

Table of Contents

Table of Contents	<i>i</i>
List of Tables	<i>iii</i>
List of Figures	<i>iv</i>
Laga Dhumuga Small Scale Irrigation Project	1
I Agronomy Study	1
1.1 Background of the study.....	1
1.2 General Objective of the Study	2
1.2.1 Specific Objectives of the Study	2
1.3 Review of Sector Policies, Strategies and Related Previous Studies	2
1.3.1 Agriculture Policy	2
1.3.1.1 Food Security Strategy	3
1.3.1.2 Growth and Transformation Plan (GTP II-2015/16-2019/20).....	3
1.3.2 Irrigation Policy.....	4
1.4 Methodology.....	5
1.5 The Physical Features of the Project Area.....	6
1.5.1 Agro-climatic Zone of the Specific Area	8
1.5.1.1 Length of Growing Periods	9
1.5.1.2 Rainfall	10
1.5.1.3 Temperature, Relative Humidity and Wind Speed.....	11
1.5.2 Land Use	12
1.5.2.1 Existing /Present Agricultural Conditions	12
1.5.2.2 Existing Crop Calendar (rain-fed agriculture).....	13
1.5.2.3 Major Rain-fed Crops of the Area	14
1.5.2.4 Livestock Production.....	16
1.5.2.5 Existing Agricultural Techniques	18
1.5.3 Existing Agricultural Problems	19
a) Shortage and Erratic Nature of Rainfall	19
b) Low Technology Input Utilization	19
c) Soil Erosion as a Result of Deforestation and Topography.....	20
d) The Prevalence of Animal Diseases & Low Livestock Productivity	20
e) Insufficient Expertise of Irrigation Farming.....	20
1.5.4 Labour Requirement.....	20
1.6 Proposed Irrigated Agriculture	21
1.6.1 Crop Selection	22
1.6.2 Cropping Pattern	24
1.6.3 Details of the Selected Crops	25
1.6.3.1 Vegetables	25
c) Tomato- (<i>Lycopersicon esculentum</i>)	26
1.6.3.2 Roots and Tubers.....	27
a) Sweet Potato (<i>Ipomoea batatas-L</i>)	27
1.6.4 Irrigation Seasons	27

1.6.5	Proposed Management	28
1.6.5.1	Method of Irrigation	28
1.6.5.2	Cultivation Activities	28
1.6.6	Fertilizer Management	29
1.6.7	Method of Fertilizer Application.....	29
1.6.8	Plant Protection	30
1.6.9	Crop Rotation and Intercropping.....	31
1.6.10	Labor Requirement.....	32
1.6.11	Area Coverage/Intensity.....	32
1.6.12	Yield Projection.....	33
1.6.13	Postharvest Activities	34
1.7	Extension Service	35
1.7.1	Market	35
1.7.2	Timely Input Provision.....	35
1.8	Crop Water Requirement.....	36
1.8.1	Calculation procedure.....	37
1.8.2	Cropwat input data	37
1.8.3	Determination of Evapotranspiration (ETo).....	38
1.8.3.1	evapotranspiration (ETo).....	38
1.8.3.2	Crop coefficient (Kc).....	39
1.8.3.3	Effective Rainfall (Pe).....	40
1.8.4	Irrigation Water Requirement.....	41
1.8.5	Net irrigation requirements.....	41
1.8.6	Irrigation Efficiency	41
1.8.7	Field Irrigation Schedules	41
1.8.7.1	Depth of irrigation application (d).....	42
1.8.7.2	Irrigation application interval (i)	42
1.9	Suggestion & Recommendation	43
Annex 1.1: AGRONOMY ANNEXES.....		44
A. Required climatic & other aerodynamic data collected from Mechara Station		44
B. Irrigation Efficiencies.....		44
C. Irrigation depth (d, mm)		44
D. Interval (days)		44

List of Tables

TABLE 1: AGRO-ECOLOGICAL DATA FOR CALCULATION OF LGP	9
TABLE 2: LAND USE PATTERN OF SHANAN KOLU WOREDA AND BADEYI KEBELE	12
TABLE 3: CHEMICAL FERTILIZERS, IMPROVED SEEDS (QT) AND AGRO-CHEMICALS (LT) USED BY FARMERS OF THE AREA.....	13
TABLE 4: EXISTING CROPPING CALENDAR (QONNA ARFAASAA) OF THE PROJECT AREA	14
TABLE 5: EXISTING CROPPING CALENDAR (QONNA GANNA) OF THE PROJECT AREA.....	14
TABLE 6: MAJOR STAPLE FOOD CROPS OF SHANAN KOLU WOREDA AND THE PROJECT KEBELE	15
TABLE 7: CROPS HARVESTED WITH RAINFALL IN SHANANA KOLU WOREDA IN THE LAST TWO YEARS.....	15
TABLE 8: CROPS HARVESTED WITH IRRIGATION IN SHANAN KOLU WOREDA IN THE LAST TWO YEARS.....	16
TABLE 9: LIVESTOCK TYPES, QUANTITIES AND COMMON DISEASES IN SH. KOLU WOREDA AND THE PROJECT KEBELES	17
TABLE 10: A HECTARE OF LABOR REQUIREMENT AS A “WITHOUT PROJECT” CONDITION.....	21
TABLE 11: GENERAL RECOMMENDED CROP MIX FOR MAJOR AGRO-ECOLOGIES OF ETHIOPIA	23
TABLE 12: CROPS SELECTED FOR DRY SEASON IRRIGATION DEVELOPMENT.....	24
TABLE 13: WET-SEASON IRRIGATION TIME SCHEDULES.....	25
TABLE 14: METHOD OF IRRIGATION AND SPACING FOR THE SELECTED CROPS.....	28
TABLE 15: MAJOR CULTIVATION ACTIVITIES IN IRRIGATED AGRICULTURE	28
TABLE 16: REQUIRED FERTILIZERS & OTHER AGROCHEMICALS PLANNED FOR EACH PROPOSED CROP	29
TABLE 17: METHODS OF FERTILIZER APPLICATION FOR THE PROPOSED CROP TYPES	30
TABLE 18: CHEMICAL & NON-CHEMICAL PLANT PROTECTION METHODS FOR THE PROPOSED CROPS.....	31
TABLE 19: A HECTARE OF LABOR REQUIREMENT AS A “WITH-PROJECT” CONDITION	32
TABLE 20: A 5-YEAR CROPPING PATTERN/INTENSITY PLAN.....	33
TABLE 21: YIELD PROJECTION FOR FIVE (5) YEAR/SEASON PRODUCTION PERIOD.....	33
TABLE 22: DUTY OF DRY-SEASON CULTIVATION	36
TABLE 23: CROP DEVELOPMENT STAGE AND CROP COEFFICIENT FOR PROPOSED CROPS.....	40

List of Figures

FIGURE 1: PARTIAL VIEW OF THE COMMAND AREA7

FIGURE 2: BOREHOLE DUG AND CLOSED BEFORE TEN YEARS8

FIGURE 3: LGP GRAPH OF THE PROJECT AREA.....9

FIGURE 4: TREND OF MEAN MONTHLY RAINFALL AND EFFECTIVE RAINFALL OF THE STUD AREA.....10

FIGURE 5: MEAN MONTHLY MAX, AND MIN TEMPERATURES OF THE STUD AREA11

FIGURE 6: MEAN MONTHLY RELATIVE HUMIDITY AND WIND SPEED IN THE PROJECT AREA11

FIGURE 7: TIE AND FEED SYSTEM OF LIVESTOCK HUSBANDRY IN THE PROPOSED PROJECT AREA.....18

Laga Dhumuga Small Scale Irrigation Project

1 Agronomy Study

1.1 Background of the study

Agriculture is the leading sector in the national economy of Ethiopia, accounting for about 39% of GDP while contributing almost 80% of export earnings and employing 80% of the population. Accordingly, the agriculture sector in the country plays the entire, pivotal and dominant roles like in food supply, job opportunity and income sources of the population. In spite of the crucial role of this sector in the economy and livelihood of the people non-significant effort was made in the past to improve its productivity. Eventually, the development and the productivity of the Agriculture sector are still at backward and traditional level. To this effect, the farmers in agriculture sector, which is featured by low input and low output production methodologies and low rainfall conditions, could not able to meet the food requirement of the ever increasing population. In other words, the available natural resources of the country have not been properly exploited so far to meet the increasingly high demand of the country for food, raw material for domestic agro-industries and for export market. Considering these facts, concerted efforts are being made at the moment both at national as well as regional levels to transform the prevailing subsistence production system to high value and market oriented production system. One of the efforts exerted in this line embarks on the judicious use of the available irrigation water potential found in different parts of the country. It is through irrigation and integrated crop development that sustainable crop production can be ensured. In this view, the feasibility study of Laga Dhumuga small scale irrigation development project was carried out in Shanan Kolu district of Arsi Zone of Oromia National Regional State to develop 200 hectares of command area.

Irrigated agriculture plays an important role in sustainable crop production in areas where the climatic variation and poor distribution of rainfall exists. The predominant agricultural system is based on smallholder production and the crop production is entirely dependent on rainfed 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. However, in the proposed project area 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 is 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 and crop failure is common in most years. In this area successful crop production is only possible with support of irrigation.

1.2 General Objective of the Study

The overall goal of the study is to increase production and productivity of the area through introduction of modern irrigated agriculture which is environmentally suitable, economically feasible and sustainable and identifying crops that are adaptable to the area and suitable for added food security/nutritional value and/or have market potential. Some 800 households (about 0.25ha/HH) which could be about 4000 people (about 5 family sizes per household) will be direct beneficiaries of the irrigation development.

1.2.1 Specific Objectives of the Study

The specific objectives of Agronomy study of this irrigation project include:

- ✚ evaluation of the existing agricultural situation of the study area,
- ✚ investigation of the agricultural suitability of soils, and climate for the proposed project,
- ✚ identification of the existing physical environment of the study area,
- ✚ identification and evaluation of crop production constraints of the study area,
- ✚ selection of suitable crops with important agronomic practices and supporting services for the crops grown under irrigation, and,
- ✚ determination of crop-water requirement and irrigation scheduling for the proposed crops.

1.3 Review of Sector Policies, Strategies and Related Previous Studies

1.3.1 Agriculture Policy

The focus of agricultural policy has been to:

- Increase food security
- Increase the supply of agricultural raw materials to the local industry
- Expand the local manufacturing industries to supply the rural areas, and
- Increase foreign exchange earnings

As part of the agricultural development policy, Ethiopia's food security strategy was first issued in 1996 and updated in 2001. It has been observed that food insecurity is one of the defining features of rural poverty affecting millions of people, particularly in moisture deficit areas. Both chronic and transitory problems of food insecurity exist. The government is tackling food deficit problem through the introduction of: i) small, medium and large-scale irrigation; ii) drought resistant and early maturing varieties and with water harvesting technology; iii) soil conservation and environmental protection; iv) improved harvesting, handling and storage facilities.

1.3.1.1 Food Security Strategy

Food security is manifested directly in three security components: adequacy of supply (production, reduction of post-harvest losses), stability of supply (production and price stability), and access to supply (increase purchasing power of households and access to employment).

The consequences of food insecurity are reflected in the high level of malnutrition. The first version of food security strategy (FSS) was prepared in 1996 and has been revised as required by the national government. For instance, the revised FSS (2002) targeted mainly to the chronically food insecure, moisture deficit and pastoral areas, water harvesting and introduction of high value crops, livestock development were key development issues in the revised strategy.

In 2004 the new coalition for food security prepared a food security program that was more comprehensive and detailed than the earlier ones. The goal of the food security program is to drastically reduce food insecurity faced by vulnerable households. Its objective is to attain food security of the chronically food insecure population and significantly improve and sustain overall food security of population within five years.

1.3.1.2 Growth and Transformation Plan (GTP II-2015/16-2019/20)

The GTP II (2015/16-2019/20) has been formulated to carry forward the basis, objectives and strategic directions of GTP I. The achievements gained, challenges faced and lessons drawn from the implementation of GTP I was the bases for the formulation of GTP II. Nevertheless, with pertaining to irrigation development GTP II has its own distinguishing features. In GTP II period, agriculture will remain the main driver of the rapid and inclusive economic growth and development. It is also expected to be the main source of growth for the modern productive sectors. Therefore, besides promoting the productivity and quality of staple food crops

production, special attention will also be given to high value crops, industrial inputs and export commodities. To this end irrigation based agriculture, horticulture, fruits and vegetables, livestock and Fisheries development will be promoted. Designing and providing support schemes to smallholder farmers where peasants and pastoralists are the main actors in the production process; and facilitating a joint participation of educated young farmers and private investors in the sector are strategic directions that will be pursued during the plan period. To this end, addressing constraints entrenched in the agricultural development and marketing systems will be given utmost emphasis and priority.

Fundamentals of the strategy include the shift to produce high value crops, a special focus on high-potential areas, facilitating the commercialization of agriculture, supporting the development of large-scale commercial agriculture where it is feasible. In addition, small, medium and large scale irrigation development and dam constructions were also targeted to be undertaken and strengthened by federal and regional government institutions. Increasing the area of land covered with irrigation from 2.34 million hectare in 2014/15 to 4.143 million hectares by the end of 2019/20 was set as the major targets with respect to irrigation development. As a result over 1,743,000 hectare additional irrigated land has been targeted to be developed during the plan period and providing access to at least one alternative water point for 80% of smallholder farmers (semi-pastoralists) of which 50% are users of the full irrigation farming package.

1.3.2 Irrigation Policy

1. Ensure the full integration of irrigation with the overall framework of the country's socio-economic development plans, and more particularly with the Agricultural Development Led Industrialization (ADLI) Strategy.
2. Promote the development of irrigation on two- pronged approaches of, i) strategic planning for achieving socio-economic goals, and ii) participatory-driven approach for promoting efficiency and sustainability.
3. Recognizing that irrigation is an integral part of the water sector and consequently develop irrigation within the domain and framework of overall water resources management.

4. Earmark on a reasonable percentage of the GDP as committed resource towards the development of irrigated agriculture, especially in capacity building and infrastructures.
5. Promote decentralization and users-based management of irrigation systems taking in to account the special needs of rural women in particular.
6. Develop a hierarchy of priority schemes based on food requirements, needs of the national economy and requirements of raw materials and other needs.
7. Support and enhance traditional irrigation schemes by improving water abstraction, transport systems and water use efficiency.
8. Ensure the prevention and mitigation of degradation of irrigated water and maintain acceptable water quality standards for irrigation.
9. Establish water allocation and priority setting criteria based on harmonization of social equity, economic efficiency and environmental sustainability requirements.
10. Integrate the provision of appropriate drainage facilities in all irrigated agriculture schemes.
11. Enhance greater participation by the Regional and Federal Governments in the development of large scale irrigated farms in high water potential basins, but with low population density (Ethiopian Water Sector Policy, 2001).

1.4 Methodology

The methods used in the study mainly focused on document review on related works and review of government policies and strategies on agriculture and irrigation as pre-field work, and direct field observation with full participation of the target community members of the proposed project area as field work. Primary data were collected by employing quantitative and qualitative methods, generated through household survey that involves structured questionnaires, key informant interviews and focus group discussions. Secondary data were collected from different sectors of the woreda development structures such as Shanan Kolu woreda agriculture office, irrigation development authority, cooperative office, livestock agency, market development office, rural land administration office, and the development agents (DAs) office of the kebele in which the proposed irrigation project is located. Mechara Agricultural Research Center and other stakeholders have also been consulted and have a great part in contributing and providing data during the consultation period. Discussion among the study crew members has also been made in the field assessment activities. In the post-field work the collected information was processed, analyzed and critically evaluated for developing the suitable agricultural production plan. For

data analysis, simple statistical models such as means, coefficient of variations, and standard deviations were used which were computed using SPSS 16.0 for Windows software. The water requirement of duly selected crops and cropping pattern was worked considering nearest station for representative meteorological parameters, crops and cropping factors, soil factors, etc. Meteorological elements for crop water assessment had been collected from pertinent stations and missing meteorological data had been filled in by missing data models. In general, the water requirement was calculated following standard scientific procedures as suggested by FAO Irrigation and Drainage, Paper No. 56 and data processing and modeling for crop water requirement was undertaken by modified method of Penman Monteith using CropWat-8.0 for windows software.

1.5 The Physical Features of the Project Area

The specific command area is found at the hill bottom in dissected, rugged and undulating landforms at slope range between $>2\%$ and an average altitude of 1458m.a.s.l at the assumed borehole site of the water abstraction area. This area is surrounded by mountainous and hilltop areas in all directions, especially in the eastern, northern and western parts. Some indigenous scattered big trees and bushes and shrubs are observed in the command area as well as on the hill surfaces surrounding the command area. Crops such as sorghum, maize, chat, H. bean, onion, tomato, sweet potato, sugarcane and some other horticultural crops are cultivated on and around the command area with rainfall and traditional irrigation. The net command area is 200ha and the soil of the command area is dominantly sandy clay loam in texture having pH value ranging from 4.7-6.6 with low to medium water holding capacity and fair to high infiltration rate. The upper horizon (25 to 30 cm) has almost partially granular structure and when goes downwards blocky to partially platy structures are observed. Red to brown color is dominant with medium agricultural depths. When wet is sticky and hard during it dries. As a general soil order, the area soil falls under Cambisols which are recently developed soil for a certain period of years with shallow depths and seems rich in organic matter (humus) from the decomposition of grassy and bushy vegetation debris and other related materials. The primary clay mineral seems a mixture of micas and vermiculites which has a medium bondage between soil particles. This condition helps the soil structure to have a fair water movement during watering the soil. Generally, from physical condition and existing crop stand observation of the project area, the soil is suitable for

most agricultural crops with minimum mitigation measures. Major soil textures of the project area include sand 50%, clay 29%, and silt 21% (data obtained from Lab. analysis). The detail chemical analysis can be referred on the soil study report of the project document.



Figure 1: Partial view of the command area

The water source of the future irrigation development is borehole around Laga Dhumuga River which dries out during the dry season. This borehole was dug and closed before ten years by the irrigation authority of Oromia regional government, but with unknown reasons it did not yet give service for the community. As information obtained from the community the borehole gave huge water yield at the time it was opened. The proposed water abstraction method is pump and stored on the top of the hill and get in the canal system with furrow irrigation method. As it is observed during the field assessment and secondary data collected from the relevant parties, the area is moisture stressed and small scale irrigation scheme development is the most required operation

for crop production and the area is suitable for irrigation with some required amendment measures.



Figure 2: Borehole dug and closed before ten years

1.5.1 Agro-climatic Zone of the Specific Area

The command area is located in Badeyi kebele of Shanan Kolu Woreda, Arsi Zone of Oromia National Regional State at about 337km (at weir axis) East of Finfinne (Addis Ababa) city, about 272km east of Asella town (zone capital), about 0.5km east of Dhumuga town, the capital of this woreda, and about 205km away from the main asphalt road that runs through Adama to Asella. The area is found in the hot dry tropical lowland agro-ecological zonation at an average altitude

of 1458masl (at headwork site) with crops having 90 to 150 days of growing period based on type of crops and varieties to be produced. Meteorological data were obtained from Mechara National Meteorology Station which is found at an average altitude of 1800m.a.s.l and about 20km air distance from the command area. All necessary climatic data for crop water requirement computation were obtained from this station.

1.5.1.1 Length of Growing Periods

Growing period describes the period in which conditions for plant growth are adequate, in this case defined by the availability of soil moisture. It is estimated in days from the beginning to the end of crop growth. The length of this period is crucial to the satisfactory development and maturation of the crop.

Table 1: Agro-ecological Data for Calculation of LGP

Climate Fac.	Unit	Moths											
		J	F	M	A	M	J	J	A	S	O	N	D
P.RF	mm/M	17.7	42	90.7	234.1	145.4	68.7	114.2	127.4	94.2	72.9	43.3	7.5
PET	mm/M	131.4	136.8	154.8	149.7	147.9	154.2	136.8	135.6	141.3	144	135.9	127.8
0.5PET	mm/M	65.7	68.4	77.4	74.85	73.95	77.1	68.4	67.8	70.65	72	67.95	63.9

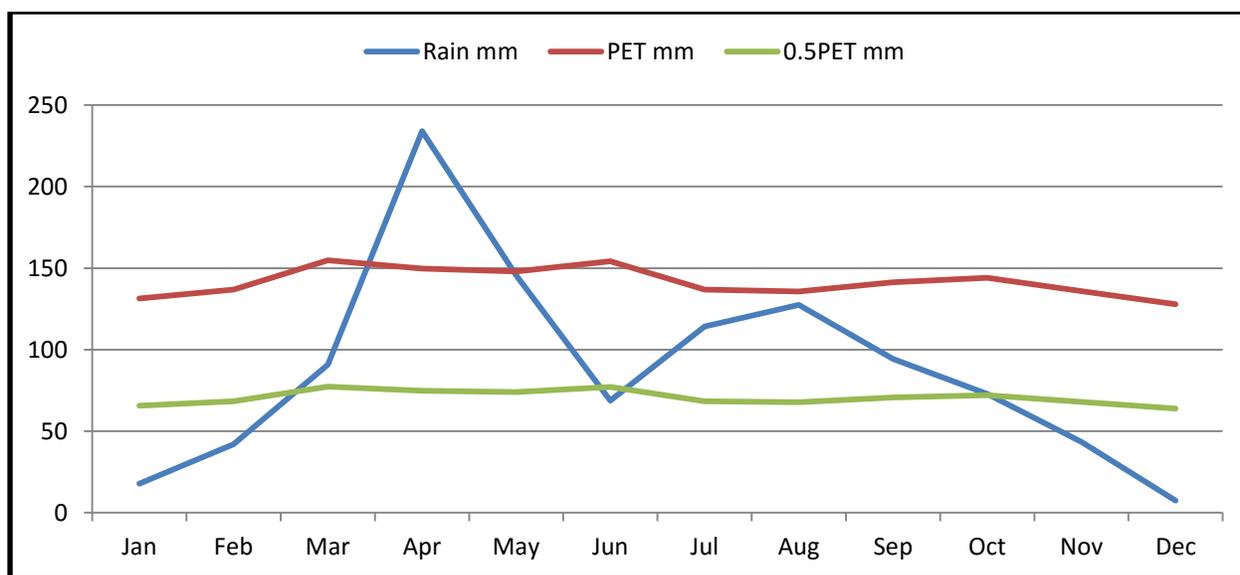


Figure 3: LGP graph of the project area

1.5.1.2 Rainfall

Rainfall needs to be examined in terms of its ability to satisfy crop requirements. By comparing the results with the potential evapo-transpiration the water available to crops could be determined. For example a positive difference between rainfall and potential evapo-transpiration for the greater part of a growing season would ensure good crop growth. A negative result during the critical growing season would indicate insufficient moisture for that crop or the need for irrigation. On the other hand, an excess of precipitation over the potential evapo-transpiration during the wet season would indicate the importance of drainage. A study of the rainfall intensity (quantity over a given period of time) would give an indication of the potential water erosive or of the runoff to be expected and of the dimensions which would have to be given to surplus water disposal channels etc. Some qualitative aspects of precipitation are also worthy of attention: for example, the duration and frequency of hail storms, in relation to the periods when the land is occupied by crops, or the occurrence of rain storms associated with strong winds, etc. As the data collected from Mechara National Meteorology Station shows the project area (Laga Dhumuga project site) has an average annual rainfall of 1058mm with effective rain to be only 598mm, seems bi-modal type, erratic distributed for about six months. From this the highest rainfall is recorded in the month of April, and the lowest is recorded in the month of December.

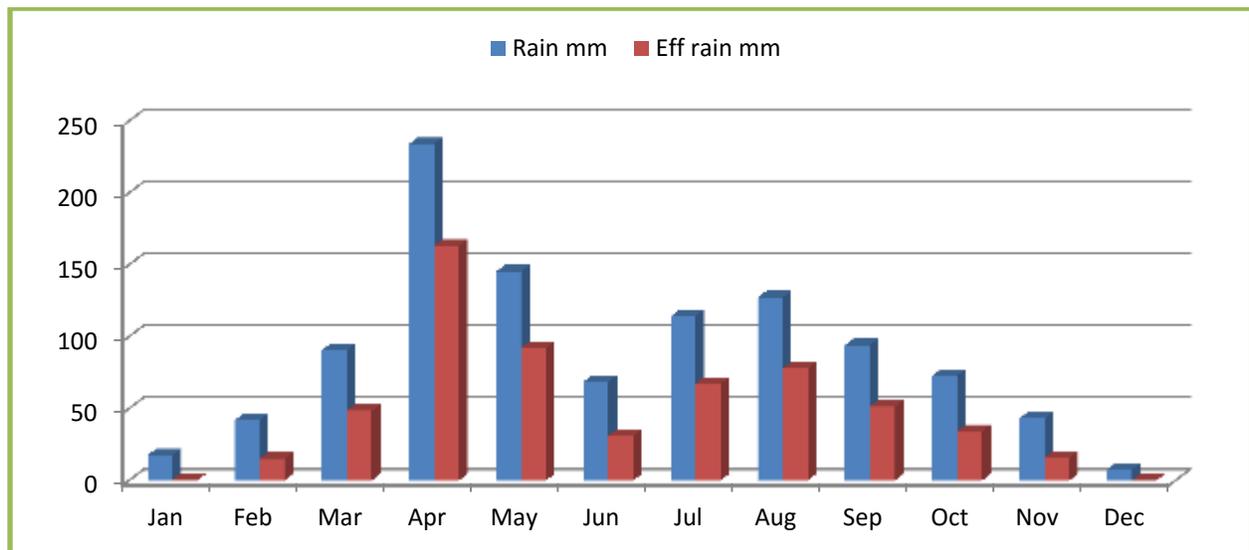


Figure 4: Trend of mean monthly Rainfall and Effective Rainfall of the stud area

1.5.1.3 Temperature, Relative Humidity and Wind Speed

Air temperature and relative humidity are the most important climatic variables that affect plant life. Each species and variety of plants and each age group of plants has its own upper and lower temperature limits. Beyond these limits, a plant becomes considerably damaged and may even be killed. Relative Humidity (RH), the water vapor contained in the atmosphere, is expressed as the percentage of the ratio of actual to saturation vapour pressure. This, together with wind, gives an indication of drying power of the air important for drying and storage of crops while fluctuations in values often affect the incidence of plant diseases as well as the safe storage of harvested crops. Therefore, temperature, relative humidity and wind speed should be considered while dealing with agricultural planning of an area. Monthly max., min. and average temperatures are 33.1⁰c, 24.6⁰c & 28.8⁰c, respectively. The hottest month is June, and the coldest one is December.

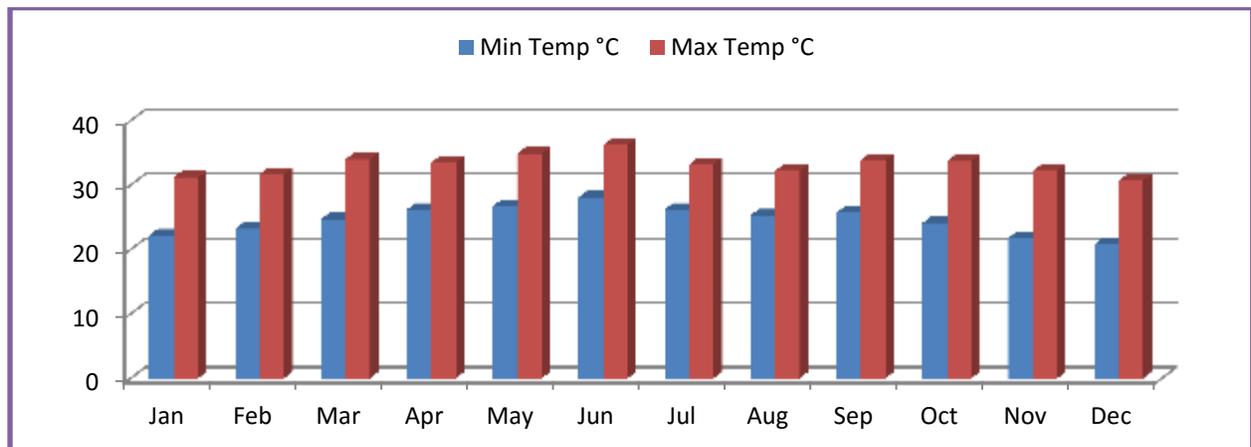


Figure 5: Mean monthly max, and min temperatures of the stud area

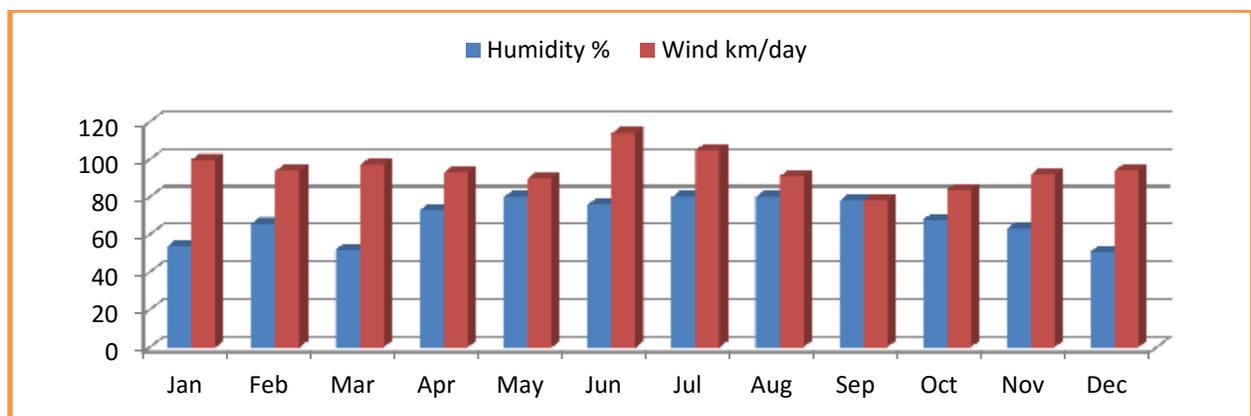


Figure 6: Mean monthly relative humidity and wind speed in the project area

1.5.2 Land Use

The land use pattern is mainly composed of an extensive grazing, subsistence type of agriculture and scattered settlement, situated within different landforms. The major land use types in the command area include cultivated land, grazing (fallow) land, bushes & shrubs, riverine forests, and scattered settlement. Among the use types, cultivated land takes the largest proportion (50%) followed by bushes & shrubs (20%), grazing land (15%), riverine forest (10%), and settlement land (5%). On the cultivated lands chat is the dominant crop, and other crops such as sorghum, maize, sweet potato, H. bean, sugarcane, and other lowland oil crops are cultivated under traditional way of farming practices. As the information obtained from the farmers and physical observation made in the field, about 20% of the command area is covered with chat and other horticultural crops such as sorghum, maize, sweet potato, sugarcane, and others take the remaining proportion with traditional way of production system during the field assessment period. Average landholding size per household is about 0.25ha in the proposed project kebele/ According to the information obtained from the woreda agriculture and DA offices, the following land use patterns for the woreda and the project areas are identified.

Table 2: Land Use Pattern of Shanan Kolu Woreda and Badeyi kebele

S/N	Types of Land Use	Shanan Kolu Woreda		Badeyi Kebele	
		(ha)	(%)	(ha)	(%)
1	Arable land	36,498	51.58	935	17.01
2	Cultivated	28,554	78.23 of arable land	685	73.26 of arable land
3	Grazing land	14,107	19.94	1000	18.20
4	Settlements	6412	9.06	240	4.37
5	Forest lands (including bushes & shrubs)	2833	4.00	900	16.38
6	Rock land	10,901	15.41	800	14.56
7	Other land	2	0.003	1620	29.48
	Total	70,753	100	5495	100

Source: Shanan Kolu Woreda Agriculture Office, and Badeyi kebele DAs office

1.5.2.1 Existing /Present Agricultural Conditions

Agriculture is the mainstay of the community at the project area. Traditional crop-livestock mixed farming practices, subsistence type of farming and high dependence on very erratic and unreliable natural rainfall dominate the sector. Out of the thirteen kebeles of the woreda nine are food insecure and totally rely on food aid as safety net programme. There is continuous crop failure experienced due to shortage of rainfall and this has been observed on the field as sorghum

dried before reaching the grain physiological maturity. However, at a specific project area crops such as tomato, sweet potato, chat, and pepper are intermittently produced using small scale traditional irrigation on some part of the command area.

As witnessed by the local farmers the use of improved agricultural technologies such as improved seeds and fertilizers is not adequately well practiced on both irrigated and rain-fed crops production. The supply of improved seeds and fertilizers to farmers in the woreda for rain-fed crop production is not adequate because the area is in the gorge, not easily accessible, less or no road network and very far away from the main road. The following table shows the supply and distribution trend of these improved agricultural technologies in the woreda for the last two years.

Table 3: Chemical Fertilizers, Improved Seeds (qt) and Agro-chemicals (lt) Used by Farmers of the area

S/N	Items	2009		2010	
		Supplied	Distributed	Supplied	Distributed
1	Fertilizer				
	NPS	458.5	457	1.5	---
	Urea	1230.5	1122	2725	2353.5
	NPSB	5107	4182.5	6174.5	5294.5
	Total Fertilizer	6796	5761.5	8901	7648
2	Seed				
	Maize- BH-540	110	110	138	138
	-BH-140	10	10	---	---
	Teff- Quncho	8	8	6.3	6.3
	Sorghum- Melkam	---	---	1	1
	Total Seeds	128	128	145.3	145.3
3	Agro-chemicals				
	2,4-D	1195	1195	1320	1320
	Total Agro-chemicals	367	316	506	428

Source: Shanan Kolu Woreda Cooperative office

1.5.2.2 Existing Crop Calendar (rain-fed agriculture)

Length of growing period of the crops is mainly determined by the area agro climatic conditions. As indicated before, agro-climatic zonation for this particular area is hot dry tropics (more of dry lowland having bi-modal, but insufficient and erratic rainfall distribution with scattered trees, bushes and shrubs). The occurrence of rainfall is erratic as the onset and offset of the rainfall varies from year to year and crop failure is common phenomena in the proposed project area.

Hence, generally crops growing with such type of climatic conditions have relatively a shorter LGP (Total Growing Period) of 90 to 150 days based on crop type and varieties. As the information obtained from woreda agriculture office, the project area development office, and from the interview of focal farmers indicated the following cropping calendar is presented for the rainy seasons.

Table 4: Existing Cropping Calendar (Qonna Arfaasaa) of the Project Area

S/N	Crops	Land preparation	Ploughing frequency	Sowing date	Harvesting date
1	Maize	Feb. - Mar.	3	April	Aug. - Set
2	H. bean	Feb. - Mar.	3	April	Late June

*Source: Shanan Kolu Woreda, Badeyi Kebele & Farmers Interview.

Table 5: Existing Cropping Calendar (Qonna Gannaa) of the Project Area

S/N	Crops	Land preparation	Ploughing frequency	Sowing date	Harvesting date
1	Teff	May - June	3-4	Early to Late July	Oct. 20 – Nov. 15
2	Sorghum	Feb. - April	2-3	May 10 - 25	Sep. to Dec
3	groundnut	Feb. - Mar.	2-3	April	October
4	Potato	Mar - Apr	3-4	Early June	Oct 10 - 20

*Source: Shanan Kolu Woreda, Badeyi Kebele & Farmers Interview.

1.5.2.3 Major Rain-fed Crops of the Area

As the soil and climate is suitable for a wider variety of crop types, different crops and varieties are growing by farmers of the kebele in the project area. However, improved technologies are not fully and adequately utilized, mainly because of inadequate extension services rendered to the farmers, inaccessibility of the area, insufficient supply, poor distribution and unaffordable price of the improved technologies. According to the data obtained from the woreda Agriculture Office and the nearby DA Center, the information about the last cropping season has been compiled in the following table.

Table 6: Major Staple Food Crops of Shanan Kolu Woreda and the Project Kebele

S/N	Major crops (rain-fed)	Shanan Kolu Woreda			Badeyi Kebele		
		Area Coverage		Yield, (qt/ha)	Area coverage		Yield, qt/ha
		ha	(%)		ha	(%)	
1	Maize	3524	21.20	21.75	372	57.49	10.0
2	Sorghum	2150	12.94	19.83	150	23.18	25.0
3	Teff	1500	9.02	13.97	---	---	---
4	H. bean	174	1.05	15.1	10	1.54	10.0
5	S. potato	150	0.90	80.0	15	2.32	120.0
6	Coffee	9122	54.88	8.0	100	15.46	5.0

Source: Shanan Kolu Woreda Office of Agriculture and Development Agents Office of the project kebele

From the above table, it can be understood that crops like maize, sorghum, and coffee are widely grown in the woreda and project areas as well. The above condition is also confirmed by the Woreda Office of Agriculture and Development Agents Centers of the project kebele. As the information obtained from the Woreda indicated, almost all types of field crops are growing in the woreda.

Table 7: Crops Harvested with rainfall in Shanana Kolu Woreda in the last two years

S/N	Crops harvested	2009		2010	
		Area (ha)	Total prod. (qt)	Area (ha)	Total prod. (qt)
1	Cereals				
1.1	Maize	2827	73,968	3524	76,646
1.2	Sorghum	5030	103,100	2150	42,640
1.3	Teff	1500	19,500	1500	20,950
1.4	Barley	---	---	110	220
2	Pulses				
2.1	H. bean	188	2128	174	2629
3	Oil Seeds				
3.1	Groundnut	680	3400	650	1300
4	Horticulture				
4.1	Sweet potato	50	4000	150	12,000
4.2	Potato	---	---	50	3000
4.3	Pepper	7	455	8	480
4.4	Tomato	12	600	15	600
5	Others				
5.1	Coffee	8500	68,000	9122	72,976
5.2	Chat	---	---	400	13,320

*Source: Shanana Kolu Woreda Office of Agriculture.

According to the table above it can be concluded that maize, sorghum, and teff are widely produced from cereal crops and cover the largest portion of arable land. Other crops such as H.

bean, S. potato, groundnut, and coffee are largely harvested from the pulses, oilseeds, and horticulture crops respectively. The productivity of these crops is low and stagnant from year to year from almost constant land unit. On the other hand, the following crops have been harvested with traditional irrigation development in Shanan Kolu Woreda for the period of 2009 - 2010 cropping seasons, which could be used as baseline for the proposed irrigated agriculture.

Table 8: Crops Harvested with Irrigation in Shanan Kolu Woreda in the last two years

S/N	Crops harvested	2009		2010	
		Area (ha)	Total prod. (qt)	Area (ha)	Total prod. (qt)
1	Cereals				
1.1	Maize	18	714	18	399
1.2	Sorghum	1	25	3	50
2	Roots & Tubers				
2.1	Beetroot	4	568	20	1194
2.2	Carrot	2	211	9	408
3	Vegetables				
3.1	Tomato	54	10,62	55	14,979
3.2	Onion	16	2156	39	5561
3.3	Cabbage	14	3222	31	6718
3.4	Pepper	6	132	8	184
4	Fruits				
4.1	Banana	120	21,558	121	43,228
4.2	Mango	18	3785	12	4870
4.3	Papaya	15	2615	10	4810
4.4	Orange	4	1073	4	1274
5	Others				
5.1	Sugarcane	154	11,513	157	70,375
5.2	Chat	3180	437,547	3299	569,394
5.3	Coffee	1328	9726	1219	9556

*Source: Shanan Kolu woreda irrigation development authority.

1.5.2.4 Livestock Production

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

in Shanan Kolu Woreda and the project Kebele (where the proposed irrigation project is located) are indicated in the table below.

Table 9: Livestock Types, Quantities and Common Diseases in Sh. Kolu Woreda and the Project Kebeles

S/N	Shanan Kolu Woreda		Badeyi Kebele	Diseases of the area
	Type of livestock	Qty	Qty	
1	Cattle	65,387	3032	Foot & Mouth disease (FMD), Anthrax, Lumpy Skin Disease, Black legs, Newcastle, fowl typhoid, Bovine and Ovine Pasturellosis, Senoryosis, Trypanosomiasis (Tryps), endo and ecto parasites (Faciolla), Coccidiosis, sheep pox, etc.
2	Sheep	8925	666	
3	Goats	32,514	2006	
4	Horses	150	---	
5	Donkeys	7012	404	
6	Mules	450	40	
7	Camels	250	---	
8	Poultry	56,784	1924	
9	Beehives			
	-Traditional	4320	56	
	-Transitional	574	2	
	-Modern	92	3	

*Source: Shanan Kolu Woreda Livestock Health Clinic and nearby Development Agents Office.

According to the information obtained from woreda livestock agency and health clinic, and the community, Anthrax, Blackleg, Tryps, FMD, Pasturellosis, Faciolla, Newcastle and Coccidiosis are the most prevalent diseases in the area. Vaccination and treatment is the major means of preventing these diseases and farmers use their traditional healing mechanisms practiced from generation. In the area natural grazing is the major sources of feed for livestock. In addition some improved forage grasses, multipurpose legume trees and few industrial byproducts are used for livestock feed in the area. Crop residues are largely consumed on the field and also collected, stored and fed during the season of feed shortage. Communal grazing land in some areas is the common means of grazing arrangements among the farmers of the area. Farmers allocate common grazing lands at the bottom of the hill, around river banks, wetland to feed their animals in common. Individually, farmers in the command area allocate and fallow some part of their crop land for animal grazing. Zero grazing is also practiced by few farmers exercising animal fattening around homesteads.



Figure 7: Tie and feed system of livestock husbandry in the proposed project area

1.5.2.5 Existing Agricultural Techniques

As observed from the field assessment and information obtained from the concerned institutions, the existing farming practice is traditional method of crop husbandry. As the project area is more of lowland the sector is dominated by lowland crops production and especially the farmers of the project area relatively produce limited range of crop types which are mainly used for their subsistence consumption and some more for additional household income generation. The supplying of agricultural inputs such as improved seeds and fertilizers for existing traditional rain-fed agriculture is low, not adequate for full potential use of the available resources. As information collected from the woreda cooperative office and local farmers the price of these agricultural inputs is increasing from time to time and get unaffordable. As a result, the farmers use few inputs, especially, fertilizers on large area of land, not according to the research recommendation. The credit service in the command area is not common and most farmers have little awareness of credit service rendering organizations. The basic agricultural techniques like crop rotation, crop diversification, double cropping, soil and water conservation and other related activities are not yet well practiced in the area. Most farmers use traditional oxen drawn plows to

plough their crop land on sloppy farmland (as the command area is dissected land and has got more cliffs), and this plow is short and can cause the formation of a hard pan beneath the top soil. This lowers the water retention capacity of the soil and exposes the upper agricultural soil to water erosion. There are great variations among the farmers, depending on the different biographical conditions, skills, the availability of labor and access to resources outside the farm. Most are marginal subsistent farmers, cultivating basic food crops only. But the production of such crops is low, not enough to meet their requirements in most years. The number of livestock is higher, but the productivity of these livestock sector is very low mainly due to the poor feeding system and lack of improved breeds. The prevalence of livestock diseases, feed shortage, and low awareness of improved management practices has its own impact to low livestock productivity.

1.5.3 Existing Agricultural Problems

Generally, the following major agricultural problems are identified in and around the project area.

a) Shortage and Erratic Nature of Rainfall

Though the area receives rainfall twice in a year (bi-modal type of rainfall), its amount is very small and erratic in distribution, resulting in serious soil moisture deficit in most cases. Because of this nature of rainfall and high temperatures causing high evapotranspiration crop failure is common in most years in the project area. This condition calls for the utilization of available surface water for crop production to feed the community in the proposed project area.

b) Low Technology Input Utilization

There is no adequate provision of agricultural inputs, like improved seeds, agrochemicals, improved breeds of livestock, and other related technology packages in the proposed development area. The farmers produce relatively limited range of improved crop types due to low awareness of improved, environmentally-friendly agricultural technologies. This might be because of continuous price increase of important agricultural inputs, especially fertilizers. The price of agricultural inputs as common is high and farmers could not afford

to purchase. Although the Woreda Agricultural Extension Office has been supplying few improved crops varieties, adoption of improved farm practices is hardly seen in the area. Crop rotation, diversification, intercropping and soil water conservation are not seen well practiced in the area.

c) Soil Erosion as a Result of Deforestation and Topography

Due to population increase which leads to horizontal expansion of agricultural lands, and the increasing firewood consumption and other related human needs (construction, fencing timber etc.) deforestation is becoming a problem in the proposed project area. Moreover, the topography of the project area is mountainous and cliffs which exposes the topsoil to water erosion. Replanting and other soil conservation activities are not yet well adopted by the community.

d) The Prevalence of Animal Diseases & Low Livestock Productivity

The production & productivity of livestock is below the expected condition (as informed by the development agents & other concerned workers). The occurrence of different animal diseases, lack of quality breeding, shortage of high nutritional feeding and the dominance of traditional way of rearing system are some of the many factors which reduce livestock productivity.

e) Insufficient Expertise of Irrigation Farming

The expansion of small scale irrigation in the study area and in the Woreda as a whole is still insignificant. This has got its own impact on the introduction of different vegetables and other cash crops in the area. Although there are many potential rivers and springs for modern irrigation development, the practice is not yet developed as required and farmers try their best in developing traditional irrigation structures.

1.5.4 Labour Requirement

Labour requirement for the existing rain-fed agriculture system is calculated on the proposed command area. This is mainly based on the field assessment and secondary data gathered from the agriculture office of Shanan Kolu woreda and the project Kebele. As per the “without project” condition, a hectare of labor requirement is specified under the following table.

Table 10: A Hectare of Labor Requirement as a “without project” Condition

S/N	Crops	Activities	Unit	Frequ ency	Qty	Total Required	Cost (Birr)
1	Teff	Ploughing	OD	4	4	16	16*80=1280
		Packing	OD	1	20	20	20*10=200
		Sowing + fertilizer	MD	1	2	2	2*60=120
		Weeding	MD	2	25	50	50*80=4000
		Harvesting	MD	1	20	20	20*80=1600
		Threshing	MD	1	10	10	10*80=800
		Transport	MD	1	4	4	4*50=200
		Total					8,200
2	Wheat	Ploughing	OD	3	4	12	12*80=960
		Sowing + fertilizer	OD	1	4	4	4*60=240
		Weeding	MD	2	20	40	40*80=3200
		Harvesting	MD	1	15	15	15*80=1200
		Threshing	MD	1	10	10	10*80=800
		Transport	MD	1	5	5	5*50=250
		Total					6,650
3	Maize	Ploughing	OD	3	4	12	12*80=960
		Sowing	OD	1	4	4	4*60=240
		Weeding/cultivation	MD	2	30	60	60*80=4800
		Fertilizer application	MD	2	4	8	8*60=480
		Harvesting	MD	1	30	30	30*80=2400
		Threshing	MD	1	40	40	40*80=3200
		Transport	MD	1	8	8	8*50=400
		Total					12,480
4	H. bean	Ploughing	OD	2	4	8	8*80=640
		Sowing	OD	1	4	4	4*60=240
		Weeding	MD	1	20	20	20*80=1600
		Harvesting	MD	1	15	15	15*80=1200
		Threshing	MD	1	10	10	10*80=800
		Transport	MD	1	4	4	4*50=200
		Total					4,680
		Grand Total					32,010

1.6 Proposed Irrigated Agriculture

Irrigated agriculture is proposed based on the objectives of the agronomic study indicated in earlier parts of this study report under the following conditions. Since assisting with installation of irrigation scheme is a key part of the proposed program and development strategy, it is essential that sound environmental, agronomic, social, economic and technical criteria are met at all stages of planning and design activities. Modern crop technology has the power to increase

farm incomes and lower food prices simultaneously, thus benefiting everyone in society, especially the poor who spend a larger portion of their income on food. Thus, clearly irrigation can and should play an important role in raising and stabilizing food production, especially in areas of the proposed project, where there is relatively better land and water potential suitable for irrigation.

1.6.1 Crop Selection

Crops are selected based on the following major criteria:

- Climatic & soil suitability of the area,
- Yield potentiality and marketability,
- Multiple purposes such as food, fodder, export value,
- Length of growing period (early maturing) and workability,
- Their places in rotation and contribution to soil fertility,
- As a basic staple food for existing community (farmers' crop selection preference), and
- Beneficiary's existing skill and level of technology utilization.

Whenever the construction of an irrigation project is proposed, it is essential first to develop a cropping pattern for the command area to facilitate proper utilization of the project potential and to make the project economically viable. Considering the factors discussed above, the following general cropping patterns are recommended for major agro-ecologies of Ethiopia.

Table 11: General recommended crop mix for major agro-ecologies of Ethiopia

No.	Major agro-ecological zones	Altitude (m)	Average Temperature (°C)	Annual Rainfall (mm)	Recommended crops
1	Moist Dega	2300-3200	12-18	900-1400	Barley, wheat, highland pulses, potato, cabbage, carrot, Swiss chard
2	Moist Weyna Dega	1500-2300	18-25	900-1400	Teff, maize, wheat, pulses, sorghum, Noug, potato, sweet potato, cabbage, carrot, Swiss chard, shallot, onion, pepper, tomato, garlic, coffee
3	Dry Weyna Dega	1500-2300	18-25	300-900	Maize, wheat, groundnut, haricot beans, sweet potato, shallot, onion, pepper, tomato, Swiss chard, coffee, banana, papaya, citrus
4	Moist Kolla	500-1500	>25	900-1400	Maize, groundnut, haricot beans, sweet potato, shallot, onion, pepper, tomato, banana, papaya, citrus
5	Dry Kolla	500-1500	>25	300-900	Maize, sorghum, groundnut, haricot bean, cotton, sweet potato, shallot, onion, pepper, tomato, banana, papaya, citrus

Source: Irrigation Agronomy Guideline, Ministry of Agriculture (2011)

Accordingly, crops such as **Pepper, Onion, Tomato, and Sweet Potato** are proposed for the project during the dry season, and crops such as **Sorghum, Maize, and Pulses** are proposed during the wet season. In selection of crops most attention was given to high value marketable crops. Vegetable crops provide steady income to producers besides using as a food, and make significant contribution to the economy in form of cash income. They are also the main source of vitamins, minerals, proteins, carbohydrates and fats.

1.6.2 Cropping Pattern

After selection of the crops to be planted using irrigation, the seasonal cropping pattern and cropping calendar for each crop should be determined. This helps in establishing which crop will occupy what part of the available land area during each season, also taking into consideration the crop rotation requirements other than perennial crops. Moreover, the cropping pattern is based on the following basic considerations.

- The objective of the project,
- Production of high value crops, at least to satisfy the local market demand, increase export needs by producing an agricultural surplus,
- The proportion of land for different crops can be adjusted according to the market needs with the increase of local and export demand in raising the crop and preferences,
- Intensification of crop production from food crops to cash income generation,
- Immediate benefit in the form of more reliable harvest higher production per unit of labor.

Table 12: Crops Selected for Dry Season Irrigation Development

S/N	Proposed Crops	Area		Selected varieties	Planting/ Sowing date	Harvesting Date	Base-period (days)
		(ha)	(%)				
1	Pepper	50	25	Marekofana, Bako Local	Oct. 10-20	Jan. 20-30	110
2	Onion	60	30	Adama Red and Bombe red	Oct. 01-05	Jan. 05-10	95
3	Tomato	50	25	Marglobe, Melkashalo red	Oct. 01-10	Jan. 15-25	115
4	S. Potato	40	20	Koka-6, Dubo, Bareda	Oct. 10-15	Feb. 10-15	125

Table 13: Wet-season Irrigation time Schedules

S/N	Proposed Crops	Area		Selected varieties	Planting/ Sowing date	Harvesting Date	Base-period (days)
		(ha)	(%)				
1	Sorghum	100	50	Gobiye, Abshir, Gedo	May 20-30	Oct. 1-10	120
2	Maize	80	40	BH-140, BH-540, Melkasa-2	Apr. 25- May 10	Oct. 20-25	125
3	H. bean	20	10	Roba-1, Awash Melka	Jun. 25-30	Sept. 25-30	90

1.6.3 Details of the Selected Crops

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

1.6.3.1 Vegetables

a) Pepper (*Capsicum spp.*)

Pepper is an important vegetable crop for fresh consumption, processing as a spice (for making stew) and has much importance in the spices extraction factories for its oleoresin. It has high content of capsaicin. Pepper grows well in areas found within altitude ranges of 1000-1800 meters above sea level. High yields can be obtained with a rain fall of 600-1250 mm during the growing period. Pepper does not require heavy rainfall. Heavy rain fall and high humidity results in rotting of fruits. The plant can grow in hot and frost free areas. The optimum growing temperature for pepper is between 21⁰C - 24⁰C. Light texture soils with adequate water holding capacity and good drainage are preferred for proper growth and development. Different types of pepper are produced in Ethiopia. The varieties vary in mode of growth, fruit size, colour, shape and pungency. At the moment two improved hot pepper varieties are widely produced in the country. These are:-Mareko Fana and Bako Local. Mareko Fana is a dark red, thick fleshed, very pungent and most accepted in local markets. Bako Local is light colored, thin skinned, smaller in size and less pungent than Mareko Fana. Seeds of red pepper may be sown directly in the field or seedlings could be raised in the nursery beds. The required seed bed area to cover one hectare for transplanting red pepper field is about 300 m². The seedlings can be transplanted to the field when they have reached a height of 10 – 12 cm. or during 45 – 50 days after sowing.

b) Onion (*Allium cepa*)

Bulbing takes place more quickly at warm than at cool temperatures provided the minimum photoperiod for the cultivars has been reached. Optimum conditions for germination are met at temperatures between 10-25⁰C and a high soil temperature kills the young seedlings. The optimum temperature for growth is 16-22⁰C. Early maturing and low yields occur at temperature <16⁰C. A low air humidity and low temperature lead to flowering. Onion is sensitive to the day length and 12-13 hours are required in the yield formation period.

Onion grows on a wide variety of soils, provided they are well aerated and friable and as long as sufficient water can be retained. Fertile, loamy textured soils are most suitable. The maximum rooting depth of the crop is 0.5m. Soil pH range is 5.5-8.2, optimum pH is 6.0-7.8.

c) Tomato- (*Lycopersicon esculentum*)

Tomato is a rapidly growing crop with a growing period of 90 to 150 days. It is a day length neutral plant. Tomato can be grown on a wide range of soils, but a well-drained light to loam soil with pH of 5 to 7 is preferred. The seed is generally sown in nursery plots and emergence is within 10 days. The seedling is transplanted in the field after 25 to 35 days. In the nursery the row distance is about 10 cm, but in the field spacing ranges from 0.3/0.60x0.6/m with a population of about 40,000 plants per ha. The crop should be grown in a rotation with crops such as maize, cabbage cowpea to reduce pest and disease, particularly nematodes.

The water requirement after transplanting, of tomato crop grown in the field for 90 to 120 days is between 400 to 600 mm depending on the climate. The plant produce flower from the bottom to top during the active development of the stem. Fruit can be harvested while the plant is still flowering at the top. In some cases three flowering periods related to three harvests can be distinguished.

Frequent light irrigation improves the size, shape, juiciness and color of the fruit, but reduces total solids (dry matter content) and acid content. However, the decrease in the solids will lower the fruit quality for processing. In selecting the irrigation practices consideration must therefore be gives to the type of end product required. Tomato is sensitive to diseases and insect pests; so apply recommended cultural and chemical control measures to control different diseases and insect pests affecting tomato production. Parasitic weed must be rouged out at earl stages before it set seeds.

1.6.3.2 Roots and Tubers

a) Sweet Potato (*Ipomoea batatas-L*)

In Ethiopia sweet potatoes are widely growing in the southern, southwestern and eastern parts of the country. Sweet potato is grown over a wide range of climatic conditions, just from sea level to 2300 m above sea level that means cultivated in the tropics, subtropical and temperate zones and increasingly being produced as a cash crop, as well as a subsistence crop grown in home gardens. The best suitable altitude ranges are from 1500 to 1800 m above sea level. Sweet potatoes require fairly high average temperatures of 20 to 30 °C optimum temperature is about 25 °C with plenty of sunshine and a good distribution of rainfall during the growing season. However, areas with an average temperature of 22 °C are best suitable for its production. Under rainfed condition it thrives best where the average annual rainfall is between 700– 900 mm, below this, the crop requires irrigation. Even though, sweet potato is considered as drought resistant crop, research results confirmed that the crop need sufficient amount of rain or supported by irrigation water, particularly in the early 6 weeks of growth, if not supplied with sufficient amount of water during this period of growth, the yield dramatically declines. Sweet potatoes are propagated frequently using vine cuttings or from tubers. Propagation from cuttings is possible only when the sweet potatoes remain in the field all-round the year. The cuttings should be 20 to 40 cm long, with 3-5 growth buds. It is best to take them from the tips of young stems, since plants from terminal cuttings produce high yields than those propagated from basal or mid stem cuttings. Sweet potato being a shallow rooted crop requires frequent irrigations of shallower depths rather than a few heavy irrigations. In this regard, on average 7 - 10 irrigations are applied during the growing period. The interval between irrigations depends mainly on soil types and the crop growth stages.

1.6.4 Irrigation Seasons

Irrigation seasons are decided based on the existing climatic condition, length of growing period (LGP) of the proposed crops and capacity (efficiency) of the beneficiaries of the project. As to the proposed project condition, one time irrigation seasons as a “Dry-season” is possibly recommended. The “Dry-Season” is considered as “Full-Time” irrigation season and the second planting season is rainfed “Wet-season” as “supplementary” irrigation. The full time irrigation season is proposed starting in the month of October. This period (October) is proposed to be a

starting month considering the (LGP) of crops, appropriate marketing time and the time for second rainfed practices.

1.6.5 Proposed Management

As a “With-Project” condition and modern farming system, all the required crop management approaches should be applied in the system. For instance crop spacing, method of irrigation, fertilizer application (type, amount, time and method) should be identified prior to the development phases. Accordingly, the following basic and integral parts of crop management approaches for the “would be” irrigated agriculture are identified below.

1.6.5.1 Method of Irrigation

The major method of water application during the cultivation seasons is furrow system for the selected crops. Farmers of the proposed irrigation area have the experience of furrow application on the traditional irrigation activities. The detail condition is indicated in the following table.

Table 14: Method of Irrigation and Spacing for the selected crops

S/N	Selected Crops	Method of Irrigation	Plant spacing (cm)		Remark
			Intra-row	Inter-row	
1	Pepper	Furrow	15	50	
2	Onion	Furrow	10	30	
3	Tomato	Furrow	45	80	
4	S. Potato	Furrow	40	100	

1.6.5.2 Cultivation Activities

Different crops require different cultivation activities. Some crops require simple hoeing and some others require earthening up. Thus, it is advisable to understand these conditions prior to the development activities. Some of the major cultivation processes of crop production are summarized in the following table.

Table 15: Major cultivation activities in irrigated agriculture

S/N	Proposed crops	Seed Rate (Kg/ha)	Soil depth during Seeding/ planting (cm)	Cultivation time/Weeding
1	Pepper	0.5 to 0.6	4-5 (Transplanting from nursery site after 30 days)	After 20 days of planting
2	Onion	3-4	Same	Same
3	Tomato	0.5	4-6 (Transplanting from nursery site after 30 days)	After 20 days of planting
4	S. Potato	33,000 cuttings	5-10	After 20 days of planting

1.6.6 Fertilizer Management

Adequate fertilization programs supply plant nutrients needed to sustain maximum crop productivity and profitability while minimizing environmental impact from nutrient use. In essence, fertilizers are used so that soil fertility is not a limiting factor in crop production. The major factors influencing the quantity of nutrients to apply are crop and soil characteristics, fertilizer placement, climate especially moisture and temperature, yield goals and economics. Considering these main factors in proper fertilizer management activities, the required fertilizers (that can be synthetic or natural), are given to the proposed crops. However, it should be applied after careful chemical analysis of the command soil. As to the proposed project condition, the following fertilizer and other agrochemicals are averagely determined. (The total yearly input required for the command area is referred in Agronomy Annexes).

Table 16: Required fertilizers & other agrochemicals planned for each proposed crop

S/N	Selected Crops	Fertilizers, (Kg/ha)		Pesticide s,(Lt, Kg/ha)			Remark
		NPS	Urea	Insecticides	Fungicide	Herbicide	
1	Pepper	100	100	Diazinone, etc.	Ardent 50 SC, Ridomil, etc.	-	Amount of pesticide is determined on the type of crop, kind of pest outbreak and type of pesticides to be used.
2	Onion	100	100	Nimbecidine, etc.	Ridomil, etc.	-	
3	Tomato	150	100	Dimethoate 40% EC, Diazinone, etc.	Mancozeb, Ridomil, etc.	-	
4	S. Potato	100	50	Diazinone, etc.	Ardent 50 SC,	-	

1.6.7 Method of Fertilizer Application

There are a number of fertilizer application methods, based on the crop and its cultivation system. Among these, deep-banding, side/basal dressing, fertigation, foliar application and others are known. However, as to the level of irrigation and user’s awareness, the basal and top dressing are the most important application methods in well managed irrigation development activities. Accordingly, the following application experiences are designed for the proposed project.

Table 17: Methods of fertilizer application for the proposed crop types

S/N	Proposed Crops	Fertilizers to be applied	Method of Application	Time of Application
1	Pepper	NPS	Top/Side dressing	At the time of transplanting
		Urea	Basal dressing	3 to 4 weeks after transplanting
2	Onion	NPS	Top/Side dressing	At the time of transplanting
		Urea	Basal dressing	3 to 4 weeks after transplanting
3	Tomato	NPS	Top/Side dressing	At the time of transplanting
		Urea	Basal dressing	3 to 4 weeks after transplanting
4	S. Potato	NPS	Top/Side dressing	At the time of transplanting
		Urea	Basal dressing	3 to 4 weeks after transplanting

In general the assigned agronomist can select one of the following fertilizer management practices during the implementation period.

- Excessive use of external inputs,
- Intensified use of local resources with few or no external inputs,
- Integrated use of external inputs and local resources.

1.6.8 Plant Protection

Controlling insect pests, diseases, and weeds is very essential for the achievement of optimum crop yield from irrigated agriculture. Pesticides may be expensive and may cause environmental problems on the area for both human beings and animals. They also kill other important pests which are enemies of the non-advantageous pests. Thus, during the cultivation period, non-chemical methods of pest control should preferably be applied together with that of chemical ones (integrated method of pest management). Accordingly, the following protection methods are summarized to be used in the future plant protection activities of the proposed project.

Table 18: Chemical & non-chemical plant protection methods for the proposed crops

S/N	Proposed Crops		The Possible Pests & Diseases	Chemical Prevention Method	Non-chemical Prevention Method
1	Pepper	Pests	Thrips, white fly, Different Worms	Use different chemicals	Field sanitation, Crop rotation, and Disease free var., proper crop and water management.
		Diseases	Fruit rot, Powdery Mildew	Use different fungicides.	Field sanitation, Crop rotation, and Disease free var., proper crop and water management.
2	Onion	Pests	Onion trips, cut worms, Onion flies, Termite.	Use different Chemicals & pesticides	Field sanitation, Crop rotation, use of Disease free var., proper crop and water management.
		Diseases	Root rot, Purple Bloch, Downey Mildew	Use different fungicides.	Field sanitation, Crop rotation, use of Disease free var., proper crop and water management.
3	Tomato	Pests	Soil borne Worms, Aphids, Army Worms	Use different Chemicals & pesticides	Field sanitation, crop rotation, and insect free var., proper crop and water management.
		Diseases	Early and Late blight, Bacterial wilt, etc.	Use of different fungicides.	Field sanitation, crop rotation, and disease free var., proper crop and water management.
4	Sweet Potato	Pests	Weevils, Caterpillars, etc.	Use different chemicals	Field sanitation, crop rotation, and disease free var., proper crop and water management.
		Diseases	Black rot, Soft rot, etc.	Use different fungicides.	Field sanitation, crop rotation, and disease free var., proper crop and water management.

1.6.9 Crop Rotation and Intercropping

Crop rotation is used to avoid the build-up of diseases and pests and to avoid or minimize loss of soil fertility. Intercropping allows efficient utilization of soil nutrients and increased harvest from limited land resource. It also enables to get minimum harvest in case of one component crop

failure, so intercropping of leguminous crops with the major component crop is advisable. The possible arrangements in crop rotations and intercropping can be the following.

- Tomato/pepper ↔ onion ↔ sweet potato, which helps for avoidance, especially of nematode build up, blight and bacterial wilt.
- Shallow rooted crops alternatively with deep rooted crops for efficient utilization of essential nutrient resources is also one of the rotational possibilities.
- Onion/pepper intercropping used for efficient utilization of limited land resources.

1.6.10 Labor Requirement

As a “With-Project” condition, labor is calculated for each selected crop, for a hectare of irrigable land. All the required activities, frequency and amounts with their justification are specified in the next table.

Table 19: A hectare of labor requirement as a “With-Project” condition

Activity	Unit	Proposed crops			
		Pepper	Onion	Tomato	S. Potato
Nursery	MD	60	60	60	40
Land preparation	OD	12	12	12	12
Pre planting operation	MD	10	12	12	10
Planting	MD	15	15	15	10
Fertilizer application	MD	4	5	4	4
Irrigation	MD	20	25	20	15
Weeding & hoeing	MD	40	40	40	20
Crop protection	MD	5	5	5	4
Harvesting	MD	30	20	40	15
Post-harvest operation	MD	10	15	15	10
Total	MD	206	209	223	140
Production Cost	Birr	16,100	13,280	17,420	10,840

1.6.11 Area Coverage/Intensity

For the irrigation project the development approach is assumed to double crop over one cropping season and the cropping intensity to approach 200%. Even though the climatic condition of the command area and experience of the beneficiaries allow producing crops twice in a year using irrigation system the cropping intensity can reach only 150% during the first year due to topography of the area and the presence of perennial crops in the command area to irrigate the

whole command lands. Accordingly, the following cropping pattern/intensity is designed for the first 5-year crop production schedule.

Table 20: A 5-year cropping pattern/intensity plan

S/N	Crops	Area coverage									
		1 st -Year/Season		2 nd -Year/Season		3 rd -Year/Season		4 th -Year/Season		5 th -Year/Season	
		ha	%								
1	Pepper	37.5	18.75	50	25	50	25	50	25	50	25
2	Onion	45.0	22.5	60	30	60	30	60	30	60	30
3	Tomato	37.5	18.75	50	25	50	25	50	25	50	25
4	S. Potato	30.0	15.0	40	20	40	20	40	20	40	20
5	Sorghum	75.0	37.5	100	50	100	50	100	50	100	50
6	Maize	60.0	30.0	80	40	80	40	80	40	80	40
7	H. bean	15.0	7.5	20	10	20	10	20	10	20	10
Intensity		300	150	400	200	400	200	400	200	400	200

1.6.12 Yield Projection

Crop yield is mainly estimated based on the level of crop management required practices, availability of agricultural inputs, proper extension services, and existing climatic situations for crop production. Apart from these basic factors, other trends should be assessed. For instance, observation of previous yield condition from traditional (rainfed) agriculture, anticipated research outputs, and other related sources are very important. Considering these parameters, the following yield projection is forecasted.

Table 21: Yield Projection for five (5) year/season production period

S/N	Crop	1 st -Year /season		2 nd -year /Season		3 rd Year /Season		4 th -year /Season		5 th -year /Season	
		Yield (qt/ha)	Prodn (Qt)	Yield (qt/ha)	Prodn (Qt)	Yield (qt/ha)	Prodn (Qt)	Yield (qt/ha)	Prodn (Qt)	Yield (qt/ha)	Prodn (Qt)
1	Pepper	25	937	28	1400	30	1500	30	1500	30	1500
2	Onion	50	2250	60	3600	65	3900	70	4200	70	4200
3	Tomato	70	2625	75	3750	80	4000	80	4000	80	4000
4	S. Potato	140	4200	150	6000	160	6400	160	6400	160	6400
5	Sorghum	40	3000	45	4500	50	5000	50	5000	50	5000
6	Maize	60	3600	65	5200	70	5600	75	6000	75	6000
7	H. bean	18	270	20	400	20	400	20	400	20	400

1.6.13 Postharvest Activities

a) Harvesting

Irrigated crops such as vegetables and fruits are highly perishable and subjected to chemical and physical changes and hence too rapid deterioration. Apart from some exceptions, most farm products are susceptible to damage, whether from mechanical shocks or climatic factors like atmospheric dryness, heat and cold. This sensitivity creates the need for a whole series of precautions in handling, storing, packing and transport. Therefore, care should be taken during harvesting and post-harvest activities. Recognition of the point of optimum maturity is important for the successful harvesting of certain fruits and vegetables. Correct handling is required during picking or lifting of crops manually. The grower must supervise the work and insists constantly that all rough handling is avoided. Every shock and small wound, even those not observable, will shorten the shelf life of the vegetable/seeds and deteriorates and reduces the quality and hence the profitability. Attention should be paid to the weather. Heat, rain, hail and dew may all damage the appearance of the crop after picking or lifting.

b) Storage

Storage under naturally ventilated conditions is the best. It is sometimes necessary to store produce for a considerable period, so as to space out the sales and avoid glutting the market. The site for the storage facility should be relatively elevated and well-exposed to the dominant winds. It can be located under the shade of a tree, with light air condition. Generally, cold storage is preferable. The crop should be spread on well-aerated open racks in layers not exceeding about 20cm in depth. The store must be kept clean and baskets and boxes packed, so that they do not interfere with the free circulation of air.

c) Packing & Grading

Packing concerns the preservation of the produce in the best possible conditions of freshness, appearance, hygiene and general attractiveness, hence protecting its market values.

d) Transport

Available transport should be prepared, at least to the farm gate condition. In hot climate where the distances to be covered are long journeys that are undertaken in day light, special protection

and proper packing for the produce is very necessary. Bad road conditions will inflict further damage on produce before it reaches the market. Frequency and reliability of transport as well as distances to the market should be assessed and planned before complete harvesting activities.

1.7 Extension Service

Farm management deals with the organization and operation of a farm with the objective of maximizing profits from the farm business on a continuing basis. And hence, proper extension activities should be applied for the fact stated above. All the concerned stakeholders have their own parts in the achievement of the project objectives. The following are to be basic factors in extension approach.

1.7.1 Market

Agricultural marketing in irrigation scheme is an integral and general understanding involved in the process of marketing from farm gate to final consumption of irrigation farm products. Adequate market information, shops in the market place for sale of the produces, access road from farm place to the market outlet and good bargaining power are basic issues for the proper development of the proposed irrigated agriculture. Therefore, the irrigators shall get current market information and technical assistance in determination of demand in different crops in their specific area or as a whole in the region.

1.7.2 Timely Input Provision

Adequate agricultural input provision is another important issue for good output from irrigation farming. Inputs, like vegetable seeds, agrochemicals and fertilizers should be supplied and this should be supported by the extension agents and other relevant stakeholders. The current supply of agricultural inputs is given a priority for rain-fed agriculture. Thus, the detail demand of irrigation in fertilizers, seeds, and chemicals shall be analyzed and quantified as per the calculated demand shall be provided on time.

1.8 Crop Water Requirement

Crop water requirement (CWR) is defined as the depth of water needed to meet the water loss through evapotranspiration of a disease free crop growing in large fields under non-restricting soil conditions including soil water and fertility and achieving full production under the given growing environment (FAO, 1977). The crop water requirement calculation is computed using Cropwat-8 software based on modified Penman-Monteith Method (conducted on FAO-Irrigation & Drainage Paper No. 56). The estimation of crop water requirement underlies effective planning of crop production at farm level. Water requirement (WR) is related to water from soil profile(s), rainfall and irrigation.

$$(IR): WR = R + IR + S$$

Under this topic, the relevant parameters for proper irrigation water management, such as Irrigation Depth (d, mm), Interval (i, days) and frequencies of irrigation are calculated. Moreover, the design supply (duty) in (l/s/ha) for the maximum value of the project is computed in this part. As shown in water requirement analysis, the net water requirement of each crop is divided by the overall efficiency of **50%** to obtain the gross water requirement. **The project supply of the irrigation project during full irrigation becomes 1.04 l/s/ha for 24 hours irrigation**. This can be determining at the outlet head or canal head regulator for calculating the discharge capacity of the main off taking canal. The detail climatic data used for computing the crop water requirement and other soil and crop data with detail calculation procedures are seen in the ANNEX part of this study report.

Table 22: Duty of Dry-season cultivation

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation deficit												
1. Pepper	133.4	40.8	0	0	0	0	0	0	0	41.9	78.3	129
2. Onion	28.3	0	0	0	0	0	0	0	0	63.8	109.3	133.7
3. Tomato	146.8	79.5	0	0	0	0	0	0	0	54.4	93.1	144.4
4. Sweet Potato	154.9	107.9	43.6	0	0	0	0	0	0	15.8	70	150.1
Net scheme irr.req.												
in mm/day	3.5	1.8	0.3	0	0	0	0	0	0	1.5	3	4.5
in mm/month	109.5	51.6	8.7	0	0	0	0	0	0	46.4	89.7	138.5
in l/s/ha	0.41	0.21	0.03	0	0	0	0	0	0	0.17	0.35	0.52
Irrigated area (% of total area)	100	70	20	0	0	0	0	0	0	100	100	100
Irr.req. for actual area (l/s/ha)	0.41	0.3	0.16	0	0	0	0	0	0	0.17	0.35	0.52
Project Efficiency	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Project Duty (l/s/ha)	0.82	0.6	0.32	0	0	0	0	0	0	0.34	0.7	1.04

1.8.1 Calculation procedure

The calculation of reference evapotranspiration (ET_o) is based on the FAO Penman-Monteith method (FAO, 1998). Input data include monthly and daily for temperature (maximum and minimum), humidity, sunshine, and wind-speed are collected from the station. Crop water requirements (ET_{crop}) over the growing season are determined from ET_o and estimates of crop evaporation rates, expressed as crop coefficients (K_c), based on well-established procedures (FAO, 1977), according to the following equation:

$$ET_{crop} = K_c \times ET_o$$

FAO (1998) has presented updated values for crop coefficients. Through estimates of effective rainfall, crop irrigation requirements are calculated assuming optimal water supply. Inputs on the cropping pattern will allow estimates of scheme irrigation requirements. With inputs on soil water retention and infiltration characteristics and estimates of rooting depth, a daily soil water balance is calculated, predicting water content in the rooted soil by means of a water conservation equation, which takes into account the incoming and outgoing flow of water.

Stress conditions in the root zone are defined by the critical soil water content, expressed as the fraction of total available soil water between field capacity and wilting point that is readily available for crop transpiration, and characterizes a soil moisture condition in which crop transpiration is not limited by any flow restrictions in the root zone. The critical soil water content varies for different crops and different crop stages and is determined by the rooting density characteristics of the crop, evaporation rate and, to some extent, by the soil type.

1.8.2 Cropwat input data

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

The impact on yield of various levels of water supply is simulated by setting the dates and the application depths of the water from rain or irrigation. Through the soil moisture content and evapotranspiration rates, the soil water balance is determined on a daily basis.

1.8.3 Determination of Evapotranspiration (ET_o)

CROPWAT is a computer program for irrigation planning and management, developed by the Land and Water Development Division of FAO (FAO, 1998). Its basic functions include the calculation of reference evapotranspiration, crop water requirements, and crop and scheme irrigation. Through a daily water balance, the user can simulate various water supply conditions and estimate yield reductions and irrigation and rainfall efficiencies. Typical applications of the water balance include the development of irrigation schedules for various crops and various water irrigation methods, the evaluation of irrigation practices, as well as rain fed production and drought effects.

The estimation of crop water requirement needs the analysis of climatic data and Agronomic practices of the project area. The effect of climate on crop water requirement is given by the reference crop evapotranspiration ET_o which is analysed using the modified Penman method.

1.8.3.1 evapotranspiration (ET_o)

Evapotranspiration (ET_o) includes transpiration of the crop as well as evaporation of water from the soil. During the study, Penman method of estimating ET_o has been utilized.

$$ET_o = c \left[W \cdot R_n + (1-W) \cdot f(u) \cdot (e_a - e_d) \right]$$

ET_o = Reference crop evapotranspiration in mm/day

W = Temperature - related weighting factor

R_n = Net radiation in equivalent evaporation in mm/day

f(u) = Wind - related function

(e_a-e_d) = difference b/n the saturation vapor pressure at mean air temperature and the mean actual vapor pressure of the air, both in mbar

C = Adjustment factor to compensate for the effect of day and night weather conditions.

Pen-Man equation was used in ET_o calculations.

1.8.3.2 Crop coefficient (Kc)

The effects of weather conditions are captured in the ETo estimate. Therefore, as ETo represents a factor of climatic demand, crop coefficient (Kc) varies mainly with the specific crop characteristics. The effects of crop transpiration and soil evaporation are combined into a single Kc coefficient. This coefficient combines differences in soil evaporation and crop transpiration rate between the crop and the grass reference surface. Crop coefficient (kc) is affected by many factors including crop type, climate, soil evaporation and crop growth stages.

Crop type: the large variation in Kc values between major groups of crops is due to the resistance to transpiration of different crops, such as closed stomata during the day (pineapple) and waxy leaves (citrus). Also, differences in crop height, crop roughness, reflection and groundcover produce different Kc values.

Climate: General climatic conditions, especially wind and humidity, affect crop coefficients. Variations in wind change the aerodynamic resistance of the crops and their crop coefficients, especially for those crops that are substantially taller than the grass reference crop. Crop aerodynamic properties also change with climate, in particular relative humidity. Kc for many crops increases as wind speed increases and as relative humidity decreases. More arid climates and conditions of greater wind speed will have higher values for Kc. More humid climates and conditions of lower wind speed will have lower values for Kc.

Soil Evaporation: Crop evapotranspiration is a combination of transpiration by the crop and evaporation from the soil surface. Differences in soil evaporation and crop transpiration between field crops and the reference surface are integrated within the crop coefficient. The Kc for full cover crops reflects differences in transpiration, as the contribution of soil evaporation is relatively small. After rainfall or irrigation, the contribution of soil evaporation is significant, especially if the crop is small and has small groundcover. For such low cover conditions Kc is largely determined by how frequent the soil is wetted.

Crop growth stages: 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.

Initial stage: the initial stage refers to the germination and early growth stage when the soil surface is not or is hardly covered by the crop (groundcover < 10%). The Kc during this initial

stage (K_c ini) is large when the soil is wet from irrigation and rainfall and is low when the soil surface is dry.

Crop development stage: the crop development stage is the stage from the end of the initial stage to attainment of effective full groundcover (groundcover 70-80%). As the crop develops and shades more and more of the ground, soil evaporation becomes more restricted and transpiration becomes the dominant process. During the crop development stage, the K_c values correspond to amounts of groundcover and plant development and thus vary.

Late season stage: the late season stage runs from the start of maturity to harvest or full senescence. The calculation of K_c and ETo is presumed to end when the crop is harvested, dries out naturally, reaches full senescence, or experiences leaf drop. The K_c value at the end of the late season stage (K_c end) reflects crop and water management practices. The K_c end value is high if the crop is frequently irrigated until harvested fresh. If the crop is allowed to senescence and to dry out in the field before harvest, the K_c end value will be small.

Table 23: Crop development stage and crop coefficient for proposed crops

Crop	LGP	Growing stage				Crop coefficient			
	(Days)	D ₁	D ₂	D ₃	D ₄	K _{c1}	K _{c2}	K _{c3}	K _{c4}
Pepper	95	15	25	35	20	0.40	0.70	1.05	0.80
Onion	95	20	30	30	15	0.40	0.70	0.95	0.85
Tomato	120	25	30	45	20	0.40	0.70	1.05	0.80
S. Potato	125	25	35	40	25	0.40	0.70	1.05	0.80

Source: FAO Irrigation and drainage paper 24 (1977) and paper 33 (1979)

1.8.3.3 Effective Rainfall (Pe)

Not all dependable rainfall is effective and some may be lost through surface runoff, deep percolation or evaporation. Only a part of the rainfall can be effectively used by the crop, depending on its root zone depth and the soil storage capacity. Different methods exist to estimate the effective rainfall (FAO, 1992). But, for the proposed irrigation project, the effective rainfall is calculated using dependable rain (FAO/AGLW formula). Accordingly, $P_{eff} = 0.6 * P - 10$ (P month ≤ 70 mm) and $P_{eff} = 0.8 * P - 24$ (P month > 70 mm) where, P_{eff} = effective rainfall (mm/month) and P = dependable rainfall (mm/month) respectively.

1.8.4 Irrigation Water Requirement

Irrigation water requirement is calculated using the crops requirements but takes into account the effective rainfall. It is derived from the formula $ET_{CROP} - P_e$ (effective rainfall). Essentially effective rainfall is that proportion of the rain which is stored in the root zone and therefore available to the plants. Rainfall which percolates beyond the root zone or is lost to the plants through surface runoff is not effective in that it is unavailable for plant growth. The texture and structure of the soil are the two important factors which influence the portion of rainfall which may be considered as effective for plant growth. When the rainfall is high, a relatively higher proportion of the water is lost through runoff and deep percolation. In hilly areas, particularly where there is little vegetative cover, runoff can account for the higher losses.

1.8.5 Net irrigation requirements

The net irrigation requirement (net water depth application) is the depth of irrigation water needed to replenish the soil water deficit at the effective root zone to field capacity. Sometimes, the contribution of ground water and the available stored water at the beginning of irrigation period may not be significant. As a result, the net irrigation requirement (NIR) is determined by considering only the effective rainfall (i.e. $NIR = ET_c - P_e$).

1.8.6 Irrigation Efficiency

To account for losses of water incurred during conveyance and application to the field, an efficiency factor was included while calculating the project irrigation requirements. Project efficiency is normally subdivided into conveyance efficiency, distribution efficiency and application efficiency. Accordingly, an overall project efficiency of **50%** for farmer managed furrow irrigation has, therefore, been adopted as the design criteria for the irrigation project. This is at the normal range of efficiencies that could be achieved for furrow irrigation. (See the detail calculation in Agronomy Annex)

1.8.7 Field Irrigation Schedules

Field irrigation schedules are based on field water balance and are expressed in depth (d, in mm) and interval of irrigation (i, in days).

1.8.7.1 Depth of irrigation application (d)

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

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

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

Where –d=depth of application in mm

P=fraction of available soil water

Sa=available soil water in mm/m soil depth

D=Rooting depth of crops in m.

Ea=application efficiency

1.8.7.2 Irrigation application interval (i)

Correct time of irrigation application is over-riding importance. Delayed irrigations, particularly when the crop is sensitive to water stress, could affect yields, which cannot be compensated for by subsequent over watering. Timing of irrigation should conform to soil water depletion requirement of the crops which are shown to vary considerably with evaporative demand, rooting depth and soil type as well as with stage of crop growth, therefore rather than basin irrigation interval on calendar or fixed schedules, considerably flexibility in time and depth of irrigation should be maintained to accommodate distinct difference needs during in crop's growth cycle water. The irrigation interval can be obtained from:

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

The average days of irrigation intervals for the proposed crops were calculated as for Pepper every **10 days**, for Onion every **9 days**, for Tomato every **9 days**, and for Sweet Potato every **12 days**. These irrigation intervals are applied only when maximum soil water depletion percentage is kept higher for all crops and when ample water is applied in single irrigation. However, **during critical water requirements of each crops, especially during flowering and seed or ball formation periods**, frequent application (less irrigation intervals) of water is highly recommended, (see the calculation procedure table on annex part).

1.9 Suggestion & Recommendation

Production of economically important crops more than twice in a year through irrigation development is highly encouraged in Ethiopia at present days. To fulfill the objectives of the project, irrigable crops which are suitable to the soil and climatic conditions of the project area, have short growing period and can give reasonable economic yield are proposed in this document. The agronomic study shows that the climate and soil of the project area is suitable for some cereals, vegetables, oil crops, and has no significant limitation for implementation of the proposed irrigation project. The time of dry spell from the offset to the onset of the natural rainfall is wider and the amount and distribution of rainfall is insufficient in the project area. This situation allows the full utilization of irrigation practices throughout the growing season provided that the surface water for irrigation is not limiting. Therefore, production of crops two times in a year using irrigation water and natural rainfall is recommended as full irrigation (dry period irrigation) and supplementary irrigation (wet period irrigation) seasons. However, irrigation is not an easy task. It needs an enormous capital investment and intensive workforce and requires integrated extension work throughout the development practices. The major actors (beneficiaries & development agents and other concerned stakeholders) must work together for sustainable irrigation development in the proposed project area. Since livestock is an integral part of the development, animals should be kept healthier and well fed. Production of animal feeds using irrigation water is also much important in order to help the animals play a vital role in agricultural development. To scale up the existing knowledge of the farmers and Subject Matter Specialists (SMS) on increasing productivity for sustainable growth and development, patterned and continuous trainings, workshops, opinion exchanges, field days, farmers field schools, etc. should be exercised.

Annex 1.1: AGRONOMY ANNEXES

A. Required climatic & other aerodynamic data collected from Mechara Station

S/n	Climate Fac.	Unit	Moths											
			J	F	M	A	M	J	J	A	S	O	N	D
1	Max. Mean tep.	°C	31.2	31.7	34	33.5	34.9	36.2	33.2	32.2	33.9	33.7	32.2	30.7
2	Min .mean tem.	°C	22.2	23.2	24.7	26.2	26.7	28.1	26.2	25.3	25.7	24.1	21.8	20.8
3	Re. humidity	%	54	66	52	73	80	76	80	80	78	68	63	51
4	W. speed	Km/day	100	94	97	93	90	114	105	91	78	84	92	94
5	Sunshine	Hrs/day	7.8	7.8	7.8	7.6	7.7	7.7	6.6	6.8	7	7.8	8.2	8
6	Radiation	MJ/m ²	19.2	20.4	21.4	21.2	20.9	20.3	18.9	19.6	20.1	20.5	20	19.1
7	P.RF	mm/M	17.7	42	90.7	234.1	145.4	68.7	114.2	127.4	94.2	72.9	43.3	7.5
8	Eff. RF	mm/M	0.6	15.2	48.6	163.3	92.3	31.2	67.4	77.9	51.4	34.3	16	0
9	Eto	mm/day	4.38	4.56	5.16	4.99	4.93	5.14	4.56	4.52	4.71	4.8	4.53	4.26
10	Eto	mm/M	131.4	136.8	154.8	149.7	147.9	154.2	136.8	135.6	141.3	144	135.9	127.8

B. Irrigation Efficiencies

Based on the type of irrigation, method of application and farmers’ capacity on the given soil type, the following efficiencies are given below.

Table 1: Project efficiencies

S/n	Type of Efficiencies		Suggested Values, in (%)
1	Conveyance Eff.	Ec	98 %
2	Distribution Eff.	Ed	85 %
3	Application Eff.	Ea	60 %
4	Project Eff.	Ep	50 %

C. Irrigation depth (d, mm)

This is calculated based on the depletion factor (p) of the crop, available soil moisture (Sa), application efficiency (Ea) of the project, and effective root zone (D) of the individual selected crop. The detail is shown in the following table.

Table 2: Irrigation depth, (d, mm)

S/n	Crops	p-value	Sa (mm/M)	p.Sa	D (mts)	Ea	d (mm)	Remark
1	Pepper	0.33	150	49	0.80	0.60	65	
2	Onion	0.42	150	62	0.60	0.60	62	
3	Tomato	0.40	150	60	0.62	0.60	62	
4	Sweet Potato	0.42	150	62	0.60	0.60	62	

D. Interval (days)

The required interval for crop watering as to their requirement is calculated based on the following condition.

S/n	Crops	p-value	Sa (mm/M)	p.Sa	D (mts)	Etc (mm/day)	i, (days)	Remark
1	Pepper	0.33	150	49	0.80	3.71	10	Average watering days are every 9 days.
2	Onion	0.42	150	62	0.60	3.94	9	
3	Tomato	0.40	150	60	0.62	4.00	9	
4	Sweet Potato	0.42	150	62	0.60	3.02	12	

E. Inputs required for the Irrigation Project for one year

Crop	Dry Season (1 st Irrigation)						
	Area, ha	DAP, qt	Urea, qt	Seeds, qt	Fungicide, lt	Insecticide, kg	Herbicide, lt
Pepper	50	50	50	0.3	150	150	---
Onion	60	60	60	2.4	180	180	---
Tomato	50	75	50	0.25	150	150	---
S. Potato	40	40	20	---	---	---	---
Total	200	225	180	2.95	480	480	---

Crop	Wet Season (2 nd Irrigation)						
	Area, ha	DAP, qt	Urea, qt	Seeds, qt	Fungicide, lt	Insecticide, kg	Herbicide, lt
Sorghum	100	100	50	8	150	---	200
Maize	80	80	160	20	240	240	240
H. bean	20	20	10	12	40	40	0
Total	200	200	220	40	430	280	440

Crop	Dry Season + Wet Season					
	DAP, qt	Urea, qt	Seeds, qt	Fungicide, lt	Insecticide, kg	Herbicide, lt
Pepper	50	50	0.3	150	150	---
Onion	60	60	2.4	180	180	---
Tomato	75	50	0.25	150	150	---
S. Potato	40	20	---	---	---	---
Sorghum	100	50	8	150	---	200
Maize	80	160	20	240	240	240
H. bean	20	10	12	40	40	---
Total	425	400	42.95	910	760	440

F. Climatic, Soil and Water Requirements for Major Selected Irrigable Crops

Crop	Total Growing Period (days)	Temperature Requirements for Growth (°C)	Specific Climatic Requirements/ Constraints	Soil Requirements	Sensitivity to Salinity	Water Requirements (mm/growing period)
Pepper	90-150 (+25-35 in nursery)	18- 23 (15-27)	Sensitive to frost	Light to Medium textured soils; pH = 5.5- 7.0	Moderately sensitive	600- 900 (1250)
Onion	100- 140 (+30-35 in nursery)	15- 20 (10-25)	Tolerant to frost; low temp. (<14-16°C) required for flower initiation, no extreme temp. or excessive rain	Medium-textured soil; pH= 6.0- 7.0	Sensitive	350-550
Tomato	90- 140 (+25-35 in nursery)	18-25 (15-28)	Sensitive to frost; high RH, strong wind; optimum night temperature 10-20 °C	Light loam, well drained without waterlogging; pH = 5- 7	Moderately sensitive	400-600
Maize	100- 140+	24- 30 (15-35)	Sensitive to frost; for germination temp. >10 oC; cool temp. causes problem of ripening	Well- drained and aerated soils with deep water table and without waterlogging; opt. pH = 5.0- 7.0	Moderately sensitive	500- 800
Sorghum	100- 140+	24- 30 (15-35)	Sensitive to frost; for germination temp. >10 oC; cool temperature causes head sterility	Light to medium /heavy soils relatively tolerant to periodic waterlogging; pH = 6- 8	Moderately tolerant	450- 650
Bean	fresh: 60-90 dry: 90- 120	15- 20 (10-27)	Sensitive to frost; excessive rain, hot weather	Deep, friable soil; well-drained and aerated; optimum pH= 5.6- 6.0	Sensitive	300- 500