing conditions of the project area, the soil condition of the project area, experience and interests of the farmers to grow, the length of the growing periods of the various crops, yield potentials, market demand of the products, crop rotation and crop diversification requirements.

For these crops, production of two cropping in a year (double cropping) is recommended, one as first phase supplementary irrigation and the other second phase supplementary irrigation.

For the proposed crops cropping calendar, cropping pattern and intensity, yield and yield projection, crop water requirement, agricultural inputs and supporting services, labour requirement and agronomic recommendations are proposed.

To full fill the objectives of the project, all the agronomic recommendations given for the crops should be followed by the development agents and the beneficiaries. Besides the use of agronomic recommendations, the efficient (intensive) use of land and water as proposed in the project is very essential. The provision of extension service must be strengthened to adequately address the essential agronomic practices including timing of the various operations, land preparation, cropping techniques, maintenance of soil fertility, managing water application, crop protection, harvesting, storing of produces and crop rotational needs. Adequate and timely supply of agricultural inputs including, improved and viable seeds, fertilizers and plant protection chemicals to the beneficiaries has paramount importance to achieve the proposed yield projection.

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.

The development of irrigation and agricultural water management holds significant potential to improve productivity and reduce vulnerability to climactic volatility in any country. Although Oromia has abundant rainfall and water resources, its agricultural system does not yet fully benefit from the technologies of water management and irrigation. Improved water management for agriculture has many potential benefits in efforts to reduce vulnerability and improve productivity. Specifically, primary rationales for developing the irrigation sector include: Increased productivity of land and labor, which is especially pertinent given future constraints from population growth, reduced reliance on rainfall thereby mitigating vulnerability to variability in rainfall, reduced degradation of natural resources, increased exports, increased job opportunities, and promotion of a dynamic economy with rural entrepreneurship.

Irrigation is the artificial exploitation and distribution of water at project level aiming at application of water at field level to agricultural crops in dry areas or in periods of scarce rainfall to assure or improve crop production. An adequate water supply is important for plant growth. When rainfall is not sufficient, the plants must receive additional water from irrigation. Various methods can be used to supply irrigation water to the plants. Each method has its advantages and disadvantages. These should be taken into account when choosing the method which is best suited to the local circumstances.

Irrigation is the key input in crop production. Full benefit of crop production technologies such as high yielding varieties, fertilizer use, multiple cropping, crop culture and plant protection measures can be derived only when adequate supply of water is assured. On the other hand optimum benefit from irrigation is obtained only when other crop production inputs are provided and technologies applied. It is through irrigation and integrated crop development that sustainable crop production can be ensured.

The districts in Borena lowlands, like Gomole, and others are among those highly vulnerable to basic needs and chronic food insecure. The ill effects of drought, unreliability of rainfall and rapid increase in population have made the efficient use of irrigation water vitally important, particularly, where the greatest potential for decreasing food deficiency and poverty is often to be able to support the food demand of the community and hence dependent on food aid so demanding development intervention of the Regional government. Therefore, irrigation based integrated development is the best alternative to divert this trend and to bring radical transformation in the community tradition. Accordingly, the Oromiya regional state has decided to intervene in the situation through Worbate small scale irrigation project, that is aimed to the improvement of agricultural production, with a view to realize the objective of food self sufficiency, food security and hence improvement of social facilities.

In this view, the feasibility study of Worbate Small Scale Irrigation Development Project was carried out in Gomole worda, Abunu kebele to develop a net command area of 205.54 ha. The data obtained from socioeconomic study shows that the beneficiaries of the proposed project area will be about 822 households if the land that will be distributed is 0.25ha per household, but if the land that will be distributed is 0.5ha per household, the beneficiaries will be 411 households (H.H).

The major farming system in the kebele is agro pastoral. The main livelihood of the people of the area is animal production. Crop production is for subsistence only and shortage of rain fall is the main constraint on crop production in the area. The area is food insecure area and the people of the area get food aid from the Government and non Government organizations.

The project area has a bimodal rainfall whereby the main rainy season is from mid March to mid May (Gannaa) and the short rainy season is from mid September to early November (Hagayya). Generally the annual total rainfall of the area is about 793.9 mm and the rainfall is highly erratic, unreliable, late on the onset, less in amount and distribution.

2. OBJECTIVES

2.1 General Objective

The general objective is to study the existing agriculture and identify crops that are adaptable to the area and recommend the improved agronomic practices to increase the productivity and production of the proposed command area through introduction of irrigated agriculture by using modern farming technology and thereby attain food self sufficiency and food security of the community of the area.

2.2 Specific Objectives

The specific objectives of agronomy feasibility study include the following important points. These include:-

- Evaluation of the existing agricultural situation of the study area (i.e. crops grown, cropping pattern and farming system).
- Investigation of the suitability of soils, climate and water for the proposed irrigation project.
- Identification of the existing physical environment of the study area.
- Identification and evaluation of crop production constraints of the study area.
- Based on the crop selection criterion, selection of suitable crops, cropping pattern and cropping calendar for the project.
- Estimation of input requirements such as seeds, fertilizers, chemicals, labour and draught power for the selected crops.
- Prediction of yield projection for the selected crops.
- Recommendation of important agronomic practices and supporting services for the crops grown under irrigation.
- Analysis of crop water requirements and irrigation scheduling of the proposed crops by taking into consideration climate, soil and crop characteristics.

3. METHODOLOGY

In order to undertake the irrigation agronomy study of this particular irrigation project, both primary and secondary data were collected. Accordingly,

- Major relevant studied documents were collected and reviewed,
- Checklists/Questioners were prepared to collect necessary information from woreda, kebele and command area,
- Field observation was performed to identify the land use patterns, cropping pattern and agronomic practices of the project area,
- Consultations were undertaken with Woreda agriculture extension workers and kebele level development agents,
- Community consultation on the benefit of irrigated agriculture and their interest for the crop selection was also undertaken in the command area,
- The necessary meteorology data representing the project area were obtained from Yabello data owing to the absence of nearby station representing the project area,
- Data processing and computation of crop water requirement was undertaken by modified Pen man-Monteith method using Cropwat 8.0 software.

4. DESCRIPTION OF THE STUDY AREA

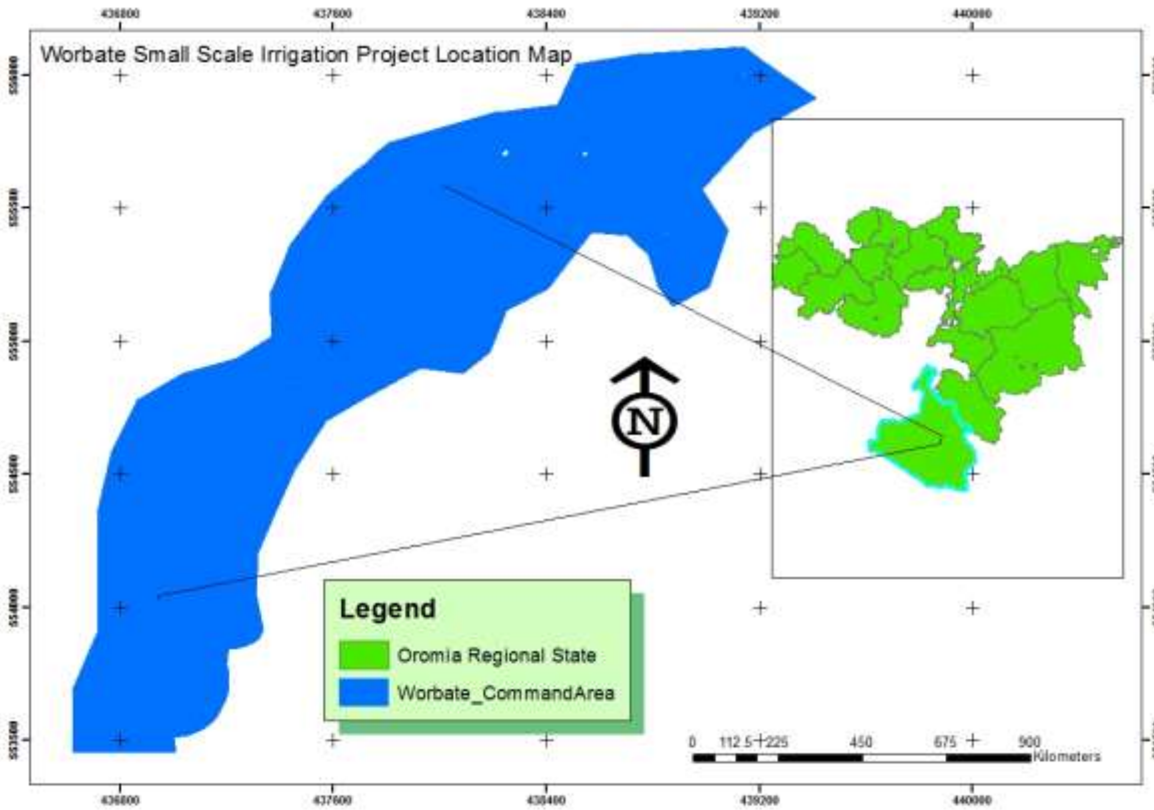
4.1 Location and Accessibility

The proposed project area is situated in Oromia regional State, Borena zone, Gomole woreda, Abunu kebele. The beneficiaries of the proposed irrigation project area are totally found in this kebele. The location of the proposed micro earth Dam site is between 436271.57 E and 552033 UTM N at an elevation of 1465 m a.s.l. and the elevation of the command area extends from 1459.28 to 1397 m.a.s.l.

The distance from the capital city of the region, Finfinne to the head work site is about 573 km and from zonal capital, Yabello town is about 52 km and from the woreda town Surupha is about 48 km of which about 18km is Asphalt up to Harobake village. The project area covers about 205.54 hectares of land (net irrigable area).

The area is accessed through dry weathers road and it is accessible only during dry seasons.

Figure 1 Location Map of the project area



Source: Soil and Land Suitability Study Draft Report

4.2 Agro-ecology

Based on traditional climatic zones of Ethiopia (i.e. temperature and rain fall), the agro-ecological classification of the proposed project area is classified as dry kola. The major crops produced in this agro-ecology are maize, sorghum, rice, millet, soybeans, sesame, linseeds, cotton, peppers, tomatoes, onions, fruits (mango, bananas). The Agro-climatic Distribution and Crop Patterns in the Oromia Region are depicted on the table below.

Table 1 Agro-climatic Distribution and Crop Patterns in the Region

Agro-climatic zone	Altitude , m a.s.l	Area %	Max-temperature ^{0}C	Crops
Wurch	Above 3,000	0.9	Less than 7.5	Barley
Dega (Highland)	2,500 – 3,500	11.8	7.5-22	Barley, wheat, teff, faba beans, field peas, chickpeas, lentils, potatoes, rapeseeds, noug, fruits (apples), garlic, onions
Weina Dega (Mid Altitude)	1,500-2,500	36.6	22-27.5	Teff, maize, sorghum, millet, haricot beans, chickpeas, groundnuts, potatoes, sweet potatoes, lentils, soybean, noug, linseed, peppers, tomatoes, fruits (avocado, guava, citrus, bananas)
Kolla (Low land)	Below 1,500	50.7	22-30 (more)	Maize, sorghum, rice, millet, soybeans, sesame, linseeds, cotton, peppers, tomatoes, onions, fruits (mango, bananas)

Source: Anger Dam Feasibility Study, 2011

4.2.1 Length of growing period

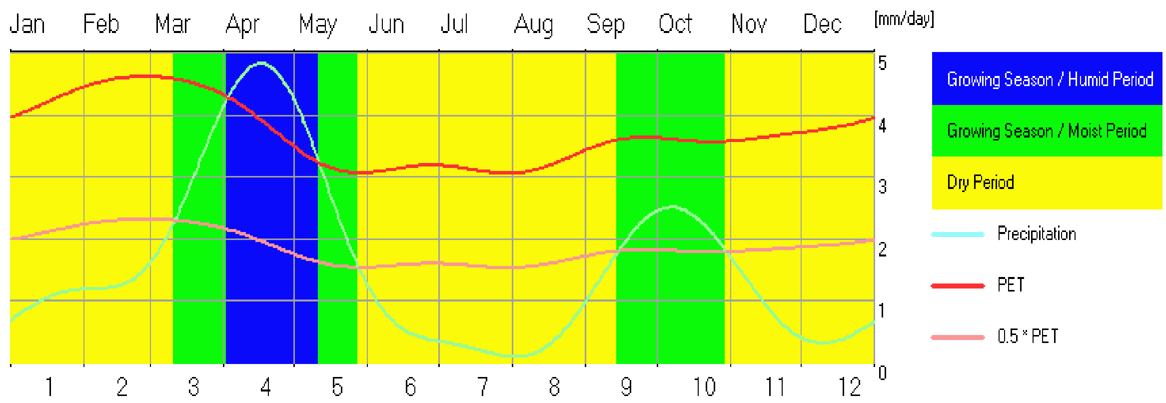
It defines as “the total number of days per annum with sufficient available moisture for crop growth.” The length of growing period could give a highlight about the potential crops and varieties to be considered to develop crop basket for the given area. Further the main constraints related to the agricultural development could be identified that can indicate the area that need more attention and intensive data assessments.

Length of Growing Period (LGP) of the study area was determined by mean rainfall and half potential evapo-transpiration (0.5PET). From the comparison of mean rainfall and half potential evapo-transpiration (0.5PET), LGP was obtained where the amount of rainfall exceeded half PET and addition of some days until the stored water was evaporated (i.e. the dates starting from the point when RF curve cross 0.5 PET and up to it goes down (RF curve crosses 0.5 PET again) was considered as LGP period of the area.

Since the area has got bimodal type of rainfall both the first phase irrigation and second phase irrigation become supplementary irrigation. Length of Growing Period in and around the project area is depicted as follows in Fig.2 and first phase irrigation is proposed starting from

December to April and second phase cropping is proposed starting from June up to September. The lengths of the growing period in the project are depicted on the graph as follows.

Figure 2 Length of Growing Period in and around the project area



Source: New LocClim V1.10 FAO, 2005

4.3 Climate

Climate is one of the components of an environment that determines formation and characteristics of natural vegetation, soil formation and farming systems of a particular area. Based on the climatic factors, the length of the growing period (LGP) for the crops produced in the study area will be described. Climate and soils gives information on the types of climate and soil that are best suited to the crop under consideration.

The climate in the project area is characterized by a bimodal rainfall and the main rainy season is from mid March to mid May and the short rainy season is from mid September to early November. However the rainfall is highly erratic, late on the onset, less in amount and poor in distribution.

The nearest metreology station to the proposed command area is Finchwuha station. But only rainfall data is available and other data were not available at Finchwuha station. Thus Yabello station is used for other data i.e. for minimum temperature and maximum temperature, relative humidity, wind speed and sunshine hour data for the computation of reference evapotranspiration and then crop water requirement was computed for all the proposed crops.

4.3.1 Rainfall

The rainfall pattern of the study area is bimodal. The total annual rainfall of the study area is about 811.4 mm. The rainfall distribution and amounts vary from year to year. The moist months of the project area are mid-March to end March and mid-September to end October and the dry months are from end October to mid beginning March and end May to mid-September. The rainfall of the project area is shown on the table as follows.

Table 2 Rainfall data of the project area

Parameter	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**
Rainfall (mm)	16.9	11.9	47.6	188.3	138.2	33.57	18.64	33.06	55.06	139.4	113.4	15.3	**811.4**

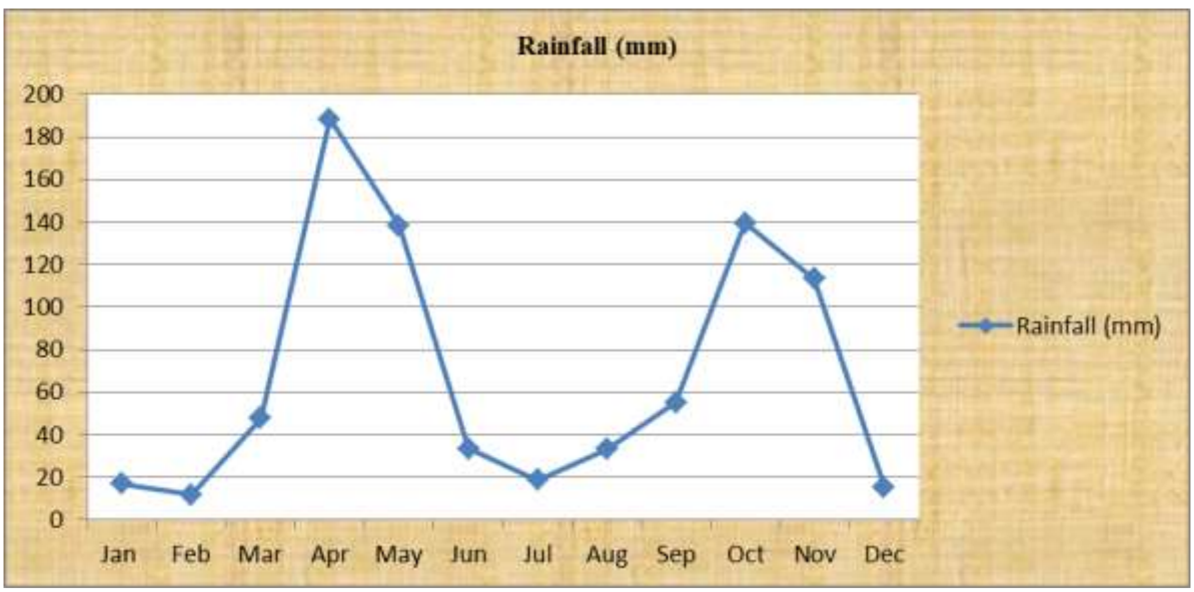


Figure 3 Mean monthly rainfall

4.3.1.1 Dependable rainfall

Monthly and annual rainfall was calculated for computation of crop water requirement. The amount of water that is available for agriculture is primarily determined by the amount of dependable rainfall that reaches the surface. Dependable rainfall which is one of the methods of effective rainfall methods was used in CROPWAT 8.0 to calculate effective rainfall of the project area.

4.3.2 Temperature

Temperature is one of the dominant climatic elements, which determines the distribution of vegetation, soil and farming system of a certain area. The temperature is inversely related to the altitude in most cases. This creates variation in crop types as indicated in Table 1.

The mean maximum temperature in the area is recorded in the month of February (29.28 ^{o}C) and the highest mean minimum is recorded in the month of April (15.91 ^{o}C). The mean maximum temperature ranges between 23.90 ^{0}c (July) and 29.28 ^{0}c (February) and the mean minimum ranges from 12.67 ^{0}c (December) to 15.91 ^{0}c (April).

Generally, the temperature of the study area is suitable for agricultural crops proposed for irrigated agriculture.

Table 3 Temperature data of the project area

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Min. Temperature (^{o}C)	12.71	13.84	15.28	15.91	15.43	14.38	13.91	14.04	14.59	15.40	14.26	12.67	14.37
Max. Temperature (^{o}C)	28.41	29.28	28.58	24.43	24.90	24.36	23.90	24.67	26.15	25.40	25.49	26.43	26.00

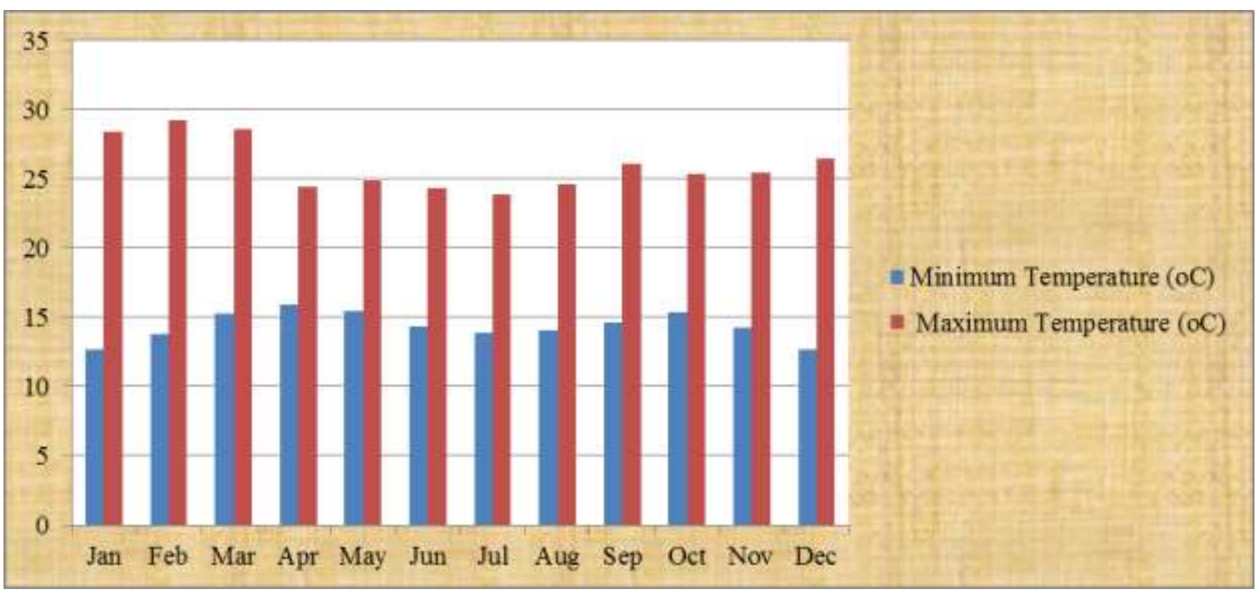


Figure 4 Mean Monthly minimum and Maximum Temperature

4.3.3. Relative Humidity

Humidity level of the atmosphere determines the level of evapotranspiration. The relative humidity distribution will show the favorability and possibility of pest infestation occurrence in which in most cases high humid areas are susceptible to insect pests and diseases; therefore, it is useful to give emphasis to incorporate pest control intervention in the project document. It also has got effect on crop water needs. The highest crop water needs are thus found in areas which are hot, dry, windy and sunny. The lowest values are found when it is cool, humid and cloudy with little or no wind.

The mean annual relative humidity in the study area varies from 49% in the month of January to 74 % in the months of October. This range of relative humidity is low during dry months of the year and high during rainy season. The rise in relative humidity favors sporadic outbreak of some crop pests and diseases.

Table 4 Relative Humidity data of the project area

Parameter	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Average**
Mean RH%	49	51	56	70	73	68	67	64	68	74	73	61	**64**

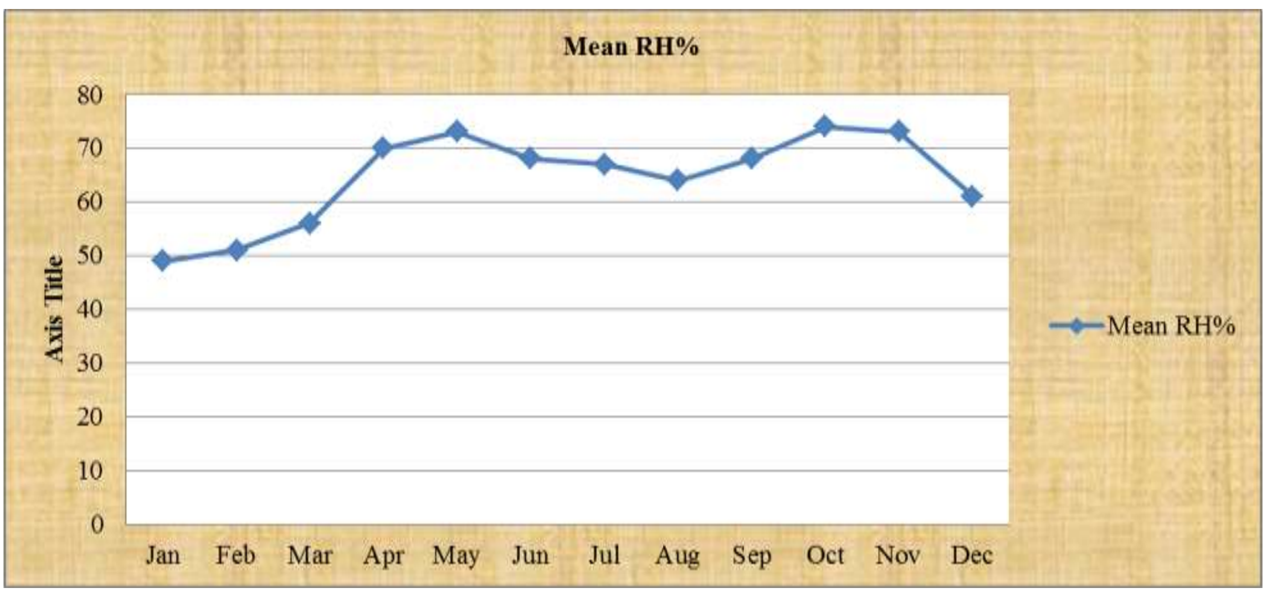


Figure 5 Mean Monthly Relative Humidity

4.3.4 Sunshine hour

Daily length/ sunshine hours and radiation are very important in photosynthetic plant growth and estimation of crop water requirement. For irrigation purpose, analysis of monthly mean of sunshine hours is crucial to investigate its effect on crops.

The study area experiences sunshine hours that vary from highest (10.3 hrs /day) in January to lowest (2.9 hrs /day) in July.

Table 5 Sunshine data of the project area

Para-meter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Sunshine hour	10.3	9.2	7.4	6.6	5.5	4.7	2.9	4.1	5.8	5.1	6.8	8.8	**6.4**

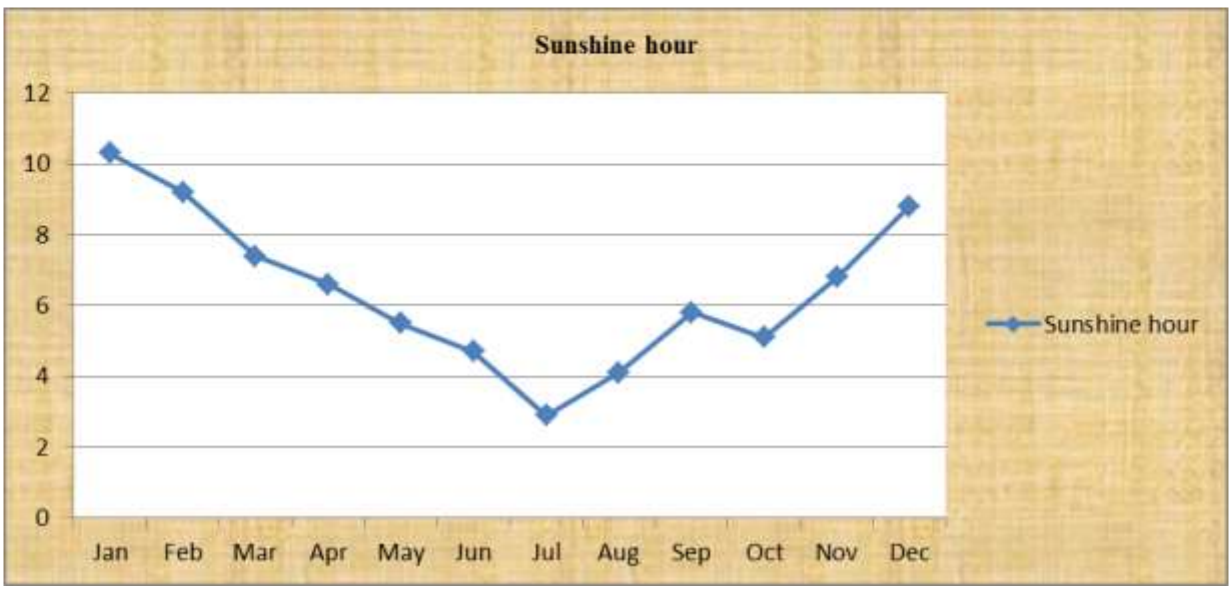


Figure 6 Monthly Mean Sunshine Hours of the Study Area

4.3.5 Wind speed

Wind speed has significant effect on crop performance especially in after late development stage. Occurrence of strong winds may result in lodging. In addition, crop water requirement of the crop increases in windy days than calm days. Mean values of wind speed is highest in the months of February and March (1.9 m/sec) and the lowest mean value is in the months of May and June (1.2 m/sec).

Table 6 Wind speed data of the project area

Para-meter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Wind (m/sec)	1.7	1.9	1.9	1.6	1.2	1.2	1.3	1.3	1.5	1.7	1.8	1.6	**1.6**

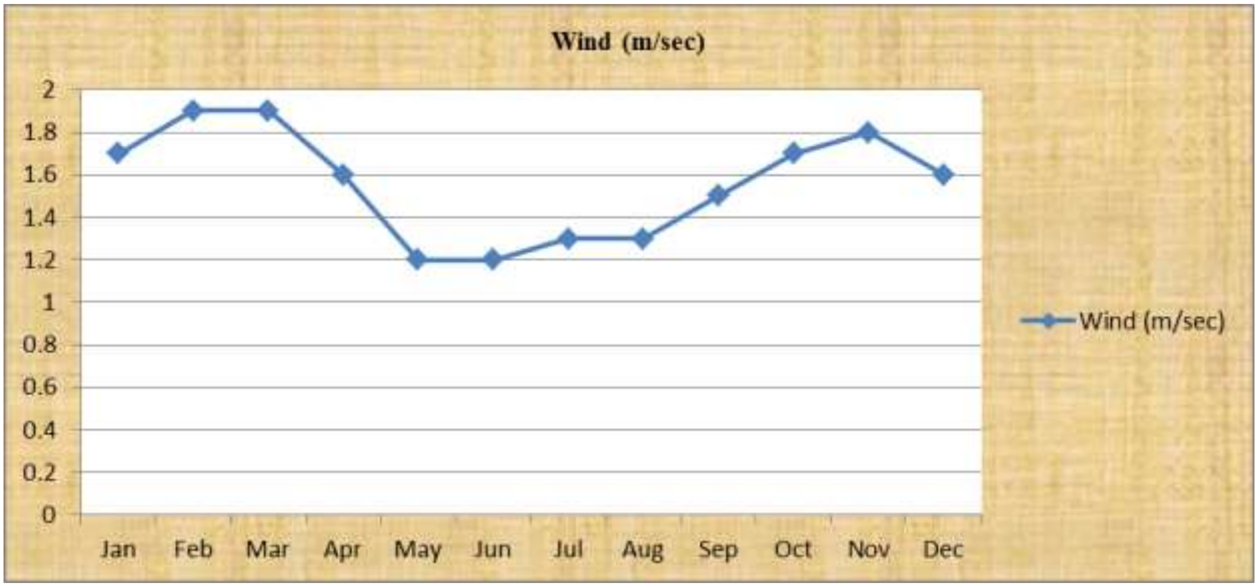


Figure 7 Monthly Mean Wind Speed of the Study Area

4.4 Water Resource

Besides flat topography and fertile soils, water resource is one of the major important requirements for irrigated agriculture. The water source for the project is rain water which going to be harvested during rainy season. Thus, micro earth Dam is the recommended water abstraction method to obtain the required water for irrigation. The discharge from the dam that is used for design is ---- lt/sec. Of the discharge of the dam about ----% is released for the downstream users. The maximum water duty calculated for the project is 1.28 lt/sec/ha for 24 hour and 2.56 l/sec/ha for 12 hour irrigation. Accordingly, the water supply condition of the project area is enough for ---- ha of land for the proposed 12 hour irrigation time.

4.5 Topography

As the soil and land suitability study report reveals, the topography of the proposed gross command area is classified as follows. About 53.6% of the total command area is flat to gently undulating plains (0- 5% slopes), about 39.4% of the command area is gently sloping and sloping (5-8% slopes) and about 6.0 % of the area is strongly sloping (8-15% slopes). On the strongly sloping areas crops are recommended with contour irrigation to minimize the soil erosion problem. Besides, soil and water conservation measures are vital on these areas to be accomplished by the community.

Furrow irrigation is the most widely used for row crops. Furrows are small channels, which carry water down the land slope between the crop rows. Water infiltrates into the soil as it moves along the slope. The crop is usually grown on the ridges between the furrows. This method is suitable for all row crops and for crops that cannot stand in water for long periods.

4.6 Soil Suitability

The crops were selected based on existing condition, climate and requirement of individual crop to the daily diet and the cash value of the crop to generate for the community. The major proposed crops are Maize, Sorghum, Haricot bean, Tomato and Onion.

As the soil and land evaluation report discloses, the suitability evaluation under irrigated condition was considered for the current land and soil condition and for future (potential) suitability after improvement of some correctable soil limitations. The major limitations that down grade the suitability level of the area are soil pH (Low pH), slope, and depth in the study area. The result indicates that with thae applicatin of fertilizers and good quality of irrigation water and integrated neutrient management some part of the command area will be improved to moderatly suitable land for intended crop production.

5. THE PRESENT STATE OF LAND USE AND FARMING SYSTEMS

The proposed command area of the project is totally bush and shrubs in its land use type. There is no cultivated land on the area both by rain fed agriculture and traditional irrigation. People of the area are agro-pastoralists so that they sell animals and animal products to generate cash income. The area has been known for its livestock and apiculture resources.

There are no crops produced in the command area by traditional irrigation. There is also no practice of traditional irrigation in the kebele. Shortage of rain fall and absence of water are the major limitations in the kebele for crop production, livestock and human for drinking.

The farming system practiced in and around the project area is mainly animal rearing. Crop production is a recent practice and not widely practiced in the area and it is also constrained by shortage of rain fall. i.e animal rearing is the major means of livelihood of the people of the area.

The proposed command area is found in Gomole woreda, Abunu kebele. The major land use types of the woreda and kebele are depicted on the table below.

Table 7 The major land use types of Gomole Woreda and Abunu Kebele

No	**Land use types**	**Woreda**		**Kebele**	
		Area (Ha)	**Proportion (%)**	**Area (Ha)**	**Proportion (%)**
1	Cultivable land	1165	1.6	-	-
2	Cultivated land	1866	2.6	33	2.4
3	Grazing land	25345	34.9	617	44.9
4	Forest land	3482	4.8	693	50.5
5	Bush and shrubs land	10580	14.6	-	-
6	Settlement	19751	27.2	30	2.2
8	Degraded land	10500	14.4	-	0
	Total	**72689**	100.0	**1373**	100

Source: Gomole Woreda Pastoralist Development Office and Abunu Kebele development center

At woreda level, grazing land (34.9%) followed by bush and shrubs land (14.6%) occupies the largest proportion of the land use types. But at kebele level, forest land (50.5%), followed by grazing land (44.9%) occupies the largest proportion of the land use types, respectively.

5.1 Land Tenure and Farm Size

The ultimate ownership of land is vested upon the government and the farmers have got the legal right to use and enjoy the advantages of their holdings. The land reform policy has however, made a provision for individual farmers to lease and pass it on by inheritance to their kin.

The reports of the development center of Abunu kebele indicates that the land holding in the proposed command area communal land holding. The people of the area use in common to graze their animals in the bush and shrubs. Thus, the proposed command area should be distributed among the beneficiaries during the implementation of the project.

6. EXISING AGRICULTURE

Knowledge of existing agricultural activities in the proposed irrigated area is necessary to provide a base line against which the compatibility of the proposed development may be judged and its impacts assessed.

Mixed farming is the existing agriculture in around the project area of which, animal rearing is widely practiced by most of the farmers. It is to a large extent a sedentary system of production in which small-scale crop and livestock productions are run side by side. Small-holder crop production is recently carried out in area with poor moisture availability.

6.1 Existing Crop Production

6.1.1 Rain fed crop production

Crop production is predominantly practiced based on rain fed agriculture during the main rainy season (Belg) both in the woreda and kebele in which the project area is found. There are double crop-growing seasons in the woreda. The existing cropping pattern in woreda indicates the growing of few cereal and pulse crops during crop growing periods. The major crops produced are Teff, Maize, and Haricot bean.

Table 8 Production and Yield Data for Crops produced by rain fed agriculture in Gomole woreda

Crop	2008/2009			2009/2010		
	Area (ha)	Prod (qt)	Yield (qt/ha)	Area (ha)	Prod (qt)	Yield (qt/ha)
Maize	246	4059	16.5	575	9487.5	16.5
Teff	210	1680	8	277	2216	8
Haricot bean	206	1545	7.5	208	1560	7.5

Source: Gomole woreda Pastoralist Development Office

The average crop yield in the woreda for rain fed agriculture is very low owing to moisture shortage. Crops do not get sufficient water trough out their growing period to give the optimum yield required. Water stress at the critical stages of crop growth causes lower tillering, branching, pegging, tuber bulking, inadequate flowering and in extreme case, flower drops, poor setting of grains or fruits, bad filling of grains or serious fruit drops depending on the type of crops.

In Abunu kebele in which the proposed command area is found, rain fed crop production is practiced mainly for subsistence. The major crops grown in the kebele are Teff, maize, Haricot bean, sorghum, Chick pea and Wheat in descending order of the cultivated area in both cropping seasons. The yield of crops per hectare is very low.

Table 9 Production and Yield Data for Crops produced by rain fed agriculture in Abubnu kebele

Crop	2009/2010		
	Area (ha)	Prod (qt)	Yield (qt/ha)
Maize	30	480	16
Teff	11	88	8
Haricot bean	5	35	7

Source: Abunu Kebele Pasoralist Development Office

In the woreda, crops are also grown with different technologies. These are:

- Local varieties without fertilizers
- Local varieties with compost /cow dung
- Local varieties with commercial fertilizers
- Improved varieties with commercial fertilizers

Most of the crops are produced by using local seeds without fertilizers followed by local seeds with fertilizers. The use of improved seeds is limited to few crops especially maize. But the data of crops produced by different technologies was not available both in kebele and woreda offices.

6.1.2 Existing irrigation practices

There is no irrigation practice both in the proposed command area and in the kebele due to the absence of river to be diverted for irrigation. But the people of the area have high interest to put into practice irrigation if this studied small scale dam irrigation project will be implemented.
There is a practice of traditional irrigation in the woreda and the major crops produced by this traditional irrigation are maize, sorghum, onion, tomato, cabbage, banana and sugarcane. These crops are mainly produced for market.

The average yields of the crops produced in the woreda by traditional irrigation are very low due to poor management, crop pests and diseases. The area and yield of crops grown in the area with traditional irrigation are illustrated on the tables below.

Table 10 Production and Yield Data for Major Crops produced by Traditional Irrigation in Gomole Woreda

Crop	2009			2010			Average Yield (qt/ha)
	Area (ha)	Prod (qt)	Yield (qt/ha)	Area (ha)	Prod (qt)	Yield (qt/ha)	
Tomato	1	50	50	1	55	55	52.5
Onion	1	70	70	1	74	74	72
H /cabbage	1	100	100	1	100	100	100
Carrot	0.2	10	50	0.2	53	265	157.5
Maize	40	2800	70	42	2940	70	70
Papaya	0.1	10	100	0.1	10	100	100
Banana	0.1	13	130	0.1	13	130	130
Mango	0.1	5	50	0.1	5	50	50

Source: Gomole woreda Irrigation Development office

6.1.3 Existing cropping pattern

Cropping pattern is the yearly sequence of crops grown and the spatial arrangement of them and fallows in a given area. It is formulated with a view to obtain maximum crop production under a given situation. The crops which are produced by rain fed agriculture around the project area are produced two times in a year owing to the bimodal characteristics of rain fall of the area.

Crop production plays a secondary role in the annual income in around the project area, and it is leaded by livestock production.

6.1.4 Existing Cropping Calendar

The cropping calendar depends on the onset and duration of rainfall, type of crop and labor availability, availability of inputs such as seeds, and farm power etc. Generally, seedbed preparation starts at the onset of the rainy season. The existing cropping calendar in the woreda is depicted on the table below.

Table 11 Existing cropping calendar for rain fed agriculture in and around the project area

Types of crops	Time of land preparation		Sowing	Time of weeding		Time of harvesting
	Ploughing	Freq.		Start of weeding	Freq.	
Hagaya season						
Maize	Sep	3	Sep 15- Nov 30	Oct	2	Dec-Jan
Teff	Sep	3	Sep 15- Nov 30	Oct	2	Dec
Haricot bean	Sep	2	Sep 15- Nov 30	Oct	2	Nov
Gana season						
Maize	Mar	3	Mar 15- May 30	Apr	2	Jun-Jul
Teff	Mar	3	Mar 15- May 30	Apr	2	Jun
Haricot bean	Mar	2	Mar 15- May 30	Apr	2	May

Source: Gomole woreda Pastoral Development office

Traditional irrigation is practiced in and around the project area and it has got its own cropping calendar. Since there is no river for diversion, water harvesting method is used in the area during rainy seasons. The cropping calendar practiced in and around the project area is depicted on the table below.

Table 12 Existing cropping calendar for traditional irrigation in and around the project area (First Phase)

Types of crops	Time of land preparation		Sowing	Time of weeding		Time of harvesting
	ploughing	Freq.		Start of weeding	Freq.	
Tomato	Jul-Aug	3	Sep	Sep-Oct	3	Dec-Jan
Onion	Jul-Aug	3	Sep	Sep-Oct	3	Dec-Jan
H /cabbage	Jul-Aug	3	Sep	Sep-Oct	3	Dec-Jan
Carrot	Jul-Aug	3	Sep	Sep-Oct	3	Dec-Jan
Maize	Jul-Aug	2	Sep	Sep-Oct	2	Dec-Jan

Source: Gomole woreda Irrigation Development Authority

Table 13 Existing cropping calendar for traditional irrigation in and around the project area (Second Phase)

Types of crops	Time of land preparation		Sowing	Time of weeding		Time of harvesting
	ploughing	Freq.		Start of weeding	Freq.	
Tomato	Jan-Feb	3	Mar	Mar-May	3	May-Jun
Onion	Jan-Feb	3	Mar	Mar-May	3	May-Jun
H /cabbage	Jan-Feb	3	Mar	Mar-May	3	May-Jun
Carrot	Jan-Feb	3	Mar	Mar-May	3	May-Jun
Maize	Jan-Feb	2	Mar	Mar-May	2	May-Jun

Source: Gomole Woreda Irrigation Development Authority

6.1.5 Existing agricultural inputs and supporting services

Agricultural inputs are the essential component of crop production to meet food security and increase household income. The use of proper agricultural inputs at the recommended rates plays a significant role in yield increment per unit area of land. There were different inputs used in and around the proposed project area to obtain an optimum yield. Farm inputs like fertilizers, improved seeds, and pesticides are made available through cooperatives. The major types of inputs used in the woreda are shown in the table below.

Table 14 Input utilization for rain fed agriculture in and around the project area

Types of crops	Types of variety	Seed rate (kg/ha)	Fertilizer rate (Qt/ha)		Cost of inputs (Birr/Qt)		
			NPS	Urea	Seed	NPS	Urea
Maize	Melkassa -1& 4	25	1	2	6000	1270	952
Teff	Cr-37	10	1	0.5	2800	1270	952
Haricot bean	Local	70-80	-	-	2000	1270	-

Source: Gomole Woreda Pastoralist Development Office

Animal manure, crop residue and fallowing the land are the traditional methods used to maintain soil fertility, while some farmers use commercial fertilizers. Herbicide is the other input used for the control of weeds in the area. The type of herbicide used in the area is 2, 4-D for the control of broad leaved weeds at the rate of 1-2lt/ha. Concerning the availability of the inputs, they are available to the farmers on time by cooperative office at kebele level. Since the inputs are provided through cooperative office there is no quality problem of the inputs. Improved seeds are distributed freely to farmers as aid, and the other inputs are given on credit basis.

6.1.6 Crop Production Constraints in and around the Project Area

Climate and soil are among the major factors determining feasibility of crop production practices in a given area. Any negative change in climate and soil is accompanied with reduced crop performance which could ultimately threaten the livelihood of the farming community. Hence, the issue of improving crop production in the study area largely depends on the efforts made to halt the negative changes observed in climatic and soil conditions of the area at large.

There are different production constraints, which cause the problem of low crop productivity in and around the project area. The major factors are: insect pests, weeds, diseases, predators/ wild animals, shortage and unreliability of rainfall which was manifested by late beginning and early offset.

6.1.6.1 Insect pests

This phyla of animals are the most successful creatures in living and reproduction and in the struggle for their life they choose the host plants for their most basic needs such as food and shelter or for protection (over wintering), or to complete their life cycle. In so doing, these animals usually cause injury to their hosts. The major insect pests of the project area can be categorized as migratory and regular pests.

Migratory Pests: Armyworm is the major insect pest recognized under this category. It is devastating pest that occurs once every four years on average in the project area. It constitutes a serious problem in the area and causes unpredictable damage unless close monitoring and integrated management measures are taken.

Regular Insect Pests*:* these represent the second category of pests that cause crop damage after migratory pests. In the study area, insect pests are known to be the most prominent crop production constraints to the farming community affecting economy. Wide ranges of insect pests are known to cause quite repeated and substantial damages, both in the field and storage condition. Shoot fly, American Fall worm, Stalk borer, aphids, whitefly, Trips and American ball worm, and termites are among the major pests of the area.

The control measures practiced locally are uprooting and destroying of the maize that was attacked by stalk borer; mound destruction and killing the queen of termites; lying down the sorghum when it is nearly start to ripen and field sanitation, spraying malathione 50% E.C at the rate of 2lt/ha, for American Fall worm. For stalk borer; spraying Sevien 5-10% WP at the rate of 1.5kg/ha have sometimes practiced; and for aphids spraying Sevien 5-10% WP at the rate of 1.5kg/ha.

6.1.6.2 Weeds

Weeds are plants growing where they are not wanted. They cause yield reduction by competing with crops for light, moisture and nutrients.

Effect of Weeds

Reduction in crop yield: Weeds compete with crop plants for nutrients, soil moisture, space and sunlight and in general an increase in one kilogram weed growth corresponds to reduction in one kilogram of crop growth. Hence, the crop is smothered and has a final effect on crop yield. Depending on type of weed, intensity of infestation, period of infestation, the ability of crop to compete and climatic conditions the loss varies.

Loss in crop quality - If a crop contains weed seeds, it is to be rejected, especially when the crop is grown for seed. For example, the wild oat weed seeds are similar in size and shape of the crops like barley, wheat, and its admixture may lead to rejection for seed purpose.

Interference in crop handling - Some weeds can make the operation of agricultural machinery more difficult, more costly and even impossible. Heavy infestation of *Cynodon dactylon* causes poor ploughing performance.

Reduction in land value - Heavy infestation by perennial weeds could make the land unsuitable or less suitable for cultivation resulting in loss in its monetary value.

Limitation of crop choice - When certain weeds are heavily infested, it will limit the growth of a particular crop. The high infestation of parasitic weeds such as *Striga lutea* may limit the cultivation of sorghum or sugarcane.

Problems due to aquatic weeds - Aquatic weeds that grow along the irrigation canals, channels and water streams restrict the flow of water. Weed obstruction causes reduction in velocity of flow and increases stagnation of water and may lead to high siltation and reduced carrying capacity.

As mentioned above, crops and weeds compete for light, water and nutrients. Weeds benefit from crop management practices such as irrigation, fertilization, and pest control that are intended to benefit the crops. Competition begins when crops and weeds grow in close proximity and supply of any necessary growth factor falls below the demand of both. Competitiveness in both crops and weeds is related to their ability to exploit and sequester the environmental resources upon which plant growth depends.

Some of the most common weeds occur in the area are Parthinium, “Shuunkii’, “Mogorree” and “Cegogit”. The traditional controlling mechanism designed so far by the farmers has been hand weeding for most crops and inter-row cultivation for large cereal crops like maize and sorghum and spraying 2, 4-D to control broad leaved weeds.

6.1.6.3. Diseases

Diseases may be due to none living things such as luck of minerals or availability of harmful minerals etc. or due to living matters such as fungus, bacteria and viruses. Among the two causes mentioned above, the functional disorders caused by living organism are very important. Diseases adversely affect the behavior of crop plants. These functional disturbances also result not only in yield reduction but also in quality deterioration and reduction of physical beauty (morphological disaster). According to data from the Pastoral office of the woreda, the most common crop diseases recognized include early blight, rust, smut, powdery mildew, downy mildew, and root rot. The control measures practiced in the area are use of clean seeds, removing the diseased plans, and keeping the sanitation of the farm land.

6.1.6.4. Predators / wild animals

The most complained wildlife species as problem in the woreda include Anubis Baboon, Vervet Monkey, pigs, and porcupine. As the information obtained from woreda pastoral development office, the extent of damage caused by these wild animals is high.

The control measure practiced by the farmers is physical protection of their crops not to be attacked by the wild animals. The farmers stay near their crops day and night by making temporary shelter inside or near the fields of their crops. Traditional control measures are not effective and the annual yield loss is significant. All crops at all growth stages are susceptible to these pests. The damage caused by vertebrate pests is increasing with time due to the laws and regulations that prohibit the killing of wildlife. Thus, the practice of protection of their crops should be strengthened and also be applied for the project when it will be implemented.

7. PROPOSED IRRIGATED AGRICULTURE

Irrigation is considered necessary when the natural supply of water is not sufficient to satisfy the crop water requirements for sustaining crop production. Therefore, the water deficit should be supplied by supplemental or full irrigation. Inadequate and uneven distribution of rainfall, with adequate but uneven distribution throughout the growing season, the need to sustain the practice of double cropping in the dry season, and ensuring of growing of high value crops are among the factors that necessitate irrigation.

Irrigation plays an important role in the development of the agriculture sector and contributes much in the national economic development of the country. Therefore, irrigation ensures production of high value crops, ensures protection of crop failures, due to drought; ensures cultivation of suitable multiple cropping practices in a season, maximizes the value of land and farmers may become prosperous and their living standard could be raised and creates an opportunity of introducing aquaculture to farmers that will improve their diet by supplementing with protein source and can be used as an additional income source. In addition, irrigation water can be used for domestic and industrial water supplies for nearby areas and Irrigated agriculture requires increased farm labours and this creates employment opportunities for the rural population.

The importance of Irrigation development, particularly in the farming sub-sectors needs prime consideration to raise production to achieve food self-sufficiency and ensure food security at house hold in particular and at a region level at large.

7.1 Development Potential of the Command Area

7.1.1. General

The development potential of the command area is a function of the agro-climate, soil, water availability and land capability in the area. Assessment of the available potential and the limitations that hinder development endeavours are essential for any agricultural planning program. Based on this, a detailed assessment was undertaken to clearly understand and identify the available potential of the project area. According to the field assessments and based on consultation with communities and local stakeholders, the current potential of the area that can be considered as an opportunity for project development includes but is not limited to the factors discussed below.

7.1.2. Agro-Climate and Topographic Suitability

According to traditional agro-climate classification, the project area is categorized under low-land (moist kola) agro-ecologic zone, which are conducive to the production of diversified lowland crops. This agro-ecological suitability allows the possibility of growing different cash and food crops for local consumption, as well as domestic and export marketing.

Concerning the topography of the proposed command area, about 53.6% of the total command area is flat to gently undulating plains (0- 5% slopes). It is highly suitable and moderately suitable for surface irrigation. About 39.4% of the command area is gently sloping and sloping (5-8% slopes) and about 6.0 % of the area is strongly sloping (8-15% slopes). Soil and water conservation measures are vital on these areas with strongly sloping to be accomplished by the community.

7.1.3 Soil

The detailed survey of the soils of this irrigation project has shown that some of the ideal physical properties of the soils are Sandy Clay loam and sandy loam texture, the moderate to weak, fine to medium sub angular blocky structures, and high level of Persentage base saturation.The soils also have no adverse chemical properties that can hinder the production of agricultural crops. The soils have problems of Acidity and fertility. The correctable limitations are the low level of organic matter of most soils, the low levels of plant nutrients such as available phosphorous, total nitrogen etc. One of the non-correctable limitations of the soils moderatly acidity 5.8 to 6.1 with average 5.9 pH in the top soil (Low pH level), shallow to mderately deep effective depth of the soils and slope greater than 15%.

7.1.4. Crop suitability

According to the soil survey, the suitability evaluation under irrigated condition was considered for the current land and soil condition and for future (potential) suitability after improvement of some correctable soil limitations. With the application of fertilizers and good quality of irrigation water and integrated nutrients management, some part of the command area will be improved to moderately suitable land for intended crop production.

7.1.5 Traditional Irrigation Practice

There is no practice of traditional irrigation in the proposed command area and in the kebele due to the problem of water in the area. But if the dam will be done in the area, it is possible to develop irrigation so that it can assist the people of the area to be self sufficient in food.

As it is well known, the community of the project area are agro pastoralists and livestock is the main practice on which the people live on for their livelihood. Thus, they are unfamiliar with irrigation practice to be done during project implementation. Thus, much effort will be needed from development agents and woreda Irrigation development office to train the beneficiaries on the utilization of improved agronomic practices proposed and irrigation water management.

7.1.6 Water Potential

According to the water availability assessment, the project area has no permanent water supply. But there is an enormous amount during rainy season which passes away within a short period of time without giving significant services to the community of the area. Thus, by conserving this water it is possible to obtain water of good quality for both crop production and livestock consumption. If properly developed and utilized, this potential is sufficient to satisfy the water needs of the intended project and other domestic needs of the area.

7.1.7 Interest of Farmers and Other Relevant Stakeholders

According to genuine observations and discussions made with farmers and other local stakeholders such as the woreda administration, woreda Irrigation Development Authority, all the project partners including direct beneficiaries of the project, all are very enthusiastic about the project implementation. The beneficiaries perceived the benefits of the project and are willing to give a priority for its implementation. During discussions, they stated their preparedness to effectively participate during implementation, as they did during the planning phase of the project and make cooperation in the way of redistributing the land and cooperating between themselves to utilize the irrigation water in an orderly manner. Besides, they agreed to participate in their labour and supply materials found around during construction of the project.

7.1.8 Regional Irrigation Development Polices and Strategies

Based on the general national development policies and strategies, the regional government designs its own development polices and strategies, particularly irrigation development policies that are directly connected with the objective of the intended project. This policy ground is another opportunity for effective implementation and sustainable utilization of the project.

7. 2. Selection of crops and Cropping Pattern

Having established the study level to analysis of all the project area and investigation of the agricultural system, the next step is to identify potential crops which can possibly grow in the project area. In crop planning for irrigation it is advisable to first identify all types of potential crops, which can possibly grow in the project area (from climate, soil and environmental aspects) to make a wide crop basket. Having got a Basket of Crops the next noble stage is selection of best crops and establishing of cropping patterns for the proposed of the Irrigation projects. The choice of crops and cropping pattern for the proposed irrigation projects depends on three major areas, namely, physical, socio-economic and policy and strategies.

Among the bio-physical factors, temperature range, altitude range, moisture availability, slope range, soil conditions, are considered as the most important land quality and land characteristics influencing land suitability for crop production. The Climatic and Soil Requirements for Major Irrigated Crops proposed in the project are depicted on the table as follows.

Table 15 Climatic and Soil Requirements for Major Irrigated Crops

Crop	Altitude	Optimum Temperature for growth, ^oC	Specific climatic requirements/constraints	Soil requirements	Sensitivity to salinity
Cabbage	500 – 3000	15- 20 (10- 24)	Short periods of frost (-6 to –10^{o}C) are not harmful; opt. RH =60- 90 %	Well- drained; opt. pH = 6.0- 6.5	Moderately sensitive
Maize	1000-2000	24- 30 (15- 35)	Sensitive to frost; for germination temp. >10 ^{o}C; cool temp. causes problem of ripening	Well- drained and aerated soils with deep water table and without water logging; opt. pH =5.0-7.0	Moderately sensitive
Onion	700-2400	15- 20 (10- 25)	Tolerant to frost; low temp. (<14 – 16^{o}C)	Medium- textured soil; pH = 6.0- 7.0	Sensitive

Crop	Altitude	Optimum Temperature for growth, ^oC	Specific climatic requirements/constraints	Soil requirements	Sensitivity to salinity
			required for flower initiation, no extreme temp. or excessive rain		
Pepper	1400-2000	18- 23 (15- 27)	Sensitive to frost	Light to Medium-textured soils; pH = 5.5- 7.0	Moderately sensitive
Potato	1500-2800	15- 20 (10- 25)	Sensitive to frost; night temp. < 1 5 ^oC required for good tuber initiation	Well- drained, aerated and porous soils; pH = 5.0- 6.0	Moderately sensitive
Tomato	1100-1800	18- 25 (15- 28)	Sensitive to frost; high RH, strong wind; optimum night temperature 10- 20 ^oC	Light loam, well-drained without water logging; pH= 5- 7	Moderately sensitive
Soy bean	1300-1850	20- 25 (18- 30)	Sensitive to frost; for some variation of temp. > 24 ^oC required for flowering	Wide range of soil except sandy, well-drained; pH = 6- 6.5	Moderately tolerant
Banana	< 1500	25- 30 (15- 35)	Sensitive to frost; temperature < 8 ^oc for longer periods causes serious damage; requires high RH and wind < 4 m/sec	Deep, well- drained loam without stagnant water; pH= 5- 7	Moderately sensitive
Ground nut	<1600	22- 28 (18- 33)	Sensitive to frost; for germination temp. >20 ^oC	Well- drained, friable, medium-textured soil with loose top soil; pH = 5.5- 7.0	Moderately sensitive

7.3 Crop basket of the area

Environmental requirement of crops are given in several literatures. However, there is a best range of climate, soil and other environmental and socio-economic condition for each crop to render an optimum yield. The checklist (crop basket) has to literally give all range of possible or group of crops. The following are the crop basket for the project area.

Cereals: Maize, Teff

Pulses: Haricot bean

Oil crops: ----------

Vegetables: Tomato, Onion, Carrot, Cabbage,

Root crops: -----

Fruit crops: papaya, banana, mango

7.4. Criteria's for selection of crops and cropping pattern

Realizing the importance of crop selection and cropping pattern in determining the fate of this particular irrigation project, due emphasis has been given to the criteria's as follows:-

- Climate of the area
- Availability of water both in quality and quantity
- Type and method of Irrigation
- Crop characteristics and growing pattern
- Cropping intensity
- Soil type and characteristics
- Availability of agricultural improved inputs (seeds, fertilizers and chemicals)
- Possibility for crop rotation
- Crop diversification
- LGP of proposed crops to intensify the cropping pattern
- Dietary habit and nutritional requirement of local people
- Food demand and food sufficiency vis-à-vis food security
- Agricultural knowledge of farmers and attitude of farmers towards irrigation and crop type.

7. 5. Proposed Cropping Pattern and Intensity

7.5.1. Proposed Cropping Pattern

Cropping pattern is the yearly sequence of crops grown and the spatial arrangement of them and fallows in a given area. It is formulated with a view to obtain maximum crop production under a given situation.

Two cropping patterns, each for first phase irrigation and second phase irrigation are proposed for the project to be adopted by the farmers in the project area.

It is also necessary to give due consideration with regard to cultivation of different crops in order to avoid growing crops of the same species repeatedly on the same land. This helps to avoid the building up of serious soil borne pests and diseases like root knot nematodes and wilt diseases. Thus, the crops should be grown in rotation.

7.5.2 Proposed Cropping Intensity

The overall objective of the project is to maximize the utilization of the land and water and that all the beneficiaries are capable of implementing the proposed program in terms of supplying the labor and other inputs required.

It is desirable for the cropping intensity to approach 200% i.e. all the irrigable land is to be double cropped over one cropping calendar year.

Hence, the cropping intensity of about 200% is proposed for the project in two cropping patterns over one calendar year and it is shown on the table below.

Table 16 Proposed cropping pattern and intensity for the project

1. First Phase Supplementary Irrigation

Types of crop	Year One			Year Two			Year Three			Year Four			Year Five		
	1st phase			1st phase			1st phase			1st phase			1st phase		
	Ha	%	Yield /ha Qt	Ha	%	Yield/ha Qt	Ha	%	Yield/ ha Qt	Ha	%	Yield/ ha Qt	Ha	%	Yield/ ha Qt
Maize	24	20	35	21.6	18	45	21.6	18	60	21.6	18	60	21.6	18	60
Sorghum	30	25	16	30	25	20	27.6	23	25	27.6	23	25	27.6	23	25
Haricot bean	24	20	10	24	20	16	24	20	20	24	20	20	24	20	20
Tomato	24	20	100	26.4	22	180	26.4	22	300	26.4	22	300	26.4	22	300
Onion	18	15	100	18	15	150	20.4	17	350	20.4	17	350	20.4	17	350
Total	**120**	**100**	**-**	**120**	**100**	**-**	**120**	**100**	**-**	**120**	**100**	**-**	**120**	**100**	**-**

2. Second Phase Supplementary Irrigation

Types of crop	Year One			Year Two			Year Three			Year Four			Year Five		
	2nd phase			2nd phase			2nd phase			2nd phase			2nd phase		
	Ha	%	Yield /ha Qt	Ha	%	Yield /ha Qt	Ha	%	Yield /ha Qt	Ha	%	Yield/ ha Qt	Ha	%	Yield/ ha Qt
Maize	24	20	35	24	20	45	24	20	60	24	20	60	24	20	60
Sorghum	30	25	16	30	25	20	24	20	25	24	20	25	24	20	25
Haricot bean	24	20	10	24	20	16	24	20	20	24	20	20	24	20	20
Tomato	24	20	100	24	20	180	24	20	300	24	20	300	24	20	300
Onion	18	15	100	18	15	150	24	20	350	24	20	350	24	20	350
Total	**120**	**100**	**-**	**120**	**100**	**-**	**120**	**100**	**-**	**120**	**100**	**-**	**120**	**100**	**-**

7.6 Crop rotation

Vegetables, like all crops should be rotated. The principal aims of crop rotation are reducing the build up of soil borne diseases, insect pests and nematodes; minimizing weed infestation and increased crop yields, maintaining soil fertility, protection of soil erosion, increasing nitrogen content in the soil, sustain proportional utilization of soil nutrients by crop plants, allowing crops to plant in sequential order considering their characteristics. Therefore, the following are important factors to be considered in establishing crop rotation cycle: Selection of crops considering the soil and climatic conditions of the area, inclusion of legume crops in the rotation cycle in order to improve the soil fertility, putting crops in their sequential orders by considering their root systems and nutrient uptake behaviours of crops, in putting crops in sequential orders it will be vital to consider weed situation of the area, disease and insect pest infestation nature of crop in order to reduce weed problem, and minimizing disease and insect pests build up in the soil, considering market situation and cultural practices of the area and further it is necessary to check whether the crop selected for planting will grow during the season of the year for which it is scheduled or not.

Whenever possible vegetables from the same families should not be grown in the same field year- after- year, at least there must be allowed 2 to 3 years elapse between crops of the same family. It is particularly important that the solanaceous crops such as tomato, potato, pepper and eggplant should not follow each other on the same field. Similarly, the same applies to cucurbits family such as melon, cucumber, pumpkin and squash. In addition, deep-rooted crops should follow shallow rooted vegetable crops in order to improve the efficient utilization of nutrients by the crops. The inclusion of legumes in a rotation has the added advantage of improving soil fertility by adding nitrogen to the soil through the activity of nitrogen- fixing bacteria which are associated with the roots of legumes and if residues are turned to the soil some of the nitrogenous material remaining in the roots and other plant parts will contribute to soil fertility. In order to establish and obtain optimum yield it is important to keep records, of which indicate the crop type sown previously in each field to plan the new crop to be planted in the same field.

Whether under rain fed or irrigation condition, crop rotation program is an integral part of the scheme. The following crop rotation scheme had been proposed with the assumption of;

- Improvement of soil productivity by inclusion of a legume crop to promote fixation of nitrogen as well as the improvement of the soil physical characteristics by way of adding plant residues.
- Reducing disease and insect pests out breaks due to crop rotation especially for soil born host specific pests
- To save some crop products in times of crop failure due to mainly environmental calamities
- Optimal use of available water

Table 17 Proposed Crop Rotation

Production year	**Crop rotation cycle**				
1	Maize	Tomato	Onion	Sorghum	H /bean
2	Tomato	Onion	Sorghum	H /bean	Maize
3	Onion	Sorghum	H /bean	Maize	Tomato
4	Sorghum	H /bean	Maize	Tomato	Onion
5	H /bean	Maize	Tomato	Onion	Sorghum

Whether under rain fed or irrigation condition, crop rotation program is an integral part of the scheme. The above crop rotation scheme had been proposed with the assumption of;

- Improvement of soil productivity by inclusion of a legume crop to promote fixation of nitrogen as well as the improvement of the soil physical characteristics by way of adding plant residues.
- Reducing disease and insect pests out breaks due to crop rotation especially for soil born host specific pests
- To save some crop products in times of crop failure due to mainly environmental calamities
- Optimal use of available water.

7.7 Proposed crop husbandry /Cultural practices

Crop husbandry / Cultural practices is the operation of different activities of crop production like seed bed preparation, sowing, weeding, harvesting, storage and etc are performed. Proper and timely performance of the activity plays a great role on the output of the project. Each of the cultural practices and the time at which they are accomplished are mentioned as follows.

7.7.1 Seed bed Preparation / Ploughing

Proper seed bed preparation is one of the most important cultural practices. It influences the level of crop yields as it promotes proper seed germination, better root development and uniform crop establishment. Moreover, good seed bed preparation also plays a significant role in minimizing the development and severity of pests including weeds, insects and diseases.

In general, farmers in the areas are used to begin land preparation after harvesting of the last season crop as soon as they receive small rain shower, usually between March and April months in main rainy season (Ganna) but for short rainy season it is between August and September (Hagaya). Since then, they repeatedly plow till the immense of next cropping season (April for Ganna and October for Hagaya. Ploughing in and around the project area is done with the traditional plough the "Maresha" which only breaks a very shallow surface of the top soil without turning it. This operation is carried out with the help of the ox-drawn implement.

Oxen are the major animals used for plouhging in and around the project area. Most of the farmers own a pair of oxen. The frequency of ploughing, however, depends on the soil type and the type of crop grown. According to the kebeles development centers, two to three ploughings are commonly practiced for most the crops produced in the area.

7.7.2 Planting/sowing

Planting period is governed by seed bed preparation and the availability of sufficient soil moisture. The commonly practiced sowing times in the area are mid and mid March for Ganna season and Mid September for Hagaya season for the major crops produced in the area by rain fed agriculture. Broadcasting of seeds and covering by passage of the "Maresha" at shallow setting is the common practice in the areas. Seeds of local varieties usually saved from previous harvest are used while very few farmers have used the improved seeds supplied by Agriculture development office of the wereda. The development agents give advices for the farmers on the time of planting and utilization of inputs.

7.7.3 Weeding

Weeds are plants growing where they are not wanted. Weeds cause low crop productivity by competing with the required crops for light, moisture, nutrients and space. Hand weeding and chemical (2, 4-D at the rate of 2lt/ha) are used in the area to control weeds. Weeding is usually delayed until weed plants attain certain heights to be grasped by hand at which time they have already caused substantial damage to crops. Weeding is further complicated due to broadcasting of seeds on the field.

7.7.4 Guarding

Guarding the crop against wildlife, domestic animals, birds, monkey and apes and any other environmentally and socially unsafe situations that devastate the crop is highly advisable

7.7.5 Soil Fertility Management

Crop rotation involving cereals and pulses, spreading decomposed animal dung on the farmland and compost are the organic methods of maintaining the soil fertility. Farmers in the area are using animals' waste products to manure their cropping land, commercial fertilizer and in a very rare cases traditional crop rotation are practiced in the area to improve the fertility of their farm land. The commercial fertilizers which are used in the area are mainly NPS and Urea that usually are not applied at recommended rates due to the lack of well developed experience of crop production. They apply below the recommended rate to cover a wide area of land. Recommended rates for the major cereals are 100kg NPS and 50kg Urea. The overall adoption rate of commercial fertilizers is very low and limited mainly to farmers participating in the extension package programs.

7.7.6 Harvesting

Harvesting is performed depending on the physiological maturity of crops. Harvesting should be done when the crops reach full physiological maturity to avoid decay/shrinkage and shattering due to early and late harvesting, respectively. In the area harvesting is in January for October planting and in August for April sowing time for the crops produced by rain fed agriculture.

7.7.7 Threshing and Winnowing

The harvested crop should be threshed in properly levelled and plastered ground and the straw removed from the seed/grain using proper winnowing mechanisms to maintain the desired quality of crop. Usually, threshing follows immediately after harvesting for most crops. Animal trapping of harvested crops and beating by sticks are the common threshing practices. The traditional forked stick is used for the removal of the straw and winnowing. The operation is associated with qualitative and quantitative yield losses and is very time-consuming.

7.7.8 Storage

In most parts of the country, crops are kept in storage either in anticipation of better market prices or for deferred use or both. Traditional and unimproved grain storage system is the sole practice adopted by small scale farmers existing in the project area. The entire peasant farmers in the project area after threshing crops store in traditional and local grain storage facility. Virtually peasants do not perform any seed dressing, clearing or seed dressing measures on their stored grains. Quite regular and substantial loses of stored grains both in quality and quantity are common mainly due to damage caused by storage pests.

This storage system is unsafe and exposed to damage by insect pests, such as rats and weevils rodents and storage fungi cause considerable qualitative and quantitative yield losses. Therefore the crop should be stored in dry, cool, and clean facilities, properly constructed in separate locations outside the living room (outdoor granary). Properly established pits in dry areas are also possible so long as these are sited and designed professionally. Perishable fruits and vegetables should be stored in aerated storage facilities until marketing and /or consumption.

7.7.9 Sorting and Grading

Traditionally, farmers sort for self-consumption and market, based on their own grading systems. This traditional grading system has to be technically supported to sort products for marketing and consumption. The sorting/grading criteria may be based on colour, size, shape, presence of inert material, shrinkage, storage life, etc., depending on crop type and producers' preference. Sorting/grading can be done by hand picking, sieving, or with grading machines. Having sorting the product, the lowest quality will be used for home/local consumption whereas the first grade/ higher quality/ product will be marketed.

7.8. Proposed Agricultural Inputs and Supporting Services

The use of different agricultural inputs in crop production plays a significant role in boosting up the yield of crops per unit area. Besides the inputs, the appropriate uses of improved agronomic practices also have got a great effect on crop husbandry. Thus, these two important factors should be integrated, which could be achieved through giving strong supporting services for the farmers. Strong extension services should be given to the farmers by the development agents on the utilization of inputs, improved agronomic practices, water, land, etc accordingly as proposed on the project.

Since irrigated agriculture requires more inputs and power (labor intensive), continuous follow up by the development agents is needed to work with the farmers by initiating them timely.

7.8.1 Improved seeds and fertilizers

The major inputs recommended for the proposed crops on the project are improved seeds and fertilizers. The types of improved seeds and fertilizers are shown on the table below.

Table 18 Seed rate, fertilizer rate and Planting distance for the proposed crops

Types of crops	Types of improved seeds	Seed rate/ha (kg)	Fertilizer rate/ha		Planting distance	
			NPS (kg)	Urea (kg)	Between rows (cm)	Between plants (cm)
Maize	BH540, BH140, Melkassa1,3&4	25-30	100	100	75	25
Sorghum	Gubiye, Abshir	8-10	100	100	60-75	15-20
Haricot bean	Awash Melkasa, Nasir, Tabor	90-120	100	50	50-90	5-20
Tomato	Marglobe, Melka Shola	0.3	150	100	100	45
Onion	Adama red, Bombay red	3.5-4	100	150	30	10

Table 19 Cost of inputs used in and around the project area

Crop	Cost of inputs (Birr/Qt)		
	Seed	NPS	Urea
Maize	5700	1281	1280
Teff	1810		-
Haricot bean	1950		-

Source: Gomole woreda Pastoral office and market assessment

7.8.2 Proposed Crop Pest Control and Management

General

Dense canopies and lush growth, typical of irrigated production, pose particular challenges in the field of plant protection. Certain pests and diseases considered minor in regular dry circumstances may become major in an irrigated setting. Plant sap composition in fertilized crops, shade and moisture typical of irrigated canopies provide an improved environment for different types of pests and diseases.

The specific measures used in efforts to control plant pests have been classified in several different ways such as biological, physical and chemical.

Pest control mechanisms are designed to reduce damage to below economic threshold levels. Use of integrated pest management (IPM) is the most economical and environmentally safe method to reduce pest population to the economically acceptable level. Integrated pest management focuses on considering the ecosystem as a whole by combining cultural, biological and chemical methods to reach equilibrium in the production environment. IPM does not always work, mainly because intensive production is an unbalanced ecosystem by definition, and certain pests thrive well in that environment. Thus, chemical methods of control are also implemented when all integrated approaches are ineffective to reduce the population to an acceptable level or economic threshold.

7.8.2.1 Methods of Pest Management

The optimal method proposed to manage the existing pest population of the project area includes cultural operation such as: crop rotation, crop sanitation, routine use of resistant or tolerant crop varieties, good tillage practices, timely planting and harvesting, thinning, fertilizer application, water management, mechanical methods, including hand destruction of pests and other types of barrier and chemical methods.

Table 20 Chemicals required for crop protection

Crops	Diseases	Chemicals	Rate/ha
Maize	Grey leaf spot (GLS), Leaf blight	Mancozeb 80%	2kg
Tomato	Early blight	Helcozeb 80%	2kg
	Late blight	Helcozeb 80%	2kg
Onion	Downey mildew	Mancozeb	3.5kg
	Purple blotch	Ridomil	3.0kg
Pests			
Maize	Stalk borer	Carbaryl 85% Wp	1.5kg
	Army worm	Malathion 50%	1.5kg
Tomato	Cutworms	Symbush or carbaryl 85% wp	2.0lt
	Aphids	Endosulphan 40%	2.0lt
Onion	Onion thrips	Cypermethrin 10% EC	0.5lt

***The average unit cost of chemical is 500 birr**

7.8.3 Seasonal and annual seed requirements

Seasonal distribution of improved seed demand would have important role in input supply management and procurement process to provide the seeds at the required time for the farmers. Then indicating the amount of seeds for dry and wet seasons is necessary for the project managers and irrigation users' cooperatives. Thus, the calculated seed requirements of the proposed crops based on the seasonal allocation of cropland and seed rate is described as follows.

Table 21 Summary of seed requirement for first year

Crop	Seed rate (kg/ha)	First phase		Second phase		Annual total seed requirement (Qt)
		Area (Ha)	Dry season requirement (Qt)	Area (Ha)	Wet season requirement (Qt)	
Maize	30	24	7.2	24	7.2	14.4
Sorghum	10	30	3	30	3	6
Haricot bean	120	24	28.8	24	28.8	57.6
Tomato	0.3	24	0.072	24	0.072	0.144
Onion	4	18	0.72	18	0.72	1.44

Table 22 Summary of seed requirement for second year

Crop	Seed rate (kg/ha)	First phase		Second phase		Annual total seed requirement (Qt)
		Area (Ha)	Dry season requirement (Qt)	Area (Ha)	Wet season requirement (Qt)	
Maize	30	21.6	6.48	24	7.2	13.68
Sorghum	10	30	3	30	3	6
Haricot bean	120	24	28.8	24	28.8	57.6
Tomato	0.3	26.4	0.0792	24	0.072	0.1512
Onion	4	18	0.72	18	0.72	1.44

Table 23 Summary of seed requirement for third year

Crop	Seed rate (kg/ha)	First phase		Second phase		Annual total seed requirement (Qt)
		Area (Ha)	Dry season requirement (Qt)	Area (Ha)	Wet season requirement (Qt)	
Maize	30	21.6	6.48	24	7.2	13.68
Sorghum	10	27.6	2.76	24	2.4	5.16
Haricot bean	120	24	28.8	24	28.8	57.6
Tomato	0.3	26.4	0.0792	24	0.072	0.1512
Onion	4	20.4	0.816	24	0.96	1.776

Table 24 Summary of seed requirement for fourth year

Crop	Seed rate (kg/ha)	First phase		Second phase		Annual total seed requirement (Qt)
		Area (Ha)	Dry season requirement (Qt)	Area (Ha)	Wet season requirement (Qt)	
Maize	30	21.6	6.48	24	7.2	13.68
Sorghum	10	27.6	2.76	24	2.4	5.16
Haricot bean	120	24	28.8	24	28.8	57.6
Tomato	0.3	26.4	0.0792	24	0.072	0.1512
Onion	4	20.4	0.816	24	0.96	1.776

Table 25 Summary of seed requirement for fifth year

Crop	Seed rate (kg/ha)	First phase		Second phase		Annual total seed requirement (Qt)
		Area (Ha)	Dry season requirement (Qt)	Area (Ha)	Wet season requirement (Qt)	
Maize	30	21.6	6.48	24	7.2	13.68
Sorghum	10	27.6	2.76	24	2.4	5.16
Haricot bean	120	24	28.8	24	28.8	57.6
Tomato	0.3	26.4	0.0792	24	0.072	0.1512
Onion	4	20.4	0.816	24	0.96	1.776

7.8.4 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, it uptake is inhibited when the soil dries. Water use efficiency is raised by fertilizer which increases dry matter production.

For instance 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 the applications of appropriate and required quantity of fertilizers has remarkable contribution to the plant water use efficiency and ultimately increase the productivity of the crops.

Table 26 Seasonal and annual fertilizer requirement for first year

Crop	Rate of NPS /ha (kg)	Rate of Urea /ha (kg)	First phase				Second phase				Total requirement (Qt)		
			Area (Ha)	NPS (Qt)	Urea (Qt)	Sub Total	Area (Ha)	NPS (Qt)	Urea (Qt)	Sub Total	NPS (Qt)	Urea (Qt)	Total (Qt)
Maize	100	100	24	24	24	48	24	24	24	48	48	48	96
Sorghum	100	100	30	30	30	60	30	30	30	60	60	60	120
H/bean	100	50	24	24	12	36	24	24	12	36	48	24	72
Tomato	150	100	24	36	24	60	24	36	24	60	72	48	120
Onion	100	150	18	18	27	45	18	18	27	45	36	54	90

Table 27 Seasonal and annual fertilizer requirement for second year

Crop	Rate of NPS/ha (kg)	Rate of Urea /ha (kg)	First phase				Second phase				Total requirement (Qt)		
			Area (Ha)	NPS (Qt)	Urea (Qt)	Sub Total	Area (Ha)	NPS (Qt)	Urea (Qt)	Sub Total	NPS (Qt)	Urea (Qt)	Total (Qt)
Maize	100	100	21.6	21.6	21.6	43.2	24	24	24	48	45.6	45.6	91.2
Sorghum	100	100	30	30	30	60	30	30	30	60	60	60	120
H/bean	100	50	24	24	12	36	24	24	12	36	48	24	72
Tomato	150	100	26.4	39.6	26.4	66	24	36	24	60	75.6	50.4	126
Onion	100	150	18	18	27	45	18	18	27	45	36	54	90

Table 28 Seasonal and annual fertilizer requirement for third year

Crop	Rate of NPS/ha (kg)	Rate of Urea /ha (kg)	First phase				Second phase				Total requirement (Qt)		
			Area (Ha)	NPS (Qt)	Urea (Qt)	Sub Total	Area (Ha)	NPS (Qt)	Urea (Qt)	Sub Total	NPS (Qt)	Urea (Qt)	Total (Qt)
Maize	100	100	21.6	21.6	21.6	43.2	24	24	24	48	45.6	45.6	91.2
Sorghum	100	100	27.6	27.6	27.6	55.2	24	24	24	48	51.6	51.6	103.2
H/bean	100	50	24	24	12	36	24	24	12	36	48	24	72
Tomato	150	100	26.4	39.6	26.4	66	24	36	24	60	75.6	50.4	126
Onion	100	150	20.4	20.4	30.6	51	24	24	36	60	44.4	66.6	111

Table 29 Seasonal and annual fertilizer requirement for fourth year

Crop	Rate of NPS/ha (kg)	Rate of Urea /ha (kg)	First phase				Second phase				Total requirement (Qt)		
			Area (Ha)	NPS (Qt)	Urea (Qt)	Sub Total	Area (Ha)	NPS (Qt)	Urea (Qt)	Sub Total	NPS (Qt)	Urea (Qt)	Total (Qt)
Maize	100	100	21.6	21.6	21.6	43.2	24	24	24	48	45.6	45.6	91.2
Sorghum	100	100	27.6	27.6	27.6	55.2	24	24	24	48	51.6	51.6	103.2
H/bean	100	50	24	24	12	36	24	24	12	36	48	24	72
Tomato	150	100	26.4	39.6	26.4	66	24	36	24	60	75.6	50.4	126
Onion	100	150	20.4	20.4	30.6	51	24	24	36	60	44.4	66.6	111

Table 30 Seasonal and annual fertilizer requirement for fifth year

Crop	Rate of NPS/ha (kg)	Rate of Urea /ha (kg)	First phase				Second phase				Total requirement (Qt)		
			Area (Ha)	NPS (Qt)	Urea (Qt)	Sub Total	Area (Ha)	NPS (Qt)	Urea (Qt)	Sub Total	NPS (Qt)	Urea (Qt)	Total (Qt)
Maize	100	100	21.6	21.6	21.6	43.2	24	24	24	48	45.6	45.6	91.2
Sorghum	100	100	27.6	27.6	27.6	55.2	24	24	24	48	51.6	51.6	103.2
H/bean	100	50	24	24	12	36	24	24	12	36	48	24	72
Tomato	150	100	26.4	39.6	26.4	66	24	36	24	60	75.6	50.4	126
Onion	100	150	20.4	20.4	30.6	51	24	24	36	60	44.4	66.6	111

7.8.5 Agro-chemical requirements

Similar to other inputs, agro-chemicals should be quantified and cost 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.
What are 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 agrochemicals
- 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 should be fixed for each crop. Based on the actual pest prevalence conditions of the project area, 30% of the crop area is suggested to be considered for chemical application.

Table 31 Summary of seasonal and annual agro-chemical requirements and cost for first year

Crop	First phase						Second phase				Annual requirement	
	Area (Ha)	Area considered (Ha) (30%)	Rate of application (lt, kg /ha)	Unit cost	Dry season requirement		Area (Ha)	Area considered (Ha) (30%)	Wet season requirement			
					Quantity (lt/kg)	Cost (Birr)			Quantity (lt/kg)	Cost (Birr)	Quantity (lt/kg)	Cost (Birr)
Maize	24	7.2	2	500	14.4	7200	24	7.2	14.4	7200	28.8	14400
Onion	18	5.4	3.5	500	18.9	9450	18	5.4	18.9	9450	37.8	18900
Tomato	24	7.2	2	500	14.4	7200	24	7.2	14.4	7200	28.8	14400

Table 32 Summary of seasonal and annual agro-chemical requirements and cost for second year

Crop	First phase						Second phase				Annual requirement	
	Area (Ha)	Area considered (Ha) (30%)	Rate of application (lt, kg /ha)	Unit cost	Dry season requirement		Area (Ha)	Area considered (Ha)(30%)	Wet season requirement			
					Quantity (lt/kg)	Cost (Birr)			Quantity (lt/kg)	Cost (Birr)	Quantity (lt/kg)	Cost (Birr)
Maize	21.6	6.48	2	500	12.96	6480	24	7.2	14.4	7200	27.36	13680
Onion	18	5.4	3.5	500	18.9	9450	18	5.4	18.9	9450	37.8	18900
Tomato	26.4	7.92	2	500	15.84	7920	24	7.2	14.4	7200	30.24	15120

Table 33 Summary of seasonal and annual agro-chemical requirements and cost for third year

Crop	First phase						Second phase				Annual requirement	
	Area (Ha)	Area considered (Ha) (30%)	Rate of application (lt, kg /ha)	Unit cost	Dry season requirement		Area (Ha)	Area considered (Ha)(30%)	Wet season requirement			
					Quantity (lt/kg)	Cost (Birr)			Quantity (lt/kg)	Cost (Birr)	Quantity (lt/kg)	Cost (Birr)
Maize	21.6	6.48	2	500	12.96	6480	24	7.2	14.4	7200	27.36	13680
Onion	20.4	6.12	3.5	500	21.42	10710	24	7.2	25.2	12600	46.62	23310
Tomato	26.4	7.92	2	500	15.84	7920	24	7.2	14.4	7200	30.24	15120

Table 34 Summary of seasonal and annual agro-chemical requirements and cost for fourth year

Crop	First phase						Second phase				Annual requirement	
	Area (Ha)	Area considered (Ha) (30%)	Rate of application (lt, kg /ha)	Unit cost	Dry season requirement		Area (Ha)	Area considered (Ha) (30%)	Wet season requirement			
					Quantity (lt/kg)	Cost (Birr)			Quantity (lt/kg)	Cost (Birr)	Quantity (lt/kg)	Cost (Birr)
Maize	21.6	6.48	2	500	12.96	6480	24	7.2	14.4	7200	27.36	13680
Onion	20.4	6.12	3.5	500	21.42	10710	24	7.2	25.2	12600	46.62	23310
Tomato	26.4	7.92	2	500	15.84	7920	24	7.2	14.4	7200	30.24	15120

Table 35 Summary of seasonal and annual agro-chemical requirements and cost for fifth year

Crop	First phase						Second phase				Annual requirement	
	Area (Ha)	Area considered (Ha) (30%)	Rate of application (lt, kg /ha)	Unit cost	Dry season requirement		Area (Ha)	Area considered (Ha) (30%)	Wet season requirement			
					Quantity (lt/kg)	Cost (Birr)			Quantity (lt/kg)	Cost (Birr)	Quantity (lt/kg)	Cost (Birr)
Maize	21.6	6.48	2	500	12.96	6480	24	7.2	14.4	7200	27.36	13680
Onion	20.4	6.12	3.5	500	21.42	10710	24	7.2	25.2	12600	46.62	23310
Tomato	26.4	7.92	2	500	15.84	7920	24	7.2	14.4	7200	30.24	15120

7.8.6 Human Labor

Under traditional and smallholder farming system human labour is a major and determinant input for agriculture, out of total labour requirements family labour taking major share while extra labour covers the remaining labour demand. The indicative labour requirement per hectare for selected crops is depicted on the table as follows.

Table 36 Labour requirement for "With-Project" condition per hectare

No	Crops	Activities	Unit	Frequency	Qty	Total	Unit price (Birr)	Total Price
1	Maize	Ploughing	MD	3	8	24	80	1920
		Pre-Irrigation	MD	1	4	4	80	320
		Planting/Sowing	MD	1	8	8	80	640
		Irrigation	MD	14	4	56	80	4480
		Cultivation/Weeding	MD	3	15	45	80	3600
		Fertilizer application	MD	2	8	16	80	1280
		Protection	MD	2	4	8	80	640
		Harvesting	MD	1	30	30	80	2400
		Threshing	MD	1	20	20	80	1600
		Transport	MD	1	8	8	80	640
2	Sorghum	Ploughing	MD	3	8	24	80	1920
		Pre-Irrigation	MD	1	4	4	80	320
		Sowing	MD	1	8	8	80	640
		Irrigation	MD	8	4	32	80	2560
		Cultivation/Weeding	MD	2	15	30	80	2400
		Fertilizer application	MD	2	8	16	80	1280
		Protection	MD	1	4	4	80	320
		Harvesting	MD	1	30	30	80	2400
		Transport	MD	1	20	20	80	1600
3	Haricot bean	Ploughing	MD	2	8	16	80	1280
		Pre-Irrigation	MD	1	4	4	80	320
		Sowing	MD	1	8	8	80	640
		Irrigation	MD	18	4	72	80	5760
		Cultivation/Weeding	MD	2	15	30	80	2400
		Fertilizer application	MD	1	8	8	80	640
		Protection	MD	1	4	4	80	320
		Harvesting	MD	1	20	20	80	1600
		Transport	MD	1	5	5	80	400
4	Tomato	Ploughing	MD	4	8	32	80	2560
		Pre-Irrigation	MD	1	4	4	80	320
		Seedling nursery	MD	1	5	5	80	400
		Transplanting	MD	1	30	30	80	2400

No	Crops	Activities	Unit	Frequency	Qty	Total	Unit price (Birr)	Total Price
		Irrigation	MD	14	4	56	80	4480
		Cultivation/Weeding	MD	3	20	60	80	4800
		Fertilizer application	MD	2	8	16	80	1280
		Protection	MD	1	4	4	80	320
		Harvesting	MD	2	20	40	80	3200
		Transport	MD	1	20	20	80	1600
5	Onion	Ploughing	MD	4	8	32	80	2560
		Pre-Irrigation	MD	1	4	4	80	320
		Seedling nursery	MD	1	5	5	80	400
		Transplanting	MD	1	30	30	80	2400
		Irrigation	MD	27	4	108	80	8640
		Cultivation/Weeding	MD	3	20	60	80	4800
		Fertilizer application	MD	2	8	16	80	1280
		Protection	MD	1	4	4	80	320
		Harvesting	MD	2	20	40	80	3200
		Transport	MD	4	20	80	80	6400

* MD= Man day

Table 37 Proposed Oxen Day and Costs for with project condition

Crops	Activities	Unit	Freq	OD (Qty)	Total (Qty)	Unit price	sub Total price	Total price per crop
Maize	Ploughing	OD	3	8	24	200	4800	6400
	Sowing	‘’	1	8	8	200	1600	
Sorghum	Ploughing	‘’	3	8	24	200	4800	6400
	Sowing	‘’	1	8	8	200	1600	
Haricot bean	Ploughing	‘’	2	8	16	200	3200	4800
	Sowing	‘’	1	8	8	200	1600	
Tomato	Ploughing	‘’	4	8	32	200	6400	8000
	Sowing	‘’	1	8	8	200	1600	
Onion	Ploughing	‘’	4	8	32	200	6400	8000
	Sowing	‘’	1	8	8	40	320	

* OD = oxen day

Table 38 Price of crops produced by rain fed agriculture in 2009-2010 production years at Surupha town

Types of crops	Price (Birr/Qt)						Average of the two years
	2009			2010			
	Maximum	Minimum	Average	Maximum	Minimum	Average	
Maize	100	600	800	1000	600	800	800
Wheat	800	700	750	1000	800	900	825
H/bean	1200	800	1000	1500	1000	1250	1125
Teff	2000	1500	1750	2500	2000	2250	2000

Source: Gomole woreda Pastoral Development office

Table 39 Price of crops produced by traditional irrigation in 2010 production year in the project area Surupha town

Types of crops	Average Price (Birr/Qt)
Tomato	2000
Potato	700
Green pepper	4000
Head cabbage	2000
Maize	800
Onion	2000
Garlic	5000
Carrot	1500
Beet root	1500

Source: Gomole woreda Trade and Industry Office

7.9 Crop yield estimate and production

Agricultural production estimate and crop yield projection are crucial output of agronomic study to explain the potential of the project to contribute to household food security and increased income. Incorporating the total production gain from the intervention is vital indictor of development which needs to be estimated to demonstrate the project potential in crop production.

7.9.1 Basis for yield estimation

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 wereda and kebele agricultural offices
- ❖ Comparative advantage of the project area for input distribution and marketing
- ❖ Intensive follow up and adequate extension service to be undertaken

To estimate the yield build up of the project, the potential yield of different crops is assessed from the research works done under different conditions. The yield projection of the proposed crops for the project is depicted on the table below.

Table 40 Yield estimate and projection (qt/ha)

Crop	Average Yield in the woreda	Year 1	Year 2	Year3	Year 4	Year5	Year 5+
Maize	43	45	55	60	60	60	60
Sorghum	-	16	20	25	25	25	25
Haricot bean	8	10	16	20	20	20	20
Tomato	55	100	180	300	300	300	300
Onion	72	100	150	350	350	350	350

7.9.2 Production projection

Based on the yield build-up and seasonal/annual area coverage of the proposed crops, the seasonal and annual crop production was calculated and presented to show the production trend over the project lifespan.

Table 41 Summary of crop production projection (Qt) for first phase supplementary irrigation

Crop	Year 1	Year 2	Year3	Year 4	Year5	Year 5+
Maize	1080	1188	1296	1296	1296	1296
Sorghum	480	600	690	690	690	690
Haricot bean	240	384	480	480	480	480
Tomato	2400	4752	7920	7920	7920	7920
Onion	1800	2700	7140	7140	7140	7140

Table 42 Summary of crop production projection (Qt) for second phase supplementary irrigation

Crop	Year 1	Year 2	Year3	Year 4	Year5	Year 5+
Maize	1080	1320	1440	1440	1440	1440
Sorghum	480	600	600	600	600	600
Haricot bean	240	384	480	480	480	480
Tomato	2400	4320	7200	7200	7200	7200
Onion	1800	2700	8400	8400	8400	8400

7.10 Cropping Calendar

Cropping calendar is the time in which the agricultural activities are performed sequentially starting from land preparation until harvesting time. Different crops need different cropping calendar based up on the climatic factors they need and their length of growing period. The right and an optimum cropping calendar are needed to get an optimum yield. Thus, the following cropping calendar has been prepared for the proposed crops on the project.

I. First phase

Types of crops	Operational calendar					
	Tillage		Date of sowing or planting	Weeding		Harvesting
	Season of ploughing	Freq		Start of weeding	Freq	
Maize	Nov	3	01/12	Mid Dec	3	09/04
Sorghum	Nov	3	01/12	Beg Jan	2	10/03
Haricot bean	Nov	2	05/12	Mid Jan	2	28/02
Tomato	Nov	4	05/12	End Dec	3	14/03
Onion	Nov	4	05/12	End Dec	3	24/03

II. Second Phase

Types of crops	**Operational calendar**					
	Tillage		**Date of sowing or planting**	**Weeding**		**Harvesting**
	Season of ploughing	**Freq**		**Start weeding**	**Freq**	
Maize	May	3	01/05	Mid Jun	3	07/09
Sorghum	May	3	01/05	Beg Jul	2	08/08
Haricot bean	May	3	01/05	Mid Jul	2	29/07
Tomato	May	4	05/05	End Jun	3	12/07
Onion	May	4	05/05	End Jun	3	22/08

The cropping calendar for first phase irrigation and second phase irrigation is summarized as follows.

crop	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Maize												
Sorghum												
H/bean												
Tomato												
Onion												

8. CROP WATER REQUIREMENT (ETcr)

The water requirement of a crop depends on the climate. Under the same condition different crops require different amount of water and the quantities of water used by particular crop vary with its stage of growth. Initially during seeding, sprouting and early growth a crop uses water at a relative slow rate. The rate will increase with growth of crop reaching the maximum in most crops as it approaches flowering and then decline towards maturity.

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.

$$ETcr = ETo \times Kc$$

The computation of Crop water requirement requires the data of Reference Crop Evapo-Transpiration, crop growth stages, crop coefficient and effective rainfall.

8.1 Reference Crop Evapo-Transpiration (ETo)

Reference crop evapo-transpiration is the rate of evaporation from an extensive surface of 8 to 15 cm tall green grass cover of uniform height, actively growing, completely shading the ground with no shortage of water. The only factors affecting ETo are climatic parameters. As a result, ETo is a climatic parameter and can be computed from weather data (i.e. temperature, humidity, wind speed, sunshine hour). ETo expresses the evaporative demand of the atmosphere at a specific location and time of the year and does not consider crop and soil factors.

The Reference crop evapo-transpiration (ETo) 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 ETo calculated is depicted on the table below.

Table 43 The Monthly ETo of the Project area

Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	m/s	hours	MJ/m²/day	mm/day
January	12.7	28.4	49	1.7	10.3	23.6	4.97
February	13.8	29.3	51	1.9	9.2	23	5.22
March	15.3	28.6	56	2	7.3	20.8	4.97
April	15.9	24.4	70	1.6	6.6	19.5	4.02
May	15.4	24.9	73	1.2	5.5	17.2	3.51
June	14.4	24.4	68	1.2	4.7	15.6	3.31
July	13.9	23.9	67	1.3	2.9	13.1	3
August	14	24.7	64	1.3	4	15.2	3.37
September	14.6	26.1	68	1.5	5.8	18.3	3.9
October	15.4	25.4	74	1.7	5.1	16.8	3.6
November	14.3	25.5	73	1.8	6.8	18.6	3.8
December	12.7	26.4	61	1.6	8.8	21	4.23
Average	**14.4**	**26**	**65**	**1.6**	**6.4**	**18.6**	**3.99**

Station - Yabelo for temperature (Minimum and Maximum), Humidity, Wind and Sunshine hour data

Finchwa for Rainfall data

Altitude - 1729 m a.s.l for Yabelo and 1634 m a.s.l for Finchwa

Latitude - 4.88° **N** for Yabelo and 5.39° **N** for Finchwa

Longitude -38.1° **E** for Yabelo and 38.26° **E** for Finchwa

8.2 Length of Crop Growing Stage

There are four main growing stages of a crop during its growth period where water requirements vary i.e. the seasonal use of water by plants is determined by their stage of growing.

1. The initial stage: germination and early crop growth, where the ground cover is less than 10%.

2. Crop development stage: from the end of initial stage to full ground cover usually between 70-80% of the land surface.

3. Mid season stage: from the attainment of full ground cover to the start of maturity indicated by leaf senescence or loss.

4. Late season stage: from the end of the mid season stage until harvest.

During the vegetative stage consumptive use continues to increase. Flowering occurs near and the peak of consumptive use of water. The fruiting stage is accompanied by a decrease in consumptive use until the transpiration essentially ceases during the latter part or the formation of dry fruits.

The growing stages of the proposed crops for the project are shown on the table below.

Table 44 The length of the growing stages of the proposed crops

Types of crops	**Length of growing stages in days**				
	Initial	**Development**	**Mid**	**Late**	**Total**
Maize	20	35	45	30	130
Sorghum	15	30	30	25	100
Haricot bean	20	30	30	10	90
Tomato	20	30	30	20	100
Onion	20	35	35	20	110

8.2.1 Critical stages of crop growth to water deficit

There are some crucial stages in the life cycle of a crop plant when the plant is badly in need of water. Allowing water stress beyond a certain limit during these stages of crop growth causes a definite setback to growth processes and that ultimately affected the yield. These stages are referred as the critical stages of water requirement of crops. However, this does not mean that these stages are coinciding with peak consumptive use of water by crops. Water stress at these stages causes lower tillering, branching, pegging, tuber bulking, inadequate flowering and in extreme case, flower drops, poor setting of grains or fruits, bad filling of grains or serious fruit drops depending on the type of crops. The critical stages of water need of most crops are indicated in table below.

Table 45 Sensitive growth periods to water deficit of major irrigated crops

Maize	Flowering > grain filling > vegetative period; flowering is very sensitive if no prior water deficit
Wheat	Flowering > yield formation > vegetative period
Groundnut	Flowering > yield formation, particularly during pod setting
Potato	Period of stolonization and tuber initiation > yield formation > early vegetative and ripening
Onion	Bulb enlargement, during rapid bulb growth > vegetative period /and for seed production at flowering/
Pepper	Throughout but particularly just prior and at start of flowering
Tomato	Flowering > yield formation > vegetative period, particularly during just and after transplanting
Banana	Throughout but particularly during first part of vegetative period, flowering and yield formation
Cabbage	During head enlargement and ripening
Alfalfa	Just after cutting (and for seed production at flowering)
Citrus	Grapefruit, lemon and orange flowering and fruit setting > fruit enlargement for lemon heavy flowering may be induced by withholding irrigation just before flowering
Cotton	Flowering and boll formation
Grape	Vegetative period, particularly during shoot elongation and flowering > fruit filling
Pineapple	During period of vegetative growth
Rice	During period of head development and flowering > vegetative period and ripening
Sugarcane	Vegetative period, particularly during period of tillering and stem elongation > yield formation
Watermelon	Flowering, fruit filling > vegetative period, particularly during vine development
Bean	Flowering & pod filling, vegetative period not sensitive when followed by ample water supply
Pea	Flowering and yield formation > vegetative, ripening for dry peas
Safflower	Flowering and pod filling > vegetative
Sorghum	Flowering > yield formation > vegetative period less sensitive when followed by ample water supply
Soybean	Flowering and yield formation, particularly during pod development
Sunflower	Flowering and yield formation, particularly during bud development
Tobacco	Period of rapid growth, yield formation and ripening

Source: Guide line on Irrigation Agronomy MOA, September 2011, Addis Ababa

8.3 Crop Coefficient (Kc)

The effect of crop characteristics on crop water requirement is given by the crop coefficient. It represents the relationship between reference (ETo) and crop evapo-transpiration (ETcr) or ETcr = Kc x ETo

Values of crop coefficient given are shown to vary with the crop, its stage of growth, growing season and the prevailing weather conditions. The Kc for a given crop changes over the growing period as the groundcover, crop height and leaf area changes. Four growth stages are recognized for the selection of Kc: initial stage, crop development stage, mid-season stage and the late season stage.

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. For the proposed crops the crop coefficients selected are shown on the table as follows.

Table 46 Crop coefficients (kc) for the proposed crops

Types of crop	Crop coefficient in growing stages			
	Initial	Development	Mid	Late
Maize	0.40	-	1.10	0.90
Sorghum	0.35	-	1.05	0.80
Haricot bean	0.35	-	1.10	1.00
Tomato	0.45	-	1.15	0.85
Onion	0.50	-	1.00	0.85

8.4 Effective Rainfall

Effective rainfall means useful or utilizable rainfall. All the rainfall received are not used by the crops because of its erratic nature such as un timeliness, lesser or higher quantity etc. Effective rainfall is the proportion of rain, which is stored in the root zone and therefore be available to the plants. Rain fall which percolates beyond the root zone or is lost to the plants through surface run off is not effective, in that it is not available for plant growth.

It is calculated using the CROPWAT 8.0 software by effective rainfall method for CWR calculations using dependable rain (FAO/AGLW formula) which is;

$$P_{eff} = 0.6*P-10 \quad \text{for P month} \le 70 \text{ mm}$$

$$P_{eff} = 0.8*P-24 \quad \text{for P month} > 70 \text{mm}$$

Where; Peff = effective rain fall

P = total rainfall in a month (mm per month)

The calculated effective rainfall of the project area is illustrated on the table below.

Table 47 Effective Rain Fall of the Project Area

Month	Rain (mm)	Eff rain (mm)
January	16.9	0.1
February	11.9	0.0
March	47.6	18.6
April	188.3	126.6
May	138.2	86.6
June	33.6	10.2
July	18.6	1.2
August	33.1	9.9
September	55.1	23.1
October	139.4	87.5
November	113.4	66.7
December	15.3	0.0
Total	**811.4**	**430.4**

Several factors influence the proportion of effective rainfall and these may act singly or collectively and interact with each other. These factors are described as follows.

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 one full irrigation.

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

Table 48 Soil Data used in crop water Requirement computation

Soil name: Sandy loam

Total available soil moisture (FC-WP)	97 mm/m (soil study report)
Maximum rain infiltration rate	30 mm/day (FAO, for red sandy Loam soil)
Maximum rooting depth	150 centimetres(soil study report)
Initial soil moisture depletion (as % of TAM)	0%
Initial available soil moisture	97 mm/m

8.5 Irrigation Scheduling

Irrigation scheduling refers to the development of schedules for the application or distribution of seasonal or total irrigation water requirement during the growing period of a given crop. In practice, it is the application of irrigation water at the time of actual need of the crop depending on the availability of water over the growing period of the crop with just sufficient water to wet the effective root zone soil. The interval between two irrigations should be as wide as possible to save irrigation water, of course, without affecting adversely the crop growth and yield. Scheduling of irrigation is considered to minimize the losses of irrigation water, due to evaporation, leaching, seepage, etc and to maximize the efficient use of available water resources.

Therefore, on-farm irrigation water management involves the manipulation of such factors as the timing and amounts of irrigation water to be applied to the crop, the flow rates to be used, and the methods of controlling the water. The principal aim is to obtain maximum crop yield by making the most efficient and economic use of the available water. Proper irrigation water management, therefore, can help to reduce the unwise use of irrigation water and energy consumption, thus, making these supplies available for irrigating more land, as well as decreasing the cost of the system.

It can reduce the loss of fertilizer, caused by leaching from the effective root zone with excess water application and consequently maximizes the efficient use of fertilizer applied to achieve the desired yields. A good management program ensures that root zone salinity is controlled at desired levels and in parallel water logging of soils and excess deep percolation losses are either diminished or eliminated. It can also help to eliminate problems such as erosion and control crop diseases resulted, due to excessive or deficient water application. In general, a good farm water management program can enable farmers consistently make the best use of the available water.

Irrigation scheduling is one of the factors that influence the agronomic and economic viability of small farms. Therefore, following proper irrigation scheduling technique is important for both water savings and improved crop yields. The irrigation water is applied to the cultivated field according to predetermined schedules based upon the monitoring of the soil water status and the crop water need at different growth stages.

Three parameters have to be considered in preparing an irrigation schedule;

- The daily crop water requirements
- The soil, particularly its total available moisture or water-holding capacity
- The effective root zone depth

8.6. Irrigation Depth (D)

Depth of irrigation (d), including application losses, applied to the soil in one irrigation application and which is needed to bring the soil water content of root zone to field capacity in mm. The depth of irrigation application (d) including application losses is;

$$D = \frac{(P * Sa) * D(mm)}{Ea}$$

Where: p = fraction of available soil water

Sa = total available soil water mm/m soil depth

D = Rooting depth, m

Ea = application efficiency, fraction

Since P, D and ETc will vary over growing season, the depth in mm and interval of irrigation in days will vary.

Table 49 Irrigation depth of application for first phase irrigation

Crop	Rooting Depth (m)	Total Available Moisture (Sa)(mm/m)	Allowable Depletions (p) (fraction)	Application efficiency (50%)	Depth (mm)
Maize	1.0	97	0.55	0.7	76.21
Sorghum	1.4	97	0.50	0.7	97.00
Haricot bean	0.7	97	0.45	0.7	43.65
Tomato	1.0	97	0.40	0.7	55.43
Onion	0.6	97	0.45	0.7	37.41

Table 50 Irrigation depth of application for second phase irrigation

Crop	Rooting Depth (m)	Total Available Moisture (Sa) (mm/m)	Allowable Depletions (p) (fraction)	Application efficiency (50%)	Depth (mm)
Maize	1	97	0.55	0.7	76.21
Sorghum	1.4	97	0.50	0.7	97.00
Haricot bean	0.9	97	0.45	0.7	43.65
Tomato	1.0	97	0.40	0.7	55.43
Onion	0.6	97	0.45	0.7	37.41

8.7 Irrigation Efficiency (E)

Not all water taken from source to be used for irrigation reaches its destination and used by plants. Part of the water is lost during transport through the canals and the fields. The remaining part is stored in the root zone and use by plants. In other words, only part of the water is used efficiently, the rest of the water is lost through Conveyance efficiency (Ec), Field canal efficiency (Ed), and Application efficiency (Ea). Accordingly, the overall irrigation efficiency (Ep) will be Ec x Ed x Ea.

The following definitions are used;

- The application efficiency is the efficiency of the water left in to the field;
- The field canal efficiency is the efficiency of water distribution in the tertiary and the field canal system and ;
- The conveyance efficiency is the efficiency of the main distribution system in secondary, primary and main canal.

8.7.1 Water application efficiency (Ea)

It is the percentage of applied irrigation water stored in the soil and available for consumptive use by the crop. Field losses consist of surface run off and deep percolation. The purpose of irrigation is to replenish the available moisture in the root zone depleted by evapotranspiration. The application of the least amount of water required to bring the root zone moisture content up to field capacity is considered as efficient irrigation. If on the other hand, the amount of water applied grossly exceeds that actually needed for replenishment; the irrigator application efficiency is very low.

$$\text{Application efficiency} \quad (Ea) = \frac{\text{Water required to bring soil to FC level}}{\text{Water received at field inlet}} * 100$$

The application efficiency used for the project is 70% for the dominant soil of the command area is medium soil and the irrigation method that will be used is surface irrigation by furrow irrigation (FAO, Irrigation & Drainage paper 24- crop water requirements).

8.7.2 The field canal efficiency (Ed)

It is the efficiency of water distribution in the tertiary and the field canal system. The distribution efficiency used for the project is 75% for blocks up to 20ha and unlined canals (FAO, Irrigation & Drainage paper 24- crop water requirements).

8.7.3 Conveyance efficiency (Ec)

$$Ec = \frac{\text{Water received at inlet to a block of fields}}{\text{Water released at project head works}} * 100$$

Primary factors affecting conveyance losses are management aspects which cause fluctuations in the supply as well as physical factors such as seepage losses through canal banks and canal outlets. The conveyance efficiency used for the project is 85%.

8.7.4 Project efficiency (Ep)

$$Ep = \frac{\text{Water made directly available to the crop}}{\text{Water released at head works}} * 100$$

The overall project efficiency represents the efficiency of the entire operation between diversion of source of flow and the crop zone. Water delivery system improvements and farm irrigation improvements would significantly improve the ability of the farmer to apply more uniform and efficient irrigation.

Thus, for the project the proposed irrigation efficiency is 50%. i.e. Ep = EC*Ed*Ea = 0.85*0.75*0.7 = **0.45 = 45%.** For the design purpose 50% project efficiency is proposed to be used.

8.8 Net and Gross Irrigation Requirements

8.8.1 Net irrigation requirement (IRn)

It is a depth of water needed to bring the soil moisture level in the effective root zone to field capacity from the soil moisture. The net irrigation requirement does not include losses that are occurring in the process of applying the water. IRn plus losses constitute the Gross Irrigation Requirement (IRg).

It is calculated by using the relationship between crop water requirement (ETcr) and effective rainfall.

i.e. Net irrigation requirement = ETcr – Effective rainfall

8.8.2 Gross irrigation requirement

The total quantity of water used for irrigation is termed as gross irrigation requirement. It includes net irrigation requirement and losses in water application and other losses in the conveyance system due to seepage, evaporation, etc.

$$\text{Gross irrigation requirement} = \frac{\text{Net irrigation requirement}}{\text{Overall project efficiency}} * 100$$

8.9 Scheme Supply of the Project

As revealed on the crop water computation, the highest irrigation requirement for actual area is found in a month of February. The net irrigation requirement for actual area was found to be 0.64 l/s/ha for 24 hour irrigation without considering the project efficiency. The net irrigation requirement is divided by project efficiency (50%) to obtain the gross water requirement which becomes 1.28 l/s/ha for 24 hour irrigation. The proposed irrigation hour for the project is 12 hour. Therefore, the scheme supply of the project is **2.56 l/s/ha** for 12 hour irrigation. This figure is important for the designs of main canals, secondary and field canals to limit their capacity. The summary of the project supply computation is depicted on table below.

Table 51 Scheme supply of the project for first phase supplementary irrigation

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation deficit												
1. Maize	142.7	161	141.2	0.5	0	0	0	0	0	0	0	58.8
2. sorghum	152.2	147.7	41.9	0	0	0	0	0	0	0	0	60.6
3. Haricot bean	148.7	154.9	0	0	0	0	0	0	0	0	0	53.7
4. Onion	127.3	146	100.9	0	0	0	0	0	0	0	0	59.8
5. Tomato	148.4	166.5	65	0	0	0	0	0	0	0	0	55.1
Net scheme irr.req.												
in mm/day	4.7	5.5	2.2	0	0	0	0	0	0	0	0	1.9
in mm/month	145.1	155.3	66.8	0.1	0	0	0	0	0	0	0	57.7
in l/s/h	0.54	0.64	0.25	0	0	0	0	0	0	0	0	0.22
Irrigated area (% of total area)	100	100	80	20	0	0	0	0	0	0	0	100
Irr.req. for actual area (l/s/h)	0.54	0.64	0.31	0	0	0	0	0	0	0	0	0.22
Project efficiency	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%
Project supply (l/s/ha)	1.08	1.28	0.62	0	0	0	0	0	0	0	0	0.44
Proposed irrigation hour	12	12	12	12	12	12	12	12	12	12	12	12
Project supply (l/s/ha) for 12 hour	2.16	2.56	1.24	0	0	0	0	0	0	0	0	0.88

For the second phase supplementary irrigation, the highest irrigation requirement for actual area is found in a month of November. The net irrigation requirement for actual area was found to be 0.35 l/s/ha for 24 hour irrigation without considering the project efficiency. The net irrigation requirement is divided by project efficiency (50%) to obtain the gross water requirement which becomes 0.7 l/s/ha for 24 hour irrigation. The proposed irrigation hour for the project is 12 hour. Therefore, the scheme supply of the project is **1.4 l/s/ha** for 12 hour irrigation. The summary of the project supply computation is depicted on table below.

Table 52 Scheme supply of the project for second phase supplementary irrigation

	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Precipitation deficit												
1. Maize	0	0	0	0	0	76.1	98.6	94.1	18.2	0	0	0
2. sorghum	0	0	0	0	0.8	81.7	89.3	18.3	0	0	0	0
3. Haricot bean	0	0	0	0	0	81.3	90.3	0	0	0	0	0
4. Onion	0	0	0	0	0	68.6	91.1	60.5	0	0	0	0
5. Tomato	0	0	0	0	0	80.8	103	32.9	0	0	0	0
Net scheme irr.req.												
in mm/day	0	0	0	0	0	2.6	3	1.3	0.1	0	0	0
in mm/month	0	0	0	0	0.2	78.4	94.4	39.1	3.6	0	0	0
in l/s/h	0	0	0	0	0	0.3	0.35	0.15	0.01	0	0	0
Irrigated area (% of total area)	0	0	0	0	25	100	100	80	20	0	0	0
Irr.req. for actual area (l/s/ha)	0	0	0	0	0	0.3	0.35	0.18	0.07	0	0	0
Project efficiency	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%
Project supply (l/s/ha)	0	0	0	0	0	0.6	0.7	0.36	0.14	0	0	0
Proposed irrigation hour	12	12	12	12	12	12	12	12	12	12	12	12
Project supply (l/s/ha) for 12 hour	0	0	0	0	0	1.2	1.4	0.72	0.28	0	0	0

9. CROP SYSTEM AND MANAGEMENT

9.1 Crop Management of the Proposed Crops

9.1.1. Maize

Recommended Cultural Practices

Seeding rate: 25-30 kg/ha;

Fertilizer rate: -The fertilizer rate recommended is 100 kg/ha of NPD at the time of sowing and 100 kg/ha of urea in split application. The first should be when the maize crop is at knee high (30cm) crop stage after about a month of sowing and the second is when the crop is at tasseling.

Spacing: 75 cm and 30 cm between rows and plants, respectively;

Weed control: twice weeding, 20-25 and 40-45 days after emergence, and the use of chemicals such as Atrazine mixed with 200 liters of water at the rate of 41t/ha for broad leaved weeds and Primagram at the rate of 4-5lt/ha for grass weeds;

Storage pests: Drying of the grain to the optimum moisture content and use of insecticide such as Pirimiphos methyl dust.

9.1.2 Sorghum

Sorghum is the fifth most important world cereal following wheat, corn, rice and barley. It is a crop of choice in drier parts of the world because of its great merit of drought resistance. In Ethiopia, it is the third in area of production next to teff and maize and third in yield per hectare and total yield per crop next to maize and wheat.

The whole grain approximately contains 6-8% protein, 2-5% fat, 68-74% carbohydrate, 1-3% fiber, and 1.5-2% ash. For food, the white grains are prepared to the red, giving more attractive flour which is used to make porridge or Injera. In Africa, sorghum is largely used for making beer, for livestock and poultry feed.

Ecological requirement: Sorghum called “camel of cereals “withstands extreme heat and dry better than other crops .It is adapted to wide range of ecological conditions and can be grown under conditions which are unfavorable for most of other cereals. For germination, optimum temperature is 18^0c, for growth, optimum temperature is 27^0c to 32^0c. The minimum and maximum temperature for growth is 15^0c and 40^0c, respectively. Sorghum is mainly grown below 1500 m and the crop adapts itself quite well to dry conditions and gives good yields with an annual rainfall of 425-625mm. However, at least 300-400mm of this rain should come during the growing period.

Sorghum can be grown on a wide range of soils from heavy clay to light soils. It can grow on soils having P^H range of 5.5-8.5. It tolerates salinity and water logging conditions better than other cereals except rice and teff. But it does best in well drained and fertile soils.

Sorghum is a short day plant. When the suited soil temperature of 7-10cm below the surface of soil is about 12^0c, it is best suited for planting and when soil moisture content is about 16%-18%, sowing can be done. So, sorghum planting date for lowland sorghum is from early June to late June.

Recommended Cultural Practices

Seedbed preparation: 2-3 times plowing;

Sowing date: 15-30 June for rain fed agriculture;

Seed rate: It can be broadcasted at 10-20 kg/ha and drilled at 5-10 kg/ha;

Weed Control: Two hand weeding, first during 20-29 days after crop emergence and second weeding during 40-50 days after planting, 2, 4-D at 1.0 l/ha (post-emergence) for controlling striga and other annual broadleaf weeds.

9.1.3 Haricot Bean

Growth habit

It is a highly polymorphic species showing much variation in habit, vegetative characters, flower color and size, and shape and color of pods and seeds. Generally, two type of growth habits; determinate and indeterminate growth habits recognized, each one having several forms. These depend on the development of the terminal part of the stem, the number of nodes, the length of the internodes and consequently, the height of the plant, its climbing ability and the degree and type of branching. All forms are annual herbs and have a well developed tap root which reaches to 1m or more.

Growth Period:

The length of the crop cycle depends on variety, growth habit, temperature and photoperiod and fluctuates between 70 to 120 Days for determinate types and between 250 and 300 days for indeterminate types.

Environmental Requirement:

Haricot beans are best suited with an altitude range 1400 to 2000 m, in Ethiopia it is found to be grown within the range of 900-2100m. Water requirements for maximum production of a 60 to 120 day crop vary between 300 and 500 mm depending on climate. Although the crop requires enough moisture during flowering it does not require an excessive amount of moisture as it drops the flower and aggravate disease prevalence. The optimal temperature for their growth ranges between 18^0 and 24^0 C. The crop is sensitive to forest. Below 13^0 C, growth is considerably retarded. Also high temperature during flowering causes the dropping of buds and flowers, which reduces yields. At temperature above 30^0 C pod and seed production are seriously affected.

Soils: Haricot beans can be grown successfully on most soil types from light sands to heavy clays, but friable, deep (at least 1m), well drained, medium texture (loams), with good organic matter contents, with optimum pH range of 5.7 to 6.7 and critical range of 5.0 and 8.1 are preferred. The crop is sensitive to salinity. The optimal amount of organic carbon in the soil should exceed 2.4%; the critical threshold is 0.8%.

Land Preparation

In the major production areas 3 frequencies of tillage are performed and the time of tillage varies based on their agro climatic features. Haricot beans do not require fine seedbed to minimize crusting, it should be a little cloddy and do not finally pulverized. Thus, only three times Ploughing, the last one together with sowing is recommended.

Sowing

Haricot beans are sown by dibbling, drilling or broadcasting, with pure stands the row width and distance within rows varies between 50 to 90 and 5 to 20 cm respectively depending on the growth habit of cultivars and others factors. Planting depth ranges from 2.5 to 5cm in heavy soils to 5 to 10cm in light soils. The seed rate varies according to cultivars, with a range between 90 to 120 kg/ha.

Fertilizer Application

Although, Haricot bean have the capacity of improving the fertility status of the soils, on poor soils it is good to apply 100kg NPS/ha and 50 Kg Urea/ha.

Crop protection

Thus, to obtain maximum production weeds should be removed before they compete with the crops. Starting from the 2^{nd} weeks of planting to flowering time the crop should be weeded two times. Hand weeding is best and cheep. However, if there is a need, herbicides Alkekelor 4 lit/ha can be used. After flowering of the crop weeding is not recommended as it results in flower dropping. The crop suffers from many diseases and insects' pests;

Insect Pests: Haricot beans are attacked by haricot bean worm, grass pea worm and haricot bean weevils. In the study area; *ABW, Magot, Cut Worm, Crickets, Thrips, BeanBeetle, and Aphids* are prevalent insects attacking the crop.

To control high planting density, seed treatment inter cropping with maize, Spraying Chemical insecticides, sanitation and fumigation of storage facilities are recommended.

Disease: Haricot beans suffers from many diseases among the major disease are Bacterial blight, Anthracnose and rust. To Control use of disease-free seeds, crop rotation and growing resistant cultivars are suggested.

Crops Grown in Association

Crop association with all their variants: mixed cropping, inter-cropping, alternate strip cropping and rely cropping possible. Maize, sorghum, millet, Soya bean, cowpea, sesame, groundnut, taro, sweet potato, cassava, chillie pepper, banana are crops commonly grown in association with common beans.

Post Harvest Management

The grain is stored either in a house with sacks or in traditional silos until it is marketed or used for home consumption. The post harvesting management practices include, keeping the seed clean, testing appropriate seed moisture for storage facilities and seed grading for usage and keeping in the store. Stored grain should be protected from rain and ground moisture, and the storage container should be rodent-proof, insect-proof and should seal tightly. Steel bins which seal tightly and are easy to clean are best.

Main products and uses

The young pods and ripe seeds are eaten in wot, soups and salads and to a lesser extent, so are the green shelled seeds. The young leaves are eaten as a vegetable or pot herb, and are also used as a cattle feed. Haricot beans can be used for the production of protein concentrates. The straw is used as forage. The straws are very important livestock feed in all the producing areas of Arsi and East Shewa.

Yield-The yield of haricot beans varies greatly according to the variation in cultivars, the agro-ecological conditions, and the level of crop management and efficiency of pest and disease control. The current national average yields of haricot bean are 615 kg/ha, in research station it ranges from 2000-3200 kg/ha.

9.1.4. Onion

a. Nursery management

Planting method: transplanting from seedlings rose on well managed seed bed.

Site selection: Availability of water, good soil and free of water logging conditions, clean field that are not used for related crops in the previous 2-3seasons are required for site selection.

Seed bed preparation: Seed bed could be raised, sunken or flat depending on climatic conditions. Bed width should be 1m and length of 5 or 10m. Seedlings are spaced 15cm between rows.

Fertilizer: well decomposed farmyard manure or 100 g Urea/5 m^2

Seeding rate: 3-4 Kg/ha of seeds that have 95% germination.

Mulching material: Dry grass for 15 days

Watering: water the seedbed early in the morning and evening as required

Stage of transplanting: Seedling of 13-15cm height or 45-55 days old.

b. Field management practices

Sowing or transplanting time: Onion is mainly irrigated crop but it could also be produced under rain fed.

Transplanting site selections: Fertile and leveled area which is not used for related crops in the previous 2-3 seasons is required.

Plant spacing: 40 x 20 x 10 cm, two rows per bed.

Fertilizer application: 100 kg/ha NPS and 150 Kg urea will be applied, 50% of urea will be applied at time of transplanting and the other 50% at one and a half month after transplanting.

Harvesting stages: when about 50-75% of the leaves fall down. Bulbs are properly dried in the field before stored or distributed.

9.1.5. Tomato

- The seed is generally sown in nursery plots and emergence is within 10days, seedlings are transplanted to the field after 25 days. In the nursery the row distance is about 10cm.
- In the field a spacing of 120cm wide bed is required and seedlings will be planted in one row on this bed at a distance of 40cm between plants for indeterminate varieties. But for the determinate varieties on a bed of 120 cm wide seedlings will be planted in two rows at a distance of 50cm between rows and 25cm between plants.
- Fertilizer recommendation is 150kg/ha of NPS and there is no need of Urea fertilizer.
- Depth of planting required is 4-5cm.
- The crop should be grown in rotation with other crops such as maize to reduce pests and diseases particularly nematodes.
- Area needed to prepare seedlings for one hectare is 250m^2.

9.2.2 Plant protection

1. Maize

1.1 Diseases

a. Grey leaf spot (cercospora zeaemaydis)

It is a foliar disease of maize. It causes complete drying of leaves before maturity.

The control measure could be achieved by the use of resistant or tolerant varieties, crop rotation, and crop residue management.

b. Leaf blight (Helmintho porium turicicum)

It is also a foliar disease of maize. It can be controlled by using resistant varieties.

1.2 Pests

a. Stalk borer (Busseola fusca)

It attacks the stalk by boring the stem. Control of this pest could be achieved by destroying residues of the previous seasons maize crop because the larvae diapauses (over wintering) in the dry stalks, by the removal of plants with dead hearts during the first six weeks and their destruction. It can also be controlled by chemicals using carbaryl 85% WP at the rate of 1.5kg/ha or simbush at 1.5kg/ha

b. Cut worm (Agrofisipsilon)

It attacks the seedlings by cutting the shoots at the base. The control can be achieved by plowing the land during the dry time, seed dressing and avoiding host weeds.

c. Army worm (spodoptera exempta)

It can cause complete devastation of the seedlings. Thus, all the out breaks should be reported to the agricultural development office of the district. It can be controlled with either malathione 50% EC at the rate of 1-2lt/ha or 25% endosulphan ULV at the rate of 1.5lt/ha.

2. Onion

a. Diseases

Downey mildew and purple blotch are the major diseases that attack onion severely; particularly during the rainy season and when the humidity is high.

Recommended measures to control the 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 weeds/weeding at least two times in the growing period;
3. Whenever necessary weekly spray with 3.5 kg/ha rate of mancozeb or 3kg of ridomil for 3 to 4 times by mixing up with 600 litres of water.

b. Pests

Onion thrips, leaf miners and cutworms are some of the common insect pests that attack onion.

Control- When 5 to 10 insects are observed per plant it is possible to control the pest by spraying with 0.5 l/ha of cypermethrin 10% EC mixing with 200 liters of water and spray every two weeks for 3 to 4 times.

3. Tomato

1. Diseases

a. Early blight (Alternaria solani)

It is a fungus disease. The fungus causes a canker and collar rot on the stem of seedlings and young plants in the field. In the leaves the fungus develops spots that may partly defoliate the plants and reduce the yield and quality of the fruits.

Control measures are use of resistant varieties, rouging out infected plants, spraying Helcozeb 80% at the rate of 2kg/ha and spraying four times during growing periods.

b. Late blight (phytophtora infestans)

The fungus causes defoliation and a very destructive rot of the plants. The first symptoms are irregular, greenish black and water soaked spots on the leaves. The spots enlarge rapidly in moist weather and sometimes show white, downy growth on the lower surface, the stems often show symptoms similar to those in the leaves. Fruit infection occurs near the stem end and may take place at any stage of growth. Small, grayish-green, water soaked areas develop which enlarge rapidly and may cover half of the fruit. The spots take on a dark green color, blotched with brown as the fruits become older.

Control measures are the same as for early blight.

3.2 Pests

a. Nematodes - Several species of nematodes attack tomato plants. The nematodes induce the development of irregular swellings or knots on the roots. The nutrient and water up take from the soil is disturbed and the plant develops poorly.

Control measures are fumigation of seed beds, rouging of infected plants, destroying plant residues after harvest and a correct crop rotation.

b. Aphids and cut worms – They can be controlled by spraying endosulphan 40% E.C at the rate of 2 liter per hectare mixed with 200 liter of water or spraying malathione 50% EC at the rate of 2 liter per hectare mixed with 200 liter of water.

4. Sorghum

A. Diseases

Sorghum diseases are often caused by fungi. These pathogens invade the endosperm of the germinating seed. Leaf disease is mainly caused by bacteria and generally do not cause major problem.

a. Smut (head smut, covered smut and loose smut): cause extensive damages to seed grains. Anthracnose and leaf blights mainly affect sorghum leaves.

Since covered smut and loose smut are seed born diseases, it is advisable to soak seeds for 20 minutes in goats or cattle urine which lasted for a week. In addition, use of thiram, rouging out infected plants and use of resistant varieties**.** However, to control head smut, as it is soil born disease**,** it is advisable to soak seeds for 20 minutes in goats or cattle urine which lasted for a week. In addition, use of thiram, rouging out infected plants and use of resistant varieties and following crop rotation practices.

B. Insects and birds

Sorghum is affected by different pests like quella quella and insects**.**

Among the insect pests**:**

a. Sorghum stalk borer

Control measures

- Removing alternate hosts
- Timely planting
- Field sanitation
- Endosulfan 5% powder at 8kg/ha
- Karate 5%E.C liquid 310mlmixed diluted with 400 liter of water

b. Sorghum shoot fly

Control measures:

- Timely planting
- Use of tolerant variety

- Carbofuran 10gm granular 0.2 kg /ha spray on the field before sowing /planting sorghum.
- Karate 5%E.C liquid 310mlmixed diluted with 400 liter of water

c. Storage insect pests (Angomois grain moth, maize weevil, red flour beetle)

To control, use of clean stored grains and clean store material , mixing with ash within the store , and use of primifos methyl 2% for soaking 1 quintal of sorghum , fumigation of the store with phostoxin chemical

9.3 Selection of Crop Varieties

In agricultural practices, besides good soil fertility, good rainfall amount and distribution (good irrigation water), the use of proper agricultural inputs, and timely performing of agricultural operations have a significant effect to get an optimum yield or output. All the agricultural inputs are inseparable and of these, improved seeds have a greater significant effect to increase the productivity per unit area.

The proposed varieties of the proposed crops are the improved varieties, which can give better yield than local varieties. Varieties perform according to their genetic potential and the environmental conditions and cultural practices to which they are exposed. Good varieties perform well under a range of environmental conditions. In selecting varieties, the preference of the farmers, the times at which the varieties can be expected to mature, method of culture, possible disease problems and the adaptability of the varieties to the soil and climate were taken into account.
The improved varieties proposed for the project are mentioned as follows.

9.3.1. Maize

Variety BH 540

Altitude (m) ---1000-2000

Water requirement (mm) -----------------------------100-1200

Maturity days --145

Yield (Qt/ha)

On research station ---------------------80-100

On-farm ---------------------------------------50-65

Variety BH 140

Altitude (m) ---1000-1800

Water requirement (mm) ------------------------------100-1200

Maturity days ---145

Yield (Qt/ha)

On research station ---------------------80-100

On-farm ---------------------------------------47-60

Variety Melkasa 2

Altitude (m) ---1000-1700

Water requirement (mm) ------------------------------600-800

Maturity days ---130

Yield (Qt/ha)

On research station ---------------------45-50

On-farm ---------------------------------------30-40

Variety Melkasa 3

Altitude (m) ---1200-1700

Water requirement (mm) ------------------------------600-800

Maturity days ---125

Yield (Qt/ha)

On research station ---------------------45-55

On-farm ---------------------------------------30-40

9.3.2. Sorghum

- **Gubiye**

Altitude (m) --below1850

Water requirement (mm) ------------------------------600-900

Maturity days ---101

Yield (Qt/ha)

On research station --------------------40

On-farm --24.9

- **Abshir**

Altitude (m) --below1850

Water requirement (mm) ------------------------------600-900

Maturity days ---101

Yield (Qt/ha)

On research station --------------------30

On-farm --24.9

9.3.3. Haricot bean

Seeds at hands of the farmers such as Awash Melkasa, Nasir and Tabor are recommended to be used because there are no new improved seeds which suit to the proposed command area.

9.3.4. Onion

Variety

- **Adama red**

Altitude (m) ------------------------------------700-200

Water requirement (mm) ------------------------350-550

Maturity days ------------------------------110-130

Yield (Qt/ha)

On- research station ---------------------------350

On-farm -----------------------------150-230

Farmer --------------------------------90-150

- **Bombay red**

Altitude (m) ------------------700-200

Water requirement (mm) ----------------350-550

Maturity days -------------------110-120

Yield (Qt/ha)

On- research station -----------------------------300

On-farm -------------------------------150-200

Farmer --------------------------------130-160

9.3.5. Tomato

Variety Marglobe

Altitude (m) ---700-1800

Water requirement (mm) ------------------------------400-600

Maturity days ---100-110

Yield (Qt/ha)

On research station --------------------320

On-farm --120-170

Variety Malka Shola

Altitude (m) ---700-2000

Water requirement (mm) ------------------------------400-600

Maturity days ---100-120

Yield (Qt/ha)

On research station --------------------430

On-farm --140-180

9.4 Irrigation Practice and Harvesting

9.4.1 Irrigation practice

Irrigation is the artificial application of water to land or the purpose of raising crops. A crop requires a certain amount of water at some fixed time interval throughout its period of growth. If the water requirement of a crop is met by natural rainfall during the period of growth, there is no need of irrigation. But when there is in adequate and uneven distribution of rainfall, irrigation is necessary.

For all the proposed crops, the irrigation method recommended is surface irrigation by furrow. Furrow irrigation refers to irrigating land by constructing furrows between two rows of crops or alternately after every two rows of crops, particularly for narrow spaced row crops such as onions, cabbage and pepper. In contrast to basin and border irrigations, it involves only wetting part of the surface of the soil and water in the furrow moves laterally by capillaries to the un wetted areas below the ridge and also downward to wet the root zone soil. This reduces evaporation losses, improves aeration of the root zone, less puddling of the soil surface and permits earlier cultivation after irrigation. Furrow irrigation adapts better than any other method to crops that are grown in rows with more than 30 cm spacing, such as vegetables, maize, groundnut, sugarcane, cotton, and potatoes. Fruit crops are also irrigated by furrow method. Crop types, farm equipment to be used and planting distances between plants are the factors that determine furrow size and shape. Contour furrow with possible soil and water conservation measures such as level soil bund as an alternative conservation measure should be applied for those cultivated lands with a slope of 3-8%.

The amount of irrigation water applied for the crops varies depending on the growth stages of crops, climatic conditions and soil types. Irrigation interval is recommended based on maximum rooting depth, readily available moisture of the soil, peak water requirement of the crop and allowable depletion of the crop. In principle, the interval between two irrigations should normally be the time taken by the crops to reduce the soil water from field capacity to the lowest level of optimum soil regime.

The interval between irrigations is given by:

$$i = d/ETc$$

$$d = p*D*Sa$$

Where; i= irrigation interval (days)

d= irrigation depth (mm)

ETc= crop water use (mm/day)

p= allowable depletion (fraction)

D = root depth

Sa= available water capacity (mm/m)

Table 53 Irrigation intervals for first phase supplementary irrigation

Crop	Rooting Depth (m)	Total Available Moisture (Sa) (mm/m)	Peak Water Requirement (ETc) (mm/day)	Allowable Depletions (p) (fraction)	Irrigation Interval (i) (days)
Maize	1.0	97	5.82	0.55	9
Sorghum	1.40	97	5.47	0.50	12
Haricot bean	0.7	97	5.77	0.45	5
Tomato	1	97	5.27	0.40	7
Onion	0.6	97	6.07	0.45	4

Table 54 Irrigation interval for second phase supplementary irrigation

Crop	Rooting Depth (m)	Total Available Moisture (Sa) (mm/m)	Peak Water Requirement (ETc) (mm/day)	Allowable Depletions (p) (fraction)	Irrigation Interval (i) (days)
Maize	1.0	97	3.39	0.55	15
Sorghum	1.40	97	3.26	0.50	20
Haricot bean	0.9	97	3.41	0.45	11
Onion	0.60	97	3.06	0.45	8
Tomato	1	97	3.54	0.40	10

- The calculated irrigation interval is based on the soil and crop data of the project. For some crops it is slightly wider than the recommended interval. Hence, it is better to irrigate the crops by observing the soil and plant conditions frequently.

9.4.2 Harvesting

Maize – To use green maize, supervise the field every time to check whether it is matured or not to be fed green. By opening the cover, see the fruits and harvest before the fruits become strong. Not to lose its quality because of evapo-transpiration, keep the harvested maize under shade and immediately supply to the market. If it is going to be transported a long distance, keeping the cover without removing any single cover, helps to keep its moisture as it is. While transporting not to lose its quality because of the increasing temperature due to evapo-transpiration, allow to be aerated

Tomato- If they are to be used in the ripe condition, tomatoes should be picked at the earliest when they are mature green. Immature tomatoes do not ripen after harvest. Tomatoes reach the mature-green condition when they are fully rounded and have changed from dark to medium or light green and the skin develops a waxy gloss. As ripening is initiated, the fruits show a pale pink, which develops through a definite pink to full red.

Most tomatoes are harvested at the early ripening or pink stage depending on market preference and the time they take to reach the retailers. Tomatoes to be consumed immediately can be harvested when fully ripe. Proper handling during harvesting and transporting is important to reduce damage of fruits.

Onion - when about 50-75% of the leaves fall down. Bulbs are properly dried in the field before stored or distributed.

10. AGRICULTURAL SUPPORTING SERVICES

10.1 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 form 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 is 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 centers 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.

10.2 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, phosphatic and potassic 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 woreda co-operatives' office by doing with the woreda agricultural development office based on the felt need of the farmers requested by the extension worker working with the farmers.

Such cooperatives activities are good potentials for agricultural development of the area since they are working on the supply of agricultural inputs, promote grain marketing and provision of credit services.

10.3 Identification of Training Needs

Farmers should be well oriented of irrigation practices. Training shall be given at all levels including Development Agents, Water User Association committee members and the beneficiaries themselves. Trained DAs shall identify farmers' needs in terms of land preparation, crop selection, cropping patterns, crop rotation practices, irrigation scheduling and application, crop protection measures, harvesting techniques and marketing of products.

Development agents will have regular training by subject matter specialists (irrigation engineers, irrigation agronomists, etc). Training materials or manuals and on-site demonstration shall support the training. Initially, on site demonstrations may be carried out.

10.4 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 cash 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.

10.5 Storage

Perishability is responsible for high post-harvest losses and marketing cost, market glut, price fluctuation and other similar problems in marketing of fruits and vegetables, etc. Storage is an interim and a repeated phase in the complex logistics of transporting agricultural products from producers to processors and from processors to consumers. Besides agricultural products like food grains need to be stored from one harvesting to next, thus demanding additional carry over as safeguard against a following crop of low yield or poor quality against speculation in price or market demand or against shortage and famines.

The storage facilities in the project area are very primitive in nature, hence attract considerable losses. The storage losses are both qualitative and quantitative, affecting nutritive value of products. Insects, rodents, spillage and fungal rot are the main causes in food grains losses.

Use of insecticides and pesticide may reduce the losses but the chemicals may enter in the food chain causing human health problem.

The perishable products like onion, fruits and vegetables are harvested at very high moisture content of 60-88% (wet basis), which limit their shelf life. Thus, to escape the loss of post harvest it is important to sell these products after few days following harvesting.

11. CONCLUSIONS AND RECOMMENDATIONS

11.1 Conclusions

Irrigation is essentially a practice of supplementing the natural precipitation for increasing production of agricultural and horticultural crops. The cost of irrigation must be kept minimum and irrigation should be done without any wastage of water, which may cause adverse effect on the soil in the form of soil salinity and water logging problems.

Time of irrigation and quantity of water to be applied (when to irrigate? and how much to irrigate?) based on soil types, climatic parameters, crop, varieties, growth stages, season, quality of water, uptake pattern of water by plants, etc., and method of application (How best to irrigate) includes conveyance of water without seepage and percolation losses and water movement in soil, are the process involving scientific irrigation management.

To achieve the main output of the project, which is increasing crop production and there by achieving food self-sufficiency and increasing farm income, crops which are adaptable to the climatic and soil conditions of the command area are proposed. For these crops, production of two cropping in a year (double cropping) is recommended, one as first phase supplementary irrigation and the other second phase supplementary.

Crop system and management (improved cultural/agronomic practices) of the proposed crops were also recommended for the proposed crops

11.2. Recommendations

The scheme will only be viable and sustainable when the following conditions are met.

- To full fill the objectives of the project, all the agronomic recommendations given for the crops should be followed by the development agents and the beneficiaries.
- Besides the use of agronomic recommendations, the efficient (intensive) use of land and water as proposed in the project is very essential.
- The provision of extension service must be strengthened to adequately address the essential agronomic practices including timing of the various operations, land

preparation, cropping techniques, maintenance of soil fertility, managing water application, crop protection, harvesting, storing of produces and crop rotational needs.

- Adequate and timely supply of agricultural inputs including, improved and viable seeds, fertilizers and plant protection chemicals.
- Infrastructural development including access roads, storage facilities, markets and market price information.
- Soil and water conservation measures should also be under taken on high slope area**.**
- The link between research and extension services should be strengthened so that every research work geared towards the development of agriculture, and in particular irrigated farming, should be based on demand driven approach to generate technologies most needed by resource poor farmers.
- The beneficiaries should be encouraged to organize themselves for operation, input provision and marketing of products.
- Since the people of the area are mainly pastoralist, persistent training and awareness creation has to be given to the farmers and development agents on crop production,
- The land use of the proposed command area totally is bush and shrubs. Thus, clearing of the area should be done during the construction time of the project to commence land preparation and irrigation immediately after the completion of the construction.

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13. APPENDIXES

CROP WATER REQUIREMENTS FOR FIRST PHASE SUPPLEMENTARY IRRIGATION

1. CROP WATER REQUIREMENTS FOR MAIZE

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Dec	1	Init	0.4	1.63	16.3	0.1	16.2
Dec	2	Init	0.4	1.69	16.9	0	16.9
Dec	3	Deve	0.52	2.34	25.7	0	25.7
Jan	1	Deve	0.74	3.48	34.8	0	34.8
Jan	2	Deve	0.94	4.68	46.8	0	46.7
Jan	3	Mid	1.1	5.58	61.4	0	61.3
Feb	1	Mid	1.11	5.73	57.3	0	57.3
Feb	2	Mid	1.11	5.82	58.2	0	58.2
Feb	3	Mid	1.11	5.73	45.8	0.1	45.7
Mar	1	Mid	1.11	5.63	56.3	1.3	55
Mar	2	Late	1.07	5.33	53.3	2	51.3
Mar	3	Late	0.99	4.61	50.7	15.4	35.3
Apr	1	Late	0.91	3.96	35.6	31.4	0.8
					559.2	**50.5**	**505.3**

2. CROP WATER REQUIREMENTS FOR SORGHUM

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Dec	1	Init	0.35	1.43	14.3	0.1	14.2
Dec	2	Deve	0.39	1.63	16.3	0	16.3
Dec	3	Deve	0.61	2.74	30.1	0	30.1
Jan	1	Deve	0.86	4.07	40.7	0	40.7
Jan	2	Mid	1.05	5.23	52.3	0	52.2
Jan	3	Mid	1.06	5.39	59.2	0	59.2
Feb	1	Mid	1.06	5.47	54.7	0	54.7
Feb	2	Late	1.04	5.41	54.1	0	54.1
Feb	3	Late	0.95	4.87	39	0.1	38.9
Mar	1	Late	0.86	4.33	43.3	1.3	42
					404.2	**1.7**	**402.5**

3. CROP WATER REQUIREMENTS FOR HARICOT BEAN

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Dec	1	Init	0.35	1.43	14.3	0.1	14.2
Dec	2	Init	0.35	1.48	14.8	0	14.8
Dec	3	Deve	0.5	2.25	24.7	0	24.7
Jan	1	Deve	0.77	3.63	36.3	0	36.3
Jan	2	Mid	1.02	5.07	50.7	0	50.6
Jan	3	Mid	1.11	5.62	61.8	0	61.7
Feb	1	Mid	1.11	5.71	57.1	0	57.1
Feb	2	Late	1.1	5.77	57.7	0	57.7
Feb	3	Late	0.98	5.04	40.3	0.1	40.2
					357.7	**0.4**	**357.3**

4. CROP WATER REQUIREMENTS FOR TOMATO

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Dec	1	Init	0.45	1.84	11	0.1	11
Dec	2	Init	0.45	1.9	19	0	19
Dec	3	Deve	0.51	2.28	25.1	0	25.1
Jan	1	Deve	0.75	3.53	35.3	0	35.3
Jan	2	Deve	0.98	4.89	48.9	0	48.9
Jan	3	Mid	1.16	5.84	64.3	0	64.3
Feb	1	Mid	1.16	5.97	59.7	0	59.7
Feb	2	Mid	1.16	6.07	60.7	0	60.7
Feb	3	Late	1.12	5.77	46.1	0.1	46
Mar	1	Late	0.99	4.98	49.8	1.3	48.5
Mar	2	Late	0.88	4.37	17.5	0.8	16.5
					437.6	2.4	435

5. CROP WATER REQUIREMENTS FOR ONION

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Dec	1	Init	0.5	2.04	12.3	0.1	12.2
Dec	2	Init	0.5	2.11	21.1	0	21.1
Dec	3	Deve	0.54	2.4	26.4	0	26.4
Jan	1	Deve	0.68	3.22	32.2	0	32.2
Jan	2	Deve	0.83	4.12	41.2	0	41.1
Jan	3	Mid	0.97	4.92	54.1	0	54.1
Feb	1	Mid	1.01	5.19	51.9	0	51.9
Feb	2	Mid	1.01	5.27	52.7	0	52.7
Feb	3	Mid	1.01	5.19	41.5	0.1	41.4
Mar	1	Late	0.99	5.02	50.2	1.3	48.9
Mar	2	Late	0.92	4.57	45.7	2	43.7
Mar	3	Late	0.86	4.02	16.1	5.6	8.4
					445.3	**9.2**	**434**

CROP WATER REQUIREMENTS FOR FIRST PHASE SUPPLEMENTARY IRRIGATION

1. CROP WATER REQUIREMENTS FOR MAIZE

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
May	1	Init	0.4	1.47	14.7	34.4	0
May	2	Init	0.4	1.41	14.1	30.6	0
May	3	Deve	0.51	1.76	19.3	21.5	0
Jun	1	Deve	0.7	2.38	23.8	9.8	14
Jun	2	Deve	0.89	2.94	29.4	0.2	29.2
Jun	3	Mid	1.03	3.32	33.2	0.3	32.9
Jul	1	Mid	1.05	3.24	32.4	0.6	31.8
Jul	2	Mid	1.05	3.14	31.4	0	31.4
Jul	3	Mid	1.05	3.27	35.9	0.6	35.3
Aug	1	Late	1.04	3.39	33.9	2.2	31.7
Aug	2	Late	1	3.36	33.6	3.1	30.6
Aug	3	Late	0.93	3.3	36.3	4.6	31.7
Sep	1	Late	0.88	3.26	22.8	3.2	18.2
					360.9	**111.2**	**286.6**

2. CROP WATER REQUIREMENTS FOR SORGHUM

Month	**Decade**	**Stage**	**Kc**	**ETc**	**ETc**	**Eff rain**	**Irr. Req.**
			coeff	**mm/day**	**mm/dec**	**mm/dec**	**mm/dec**
May	1	Init	0.35	1.29	12.9	34.4	0
May	2	Deve	0.38	1.34	13.4	30.6	0
May	3	Deve	0.59	2.02	22.3	21.5	0.8
Jun	1	Deve	0.81	2.75	27.5	9.8	17.7
Jun	2	Mid	0.98	3.26	32.6	0.2	32.3
Jun	3	Mid	1	3.2	32	0.3	31.7
Jul	1	Mid	1	3.09	30.9	0.6	30.3
Jul	2	Late	0.98	2.93	29.3	0	29.3
Jul	3	Late	0.88	2.75	30.2	0.6	29.6
Aug	1	Late	0.79	2.55	20.4	1.7	18.2
					251.4	**99.8**	**189.9**

3. CROP WATER REQUIREMENTS FOR HARICOT BEAN

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
May	1	Init	0.35	1.29	12.9	34.4	0
May	2	Init	0.35	1.23	12.3	30.6	0
May	3	Deve	0.49	1.7	18.7	21.5	0
Jun	1	Deve	0.74	2.51	25.1	9.8	15.3
Jun	2	Mid	0.98	3.24	32.4	0.2	32.1
Jun	3	Mid	1.07	3.41	34.1	0.3	33.8
Jul	1	Mid	1.07	3.3	33	0.6	32.4
Jul	2	Late	1.06	3.19	31.9	0	31.9
Jul	3	Late	0.95	2.95	26.6	0.5	26
					227	**97.9**	**171.5**

4. CROP WATER REQUIREMENTS FOR TOMATO

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
May	1	Init	0.45	1.66	9.9	20.7	0
May	2	Init	0.45	1.58	15.8	30.6	0
May	3	Deve	0.51	1.74	19.2	21.5	0
Jun	1	Deve	0.73	2.45	24.5	9.8	14.7
Jun	2	Deve	0.95	3.13	31.3	0.2	31
Jun	3	Mid	1.1	3.54	35.4	0.3	35.1
Jul	1	Mid	1.11	3.45	34.5	0.6	33.8
Jul	2	Mid	1.11	3.33	33.3	0	33.3
Jul	3	Late	1.06	3.32	36.5	0.6	35.9
Aug	1	Late	0.91	2.96	29.6	2.2	27.4
Aug	2	Late	0.82	2.77	5.5	0.6	5.5
					275.5	**87.1**	**216.8**

5. CROP WATER REQUIREMENTS FOR ONION

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
May	1	Init	0.5	1.84	11	20.7	0
May	2	Init	0.5	1.76	17.6	30.6	0
May	3	Deve	0.53	1.84	20.2	21.5	0
Jun	1	Deve	0.67	2.25	22.5	9.8	12.8
Jun	2	Deve	0.8	2.65	26.5	0.2	26.3
Jun	3	Mid	0.93	2.98	29.8	0.3	29.6
Jul	1	Mid	0.97	3.01	30.1	0.6	29.4
Jul	2	Mid	0.97	2.91	29.1	0	29.1
Jul	3	Mid	0.97	3.03	33.3	0.6	32.7
Aug	1	Late	0.94	3.06	30.6	2.2	28.4
Aug	2	Late	0.87	2.93	29.3	3.1	26.3
Aug	3	Late	0.83	2.93	5.9	0.8	5.9
					285.9	**90.4**	**220.3**

LONG TERM RAINFALL DATA OF FINCHWUA STATION

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Sum
1997	0	0	16.3	194.4	140	9.5	27.2	28.7	36.4	274.5	402	17.93	**1147**
1998	141.9	17.4	8.1	119.2	133	62.4	23.4	3.6	6	17.6	8.5	0	**541.1**
1999	0	0	56.9	78.4	12.9	26.97	20.8	3.2	60.5	33.9	18.1	37.4	**349.1**
2000	0	0	5.9	138.4	274.1	4	0	30	10.5	206.3	78	16.4	**763.6**
2001	16.6	0	54.1	206.7	81.1	36.6	3.5	43.5	75.3	48.8	99.6	0	**665.8**
2002	12.8	5.4	94	125	121.2	40.3	9.2	0	36.1	110.6	10.7	96.4	**661.7**
2003	22.4	5.7	76.7	350.9	242.3	0	0	37	23	63.1	51.4	79.5	**952**
2004	72.7	9.5	33.1	141	89.3	8.9	16.2	11.6	58.4	71.9	227.4	5.4	**745.4**
2005	21.6	9.5	78.3	158.9	364.6	17	9.5	17.1	31.1	162.5	41.1	0	**911.2**
2006	0	20.6	55.2	303	48.7	12.9	5.1	26.9	45.2	318.3	126.1	50.7	**1013**
2007	5.3	10.03	24.3	208.9	69.6	83	0	58.9	145.2	78.3	26.2	0	**709.7**
2008	2.6	0	59	127.9	42.1	30.2	22.5	14.1	109.8	176.2	109.5	0	**693.9**
2009	30.2	0	66	87.3	149.8	18.9	18	0	13.7	72.6	45.9	0.433	**502.8**
2010	12	41.5	89.6	382.8	187.5	202	51	52.6	25.5	115.1	2	1.3	**1163**
2011	0	12.5	3.9	150.2	136.4	33.6	12.2	122.6	81.4	123.4	249.1	0	**925.3**
2012	0	0	72.6	111.5	106.1	38.4	61.8	70.7	98.7	128.1	121.2	0	**809.1**
2013	0	29.57	24.9	318.1	109.3	7.3	24.7	46.7	69.9	145.7	121.2	0.144	**897.5**
2014	0	76.2	113.6	198.6	85.5	27.7	21.63	31.1	29.6	262.5	112.5	0.433	**959.4**
2015	0	0	20.2	262.9	190.7	11.67	7.5	0	76.6	182.1	363.6	0	**1115**
2017	0	0	0	102	179	0	38.5	62.8	68.3	196.8	53.9	0.433	**701.7**
Avg	**16.91**	**11.9**	**47.64**	**188.3**	**138.2**	**33.57**	**18.64**	**33.06**	**55.06**	**139.4**	**113.4**	**15.32**	**811.4**