AMHARA NATIONAL REGIONAL STATE
WATER, IRRIGATION & ENERGY DEVELOPMENT BUREAU (BOWIED)

FEASIBILITY STUDY & DETAIL DESIGN OF AGAM WUHA SMALL-SCALE IRRIGATION PROJECT

IRRIGATION AGRONOMY STUDY FINAL REPORT

CONSULTANT:
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(ADSWE)

Amhara National Regional State

Water, Irrigation and Energy Development Bureau

(BOWIED)

Feasibility Study and Detail Design

of

Agam wuha Diversion Small Scale Irrigation Project

Volume III: Irrigation Agronomy Study

Final Report

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FEASIBILITY STUDY & DETAIL DESIGN REPORT STRUCTURE

- Volume I: Watershed Management
- Volume II: Engineering Geology
- **Volume III: Irrigation Agronomy**
- Volume IV: Engineering Design
- Volume V: Socio Economy
- Volume VI: Environmental Impact Assessment
- Volume VII: Economic and Financial Analysis

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ACRONYMS

ADSWE	:	Amhara design and supervision works enterprise
ADO	:	Agricultural development offices
BoFED	:	Burea of Finance and Economic Development
CEC	:	Cation exchange capacity
Cm	:	Centimeter
DA	:	Development agent
EC	:	Electrical conductivity
ETc	:	Evapotranspiration of crop
ETo	:	Potential evapotranspiration
FAO	:	Food and Agriculture Organization
FHI	:	Food for hanger Ethiopia/International
GIWR	:	Gross irrigation water requirement
Ha	:	Hectare
Hr	:	Hour
IPM	:	Integrated pest management
Kc	:	Crop coefficient
Kg	:	Kilo gram
Km/hr	:	Kilometer per hour
Lt	:	Liter
L/S/H	:	Litter per second per ha
LGP	:	Length of growing period
MASL	:	Meter above sea level
M/S	:	Meter per second
MM	:	Millimeter
M	:	Meter
NIWR	:	Net irrigation water requirement
NGO	:	Non-governmental organization
OC	:	Organic carbon
OM	:	Organic matter
ORDA	:	Organization for rehabilitation development association
PPM	:	Parts per million
qt	:	Quintal
RF	:	Rainfall
RH	:	Relative humidity
SWC	:	Soil and water conservation
Sec	:	Second
S/N	:	Serial number
UTM	:	Universal Transverse Mercator

SALIENT FEATURES OF THE IRRIGATION PROJECT

Name of the Irrigation Project: Agam Wuha Weir diversion Irrigation Project

Location: Amhara Region, North Gondar Zone, Gonder zuria Woreda, Baja Ferfer Kebele

Project site elevation:	1854 masl
Soil texture:	clay
Net irrigable land for full irrigation farming:	90 ha
Net irrigable land for supplementary irrigation farming:	90 ha
Water abstraction system:	Diversion weir
Client:	ANRS BoWRD
Consultant:	ADSWE

1. INTRODUCTION

1.1. General

Amhara National Regional State (ANRS) is one of the nine regions of the country, located in the northern part of Ethiopia, extending from 9° to 14°N and 36° to 40°E and covers a total land area of 1, 61828.4 square kilometers or 16,182,840 hectares which makes up 11% of the size of the country; and inhabited by with an estimated population of 19.24 million people (ANRS BoFED, 2013 population projection).

Interms of spatial distribution of the Region's population, close to 90 % lives in the rural areas whose economy is mainly based on agriculture. Hence the agricultural sector is the main sources of income and employment for the bulk of the population. It also accounts a great share for the country's total GDP and foreign/export earnings. Although the region is within the high agricultural potential of the country, agricultural productivity remains low, mainly due to unreliable rainfall and backward agricultural systems; its growth has not been rapid enough to meet the challenges that it has faced. The dependency of the sector on rain-fed production, the low utilization of modern agricultural inputs, inadequate infrastructural development, poor marketing, etc, are some of the critical factors that impedes the rapid growth of the sector. These constraints coupled with high population growth have exposed the region to the problems of food shortage and mass poverty.

Farmers in the region largely practices mixed farming where they grow crops and rear animals. Especially crop production is highly dependent on rainfall and is the predominant activity of the region. However, the production capacity of the sector is lagging behind the actual demand of the region. Especially in drought prone woredas of the region food self-sufficiency, at household level, is not assured.

In terms of economy, the sector faces at least two major challenges. The first challenge is that being unable to produce the volume of grain crops required to meet the food demand of the rapidly growing population of the region. The second challenge is the limitations to produce the raw materials and savings required to enhance the growth of the industrial sector and the urban economy as a whole in order to generate the employment opportunities that will absorb the excess labour engaged in agriculture and also to alleviate both urban and rural poverty.

On the other hand, the region has plenty of natural resources such as water potential and suitable irrigable land areas. The total irrigation potential of the region is estimated to be about 1,200,000 ha, out of which 620,428 hectare (51.7%) is under utilization (ANRS BOA, 2012). Thus, strong effort and commitment is highly required to bring these potentials into use. The development of irrigation at all levels facilitates increment of agricultural production in sustainable manner and assist in overcoming of the problem of depending only on natural rainfall for smallholder farmers. In order to mitigate these gaps of production, the Amhara regional government has designed a strategy of sustainable irrigation development and environmental rehabilitation inline with the national government of Ethiopia irrigation development polices and strategies. This strategy is designed to alleviate the problem of erratic and uneven distribution of rainfall occurrences through supplemental (wet season) and full irrigation (dry season) thereby sustainable and increased crop yield can be obtained.

Hence, as parts of regional strategy, the ANRS Bureau of Water Resources Development (BOWRD) has planned to undertake river diversion irrigation project study in North Gondar Administrative Zone, Gonder zuria Woreda in Ferfer kebele. Amhara Design and Supervision Works Enterprise (Consultant), has been commissioned to undertake the study. Thus, this agronomy report is prepared as per the consultancy agreement made between the two parties.

The present agronomy feasibility study report contains: introduction, objectives, study methodology, the project area profile, existing rainfed and irrigated crop production systems, existing agronomic practices, major crop pests and their controlling measures, inputs requirements and utilizations, proposed crops and cropping patterns, crop water requirements, irrigation duty, irrigation schedules, supporting services, conclusion, recommendations, etc.

The feasibility study report also includes references and annexes. In general, the study report can serve as the baseline or guideline for the implementation and development of the Agam wuha River Diversion Irrigation Project (WWRDIP), particularly for agronomy part.

1.2. Objectives

1.2.1 General Objective

The general objective of the project is to bring food self-sufficiency of the beneficiaries and to produce marketable surplus through the provision of irrigation water and modern crop production techniques both in wet and dry seasons.

1.2.2 Specific Objective

The specific objectives of the Agronomy study is to make inventory on :

- The existing agricultural practice (farming and cropping systems, cropping pattern, crop calendar, crop rotation, etc),
- Level of support services (agricultural extension, finance and credits, research and development, agricultural inputs requirements and utilization and crop protection),
- Existing physical features in the study area (i.e. agro-climatic zones, soil conditions, land use, etc.), both traditional and modern irrigation schemes,
- Potentials and constraints that exist in the project area so as to:
  - Study the existing physical features and agricultural situations in the study area /agro-ecology, land use, soil conditions, farming system, cropping systems, etc. /.
  - Assess the existing crop production situation (cropping pattern, crop calendar, etc).
  - Assess the present situations, crops and level of production, cropping systems and rotations, and support services such as extension, finance and credit, research and development, level of agricultural inputs requirements and utilization, crop protection level.
  - Identity the potential and main constraints in the project area and propose suitable development interventions;
  - Propose the necessary interventions measures and thereby ensure the possible increase in crop productivity.
  - Propose measures to upgrade for the community based small-scale crop farming;
  - Improve crop production and productivity on sustainable base by use of appropriate technologies;

- Develop socially acceptable, environmentally friendly, technically feasible and economically viable crops;
- Create employment opportunities in the project area through intensive farming system;
- Develop high yielding, diversified and market-oriented cash crops to replace in the long-run existing subsistence cropping system.
- Compute and analyze the proposed crops water requirement and propose faire irrigation intervals for the understudy project.

1.3. Methodology

In the project area agronomic survey was carried out in the field during the month of April 2015. The field survey study was carried out through field observation of the proposed command area, interview of key informants, primary and secondary data collection and conducting direct discussions with the concerned development agents (DAs) and consultation of relevant woreda offices particularly the agricultural development office.

Observation has been done to identify the on-going agricultural activities, vegetation cover and crop cover of command area, soil types, constraints, potentials and opportunities and the existing irrigation practices.

Primary data sources are directly taken from key informants and individual farmers in their farmland using prepared checklist/formats. Assumption and parameters are based on the result of observation and discussion carried out among the informants and Development Agents (DAs). During discussion, different crop production system and other detail environmental situation of the area has been identified.

Technical data (number of households, land use type, existing cropping pattern, input use, pest occurrence and control measures, etc), are collected from kebele agriculture development offices. Furthermore, climate, topography, agro-ecology, land holding size, cropping calendar, agricultural extension services, draft power (oxen) possession, traditional irrigation practices and technical support, man and oxen day requirements, general production constraints and mitigating measures are the major areas given much attention. Finally, primary and secondary data are cross cheeked and the summary of the two data are incorporated in to this report.

2. DESCRIPTION OF THE PROJECT AREA

2.1 Location and Accessibility

Agam wuha River Diversion Irrigation Project is found in Amhara National Regional State, North Gondar Zone, West Belesa woreda, in Bajja Ferfer kebele about 37 km far from Arbaya (wereda town) in south direction. The project area has 37 km distant gravel road running to Degoma (East Belesa) to Arbaya town and turning to the right 14km far until project headwork site. The geographical coordination of the command area lies at approximately 378437 UTM East longitudes and 1361816N UTM North latitude and an elevation range of from 1864m meters above sea level (masl).

2.2 Agro-Ecology and Climate Condition

2.2.1 Agro-Ecology

According to the traditional Ethiopian agro-ecological zones classification (MOA, 2001) the proposed irrigation project area is basically categorized under Weina dega agro-ecology which is conducive to the production of tropical and sub-tropical crops. The elevation of the command area ranges 1864 meters above sea level (masl).

2.2.2 Climate Conditions

Climate has an important influence on the nature of the natural vegetation, the characteristics of the soil, the crops that can be grown and the type of farming that can be practiced in the region. The climate of an area is highly correlated with its vegetation and, by extension, the type of crop that can be cultivated. The following are the major elements of climate.

2.2.2.1 Rainfall pattern

The proposed project area has unimodal rainfall pattern, which extends from mid June to Late Augest. The mean annual rainfall that the project area received according to the addis zemen station is 1351 mm.

Generally, the rainfall of the project area is characterized by its high variability in both amount and **distribution.** Thus, the main bottleneck for successful crop production in the area is the nature of **erratic** and uneven distribution of rainfall. Hail, and flood are also major problems that occur during July and Augest. *Meher* or *Kiremt* rainfall is largely received in these months. Fifteen years of rainfall, data was used to analyze the computation of irrigation water requirement. However, there is no station that can exactly indicate the project area climatic condition. Addis zemen station is considered for approximation.

Addis zemen station rainfall data has been taken to represent the project area (see Annex).Using CropWat 8.0 software Addis zemen rainfall data was used for the computation and analyses of irrigation water requirements.

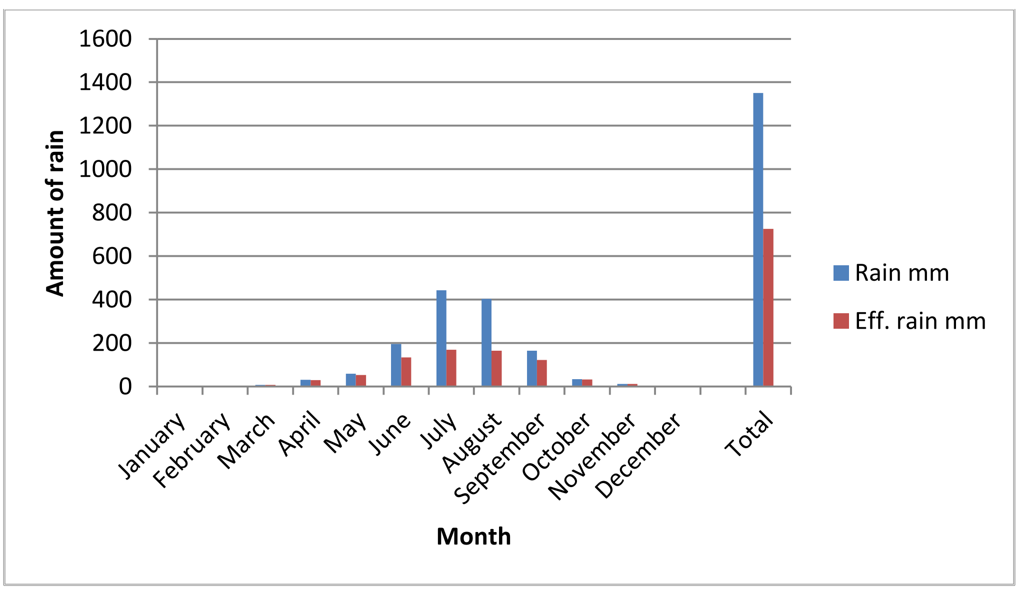

Figure 1*: Average & effective Rainfall at Addis zemen Station*

The pattern of the seasonality of rainfall in the project area is determined by computing mean monthly rainfall ratio with that of rainfall module as rainfall coefficient according to Daniel Gemechu classification shown below:

Rainfall Coefficient	Designation/Representation
<0.6	Dry (represent a dry season/month)
≥ 0.6	Rainy (represent a rainy season/month)
0.6 to 0.9	Small Rains (represent small rain season/month)
≥ 1	Big rains
1.0 to 1.9	Moderate (represent big-rains with moderate concentration)
2 to 2.9	High (represent big-rains with high concentration)
3.0 & over	Very high (represent big-rains with very high concentration).

Rainfall coefficient, which is defined as the ratio of mean monthly rainfall-to-rainfall module (one-twelfth of the annual total), is shown in Table 1.

Table 1: Monthly Average and Rainfall Coefficients

Month.	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total	RF module
Rain	0	0.6	7.1	31.1	58.5	195.9	443.2	404	165	33.9	11.8	0.2	1351	112.58
	0	0.01	0.06	0.28	0.52	1.74	3.94	3.59	1.47	0.301	0.105	0		

According to the above-illustrated data, the dry season for the given area is ranging from October to May; while in June and September the rainfall identified as big rain with moderate concentration. In months of July and Augest, the rain is characterized by big-rains with very high concentration. The rainfall coefficient indicates that the project area has 8 months for full irrigation agriculture interventions, while the remaining months might consider for supplementary irrigation.

2.2.2.2 Temperature, wind speed, relative humidity and sunshine hours

The prevailing temperature considerably influences selection of crops and their growing periods. Optimum temperature plays an important role on the growth period and the production of crops. In the project area the mean monthly maximum air temperature ranges between 25 and 33.1^{O}C; while the mean monthly minimum air temperature ranges between 8.7 and 13.1^{O}C. The annual mean minimum and maximum air temperature of the area is 11.3 and 29.3 ^{O}C, respectively.

The sunshine hour's duration of the project area ranges from 1.8 to 9.9 hours/day, in the months of July and February, respectively.

Humidity level of the atmosphere determines the level of evapo-transpiration. Therefore, it determines the water requirement of the crops. High humidity reduces irrigation water requirement of crops as the evapotranspiration losses from crops depends on atmospheric humidity. There are also harmful effects of high humidity. It enhances the growth of some saprophytic and parasitic fungi, bacteria, and pests, the growth of which causes extensive damage to crop plants. Relative humidity (RH) in the project area varies from the lowest 37(March) to the highest 72% (Aug) and the mean relative humidity is 51%. For almost all crops it is always safe to have moderate relative humidity of above 40% and below 80 which can be considered as conducive for growth and development of crops.

High desiccating wind in the form of storm not only increases crop water requirements, due to increased evapotranspiration, but also adversely affects the growth and yields of crops depending on the crops growth stage, at which it occurs. However, the wind speed, experienced in the area, ranges from 1 m/sec (Augest) to 1.8 m/sec (Jan, Feb, May, and June) which is low and not likely to cause any damage to the crops.

2.3 Topography

Topography is an important factor for the planning of any irrigation project so long as it influences method of irrigation, drainage, erosion, costs of land development, mechanization, labour requirement and choice of crops.

The topographic feature of the command area ranges from moderately sloping to gentle slope and crossed by some moderate and small gullies. The slope gradient class is from 2% to 5% (moderately sloping). The slope gradient indicates that the proposed command area is suitable for surface irrigation (see figure 2).

Figure 2 : Partial view of the command area

2.4 Land Use System and Soil Characteristics

2.4.1 Land Use System

As there are no technically supported land use systems from the grass root level up to regional level, for this reason, the land use data of Ambo ber Agam Wuha kebele is more of approximate. The approximated land use system data obtained from kebele agricultural development office has showed that the total area of this kebele is estimated to be 2,069 hectares. Out of which the share of cultivated land is 1480 ha(71.5%) covered with different crops; and the remaining is divided among forest & bush lands 112.5 ha (5.4%) but the rest are not defined.

The existing land use pattern of the command area is mainly under cultivation; that is under cultivation of field crops in wet seasons by smallholder farmers. The existing land use pattern/practice of kebele where the project command area found has been presented in table below.

According to Ethiopian constitution, every Ethiopian who wants to make a livelihood from farming is entitled to have a plot of land free of charge. Furthermore, private investors, who wish to engage in large-scale agricultural activities, have a right of access to land on a long-term lease basis. Based on key informants interview conducted at selected samples, there is a growing perception that the use rights are augmented by induced land certification. It has also been proved that certification helped in the reduction of conflicts, increasing investments, soil conservation, renting out land as well as improving women's situations.

The average farmland holding size of individual households (HH) is about 0.75 hectare and out of which 0.625 ha is annually cultivated. In addition, most of the HHs found in the project area has fragmented lands on average from three places. In general, the individual households' average land holding size is decreasing through years owing to population number increase. In such situations, to satisfy the needs of additional food requirements, crop yields has to be increased by employing agricultural intensification approaches such as application of irrigation water, introduction of improved farmland inputs, use of appropriate farm managements, employing better cultivation techniques, etc.

2.4.2 Surface Characteristics

As to the surface characteristics (stoniness, rock out crops, water logging and flooding) of the command area, it has estimated that the command area has few to many stones and no rock out crops. Parts of command area having many stones may not suitable for full capacity of crop seedling emergence. Though soils of the command area are heavy clay, soils of the command area may not have seasonal water logging characteristics due to sloppy nature of the command area and low. Majority of the command area have black clay soils, and deep soil characteristics, which is a workable soil depth for crop production; and have slight to severe erosion hazards.

2.4.3 Soil Characteristics

Soil properties (physical, chemical, etc.) greatly influence the growth and thereby yield of crops which is grown. For the determination of important micro/macro elements for the required fertilizer application and for a general soil management, a composite nature of sampling has been made with 0 - 30 cm and 30 - 60 cm soil depths. The laboratory results of physical and chemical analysis of the composite soil samples has presented in Table 4.

Table 2: Summary of physical and chemical analysis of soils of the command area

Soil auger composite sample no	Soil depth (cm)	% Sand	% Clay	% Silt	Textural Class	CEC cmol(+)/kg	pH (H_2O) (1:2.5)	ECe, (dS/m)	% OC	% OM	% TN	Av. P (mg/kg, ppm)
A-1	0-30	32	34	34	Clay loam	53.89	6.03	0.17	1.17	2.02	0.10	8.08
B-1	30-60	24	44	32	Clay	66.40	6.35	0.14	1.01	1.75	0.09	6.59
A-2	0-30	24	42	34	Clay	86.40	6.94	0.56	1.33	2.29	0.11	6.72
B-2	30-60	18	52	30	Clay	89.73	8.04	0.51	0.70	1.21	0.06	3.60
A-3	0-30	22	38	40	Clay loam	90.95	7.68	0.32	0.98	1.68	0.08	3.26
B-3	30-60	14	58	28	Clay	84.21	8.14	0.40	0.90	1.55	0.08	1.16

Source: ADSWE soil laboratory, 2015

2.4.2.1 Soil physical properties

a) Texture

Soil texture refers to the relative proportion of sand, silt and clay in a mass of soil. Texture is important in that it helps to determine the capacity of the soil to retain moisture and air as both are necessary for plant growths. Soils with greater proportion of large particles are well aerated and allow water to pass through the soil more quickly.

Based on field observations and soil laboratory results, from soil samples collected from command area and submitted to ADSWE soil lab, the command area has predominantly clay textured. (table 2)

b) Effective soil depth

According to FAO, soil depth is categorized as follows:

Very shallow	< 30 cm
Shallow	30 – 50 cm
Moderately deep	50 – 100 cm
Deep	100 – 150 cm
Very deep	> 150 cm

The effective soil depth of the command area was measured during field working period; and hence, most of the study area soils are categorized as deep-to- very deep soil (100-150 cm and more than 150 cm meters).

2.4.2.2 Soil chemical characteristics

a) Soil reaction (pH)

The pH of soils can provide overall information of soils condition for crop growth and for crop selection. For these purposes soils reaction was measured in a 1:2.5 (H_2O) soil suspension.

Table 3: **General rating for soil pH**

Rating	pH	General Interpretation
Very high	>8.5	Ca and Mg unavailable, may have high Na, possible B toxicity otherwise as below
High	7.0-8.5	Decreasing availability of P and B above 7.0 increasing liability of P,deficiency of Co, Cu, Fe, Mn, Zn.
Medium	5.5-7.0	Preferred range for most crops
Low	< 5.5	Acidic soil. Possible Al toxicity and excess Co, Cu, Fe, Mn, Zn. Deficiency in Ca, K, N, Mo, P, S

The pH values of soils of the study area ranges from 6.03 to 8.14 for pH (H2O) soil suspension test in the top 0-60cm soil depth. Based on soil Lab results (Table 4) and pH rating (Table 5), the pH of the command area soil at 0-30 cm depth is mainly found at prefered range while 30-60cm depth is found at high level where 5.5 -7.0 range preferred for most crops growth and development. Micronutrients like zinc, copper, iron and manganese are less available and phosphorus is tied up by the abundantly available Calcium and Magnesium in soils having pH range 7.0 – 8.5. In general, most crops grow satisfactorily on soils with a pH ranging from 6.2 to 8.3; and where soils with a pH of 8.3 or greater than these values usually have high sodium contents. Conversely, soils with a pH below 5.5 are strongly acidic soils and limit the availability of essential elements (N and P).

b) Electrical conductivity (ECe)

The best method for assessing soil salinity is to measure the electrical conductivity of the saturated soil extract, the ECe. Salinity effects on plants, as measured by the electrical conductivity of the saturated extract, ECe, in decisiemens per meter, dS/m, are indicated in Table 6.

Table 4: Electrical conductivity expressed in dS/m

Rating	EC (dS/m)	Crop Reaction
Non-saline	< 2	Salinity effects mostly negligible
Slightly saline	2- 4	Yields of very salt-sensitive crops may be restricted
Moderately saline	4 - 8	Yield of many crops restricted
Strongly saline	8 - 16	Only salt-tolerant crops yield satisfactorily
Very strongly saline	> 16	Only a few very salt-tolerant crops yield satisfactorily

Source: Based on Fundamentals of Soil Science, 8th Edition.

The effect of salts on plants is mainly indirect, that is, the effect of salt on the osmotic water potential. Decreasing water potential due to salt reduces the rate of water uptake by roots and germinating seeds.

Based on the soil lab result (ADSWE, 2014), soils of the command area has ECe values ranging from 0.14 to 0.56 dS/m, which indicates a non-saline effect on the selected crops, as presented in Table 4 & 6.

c) Total Nitrogen

The general rating for the total nitrogen according to the Kieldahl's method is as indicated in Table 6.

Table 5: Interpretation of total Nitrogen

N (%)	Rating
> 1.0	Very high
0.5 - 1.0	High
0.2 - 0.5	Medium
0.1 - 0.2	Low
< 0.1	Very low

Total nitrogen values of the command area soils ranges from 0.06 to 0.12% in the top 0-60cm soil depths, which indicates the range low to very low level of TN in the soil profile. Thus, N source fertilizers response is high (See Table 4 and Table 7).

d) Available phosphorus

Available phosphorus (P) has been determined by the Olsen method of bicarbonate extraction.

Table 6 : Interpretation of phosphorus by Olsen's method

Available P (ppm)	**Value**	**Comment**
> 15	High	Fertilizer response unlikely
5 –15	Medium	Fertilizer response probable
< 5	Low	Fertilizer response most likely

Soils of the command area have showed high available P values. The available P range for the command soil is from 1.16 to 8.08 mg/kg or ppm in the top 0-60cm soil depths. Therefore, the soil lab result has indicated that soils of the command area are low to medium in available P; hence, P source fertilizers response most likely in the command area (Table 4 and Table 7).

e) Organic matter (OM) and organic carbon (OC) content

Organic matter is a good reserve for plant nutrition. Almost all life in the soil is dependent on OM for nutrients and energy. The importance of OM for plant growth is so vital. The primary or original source of soil OM is the production of the primary producers (the higher plants). This organic material is subsequently consumed and decomposed by soil organisms. The result is the decomposition and the accumulation of OM in soils that has great diversity and a highly variable composition.

During decomposition of plants and animals residues, there is a loss of carbon as carbon dioxide and the conservation and reincorporation of nitrogen into microbial products, which eventually are incorporated into humus. Consequently, humus contains about 50-60% carbon (C) and 5% nitrogen (N) producing a C: N ratio of 10 or 12 to 1. The more decomposed the humus is the lower or narrower will be the C: N ratio. Humus is a good source of biologically available nitrogen. Humus is also a significant source of sulfur and phosphorus.

Based on the soil lab results, soils of the command area OC content ranges from 0.7% to 1.17% in 0-60cm soil depths, which indicates a very low contents of OC; whereas the OM content ranges from 1.21% to 2.29% in the same depths of soils, which is indicating very low to medium contents of OM (Table 4 and 9).

Table 7 : Interpretation of OM and OC contents

Parameter	Range	Rating
Organic matter (%)	>6	Very high
	4–6	High
	2–4	Medium
	1–2	Low
	<1	Very low
Organic carbon (%)	> 20	Very high
	10-20	High
	4-10	Medium
	2-4	Low
	<2	Very low

2.5 Water Resources

Mena and Agam wuha are perennial rivers in the project area and are major springs. Currently, there is no any irrigation practice in the project area. Aba merfo, Awura Gina, and Tikur are major streams and springs found in the project area. Agam wuha is the river on which small-scale irrigation scheme is studied.

2.6 Natural Vegetation Cover

According to Bajja Ferfer kebele Agriculture office, it has estimated that from the total area of the kebele 112.5 ha of land is covered by bushes, shrubs and trees. The major trees grown are: Abalo, Dedeho, Chibaha, *acacia*, *eucalyptus and* bushes are *Atat*, *kitikita*, *Zigta and Agam.*

3. THE PRESENT AGRICULTURAL SITUATION

3.1 Farming System

Rain-fed with mixed crop-livestock farming systems are the major farming systems in which cereals are dominant, mostly mono cropping and mixed farming where livestock production is undertaken complementary to crop production. This farming system, which accounts for the bulk of food production in the area, is characterized by subsistence farming with its typical feature of low input – low output productivity. Crop production is predominantly carried out under rain fed condition and is frequently vulnerable to natural hazards such as droughts/or erratic rainfall, crop pests, weeds, diseases, etc.

At present, the project area is being farmed, entirely, by small-holder farmers. Farmers use their land predominantly for rainfed subsistence cropping. Almost all of their staple food production comes from this system. Irrigated farming is not a new phenomenon in the project area; and it is practicing at small scales mainly by using traditional and modern river diversions.

3.2 Cropping System

The term cropping system is used to describe the pattern in which crops are grown in a given area over a period, and it includes the technical and managerial resources that are utilized. The major cropping systems practiced in the study areas are crop rotation, mono cropping and inter cropping or mixed cropping.

3.2.1 Mono Cropping

It refers to the presence of a single crop in a field. This term is often used to refer to growing the same crop year after year in the same field; this has several disadvantages: it cannot maintain the soil; it encourages pests, diseases and weeds; and it can reduce the soil fertility and damage the soil structure. Hence, mono cropping should be avoided. It is much better to rotate crops, or use intercropping or strip cropping.

3.2.2 Intercropping

This means growing a two or more crops in the same field at the same time. It is possible to do this in different ways: Broadcasting the seeds of both crops, or dibbling the seeds without any row arrangement or planting both the main crop and the intercrop in rows. The main inter cropping practices done in the project area are presented below in the table.

Table 8: The existing inter cropping practice in the project kebele

Main crop	Subsidiary crop	Sowing method
Maize	Faba bean/sorghum/cotton	Broadcasting
Tef	Sorghum/safflower/sesame	Broad casting

3.2.3 Crop Rotation

This means changing the type of crops grown in the field each season or each year (or changing from crops to fallow). Crop rotation is a key principle of conservation agriculture because it improves the soil structure and fertility, and it helps to control weeds, pests and diseases.

Rotating crops is one of the key principles of conservation agriculture. It has many advantages: It improves the soil structure. Some crops have strong, deep roots. They can break up hardpans, and tap moisture and nutrients from deep in the soil. Others have many fine, shallow roots. They tap nutrients near the surface and bind the soil. They form many tiny holes so that air and water can get into the soil. Crop rotation increases soil fertility. Legumes (such as groundnuts and beans) fix nitrogen in the soil. When their green parts and roots rot, other crops such as maize can use this nitrogen. The result is higher, more stable yields, without the need to apply expensive inorganic fertilizer. It helps control weeds, pests and diseases. Planting the same crop season after season encourages certain weeds, insects and diseases. The following are the major crop rotations practiced in the project area.

Table 9: The existing crop rotation patterns of the project area(Agam wuha kebele)

Meher Season (1st)	**Meher Season (2nd)**
Faba bean	Barley/tef/finger millet/sorghum
Sorghum	Chick pea/tef/faba bean
Tef	Sorghum /chick pea/ lentil
Chick pea	Tef /sorghum
Barely	Faba bean/chick pea
Finger millet	Faba bean/sorghum/tef
Wheat	Faba bean/sorghum

Source: Farmers of the project area during agronomy survey

Inter cropping helps for efficient available resource utilization. It increases soil fertility. It also helps yield stability/minimizes risk of crop failure and reduces rapid pest spreads. However, not fit for mechanization and competition between component crops.

3.3 Crops Production and Yields

3.3.1 Rainfed Crops, Cropping Patterns and Crop Calendar

Crop production in the project area is mainly characterized by rain fed subsistence farming in which the average productivity has been significantly decreased due to different constraints particularly moisture stress, serious pests attack on crops, low level or lack of use of modern technologies, etc. The project area is lacking improved practices and inputs for crop production. There is no row planting, no mineral fertilizer use, and poor improved seed use and generally, crop management is considered as very poor.

In the project area, the longer rainy season (*kiremt*) occurs from mid-June to Late-Augest; however, sometime the rain ends in the early-September. During this time of span different crops are grown. Depending on the climatic factors, i.e., late or early start of kiremt rainfall, the cultivated land coverage or cropping pattern vary from year to year. Furthermore, farmers' preferences, market values, quality of land preparation, pest incidences, input availability, length of growing period (LGP), food values of the crops and so on also determines the cropping pattern. Production, productivity, and cropping pattern of the Bajja Ferfer kebele where the project found is presented below the table.

Table 10: Existing crop production and cropping pattern of Bajja Ferfer, (rainfed-cropping season).

Crop type	2005/6			2006/07		
	Cropped Area (ha)	Production (qt)	Productivity (qt/ha)	Cropped Area	Production (qt)	Productivity (qt/ha)
Sorghum	327	3597	11	320	2560	8
Tef	414	4140	10	318	3816	12
Chick pea	280	4200	15	380	3040	8
Maize	106	3180	30	106	1060	10
Faba bean	120	1200	10	108	540	5
Wheat	10	120	12	8	80	10
Barley	35	490	14	40	320	8
Field pea	80	720	9	65	260	4
Lentil	5	35	7	5	15	3
Haricot bean	10	80	8	-	-	-
Niger seed	12	60	5	8	24	3
Linseed	8	48	6	8	24	3
Pepper	6	66	11	8	48	6
Fenugreek	8	40	5	10	30	3
Onion	22	880	40	-	-	-
Potato	9	432	48	-	-	-
Cotton	4	80	20	-	-	-
Sesame	-	-	-	4	14	3.5
Finger millet	-	-	-	26	156	6

Source: Bajja Ferfer Agricultural Development Office.

3.3.2 Existing Irrigated Agriculture and Practices

Irrigation enables smallholders to adopt more diversified cropping pattern, and to switch from low value subsistence production to high-value market-oriented production. It enables farmers to improve crop production and intensification thereby sustaining, improving livelihoods, and food security. Irrigation benefits the poor through higher production, higher yields, lower risks of crop failure, and higher and year round farm and non-farm employment. It is expected to contribute to the national economy in several ways. At the micro level, irrigation could lead to an increase in yield per hectare and subsequent increases in income, consumption and food security.

The existing low productivity/production capacity of crops, due to uneven distribution of rainfall and hail damage enforced farmers to develop traditional irrigation practices. Therefore, irrigated agriculture has gradually developed following rainfall abnormalities and scarcity of land. In the project area there is no trend of irrigated crop production but within the kebele there are traditional irrigation practices. Rain fed crop production is the main income base and covers majority of the annual cultivated land.

According to Bajja Ferfer kebele Agricultural Development Office annual irrigated crops area and yield estimation data, a total of 320 hectares of land was covered by irrigated crops and 15361 quintals. This shows the trend in irrigation practice in the project kebele is poor and productivity of crops is low due to lack of improved technology use (Table 13). Furrow irrigation and surface flooding are widely used irrigation methods practiced in the kebele.

Table 11: Existing traditional irrigated cropping pattern and production in Bajja Ferfer Kebeles

Crop type	2007		
	Cropped Area (ha)	Production (qt)	Productivity (qt/ha)
Potato	21	3550	169
Onion	101	3467	34
Garlic	196	8107	41
Tomato	0.5	219	438
pepper	1.5	18	12

Source: Bajja Ferfer **Kebele Agricultural Development Office, 2015**

3.3.3 Experience of Private and State Agricultural Enterprises

There are no private investment farming companies and state agricultural enterprises in the project area other than smallholder farmers.

3.4 Cropping Practices and Use of Technologies

Analysis of existing agricultural practices must be one of important elements in agricultural development planning. This includes both pre- and post-harvest practices (tillage, land preparation, seed bed preparation, planting methods and date of planting, transplanting, irrigation, application of fertilizers and/manure, cultivation, disease and pest control, crop rotation, harvesting, threshing and winnowing, transport, storage, marketing, etc). All farmers in the area have done these practices even though the degree of implementation varies and not as required.

3.4.1 Pre-Harvest Practices

3.4.1.1 Tillage and land preparation

In the project area land preparation, starts from land clearing if some shrubs, weeds and plant residues are there which otherwise directly starts plowing since many of the pieces of lands are cultivated year after year. Tillage for seedbed preparation is intended to destroy existing weeds and to stimulate germination of weed seeds in the topsoil layer. Tillage mainly uses to loosen, turn and mixes the soil, burying crop residues, vegetation or manure so as to prepare good seedbed. Seedbed preparation in the project area has been carried out using animal drawn local plough called "*Maresha*". According to the project area farmers interview, the highest frequency of plowing is done for teff which is 3. Sowing for most crops is done by broadcasting.

Table 12 : Existing land preparation and weeding frequencies

No.	Crop type	Plowing frequencies(do not include plough for sowing)	Weeding and/or cultivation
I	**Meher crops**		
1	Tef	3(average)	2
2	Finger millet	2(")	2
3	Chick pea	2(")	1
4	Faba bean	2(")	1
5	Sorghum	2(")	1
6	Wheat	2(")	1

Source: Bajja Ferfer Kebele key informant interview, 2015

3.4.1.2 Planting/sowing

Following land preparation sowing (planting) operation starts mid May for finger millet and extends up to early September for chickpea. In general sowing begins shortly after the first rain shower for rainfed crops and usually done by broad casting. Row planting is being mainly practiced for horticultural crops (like potato, pepper, etc) but even not done for some cereals like maize and sorghum. According to the information obtained from project area key informants, the trend of using improved seeds is still very poor, most farmers use local seeds, which are poor in performance (low in yield potential) because of lack of awareness, access and/or some economic reasons.

3.4.1.3 Crop protection practices

Every year a significant amount of crop yield is lost due to crop pest infestation. In this day, in most farming systems, natural mechanisms of regulating the population of crop pests and other organisms have been disturbed or partially replaced by artificial mechanisms such as chemicals and drugs. Under such unnatural conditions, if not using chemicals it will lead to considerable production losses. Hence, instead of direct use of chemicals, other alternative pest control measures are growing such as application of integrated pest management (IPM) method.

In integrated pest management, in the context of farmers environment and the population dynamics of the pest species all suitable techniques and methods are used in the most compatible manner possible so as to maintain pest population at level below those causing economic injury.

Generally, chemical pest control measures are recommended only if all the mechanical, biological and physical measures are ineffective to bring the losses caused by the pest below economic injury level. In the project area, there are economically important insect pests, weeds and diseases of crops.

a) Insect pest

Some of the important insect pests that commonly occurring and causing extensive damages to different crops are presented in the table below.

Table 13: **Common insect pests and crops infested**

S/N	Insect pests		Crops infested	Extent of Damage
	Common name	Scientific name		
1	Ball worm	Heliothis armgera	Chick pea, grass pea	High
2	Cut worm	Agrotis segetum	Potato, chick pea	Medium
3	Aphids	Aphis sp.	Cabbage, barley, wheat	High
4	Red tef worm	Mentalia ignicolis	tef	high
5	Stalk borer	Buseola fusca	Maize, sorghum	high

Source: Bajja Ferfer kebele Agricultural Development Office., **2007/2015.**

b) Weeds

Weeds reduce quality and quantity of crop yield. The major control mechanism used in the project area by farmers is hand weeding for most crops and hoeing for some other crops like potato, maize, garlic, etc. There is also trend of chemical use like 2.4- D to control weeds. Common weeds found in the project area, crops infested are presented below the table. The number of weeding/hoeing varies from one (tef) to four for horticultural crops (like pepper).

Table 14 : some common weed species and crops infested

S/N	Local name /Common Name	Scientific Name	Crops infested	Common control methods used
1	Cuscuta	Cuscuta sp	Faba bean, niger seed	Hand weeding
2	Akenchira	Striga stramonium	Maize, sorghum	Hand weeding, chemical
3	Meskel dais (Adey Abeba =Amharaic)	Bidens pachyloma	All crops	Hand weeding
4	Bermuda grass	Cynodon dactylon	All crops	Hoeing
5	*Purple sedge*	*Cyprus spp*	All crops	Hand weeding
6	Clover	Trifolium rueppellianum	All crops	Hand weeding
7	Mech	Guizotia scabra	All crops	Hand weeding

Source: Bajja Ferfer Kebeles Agricultural Development Office, 2007/2015.

c) Crop disease

Farmers in the project area do not have the concept of crop diseases and they relate the effects with insect pests. Hence, farmers don't practice direct control measures. Diseases are not scientifically diagnosed by expertise in the area and hence shortfall of clear understanding of diseases is another problem. The most common crop diseases identified and cause crop's yield reductions in the project area are: rust on tef, wheat and garlic, late blight on potato, and smut on barley, etc (Table 15).

Table 15: Major crop diseases and crops affected

	Disease types		Crops attacked	Extent of Damage
1	Rust	Puccinia spp.	Wheat, tef	Medium
2	Smut	Sphacelotheca spp.	Barley	Medium
3	Checolate spot	Butrytis fabae	Faba bean	Medium
5	Root rot	Pythium spp	Pepper, onion, garlic	Medium

Source: Bajja Ferfer Kebele Agricultural Development Office, 2007/2015.

d) Vertebrate pest

Birds and Rats are important vertebrate pests in the project area. Mainly they affect maize and sorghum. Traditional control measures are used to control this pests but not effective; and hence significant amount of yield are lost yearly.

3.4.2 Post-Harvest Practices

Harvesting and threshing are the most labour intensive and time-consuming operations and are done in a traditional manner in the project area. Harvesting is practiced for maize, sorghum and teff with sickle; chickpea with hand pulling; onion, garlic and potato with the help of digging hoe, tomato and cabbage hand picking. Cereal and pulse crops are left on the ground for some time to dry after harvest and piled up for short duration. For maize, after the cobs are harvested with its stocks, allowed to dry for some times, the cobs are picked by hand, and then taken to the store (*Gottera*). For horticultural crops after harvest, they are taken soon to the market for sale. Chickpea has been harvested before fully ripe to avoid loss due to shattering. The stalks of maize and sorghum are piled up in the field to be used for different purposes (as fuel and animal feeds for livestock).

Threshing is done after a threshing ground has selected, cleaned and compacted; for teff, and wheat also plastered with cow dung. Crops like teff, chickpea and sorghum are threshed on the prepared ground and oxen, trampling on it, carry out threshing and farmers continuously turn the straw with a forked stick to get the panicles exposed to the oxen hooves and the grain to get loosen and separated. The mixture of chaff and grain are separated by winnowing.

After cleaning the grain from chaffs the produce is mostly packed by plastic bags (*Madaberia*) and transport to home for storage by loading on donkeys' or camels' back. In the project area, the produces are stored in different storage structures; teff, maize, sorghum and chickpeas are commonly stored in "*gotta''* a local storage which is made of fermented mud. Otherwise, bags are the common and temporary storage material that all farmers are using. All storage structures are placed in door. The size and capacity of different storage structures varies from farmer to farmer.

Regardless of the types of structures used and the precautionary measures taken, the overall annual losses of stored grains (by rodents, birds and insect pests like *weevils*) are high. As project kebele experts, stated post harvest losses are estimated up to 15%.

Table 16: Existing crop production schedule/crop calendar for the different farming activities

S/N	Crop type	Land preparation	Sowing	Weeding /cultivation	Harvesting	Threshing
I	**Meher crops**					
1	Duragna	Early Dec– May 15	Early Jun –Late Jun	Early Jul –Mid Jul	mid Oct – Late Oct	Early Nov- Late Dec
2	Wheat	Early Dec–Mid May	Early May - Late Jun	Early Jul – Mid Jul	Mid Oct – Late Oct	Early Nov – Late Dec
3	tef	Early Dec – Mid June	Early Jul to Mid Jul	mid Aug -mid Sep	Early Nov – mid Dec	Mid Dec – Mid jan
4	Faba bean	Early Dec – Mid June	Mid May - Mid Jun	Mid July – Late Jul	Mid Oct – Late oct	Early Nov – Mid Nov
5	Chick pea	Mid Aug – Early sep	Late Aug - Early sep	……	Mid Dec – Late Dec	Late Dec – Mid Jan
6	Sorghum	Early Dec–Early May	Early May - Mid Jun	Early Aug – Mid Sep	Early Dec - Mid Dec	Mid Dec – late Dec

Source: Bajja Ferfer Kebele key informant interview, 2015

3.5 Use of Productivity Enhancing Agricultural Inputs

The challenge for agriculture over the coming decades will be to meet the worlds increasing demand for food in a sustainable way. Declining soil fertility and mismanagement of plant nutrients have made this task more difficult. As long as agriculture remains a soil-based industry, major increases in productivity are unlikely to be attained without ensuring that plants have an adequate and balanced supply of nutrients. The use of improved crop varieties and improved agricultural technologies are also very crucial.

3.5.1 Organic Input Use

Field observation in the study area revealed that farmers use crop residue for animal feed and for fuel, and they also use cow dung for fuel. Because of this severe organic matter, depletion is resulted. There is also severe top soil erosion because steep slopes are under cultivation without appropriately designed soil and water conservation practices.

Even though many-trainings have been given for many of the local farmers on compost preparation and its uses, few farmers have still adopted preparing compost. Generally, very few farmers of the project area have adopted compost preparation and utilization.

3.5.2 Commercial input use

The two essential agricultural inputs (fertilizers and improved seeds) are supplied by cooperatives in the project area; and the other essential input, agro-chemicals, are purchased from private traders in the free market by individual farmers. Fertilizers and improved seeds are supplied through farmers' service cooperatives from respective union. The supplies of fertilizers are summarized in below. However, supply of improved seeds is below the demand.

Agro-chemicals like insecticides and private merchants supply herbicides. However, according to the information obtained from key informants, private merchants supply poor quality and expired agrochemicals and the cost is not affordable. Government organizations or cooperatives are not involved in the distribution of agro-chemicals; however, during the outbreak of major regular pests like ball worm the government office will supply the required chemicals.

Modern inputs such as chemical fertilizers (DAP and UREA), improved seeds, and agrochemicals are introduced into the area through agricultural extension systems. However, farmers of the area are not active in use of inputs. The reason explained by the local farmers for its low use or that they do not use at all is fear of natural hazards (shortages of rainfall), high price of inputs, late arrival/supply of inputs for the consumer farmers; and demand based supply of inputs is not practicing, and their poor economic base to repay the loan. Therefore, strong credit facilities and agricultural extension supports should have to be designed to improve the existing low input use in the project area; otherwise, the level of inputs use will become low in the coming years and hence production becomes lower than the present.

Rural populations of the region in general and project area in particular earn their living by manual labour (human labour and oxen power). As compared to mechanized agriculture, manual labour requires mobilization of more human labour at a time for seasonal farm operations. Human labour, Oxen and donkey powers are the most important power sources of the project area. This labour is readily available and relatively cheap in some months of the year except from June to December where critical farming operations take place.

Draught animals, such as oxen and donkey are the main power sources of traction and threshing in the project area, and Oxen are the major source of draft-power. The total numbers of oxen and households found in the project kebele are about 616 and 1287, respectively. According to the project kebele Agriculture and rural development office, data 114 households do not posses draft oxen.

Farmers, who have no farm oxen, grow crops using a traditional renting agreement, that is, by renting their farmlands to those who have oxen at a crop share of 50 percent. Another option for landowners but who are oxen less farmers is that requesting farm oxen from their relatives who have farm oxen.

In the project area, when farmers face a problem of shortage of labour, they use community labour, where group of farmers work together for each one of the group turn by turn. Such types of group working system locally call it '*Debeyat*'. The major agricultural activities and time where community labour are needed and used are during weeding (hoeing), harvesting and threshing.

When shortage of labor becomes much pronounced the farmers use hired labour at the rate of 50 birr/person per day for both male and female labourers. The existing labour and oxen requirements for various farm operations of major crops, in the project kebele, are presented below the table 17.

Table 17 : Existing labour and oxen requirements for major crops

Crop type	Man & Oxen	Land Preparation (Oxen-paired)	Sowing & Fert app (Oxen-paired)	Weeding & cultivation	Irrigation	Harvesting
Tef	M	22	8	45	-	40
	O	11	4	-	-	-
Sorghum	M	10	6	20	-	20
	O	5	3	-	-	-
Finger millet	M	10	6	80	-	40
	O	5	3	-	-	-
Chick pea	M	14	10	20	-	25
	O	7	5	-	-	-
Wheat	M	10	8	50	-	40
	O	5	4	-	-	-

Source: Bajja Ferfer kebele Key informant interview

3.7 Agricultural Support Services

3.7.1 Agricultural Extension and Training

Agricultural extension is the technology dissemination service to potential producers (i.e., smallholder farmers, private investors, etc). To facilitate the technology dissemination process and the information transfer four development agents are assigned in the kebele who have trained and working in different disciplines, i.e., crop production, livestock production, natural resource management, and animal health. Agricultural development center head person has also assigned to lead and manage all the activities carried out within the kebele.

Technical staffs from the woreda provide technical supports to development agents as required. In-service trainings are also given to development agents to improve their skills and introduce extension package programs.

Although the objectives of construction of farmers' training centers (FTC) in every kebeles is to train and capacitate farmers, on improved and modern agricultural technologies and packages' application by demonstration (for 3 or 6 months), the FTC site has no still started delivering the service and FTC constructions are destroyed. The current and flourishing approach for the dissemination of agricultural technologies to farmers, within the region in general and the project area in particular, is scaling up. This approach is mainly focused on the addressing of best agricultural practices that were tested and/or exercised by few farmers before but very poor in practice.

3.7.2 Agricultural Research

Though the project site is located under the working areas of Gondar Agricultural Research Center, the dissemination/diffusion levels of new technologies to the project area can be considered as very low. In general, there are no Research-Extension-Farmer linkages in the area.

3.7.3 Credit Facility

Amhara Credit and Saving Institute (ACSI) and Co-operatives are the major credit suppliers found in the area. ACSI is working at woreda level (Arbaya town) and cooperatives are working at kebele level. Credit is supplied for improved seed and fertilizer purchasing. However, the amount of credit supplied and the timeliness of the credit to be supplied are not sufficient to satisfy the credit needy farmers. 19

out of 30 kebeles of the wereda are under the support of Safety Net program for food security. The project area kebele is not under Safety Net Program.

3.8 Constraints and Opportunities of Agriculture and Irrigation Development

3.8.1 Agricultural Development Constraints

Based on discussions made with the local farmers and DAs of Kebele and also confirmed by visual observation, during field study, the major constraints for the growths of crop production and productivity are categorized under three main groups and are listed as follow.

3.8.1.1 Social and organizational constraints

- Poor awareness of farmers towards new technologies and improved practices.
- High price of agricultural inputs (i.e., fertilizers, improved seeds, agro-chemicals, etc). Because of this, farmers use local seeds and low amount of inputs, especially low rate of artificial fertilizers per hectare basis.
- Poor working habit(not use their time effectively and wisely).
- Presence of many cultural holidays competing working days of farmers. Institutional constraints
- Poor agricultural research, extension and farmer linkage
- Poor/weak agricultural extension services and trainings.
- Delayed input supply (eg. late arrival of improved seeds that is after farmers covered his farmland with his local seeds).
- Lack of agro-ecology based improved seeds supply.
- Lack of access of Agro-ecologically fit improved crop varieties.
- No agricultural inputs supply for irrigated crops in dry seasons other than the left over ones from Meher seasons.
- Farmers cooperatives are not strong enough institutionally and hence their services supply and managements are poor.
- No sufficient number of credit supplier institutions and credit accesses in the area; and also no timely credit supplies for farmers too.
- Insufficient amount credit supplies for the purchase of agricultural inputs and imposition of inputs direct purchase system (by cash).

3.8.1.3 Agronomic and environmental constraints

- Uneven distribution of Meher rain (interruption of rainfall in wet seasons)
- High moisture stress
- Periodic hail damage and soil erosion problems
- Poor soil fertility status and use of low amount of chemical fertilizer per hectare basis by local the farmers.
- Low level of composting and manure utilization practices of local farmers.
- Occurrences of crop pests' (insect pests, crop diseases, noxious weeds, etc) and their severe attacks on different crops and insufficient controlling mechanisms.
- Lack of good quality agro-chemicals and shortage of chemical sprayers supply.
- Wastage of irrigation water due to poor conveyance structures and unwise utilization (such as, practicing flood irrigation).
- Lack of drought tolerant and early maturing varieties of crops.
- Weed infestation problems at peak periods

3.8.2 Development Opportunities for Irrigated Agriculture

Assessing the available resources in the project area and estimating the gaps that requires from outside is an essential parameter to determine the success or failures of any project. Based on field study and meteorological data analysis on potentials of the project area, the project area has inadequate rainfall for crop production; and farmers' of the area have poor experiences in irrigation agriculture.

There is 14km dry weathered road (from project kebele to road passing to Guahila) and then gravel road access up to Arbaya town for crop input- output transport. The water resource management policy of the country, presence of government development policies and strategies, availability of agricultural support services, cash crop production systems, eagerness of the society for the project, and cheap labour availability are the main potentials and/or opportunities for the development of irrigation projects. Availability of Institutions like FTC, ACSI, and co-operatives in the project area are other potentials for agriculture development.

3.8.3 Development Strategy for Irrigated Agriculture

To achieve the goals of the project (i.e., to attain the food demand of the farmers and produce cash crops for domestic and export markets, and to generate/improve household income) the project has to combine/integrate the following alternative strategies to attain higher farm return.

a) Crop specialization and Crop diversification

Crop specialization is one of the crop production improvement option focused on single crop or a group of crops. For this project, crop specialization is significant for certain crops like vegetables, wheat, etc if supported by strong market- linkage and agro processing industries.

The agricultural development of the project area can be maintained by producing different mixed crops by individual farmers that minimize risks, which is a typical livelihood strategy of the smallholders. In this option the farmers will get more alternative crops from the crop basket to grow for different markets. The crops could be selected from different crop groups like cereals, pulse, oil seeds, fiber crops, perennials. The crop diversity could include food crops to meet the demand of the households. From cereals teff, finger millet, wheat and barley; pulses (chick pea, grass pea, faba bean) and vegetables has to be given more attention for crop diversification.

b) Domestic market oriented

This project relies entirely on domestic markets mainly found in the vicinity of the project area.

4. AGRICULTURAL DEVELOPMENT PLAN

4.1 Project Rationale and Objectives

Rainfall rarely meets the time with required amount of application for plant growth. As a result, average yield of agricultural crops under rain-fed agriculture is low compared to irrigation, which is the application of controlled amount of water at specified time of application. In the project area, traditional rain fed agriculture is the dominant form of farming in which the smallholder farms contribute the largest proportion of the total agricultural production.

However, rainfall in most cases is unreliable and erratic and moreover, productivity is constrained by several interlinked factors such as unpredictable climate (flood, frost, pest etc.) small and fragmented land holding, land degradation, limited technological inputs, etc. Unreliable rainfall, recurrent drought and limited use of the available water resources, coupled with heavy reliance on rain-fed subsistence agriculture, have contributed adversely to the economy of project area.

In the government policy documents, irrigation development is identified as an important tool to stimulate sustainable economic growth and rural development and is considered as a cornerstone of food security and poverty reduction.

The present feasibility study on Agam wuha diversion weir irrigation project would contribute towards the supply of additional foods and cash incomes in the project area, specifically for those farmers who are the farmland owners of the command area and are in low standard of livings. In view of that, food self-sufficiency could be assured and household incomes would be improved.

The main objectives of developing Agam wuha small scale weir diversion diversion irrigation project are:

- to enable smallholders to adopt more diversified cropping pattern, and to switch from low value subsistence production to high-value market-oriented production.
- to enables farmers to improve crop production and intensification thereby sustaining, improving livelihoods, and food security.
- to benefit the poor through higher production, higher yields, lower risks of crop failure, and higher and year round farm and non-farm employment.

- to the micro level, irrigation could lead to an increase in yield per hectare and subsequent increases in income, consumption and food security..

The proposed project has designed to irrigate a net area of 115.5 hectare under both dry and wet seasons at 200 % crop intensity.

4.2 Selection of Crops

4.2.1 Crop Basket Determination

Before the start of the selection of potential crops for the proposed irrigation project, the crop basket or list of crops growing in the project area has prepared and presented in Table 21. The crop basket not necessarily includes all the list of crops currently growing in the project area rather based on the agro-climatic and soil conditions. All possible crops are incorporated in the crop lists because there are potential and suitable crops, which are not currently found in the cropping patterns of the project area and need to be considered in new development intervention.

Table 18: The possible list of crops for irrigated agriculture

Crop group	Type of crops
Cereals	Wheat, barley, Maize ,sorghum, finger millet
Pulses	Chick pea, grass pea, lentil, cow pea, haricot bean, soya bean, mung bean
Oil crops	Safflower, sunflower, sesame
Vegetables	Potato, onion, garlic, cabbage, carrot, Swiss chard, lettuce, tomato
Spices	Fenugreek,
Fruits	Banana, Mango, avocado, orange, papaya, Guava
Other perennial crops	Hops

4.2.2 Crops Selection Criteria

In the project area the smallholder farmers have two major objectives to carry out irrigation agriculture on their plots of land; the primary objective is attaining the food demand of the family members, while the second important objective is growing cash crops to generate household income. Under small-scale irrigation the crops selection should take into account the optimum utilization of water, land and labor to attain the objective of the project. Crop selection is a main and determinant process to ensure the sustainable development of irrigation projects, because the overall goals of the irrigation project are screwing to the improvement of crop outputs.

The criteria for selecting the potential crops should follow multidimensional approach to cover various issues. The criteria could categorize into agronomic, social, environmental, cultural, and business sectors to simplify the determination of the selection criteria. Three major targets of the criteria are: increased crop production, high income generation and restoration of soil fertility.

The criteria considered for the choice/selection of crops are:

- Suitability to the given agro-ecology (soils, agro-climate) and to irrigation technology
- Yield potential of the crop (high productivity)
- Growers' preference and existing cropping experience in commercial farms (farmers existing knowledge and experiences in irrigated agriculture)
- Market opportunity in local and export markets
- Crop potential for irrigated agriculture (irrigation characteristics of the crop);
- Length of growing period (LGP) of the crops (early maturing type).
- Farmers potential attitude to the introduction of new crops;
- Potential of the irrigation water source
- Soil types and soil characteristics
- Availability of high yielding variety with adequate supply and other improved inputs;
- High market value and potential for export market (marketability);
- Potential for maintenance of soil fertility
- Cropping intensity
- Recurrent prevalence of pest infestation
- Consumption habit of the community
- Government policy and development strategies.

4.2.3 Proposed Crops and Cropping Pattern

Based on the aforementioned selection criteria the proposed crops for Agam wuha diversion irrigation project includes: Chick pea, mung bean, sorghum, tef, and wheat for wet season; onion, tomato, garlic, potato, and maize for dry season. In general, the proposed smallholder farm cropping patterns has presented in the table below.

Table 19: Cropping pattern for the proposed crops of the project

Crop	Net command Area (ha)	Area (%)	Planting	Harvesting
Wet season	90	100		
Chick pea	18	20	7-Dec	30-Aug
Tef	18	20	8-Oct	11-Jul
Wheat	27	30	1-Nov	30-Jun
sorghum	18	20	12-Oct	15-Jun
Mung bean	9	10	12-Sep	15-Jun
Dry season		**100**		
Onion	36	40	14-Mar	15-Nov
Tomato	9	10	14-Mar	15-Nov
Garlic	18	20	21-Feb	25-Oct
Potato	18	20	23-Apr	25-Dec
Maize	9	10	3-Mar	15-Oct

4.3 Agricultural Input Requirements

4.3.1 Seed Requirements

Improved Seeds Requirements: Smallholder farmers are intended to utilize high yielding crop varieties under irrigated agriculture. Crop varieties that have been released from agricultural research centres and are tested in similar agro-ecologies can be essential inputs. Shortage of certified crop seeds are identified as one of the major bottlenecks facing farming communities in the project area. To establish reliable seed sources, the smallholder fields shall be involved in seed multiplication activities in order to fulfil their requirement and sell to surrounding smallholder farmers. The estimate of improved seed requirements has given in the table 20.

Table 20: Summary of seed requirement format

Crops	Seed rate (kg/ha)	command (ha)	Requirement (qt)	Potential sources
Wet season				
Chick pea- Shasho, Arerti, Akaki, Mariye, Dubie DZ-10-4, HABRU	120	18	21.6	Seed Enterprises
Sorghum (Birmash, Chiro,Baji)	20	18	3.6	Seed Enterprise

Crops	Seed rate (kg/ha)	command (ha)	Requirement (qt)	Potential sources
Wheat -Magala (HAR 1595) ,Hawii(HAR 2501) ,Doddota (HAR 2508) , Bobitcho ,Udie Yerer ,Foka ,Boohai	175	27	47.25	Seed Enterprises
Tef -Etsub(Dz-01-3186), Dukem(DZ-01-974), Gerado (DZ-01-1281), DZ-Cr-82 and Tseday(DZ- Cr-37)	25	18	4.5	Seed Enterprises
Mung bean- M76, M140, M1134, M-109	32	9	2.88	…
Dry season				
Garlic (Tsedey 92, Bishoftu)	900(tuber)	18	162	Seed Enterprises
Tomato Mersa (Carmen) ,Sirinka I (Cardinal)	0.35	9	0.032	Seed Enterprises
Potato(Zengena (CIP-380479.6), Guasa (CIP -384321.9))	1900(tuber)	18	342	Seed Enterprises
Onion(Bombey red, Adama red)	4	36	1.44	Seed Enterprises
Maize –BH 540, Current released var.	25	9	2.25	
Total				

4.3.2 Fertilizer Requirements

Fertilizer is an important input to ensure high production under improved irrigation agriculture. Moreover, the commercial farmers need maximum yields to sustain their businesses; therefore use of fertilizers will be part of the interventions in the cropping system. Based on the proposed cropping patterns and the fertilizer application rate recommendations given by the research institutions, for different crops, the following requirements has computed and shown in the table 24.

Table 21: Seasonal & annual fertilizer recommendation for full & supplementary irrigated crops

Crop	Command Area (ha)	DAP (qt/ha)	Sub total (qt)	Urea (qt/ha)	Sub total (qt)	Total (DAP + UREA) requirement (qt)
Wet season	90					
Chick pea	18	1	18	1	18	36
Tef	18	1.3	23.4	1	18	41.4
Wheat	27	1.25	33.75	1	27	60.75
Sorghum	18	1	18	0.5	9	27
Mung bean	9	1	9	0.5	4.5	13.5
Dry season						
Onion	36	1	36	1.5	54	90
Tomato	9	2	18	1	9	27
Garlic	18	2	36	1.5	27	63
Potato	18	2	36	0.75	13.5	49.5
Maize	9	1	9	1	9	18
Total						

4.3.3 Agro-Chemicals Requirements

Agro-chemicals: the estimate of the seasonal and annual required pesticides/agro-chemicals for the project and its costs has been presented below in the table. The approach of estimation is done by considering the area likely to require treatment each year, rather than to provide a more expensive "prophylactic" costing.

Table 22: Estimation of seasonal and annual agro-chemicals requirement

Crop	Area (ha)	Rate of application (lt/kg /ha)	Pesticides required (lt/kg)
Wet season			
Chick pea	18	2	36
Sorghum	18	2	36
Tef	18	2	36
Wheat	27	2	54
Mung bean	9	2	18
Dry season			
Garlic	18	2	36
Potato	18	2	36
Maize	9	2	18
Onion	36	2	72
Tomato	9	2	18
Total			

4.3.4 Human Labour and Machinery Requirements

As most parts of the region, human labour and oxen power is the main source of power for any agricultural development. No development is expected without the direct involvement of human labour. Human labour is a driving force to facilitate and organize any farm operation. As compared to mechanized agriculture, manual labour requires mobilization of more human labour at a time for seasonal farm operations. Oxen power is the most important power source of the project area next to human labour. This unskilled labour has been used for the last centuries and is still in use without any modification. Based on interview result and experiences the labour and oxen power requirement of the proposed crops to be grown in the project area per hectare bases are presented in Table 23.

Table 23: Labour requirements in Man-days and Oxen-days

Crop Type	Labor Requirements (man-day/ha)	Oxen power Requirements (Oxen-day/ha)-not paired
Chick pea	77	39
Tef	129	55
Wheat	118	48
Sorghum	67	36
Mung bean	77	38
Onion	260	48
Tomato	250	40
Garlic	230	48
Potato	270	48
Maize	120	60

Source: Key informant interview and expert estimates

4.4 Calculation of Crop Water Requirement

Crop water requirement is defined as the total water needed for evapotranspiration from planting to harvest for a given crop in a specific climatic regime when adequate soil water is maintained by rainfall and/or irrigation so that it does not limit plant growth and crop yield. Water is needed mainly to meet the demands of evaporation, transpiration and metabolic activities of the plant. The most important and initial step for planning, designing and implementation of irrigation projects is the determination of crop water requirements.

Several methods and procedures are available for this. The Food and Agriculture Organization (FAO) of the United Nations has also made available several publications on this subject and other issues related with this. The computer program available in FAO Irrigation and Drainage Paper No. 56 “CROPWAT” has been used for the calculation of crop water requirement. This program is based on

Penman-Monteith approach and procedures for calculation of crop water requirements and irrigation requirements are mainly based on methodologies presented in FAO Irrigation and Drainage Paper No. 24 "Crop Water Requirements" and No. 33 "Yield Response to Water".

As recommended in FAO Publications three steps (procedures) are involved in the calculation of the crop water requirement.

4.4.1 Reference Evapotranspiration (ETo)

The Reference Evapotranspiration (ETo) represents the potential evaporation of a well-watered grass crop. The water needs of other crops are directly linked to this climatic parameter. Although several methods exist to determine ETo, the Modified Penman-Monteith Method has been recommended as the appropriate combination method to determine ETo from climatic data, on a monthly basis, on temperature, humidity, sunshine, and wind speed.

Based on this calculation the value of ETo varies from 2.73 mm/day August to 5.22 mm/day in April, and the average reference evapotranspiration is 4.13 mm/day. All climatic data required for ETo calculation and calculated ETo has tabulated in Annex.

4.4.1.1 Climate data collection

The methods of calculating evapotranspiration from meteorological data require various climatological and physical parameters. The meteorological factors determining evapotranspiration are weather parameters which provide energy for vaporization and removal of water vapour from the evaporating surface. The evapotranspiration process is determined by the amount of energy available to vaporize water. Solar radiation is the largest energy source and is able to change large quantities of liquid water into water vapour. The principal weather parameters are: rainfall, temperature, relative humidity, wind speed, and sunshine hour.

The ETo estimation for Agam wuha diversion weir Irrigation Project is based on Addis zemen meteorological station data.

For the project, the FAO CropWat version 8.0 Software has used to estimate the evapotranspiration by using data obtained from Addis zemen (Rainfall, Temperature, RH, WR and SS) meteorological stations. The monthly ETo for the reference crop has presented in Annex .

4.4.1.2 Climate data conversion

Climate data are, commonly, standardized by the National Meteorological Service Agencies. However, some conversions are required in order to adjust the data into the format accepted by CropWat 8.0 software, i.e. conversion of all the climatic data to the units required for CropWat 8.0. Climate data used for the crop water requirement computation were collected from Addis zemen station to represent the project area (see Annex).

4.4.2 Crop Coefficient (Kc) and Crop Evapotranspiration (ETc)

The effect of crop on its water requirement is represented by crop coefficient (Kc). This is presented by the relationship between reference Evapotranspiration (ETo) and crop evapotranspiration ETc as $ETc = Kc \times ETo$. The values for crop coefficient vary with the crop, its stage of growth, growing season and prevailing water condition. Hence, the second step is required to select suitable values for crop coefficient. Based on the recommendation of FAO Irrigation and Drainage Paper No. 56 and No. 33 Yield Response to Water, crop coefficients (Kc values) and other factor or aspects have been used for the selected crops in the calculation as presented in Annex.

4.4.3 Effect of Agricultural Practice and Local Conditions

This requires evaluating the effect of climate and its variability over time and area. This also requires to evaluate the effect of soil water availability and agricultural and irrigation practices.

4.4.3.1 Effective rainfall (Peff)

The proportion of rainfall that can enter and support plant evapotranspiration is said to be effective rainfall (Peff). Of the various methods used for CWR calculation, the USDA soil conservation service method has been used to estimate the effective rainfall for this project, that is:

- Peff = (P* (125 - 0.2 * P))/125 ………………for $P \leq 250$ mm
- Peff = 125 + 0.1 * P ………………………….for $P > 250$ mm

Where, Peff = Effective rainfall,

P = Total rainfall

Addis zemen meteorological station data was directly used to calculate Irrigation Water Requirement (IWR) for Agam wuha irrigation project.

4.4.3.2 Irrigation efficiency

To complete the evaluation of the demand, the efficiency of the water distribution system and efficiency of application must be known.

The gross requirement of water for irrigation system is very much dependent on the overall efficiency of the irrigation system, which in turn is dependent on several factors: Method of irrigation, type of canal (Lined and/or Unlined), method of operations (simultaneously and continuous or rotational water supply), and availability of structures (for controlling and distribution and measuring and monitoring).

Based on these factors, the project has planned to impose surface (furrow & basin) irrigation method. Based on Geology study results, concerning the canal systems, only the main canal is lined. Hence, the conveyance efficiency has estimated to be 85%; and the field application efficiency has estimated to be 60% seeing that the soil texture of the command area is predominantly clay type (according to ADSWE soil Lab result). Thus, the overall/project efficiency has estimated to be 43%.

4.4.4 Calculation of Irrigation Water Requirement (IWR)

The crops irrigation water requirement for Agam wuha command has been calculated and presented in annex for both wet and dry seasons as supplementary and full irrigation systems, respectively. The detail NIWR for the proposed cops has presented in Annex.

Irrigation duty

Irrigation duty is the volume of water required per hectare for the full flange of the crops; and it is also the relationship between the volume of water and the area of the crop matures. Moreover, it helps in designing an efficient irrigation canal system. The area, which will be irrigated, can be calculated by knowing the total available water at the source and the overall duty for all crops required to be irrigated in different seasons of the years.

The proposed cropping pattern gives a maximum irrigation water requirement (IWR) in the month of *December, January, February, March and April for dry season crops and Sept and Oct for wet season crops.* The maximum IWR has to be taken for the designing of the irrigation water application and the flows in the entire canal system. However, here for the convenience of the designing and operation of the project, from all the proposed crops, the Maize crop peak net irrigation water requirement (NIWR) which is 5.69 has been taken for the irrigation project duty calculation (for dry season). *The wheat peak NIWR is 4.65 mm/day in the month of October (for wet season).*

$$e = \frac{ec * ea*ed}{100} = \frac{85*60*85}{100} = 43\%$$

Where, e = Scheme irrigation efficiency (%)

ec = Conveyance efficiency (%)

ea = Field application efficiency (%)

ed = distribution efficiency (%)

For the designing of the project, the GIWR is given as follows:

GIWR = NIWR/e = 4.65/0.43 = 10.81 [mm/day] for supplementary irrigation

GIWR = NIWR/e = 5.69/0.43 = 14.4 [mm/day] for full irrigation

The GIWR (14.4 and 10.81 mm/day) represents the daily quantity of water that is required to be applied for dry and wet season crops, respectively. This water quantity is also used for the determination of the canal discharge in consideration of the time of flow and defined as the duty, expressed as l/s/ha.

The duty is calculated by:

$$\text{Duty (D)} = \text{GIWR} \times 1000 \times 10 / (t \times 60 \times 60)$$

Where; Duty – the duty [l/s/ha]

GIWR – Gross Irrigation Requirement [mm/day]

t – Daily irrigation or flow hours [hrs]

The duty for GIWR of 14.4 mm/day (dry season) and 10.8 mm/day (wet season) for daily irrigation time (t = 20 hrs for dry and wet seasons) is supported to be used with surface irrigation method. Thus, duty for 20 irrigation hours of full and supplementary irrigations has computed as follows:

D = (14.4 x 10 x 1000) / (20 x 3600) = 1.83 l/s/h (for full irrigation during dry season)

D = (10.8 x 10 x 1000) / (20 x 3600) = 1.5 l/s/h (for supplementary irrigation during wet season)

4.4.5 Irrigation System/Methods

Among the different irrigation systems, perennial irrigation system will be used for the project site. The irrigation water will be obtained from Agam wuha River, which is perennial, through canals and will be diverted to the command area in right sides of the river.

Among the various irrigation methods, surface irrigation method has been selected for this project. Of the surface irrigation methods furrow, border and basin irrigation methods can be used to supply irrigation water to the plants/crops. However, each method has its own advantages and disadvantages. Care should be taken into account when choosing the method, which is best, suited to the local circumstances; that is, depending on the command area slopes, soil types, types of crops, the amount of water and irrigation equipment available.

Based on the above factors furrow irrigation method has proposed for majority of the proposed crops for this project. The method allows applying light irrigation and can be laid out in sloping fields along the contour. Furrow irrigation method is best suited to the topography and soils of the command area and to the proposed row planted crops. In general, furrow irrigation method is simple, manageable and widely practiced irrigation method. This method is suitable for row crops that cannot stand in water for long periods. The only thing required to use this method is row planting of crops. Besides, basin and border irrigation method would be used for the non-row planted crops. Rotational flow water distribution is also recommended for the project area.

Irrigation schedule (IS)

Irrigation scheduling is one of the managerial activities that aim at effective and efficient utilization of water. Irrigation scheduling is a means of conserving water, which helps in making decisions on allocation of quantity and timing of water supply match with crop needs.

Irrigation schedules are expressed in terms of frequency rate and duration of how water is delivered to a farm unit. The number and timing of irrigation vary widely for different crops. It is the function of crops, soil and climate. Field irrigation scheduling is based on the field water balance, expressed in depth (d in mm), and interval of irrigation (I).

The following relationship is used to determine the irrigation schedules of the proposed crops in the irrigation scheme.

A) Depth of Irrigation application (d):

$$d = \frac{(PxSa)\ xD}{ea}$$

Where; d = Depth of irrigation application

Sa = Total available soil moisture (water) mm/m soil depth.

P = Fraction of available water

(P.Sa) = Readily available soil water (mm/m)

D = Rooting depth (m)

ea = Application efficiency factor

However, since ETc will vary over the growing seasons, the depth in mm and interval of irrigation in days will vary. Hence, the irrigation interval of each proposed crops is computed using the following formula:

Irrigation interval (I):

$$I = \frac{PxS_axD}{ETc}$$

Where; I = Irrigation interval (days)

ETc = Maximum crop evapotranspiration per day (mm/day)

In this project study, it has tried to determine the irrigation intervals of the proposed wet and dry season crops (Table 27). For the wet season, supplementary irrigation will be provided according to the irrigation schedule and following the cessation of *Meher/kiremt* rainfall (Sept and Oct). Generally, it is supplemented depending on the distribution of the *kiremt* rainfall.

The irrigation schedule was determined for the period of peak water demand (mid-season stage). In the early crops growth stages, when the plants are small, the crop water need is less than the mid-season stage. Hence, during the early stages of crops growth, it is possible to irrigate with smaller amount of irrigation water application and frequently.

Generally, timing of irrigation should conform to soil water depletion requirements of the crop, which are shown to vary considerably with evaporative demand, rooting depth and soil type as well as with stages of crop growth.

Table 24 :Irrigation depth and Intervals of proposed crops

Crop	Root depth, (m)	P	Etc, (mm/day)	d = (p*Sa*D)/ea (mm)	I=(P*Sa*D)/Etc (Days)
Wet season					Supplementary irrigation
Wheat	1	0.55	4.65	179	17 (Sept, Oct)
Chick pea	0.6	0.5	4.49	98	19(Oct, Nov)
Tef	0.5	0.5	3.53	81	10 (Sept)
Sorghum	1.5	0.55	3.69	269	31(Aug, Sept)
Mung bean	0.6	0.45	3.21	88	12(Aug)
Dry season					Full irrigation
Onion	0.3	0.3	5.24	29	3(Dec,Jan,Feb, Mar)
Tomato	0.3	0.3	5.26	29	2((Jan, Feb, Mar)
Garlic	0.3	0.3	4.51	29	3 (Dec, Jan, Feb)
Potato	0.4	0.35	6.21	46	3(Jan,Feb,Mar, Apr)
Maize	1	0.55	5.69	179	14(Dec, Jan, Feb)

Note: The irrigation intervals have been determined for clay textured soil (Sa = 140mm/m) throughout the profile.

Critical stages of crops at which moisture stress adversely affects the growth, flowering, seed formation and development, and ultimately the yield. Care has to be taken that crops are adequately irrigated at these stages. Proposed crops critical stages are presented on Table 28.

Table 25 : The most critical moisture sensitive crop growth stages for proposed crops

Crop	Growth stages
Teff	Flowering , grain filling , vegetative period; flowering is very sensitive if no prior water deficit
Wheat	Flowering, panicle initiation, grain formation, tillering
Chick pea	Flowering and yield formation
Onion	Throughout but particularly during bulb formation and enlargement
Potato	Tuber initiation, yield formation, early vegetative period
Chick pea	Throughout but particularly during flowering and pod-setting
Sorghum	Flowering , yield formation , vegetative period less sensitive when followed by ample water supply
Tomato	Flowering , yield formation ,vegetative period, particularly during just and after transplanting
Garlic	Late vegetative stage, bulb enlargement.
Maize	Flowering, grain filling, vegetative period
Mung bean	Flowering, pod filling

Source: AGP, training Manual 2010

Critical stages of crops are at which moisture stress adversely affects the growth, flowering, seed formation and development, and ultimately the yield. At these stages care has to be taken with the intention that crops are adequately irrigated. Hence, the proposed crops critical stages has presented in Table 28 .

4.4.6 Organizational Aspects of Irrigation Schemes

Administrative and technical problems cause great failure of crops yield and irrigation extension, in irrigated agriculture, unless they are solved as quickly as possible. Thus, water users association has to be established; and due attentions should have to be given by the woreda administrative councils and development sectors in solving both social and technical problems.

The project beneficiaries, who organize under the water users association, would have the following advantages:

- Problems of local administration will be solved.
- Damaged irrigation weir and canal structures could be maintained easily and sooner after close supervisions are made by the members of the association and irrigation water managing bodies of the project.
- The organization could construct common storage facilities so that they could store their surplus and low costly productions and sells when the price rises up.
- When the association get the by-Laws can take credits of agricultural inputs, farm tools and equipments for its members.
- The association controls the whole irrigation structures, irrigation water distribution and management operation and maintenance of the weir and canals.

Therefore, the woreda agricultural development office and the woreda cooperative promotion agency should have to take the lion share to carry out the organization of the water users association and its structural set up.

4.5 Crop Yield Estimate and Projection

4.5.1 Crop Yield Estimation

Estimates of with-project crop yields consider the existing yields, which are attained with presently available technology. Projected yields are targeting crop productivity under improved agricultural practice. The number of production years that are required to attain the planned optimum yields depends on suitability of the area, level of farmers' exposure to given technologies and efficiency of supporting institutions.

The following assumptions are made to estimate achievable yield and yield projection: appropriate input supply system, proper irrigation application, appropriate farm management, and provision of consistent agricultural support by competent institutions. Based on the research findings on farmers' fields and farmers' experience the following crop yields are used to compute the expected crop production.

Yield projections are normally required in order to determine the feasibility of the irrigation project. Yield projections are usually made for the first three years of the project over which time the exploitable genetic potential of the different crops is captured. Then the yields stabilize at the same rate for following years provided all other conditions, such as proper use of inputs, viability of the seeds, efficient use of water and good management practices are maintained. Such projections are made for smallholders as it has illustrated in the table.

For the estimation of yield build-up/projection, it is expected that the with-project yields will be improved due to the following favourable conditions:

- Access to full irrigation in the dry season and supplementary irrigation as required during the wet season;
- Reduced flooding and water logging due to drainage works;
- Farmers acquiring necessary agricultural skills and knowledge due to the provision of trainings and strong agricultural extension services;
- Improved access to improved seed varieties and other farm inputs, including fertilizer and agro-chemicals;
- Improved access to improved equipment, credit services;
- Reduced crop losses due to better control of insect pests, diseases and weeds;
- Present average yields obtained by farmers and research institutes.

However, the yield projections (see Table 29) are rough estimates and can be treated with same degrees of flexibility until determined by trials.

Table 26: Yield estimation and projection for smallholder farmers' crops, qt/ha

Crop Types	Without project		With project			Ratio[4]
	Current local average yield estimate[1]	Amhara Region, CSA data, 2005 (EC)[2]	Future Projected Yields (qt/ha)[3]			
Wet season			Year 1 (80%)	Year 2 (90%)	Year 3 (100%)	
Wheat	12	17.8	52	58.5	65	271
Tef	10	14	28.8	32.4	36	240
Chick pea	15	17	40	45	50	500
Sorghum	11	19	40	45	50	278
Mung bean	20	-	24	27	30	150
Dry season			Year 1 (80%)	Year 2 (90%)	Year 3 (100%)	
Onion	40	126	280	315	350	340
Garlic	46	111	104	117	130	137
Potato	48	155	240	270	300	273
Maize	30	29	80	90	100	125
Tomato	160	94	360	405	450	281

[1] *Present study estimate of rainfed & irrigated yields based on kebele survey data, regional data and agronomic assessment*

[2] *CSA STAT database (Amhara, 2013/14)*

[3] *Future yield development rate based on management system (rainfed with supplementary and irrigated)*

[4] *Ratio between present and maximum expected yield*

4.6.2 Production Projection

Taking into account the above yield estimates and the proposed cropping patterns for smallholder farmers, crop production is estimated for both the wet and dry cropping seasons. It is assumed that farmers will use inputs properly and they will receive appropriate technical supports. The crop production estimates at full development stage of the project has presented in table 30.

Table 27: Estimated with-project of smallholder farmers' crops production

Wet season			Dry season			Annual production(tone)
Crops	Area (ha)	Production(tone)	Crops	Area(ha)	Production(tone)	
Check pea	18	90	Garlic	234	18	
tef	18	64.8	Potato	540	18	
wheat	27	175.5	Onion	1260	36	
Sorghum	18	90	Maize	90	9	
Mung bean	9	27	Tomato	405	9	
Sub Total	90	447.3	Sub total	2529	90	Total =2976.3

Source: Expert estimate

4.6 Supporting Interventions

Extension

The success of any project will be measured by the ability to meet designed objectives and targets. Extension support has mainly designed to achieve the following:

- Increasing the agricultural returns, there by improve living standard and alleviate poverty.
- Improving the farmers' capacity to develop agricultural production so that schemes achieve its economic potential.

The achievement of successful schemes and viable project therefore obtained with strong endeavor of the beneficiaries and should not end on completion of the infrastructure. For the farmers to be able to increase the total value of their input, they need not only regular access to markets, credit and on farm inputs but also exposure to technological improvements and an opportunity to learn new skills. It is necessary to ensure that, the level of extension, remains high enough especially during the first three to five years of cropping as this is the time when farmers will need to adopt changes in the cropping pattern, increasing intensity and agricultural practices that can be expected from introduction of development projects. Therefore, it is important to note that, the extension services are in place and prepared prior to the onset of the project.

Training, demonstration, and extension system are proposed for the project. Demonstration on new technologies and improved working practices would be carried out to the project beneficiaries on the field of FTC (farmers training center). Training of farmers on different techniques and crop management practices is essential. Seasonally scheduled trainings should be provided for extension staff of irrigation process including DAs and related woreda experts.

Irrigation development agent, who is qualified in plant sciences and well experienced in irrigation agronomy, has to be assigned to deliver crop irrigation aspect extension service for the beneficiaries of the project.

Research and demonstration

Specific applied research and development for selecting new superior varieties suited to the proposed project and extension activities in dissemination will become instrumental in increasing awareness among growers concerning the values of good varieties and superior seed quality.

Issues that need prompt research include: Develop improved crop management practices specifically in irrigated agronomy, integrated pest management practices (IPM) and post harvest technology. This includes:

- ✓ Varieties development for irrigated cropping.
- ✓ Demonstration works such as farm verification and adaptive field trial should be carried out to demonstrate for farmers practically.
- ✓ Irrigation method and Irrigation scheduling
- ✓ Cropping intensity and input utilization rates, etc.

4.7 Agronomic Practices

To promote the irrigated farming and make economically feasible use of improved agronomic practices are vital. High level of production can be attained after farmers of the project area are adopted improved agronomic practices. Agricultural technologies are too broad and may need specification and modification based on local tangible conditions or test on actual fields. During the project implementation time the following improved agronomic practices should be executed:

Field sanitation and land preparation: Crop residues that harbor insect pests, plant diseases and weed seeds should have to be removed out before land preparation on the project farm field. Deep tillage is required to improve the aeration and water retention conditions of the soil and it helps the root of the crops to penetrate easily into the soil to extract moisture and nutrients from the lower layers of the soil. Frequent plowing in similar soil depth should be avoided to prevent the formation of plow pan, which hinders the root penetration and permeability. Plowing is also necessary to destruct the roots of weedy plants and exposing eggs of crop pests that buried in the soil to heavy sun hit. In poorly drained soils (heavy clay), to prevent water logging, crops have to be grown on raised beds.

Planting method and planting materials: in order to have vigorous growth and obtain optimum yields, recommendations of seeding rate (plant population), spacing between plants and rows, for proposed crops should be followed or adopted. Planting/sowing has proposed on rows. Standardized quality planting materials (seeds) that are insect pest, disease and weed seeds free, unbroken seeds and healthy seedling material should be used. Use of improved seed (crop varieties) has paramount importance to ensure increased production and productivity.

Fertilizer application: fertilizers are used to increase crop production by adding nutrients to the soil, to restore, and to maintain the soil fertility. Furthermore, it is important to use the proper type, placement and application rate at the right time, to ensure increased crop production and productivity. Apart from supplying essential plant nutrients, organic manures are useful to improve the physical structure of the soil, water holding capacity, drainage, workability, etc. Hence, application of organic fertilizers/manures (compost, farmyard manure, crop residues, green manuring, etc) is very important since it improves soils physical, chemical as well as biological conditions.

Irrigation: During irrigation season, sufficient amount of water should be provided to the irrigated crops and supplement wet season crops when rain shortage occurs. According to the recommended schedule, consideration has to be taken particularly during the critical moisture sensitive crop growth stages.

Harvesting: Harvesting of grain crops should be executed when the crop attains full physiological maturity and optimum moisture content. Harvesting of vegetable crops depends on the purpose to be used, availability of storage facility and maturity.

Threshing: after harvesting grain crops should be sun dried, for a certain period (days) in the field, to reduce the moisture content, for threshing. Threshing should be done on clean, well-compacted and animal dung plastered ground.

Storage: the crop product to be stored should be clean, dry and free from field pest infestations. Furthermore, the storage structures should be clean, aerated, rodent and termite proof. To control storage pest attacks different chemicals, botanicals and cultural methods can be used.

4.8 Agricultural Development Scenarios and Options

4.8.1 General

The major target of the irrigation development study at any level is to prepare a developable, feasible, fundable and above all sustainable project to the planners and decision makers for implementation. After formulating cropping pattern, farm inputs, yield estimation and build up crop water requirements in pervious sections, etc the next decisive step of agricultural development planning is to provide at most possible scenarios, options and alternatives.

Agricultural Development Scenarios and Options should give the choice of possible crop mix and farming enterprise available. Justifications for those scenarios and options have to be in place.

4.8.2 Basis of agricultural development scenarios and options

Basis for formulation of scenarios could be: crop types and cropping pattern, settlement and land consolidation, land allocation and re-allocation, development of agro-processing industries and raw materials, integration of livestock with irrigation (such as, livestock & irrigated pasture), fishery and tourism (i.e., creation of a reservoir for development of irrigation could stimulate fishery and lake tourism), irrigation and apiculture (i.e., their compatibility), etc.

On top of the above exemplary basis for the formulation of agricultural development scenarios; "High value crops, particularly vegetables should be grown under irrigation". Justification for these scenarios:

- In the project area rainfall is more or less sufficient to produce one rain-fed crop per year, crops such as cereals, pulses, and oil crops which may give relatively less return can be grown during these season.
- The agro-ecology of the project area is suitable for vegetable production
- Availabilities of road and transport accesses for the produce(although withered road)
- The vicinity of the project area to Gondar town
- There is market access (such as Bahir Dar, Gonder, Addis Zemen)

4.9.3 Pilot scheme and/or research

The recommended cropping patterns and scenarios/options have to be tested on a pilot basis before it is extensively adopted on the whole project area. A pilot scheme serves, for example, to adopt new and presently untried varieties of selected crops to display new agro-technologies and agricultural practices, etc. Recommended crop varieties and new practices for the irrigation project have to be demonstrated as pilot.

5. CONCLUSION AND RECOMMENDATION

It is hoped that in the subsequent years of project implementation crop production and incomes of farmers would be increased through the adoption of double or triple crop intensity, adequate inputs utilization, growing more income generating crops, and applying proper crop management practices during the course of crop production processes. Agricultural production will be more confidential as irrigation water supply will be available throughout the year and dependency on rainfall would be minimized. Irrigation development project also will create an employment of labor in the project area.

For the success full implementation of the project the following points are recommended:

- The project Water Users Association (WUA) should be strengthened.
- Training on irrigation agronomy and management should be provided to DAs and beneficiary framers to equip them with sufficient techniques and skills of irrigation methods, soil and water management, utilization of agricultural inputs, etc.
- It is quite important to implement the project in accordance with the proposed cropping pattern and calendar so as to avoid irrigation water management related problems.
- Regular and timely inputs supply, credit facilities and marketing channels should be arranged.
- Since soils of the command area are clay textured, careful water and soil management should be carried out and optimum moisture content should be maintained to improve workability of the soil during land preparation; and mulching should be practiced after sowing.
- Irrigation water should be used as efficiently as possible. Wastage of water should be avoided; night store should be carried out.
- Different demonstration and adaptation trials should be adopted on farmers' fields.
- Strengthen the existing soil and water conservation practices.
- Timely weeding and adequate number of weeding practices should be executed.
- Frequent pest infestation assessment and adequate control measure on time has to be done.

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7. ANNEXES

Annex 1: Monthly reference evapotranspiration using modified Penman-Monteith method

Country: Ethiopia Station: Addis Zemen

Agam wuha : Alt: 1854 masl; Lat: 12.19^0; Long: 37.53^0

Month	Min Temp	Max Temp	Humidity	Wind	Sunshine	Radiation	ETo
	°C	°C	%	m/s	hours	MJ/m²/day	mm/day
January	9.3	30.9	41	1.8	8.9	19.9	4.22
February	10.3	31.9	39	1.8	9.9	22.8	4.82
March	11.3	33.1	37	1.7	9.5	23.6	5.22
April	13.1	29.3	42	1.5	8.8	23.1	4.96
May	12.7	31.3	47	1.8	7	20.1	4.76
June	13.1	28.2	60	1.8	5.8	18	4.11
July	12.7	26.1	70	1.2	1.8	12.1	2.82
August	13	25	72	1	1.9	12.3	2.73
September	11.5	25.4	70	1.2	6.8	19.6	3.66
October	10.9	29.7	53	1.5	8.9	21.6	4.32
November	9.3	29.4	50	1.5	9.6	21.1	4.05
December	8.7	30.7	44	1.4	9.4	20	3.85
Average	11.3	29.3	52	1.5	7.4	19.5	4.13

Annex 2: Rainfall data of the study area

Station: Addis Zemen

Month	Rain in mm	Eff. Rain in mm
January	0	0
February	0.6	0.6
March	7.1	7
April	31.1	29.6
May	58.5	53
June	195.9	134.5
July	443.2	169.3
August	403.7	165.4
September	165	121.4
October	33.9	32.1
November	11.8	11.6
December	0.2	0.2
Total	1351	724.7

Annex 3: Length of growing period (LGP), crop coefficient (Kc) and others data for irrigated crops

Crops proposed	LGP	Initial	Dev.	Mid	Late	Planting Date (G.C)	Harvesting date	Land share %	Yield response					Critical deplition (P)			Root depth (m) (stages)		crop max.ht (m)
Wet Season								**100**	**1**	**2**	**3**	**4**	**5**				Initial	Late	
Chick pea	100	15	30	35	20	30-Aug	7-Dec	20	0.30	0.55	0.60	0.20	0.80	0.45	0.50	0.50	0.10	0.60	0.4
	Kc	0.4		1.0	0.35														
Teff	90	15	20	35	20	11-Jul	8-Oct	20	0.20	0.60	0.50	0.20	1.00	0.45	0.50	0.50	0.05	0.50	1
	Kc	0.7		1.0	0.3														
Wheat	125	20	35	45	25	30-Jun	1-Nov	30	0.20	0.65	0.55	0.20	1.15	0.50	0.55	0.55	0.15	1.00	1.0
	Kc	0.3		1.2	0.25														
Sorghum	120	20	35	40	25	15-Jun	12-Oct	20	0.20	0.55	0.45	0.20	0.90	0.50	0.55	0.55	0.10	1.50	1.5
	Kc	0.7		1.1	0.55														
Mung bean	90	15	20	35	20	15-Jun	12-Sep	10	0.20	0.80	1.00	0.30	0.85	0.40	0.45	0.45	0.25	0.60	0.4
	Kc	0.4		1.2	0.35														
Dry								**100**											
Onion	120	25	50	25	20	15-Nov	14-Mar	40	0.45	1.00	0.80	0.30	1.10	0.3	0.3	0.3	0.15	0.30	0.4
	Kc	0.7		1.05	0.75														
Tomato	120	25	35	40	20	15-Nov	14-Mar	10	0.40	1.10	0.80	0.40	1.05	0.4	0.4	0.4	0.15	0.70	0.6
	Kc	0.6		1.05	0.7														
Garlic	120	20	35	40	25	25-Oct	21-Feb	20	0.2	1.1	0.8	0	1.2	0.25	0.30	0.30	0.10	0.30	0.3
	Kc	0.7		1	0.7														
potato	120	15	30	45	30	25-Dec	23-Apr	20	0.45	0.8	0.7	0	1.1	0.30	0.35	0.35	0.10	0.40	0.6
	Kc	0.5		1.2	0.65														

Maize	140	25	40	50	25	15-Oct	3-Mar	10	0.4	1.3	0.5	0	1.3	0.5 0	0.5 5	0.5 5	0.10	1.00	2
	Kc	0.7		1.2	0.6														
								200											

Annex 4: Net Crop Water Requirements for Agam wuha Diversion weir Irrigation Project

- ***Wet season crops***

Chick pea

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Aug	3	Init	0.4	1.19	2.4	9.4	2.4
Sep	1	Init	0.4	1.34	13.4	46.8	0
Sep	2	Deve	0.46	1.67	16.7	42.6	0
Sep	3	Deve	0.66	2.56	25.6	31.9	0
Oct	1	Deve	0.87	3.61	36.1	18.5	17.6
Oct	2	Mid	1.02	4.49	44.9	7.4	37.4
Oct	3	Mid	1.02	4.39	48.3	6.2	42
Nov	1	Mid	1.02	4.23	42.3	5.9	36.4
Nov	2	Late	1	4.06	40.6	3.5	37.1
Nov	3	Late	0.74	2.93	29.3	2.3	27
Dec	1	Late	0.45	1.77	12.4	0.2	12.1
					311.9	174.6	212.1

Tef

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Jul	2	Init	0.7	1.91	19.1	58.2	0
Jul	3	Deve	0.73	1.98	21.8	57.2	0
Aug	1	Deve	0.86	2.31	23.1	56.8	0
Aug	2	Mid	0.97	2.54	25.4	57	0
Aug	3	Mid	0.98	2.9	31.9	51.5	0
Sep	1	Mid	0.98	3.27	32.7	46.8	0
Sep	2	Late	0.97	3.53	35.3	42.6	0
Sep	3	Late	0.72	2.8	28	31.9	0
Oct	1	Late	0.42	1.74	13.9	14.8	0
					231.2	416.7	0

Wheat

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Jun	3	Init	0.3	1.1	1.1	5	1.1
Jul	1	Init	0.3	0.95	9.5	53.8	0
Jul	2	Deve	0.3	0.82	8.2	58.2	0
Jul	3	Deve	0.47	1.27	14	57.2	0
Aug	1	Deve	0.72	1.94	19.4	56.8	0
Aug	2	Deve	0.96	2.52	25.2	57	0
Aug	3	Mid	1.13	3.36	37	51.5	0
Sep	1	Mid	1.14	3.81	38.1	46.8	0
Sep	2	Mid	1.14	4.16	41.6	42.6	0
Sep	3	Mid	1.14	4.41	44.1	31.9	12.2
Oct	1	Late	1.12	4.65	46.5	18.5	28.1
Oct	2	Late	0.84	3.69	36.9	7.4	29.5
Oct	3	Late	0.46	1.99	21.9	6.2	15.6
Nov	1	Late	0.25	1.04	1	0.6	1
					344.7	493.5	87.5

Sorghum

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Jun	2	Init	0.7	2.87	17.2	28.2	0
Jun	3	Init	0.7	2.57	25.7	50.2	0
Jul	1	Deve	0.72	2.29	22.9	53.8	0
Jul	2	Deve	0.81	2.19	21.9	58.2	0
Jul	3	Deve	0.9	2.46	27	57.2	0
Aug	1	Mid	0.99	2.68	26.8	56.8	0
Aug	2	Mid	1.02	2.68	26.8	57	0
Aug	3	Mid	1.02	3.03	33.4	51.5	0
Sep	1	Mid	1.02	3.42	34.2	46.8	0
Sep	2	Late	1.01	3.69	36.9	42.6	0
Sep	3	Late	0.86	3.34	33.4	31.9	1.5
Oct	1	Late	0.68	2.82	28.2	18.5	9.7
Oct	2	Late	0.56	2.49	5	1.5	5
					339.5	554.1	16.2

Mung bean

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Jun	2	Init	0.4	1.64	9.9	28.2	0
Jun	3	Deve	0.4	1.49	14.9	50.2	0
Jul	1	Deve	0.65	2.08	20.8	53.8	0
Jul	2	Mid	1.04	2.82	28.2	58.2	0
Jul	3	Mid	1.18	3.21	35.3	57.2	0
Aug	1	Mid	1.18	3.17	31.7	56.8	0
Aug	2	Mid	1.18	3.1	31	57	0
Aug	3	Late	1.04	3.1	34.1	51.5	0
Sep	1	Late	0.62	2.07	20.7	46.8	0
Sep	2	Late	0.37	1.36	2.7	8.5	2.7
					229.2	468.1	2.7

Dry season crops

Onion

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Nov	2	Init	0.7	2.84	17	2.1	15.3
Nov	3	Init	0.7	2.79	27.9	2.3	25.6
Dec	1	Deve	0.7	2.75	27.5	0.3	27.2
Dec	2	Deve	0.75	2.89	28.9	0	28.9
Dec	3	Deve	0.83	3.3	36.3	0	36.3
Jan	1	Deve	0.91	3.74	37.4	0	37.3
Jan	2	Deve	0.99	4.17	41.7	0	41.7
Jan	3	Mid	1.07	4.71	51.8	0.1	51.8
Feb	1	Mid	1.09	5.02	50.2	0	50.1
Feb	2	Mid	1.09	5.24	52.4	0	52.4
Feb	3	Late	1.05	5.18	41.5	0.7	40.8
Mar	1	Late	0.91	4.64	46.4	1.1	45.3
Mar	2	Late	0.81	4.21	16.9	0.6	16.1
					475.8	7.3	468.7

Tomato

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Nov	2	Init	0.6	2.43	14.6	2.1	12.9
Nov	3	Init	0.6	2.39	23.9	2.3	21.6
Dec	1	Deve	0.6	2.36	23.6	0.3	23.3
Dec	2	Deve	0.69	2.66	26.6	0	26.6
Dec	3	Deve	0.84	3.33	36.7	0	36.6
Jan	1	Deve	0.99	4.04	40.4	0	40.3
Jan	2	Mid	1.09	4.58	45.8	0	45.8
Jan	3	Mid	1.09	4.82	53	0.1	52.9
Feb	1	Mid	1.09	5.04	50.4	0	50.4
Feb	2	Mid	1.09	5.26	52.6	0	52.6
Feb	3	Late	1.04	5.18	41.4	0.7	40.7
Mar	1	Late	0.89	4.52	45.2	1.1	44.1
Mar	2	Late	0.77	4	16	0.6	15.2
					470.2	7.3	463

Garlic

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Oct	3	Init	0.7	3.01	21	4	17.9
Nov	1	Init	0.7	2.9	29	5.9	23.1
Nov	2	Deve	0.73	2.94	29.4	3.5	26
Nov	3	Deve	0.82	3.26	32.6	2.3	30.3
Dec	1	Deve	0.91	3.58	35.8	0.3	35.5
Dec	2	Mid	1	3.87	38.7	0	38.7
Dec	3	Mid	1.03	4.1	45.1	0	45.1
Jan	1	Mid	1.03	4.22	42.2	0	42.2
Jan	2	Mid	1.03	4.35	43.5	0	43.5
Jan	3	Late	1.02	4.51	49.6	0.1	49.5
Feb	1	Late	0.92	4.24	42.4	0	42.4
Feb	2	Late	0.8	3.85	38.5	0	38.5
Feb	3	Late	0.73	3.63	3.6	0.1	3.6
					451.6	16.1	436.4

Potato

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Dec	3	Init	0.5	1.99	13.9	0	13.9
Jan	1	Deve	0.51	2.08	20.8	0	20.7
Jan	2	Deve	0.67	2.83	28.3	0	28.3
Jan	3	Deve	0.91	4.04	44.4	0.1	44.3
Feb	1	Mid	1.14	5.27	52.7	0	52.7
Feb	2	Mid	1.19	5.73	57.3	0	57.3
Feb	3	Mid	1.19	5.89	47.1	0.7	46.4
Mar	1	Mid	1.19	6.05	60.5	1.1	59.4
Mar	2	Mid	1.19	6.21	62.1	1.6	60.5
Mar	3	Late	1.14	5.88	64.6	4.3	60.3
Apr	1	Late	0.97	4.9	49	7.3	41.6
Apr	2	Late	0.8	3.94	39.4	9.9	29.6
Apr	3	Late	0.68	3.34	10	3.7	3.8
					550.3	28.8	519

Maize

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Oct	2	Init	0.7	3.09	18.6	4.5	14.8
Oct	3	Init	0.7	3.01	33.1	6.2	26.8
Nov	1	Deve	0.7	2.92	29.2	5.9	23.3
Nov	2	Deve	0.8	3.26	32.6	3.5	29.1
Nov	3	Deve	0.94	3.76	37.6	2.3	35.3
Dec	1	Deve	1.08	4.24	42.4	0.3	42.1
Dec	2	Mid	1.22	4.69	46.9	0	46.9
Dec	3	Mid	1.26	4.99	54.9	0	54.9
Jan	1	Mid	1.26	5.14	51.4	0	51.4
Jan	2	Mid	1.26	5.3	53	0	53
Jan	3	Mid	1.26	5.55	61	0.1	61
Feb	1	Late	1.23	5.69	56.9	0	56.9
Feb	2	Late	1.03	4.96	49.6	0	49.6
Feb	3	Late	0.81	4.03	32.2	0.7	31.5
Mar	1	Late	0.68	3.47	10.4	0.3	9.8
					609.9	23.8	586.5

Annex 5: Irrigation Schedule of Agam wuha Diversion weir Irrigation Project

- ***Wet season crops***

Chick pea

Date	Day	Stage	Rain	Ks	ETa	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
30-Aug	1	Init	0	1	100	50	7.7	0	0	11.1	1.28
15-Oct	47	Mid	0	1	100	51	43.2	0	0	61.7	0.16
26-Oct	58	Mid	0	1	100	51	43	0	0	61.4	0.65
6-Nov	69	Mid	0	1	100	53	44.3	0	0	63.3	0.67
18-Nov	81	End	0	1	100	55	45.9	0	0	65.6	0.63
4-Dec	97	End	0	1	100	50	42	0	0	60	0.43
7-Dec	End	End	0	1	0	4					

Tef

Date	Day	Stage	Rain	Ks	ETa	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
11-Jul	1	Init	0	1	100	51	8	0	0	11.4	1.32
8-Oct	End	End	1.2	1	100	2					

Wheat

Date	Day	Stage	Rain	Ks	ETa	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
30-Jun	1	Init	0	0.46	46	79	18.4	0	0	26.2	3.04
20-Oct	113	End	0	1	100	56	78.6	0	0	112.3	0.12
1-Nov	End	End	0	1	0	12					

Sorghum

Date	Day	Stage	Rain	Ks	ETa	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
15-Jun	1	Init	0	0.59	59	80	14.1	0	0	20.1	2.32
20-Jun	6	Init	0	1	100	57	20.2	0	0	28.9	0.67
12-Oct	End	End	0	1	0	10					

Mung bean

Date	Day	Stage	Rain	Ks	ETa	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
15-Jun	1	Init	0	1	100	43	15.5	0	0	22.1	2.56
12-Sep	End	End	0	1	100	11					

Dry season crops

Onion

Date	Day	Stage	Rain	Ks	ETa	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
15-Nov	1	Init	0	1	100	26	5.6	0	0	8	0.93
18-Nov	4	Init	0	1	100	31	6.9	0	0	9.8	0.38
20-Nov	6	Init	0	1	100	25	5.7	0	0	8.2	0.48
23-Nov	9	Init	1.2	1	100	31	7.3	0	0	10.4	0.4
26-Nov	12	Init	0	1	100	35	8.5	0	0	12.1	0.47
29-Nov	15	Init	0	1	100	33	8.4	0	0	12	0.46
2-Dec	18	Init	0	1	100	32	8.3	0	0	11.9	0.46
5-Dec	21	Init	0	1	100	31	8.3	0	0	11.8	0.46
8-Dec	24	Init	0	1	100	29	8.1	0	0	11.6	0.45
11-Dec	27	Dev	0	1	100	30	8.4	0	0	12	0.46

Date	Day	Stage	Rain	Ks	ETa	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
14-Dec	30	Dev	0	1	100	30	8.7	0	0	12.5	0.48
17-Dec	33	Dev	0	1	100	29	8.7	0	0	12.5	0.48
20-Dec	36	Dev	0	1	100	28	8.7	0	0	12.5	0.48
23-Dec	39	Dev	0	1	100	31	10	0	0	14.2	0.55
26-Dec	42	Dev	0	1	100	30	10	0	0	14.2	0.55
29-Dec	45	Dev	0	1	100	30	10	0	0	14.2	0.55
1-Jan	48	Dev	0	1	100	30	10.4	0	0	14.8	0.57
4-Jan	51	Dev	0	1	100	32	11.2	0	0	16.1	0.62
7-Jan	54	Dev	0	1	100	31	11.2	0	0	16.1	0.62
10-Jan	57	Dev	0	1	100	30	11.3	0	0	16.1	0.62
13-Jan	60	Dev	0	1	100	33	12.6	0	0	17.9	0.69
16-Jan	63	Dev	0	1	100	33	12.6	0	0	17.9	0.69
19-Jan	66	Dev	0	1	100	32	12.6	0	0	17.9	0.69
22-Jan	69	Dev	0	1	100	34	13.6	0	0	19.5	0.75
25-Jan	72	Dev	0	1	100	34	14.2	0	0	20.2	0.78
28-Jan	75	Dev	0	1	100	34	14.1	0	0	20.2	0.78
31-Jan	78	Mid	0	1	100	34	14.1	0	0	20.2	0.78
3-Feb	81	Mid	0	1	100	36	15	0	0	21.5	0.83
6-Feb	84	Mid	0	1	100	36	15.1	0	0	21.5	0.83
9-Feb	87	Mid	0	1	100	36	15.1	0	0	21.5	0.83
12-Feb	90	Mid	0	1	100	37	15.5	0	0	22.1	0.85
15-Feb	93	Mid	0	1	100	37	15.7	0	0	22.4	0.87
18-Feb	96	Mid	0	1	100	37	15.7	0	0	22.4	0.87
21-Feb	99	Mid	0	1	100	37	15.7	0	0	22.4	0.86
24-Feb	102	End	0	1	100	36	15.2	0	0	21.7	0.84
27-Feb	105	End	0.3	1	100	36	15.2	0	0	21.7	0.84
2-Mar	108	End	0	1	100	34	14.5	0	0	20.7	0.8
5-Mar	111	End	0	1	100	33	13.9	0	0	19.9	0.77

Date	Day	Stage	Rain	Ks	ETa	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
8-Mar	114	End	0	1	100	32	13.4	0	0	19.1	0.74
11-Mar	117	End	0	1	100	32	13.5	0	0	19.3	0.74
14-Mar	End	End	0	1	0	18					

Tomato

Date	Day	Stage	Rain	Ks	ETa	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
15-Nov	1	Init	0	0.94	94	49	11	0	0	15.7	1.82
19-Nov	5	Init	0	1	100	37	10	0	0	14.3	0.41
24-Nov	10	Init	0	1	100	40	13.4	0	0	19.1	0.44
30-Nov	16	Init	0	1	100	39	16.2	0	0	23.2	0.45
7-Dec	23	Init	0.2	1	100	39	19.7	0	0	28.2	0.47
14-Dec	30	Dev	0	1	100	36	21.3	0	0	30.4	0.5
22-Dec	38	Dev	0	1	100	38	26.7	0	0	38.2	0.55
30-Dec	46	Dev	0	1	100	38	30.7	0	0	43.9	0.63
7-Jan	54	Dev	0	1	100	39	35.6	0	0	50.9	0.74
16-Jan	63	Mid	0	1	100	43	42.1	0	0	60.2	0.77
25-Jan	72	Mid	0	1	100	43	42.4	0	0	60.6	0.78
3-Feb	81	Mid	0	1	100	45	44	0	0	62.8	0.81
11-Feb	89	Mid	0	1	100	41	40.5	0	0	57.9	0.84
19-Feb	97	Mid	0	1	100	43	42.1	0	0	60.1	0.87
27-Feb	105	End	0.3	1	100	42	40.8	0	0	58.3	0.84
8-Mar	114	End	0	1	100	41	40.2	0	0	57.5	0.74
14-Mar	End	End	0	1	0	21					

Garlic

Date	Day	Stage	Rain	Ks	ETa	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
25-Oct	1	Init	0	1	100	34	4.9	0	0	7	0.81
28-Oct	4	Init	0	1	100	41	6.5	0	0	9.3	0.36
30-Oct	6	Init	0	1	100	36	6.1	0	0	8.8	0.51
1-Nov	8	Init	0	1	100	33	6	0	0	8.6	0.5
4-Nov	11	Init	0	1	100	30	5.9	0	0	8.5	0.33
6-Nov	13	Init	0	1	100	29	5.9	0	0	8.5	0.49
8-Nov	15	Init	0	1	100	27	5.8	0	0	8.3	0.48
10-Nov	17	Init	0	1	100	26	5.8	0	0	8.3	0.48
13-Nov	20	Init	1.7	1	100	29	7.1	0	0	10.1	0.39
16-Nov	23	Dev	0	1	100	34	8.8	0	0	12.6	0.49
19-Nov	26	Dev	0	1	100	32	8.8	0	0	12.6	0.49
22-Nov	29	Dev	0	1	100	33	9.5	0	0	13.5	0.52
25-Nov	32	Dev	0	1	100	32	9.8	0	0	14	0.54
29-Nov	36	Dev	0	1	100	37	11.9	0	0	17	0.49
2-Dec	39	Dev	0	1	100	31	10.4	0	0	14.9	0.57
5-Dec	42	Dev	0	1	100	30	10.7	0	0	15.3	0.59
8-Dec	45	Dev	0	1	100	29	10.6	0	0	15.1	0.58
12-Dec	49	Dev	0	1	100	38	14.9	0	0	21.3	0.62
16-Dec	53	Dev	0	1	100	38	15.5	0	0	22.1	0.64
20-Dec	57	Mid	0	1	100	37	15.5	0	0	22.1	0.64
24-Dec	61	Mid	0	1	100	39	16.4	0	0	23.4	0.68
28-Dec	65	Mid	0	1	100	39	16.4	0	0	23.4	0.68
1-Jan	69	Mid	0	1	100	39	16.5	0	0	23.6	0.68
4-Jan	72	Mid	0	1	100	30	12.7	0	0	18.1	0.7
7-Jan	75	Mid	0	1	100	30	12.7	0	0	18.1	0.7
10-Jan	78	Mid	0	1	100	30	12.7	0	0	18.1	0.7
13-Jan	81	Mid	0	1	100	31	13	0	0	18.6	0.72

Date	Day	Stage	Rain	Ks	ETa	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
16-Jan	84	Mid	0	1	100	31	13	0	0	18.6	0.72
19-Jan	87	Mid	0	1	100	31	13	0	0	18.6	0.72
22-Jan	90	Mid	0	1	100	32	13.4	0	0	19.1	0.74
25-Jan	93	Mid	0	1	100	32	13.5	0	0	19.3	0.75
28-Jan	96	End	0	1	100	32	13.5	0	0	19.3	0.74
31-Jan	99	End	0	1	100	32	13.5	0	0	19.3	0.75
3-Feb	102	End	0	1	100	30	12.7	0	0	18.2	0.7
6-Feb	105	End	0	1	100	30	12.7	0	0	18.2	0.7
9-Feb	108	End	0	1	100	30	12.7	0	0	18.2	0.7
13-Feb	112	End	0	1	100	38	15.8	0	0	22.6	0.65
17-Feb	116	End	0	1	100	37	15.4	0	0	22	0.64
21-Feb	End	End	0	1	0	28					

Potato

Date	Day	Stage	Rain	Ks	ETa	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
25-Dec	1	Init	0	1	100	33	5	0	0	7.1	0.82
28-Dec	4	Init	0	1	100	37	6.5	0	0	9.3	0.36
31-Dec	7	Init	0	1	100	32	6.5	0	0	9.3	0.36
4-Jan	11	Init	0	1	100	37	9.1	0	0	12.9	0.37
8-Jan	15	Init	0	1	100	32	9.1	0	0	12.9	0.37
12-Jan	19	Dev	0	1	100	33	10.6	0	0	15.1	0.44
16-Jan	23	Dev	0	1	100	34	12.1	0	0	17.3	0.5
21-Jan	28	Dev	0	1	100	41	16.3	0	0	23.3	0.54
25-Jan	32	Dev	0	1	100	38	16.9	0	0	24.1	0.7
29-Jan	36	Dev	0	1	100	35	16.9	0	0	24.1	0.7
2-Feb	40	Dev	0	1	100	38	19.4	0	0	27.7	0.8
6-Feb	44	Dev	0	1	100	40	21.8	0	0	31.2	0.9

Date	Day	Stage	Rain	Ks	ETa	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
10-Feb	48	Mid	0	1	100	38	21.1	0	0	30.1	0.87
14-Feb	52	Mid	0	1	100	41	22.9	0	0	32.8	0.95
18-Feb	56	Mid	0	1	100	41	22.9	0	0	32.8	0.95
22-Feb	60	Mid	0	1	100	42	23.3	0	0	33.2	0.96
26-Feb	64	Mid	0	1	100	42	23.6	0	0	33.7	0.97
2-Mar	68	Mid	0	1	100	43	23.9	0	0	34.1	0.99
6-Mar	72	Mid	0	1	100	43	24.2	0	0	34.6	1
10-Mar	76	Mid	0	1	100	43	24.2	0	0	34.6	1
14-Mar	80	Mid	0	1	100	43	24.1	0	0	34.4	0.99
18-Mar	84	Mid	0	1	100	43	24.1	0	0	34.4	0.99
22-Mar	88	Mid	0	1	100	43	24.2	0	0	34.5	1
26-Mar	92	End	0	1	100	42	23.5	0	0	33.6	0.97
30-Mar	96	End	0	1	100	42	23.5	0	0	33.6	0.97
4-Apr	101	End	0	1	100	39	21.6	0	0	30.9	0.72
9-Apr	106	End	0	1	100	37	20.7	0	0	29.5	0.68
16-Apr	113	End	0	1	100	42	23.4	0	0	33.5	0.55
22-Apr	119	End	0	1	100	40	22.5	0	0	32.1	0.62
23-Apr	End	End	0	1	0	0					

Maize

Date	Day	Stage	Rain	Ks	ETa	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
15-Oct	1	Init	0	0.46	46	86	13.7	0	0	19.6	2.27
19-Oct	5	Init	0	0.96	99	64	15.2	0	0	21.8	0.63
24-Oct	10	Init	0	0.98	100	60	19.9	0	0	28.5	0.66
30-Oct	16	Init	0	1	100	54	24.4	0	0	34.9	0.67
8-Nov	25	Init	0	1	100	54	33.9	0	0	48.4	0.62

Date	Day	Stage	Rain	Ks	ETa	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
18-Nov	35	Dev	0	1	100	53	43.6	0	0	62.3	0.72
29-Nov	46	Dev	0	1	100	53	54.7	0	0	78.1	0.82
11-Dec	58	Dev	0	1	100	54	68.7	0	0	98.2	0.95
26-Dec	73	Mid	0	1	100	58	81.3	0	0	116.1	0.9
11-Jan	89	Mid	0	1	100	58	81.7	0	0	116.7	0.84
26-Jan	104	Mid	0	1	100	58	80.9	0	0	115.6	0.89
9-Feb	118	End	0	1	100	56	78.9	0	0	112.8	0.93
26-Feb	135	End	0	1	100	57	79.1	0	0	113.1	0.77
3-Mar	End	End	0	1	0	10					

Annex 6: Irrigation Scheme of Agam wuha diversion weir Irrigation Project

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation deficit												
1. chick pea	0	0	0	0	0	0	0	4.2	0	95.3	95.5	10.7
2. tef	0	0	0	0	0	0	0	0	0	0	0	0
3. wheat	0	0	0	0	0	1.3	0	0	12.2	73.2	1	0
4. Sorghum	0	0	0	0	0	0	0	0	2.1	15.7	0	0
5. mung bean	0	0	0	0	0	0	0	0	2.7	0	0	0
6. Onion	127	138.2	59.7	0	0	0	0	0	0	0	40.9	91.6
7. tomato	133.2	137.3	57.3	0	0	0	0	0	0	0	34.4	85.2
8. Garlic	129.6	81.9	0	0	0	0	0	0	0	17.9	78.6	114.8
9. maize	97.2	139.8	185	141	27.6	0	0	0	0	0	0	19.5
10. maize	158.5	132.6	9.5	0	0	0	0	0	0	41.7	86.4	138.4
Net scheme irr.req.												
in mm/day	4	4.5	2.2	0.9	0.2	0	0	0	0.1	1.7	2.1	2.8
in mm/month	125.3	126.6	67.6	28.2	5.5	0.4	0	0.8	4.3	51.9	63.6	88
in l/s/h	0.47	0.52	0.25	0.11	0.02	0	0	0	0.02	0.19	0.25	0.33
Irrigated area	100	100	80	20	20	30	0	20	60	100	130	120
(% of total area)												
Irr.req. for actual area	0.47	0.52	0.32	0.54	0.1	0	0	0.02	0.03	0.19	0.19	0.27
(l/s/h)												