INTERNATIONAL JOURNAL OF ADVANCE RESEARCH, IDEAS AND INNOVATIONS IN TECHNOLOGY

ISSN: 2454-132X
Impact factor: 4.295
(Volume3, Issue3)
Available online at www.ijariit.com

Irrigation Water Management and Crop Production

Ebissa G. K
Indian Institute of Technology, Roorkee
ebissagadissa@gmail.com

Abstract:* *Agriculture being a key element of the national economy is challenged by variety of problems in development planning. Among these the major ones are climatic changes, topographic constraints, population pressure, ecological degradation & low level of technological advancement, so it needs good potentials of agricultural development. One of the mitigation to reduce challenges of this development is Irrigation practices Looking at this Irrigation Project area, it is with trace amount of rainfall over the year, this does have direct impact on human & cattle population, so it has to be supported by irrigation. Residents of the area develop Teff, Maize & sorghum though the available rain is not promising to harvest yield that even can feed few months. There is no promising grazing area for the cattle of the area too. Irrigation from its very nature has the capacity to solve animal feeds.

The methodology used in this development study was aimed at plainly defining and describing the agronomic situation of the area and out lining the major crop production constraints and developing recommendation for implementation.

Primary and secondary data were collected from the Kebele development agents, farmers and Wareda agricultural and development office using checklists through group discussion and key informant interview on crop production, cropping pattern, farming practice and production constraints.

Crop water requirements of crops are computed using crop wat 4 windows model.

In general, as a conclusion the agro-climatic condition of the project site, the suitability of the soil for crop production, physical feature of the command area and the availability of irrigation water are suitable for development of irrigation.

Despite the above facts, the sustainability of the project is very much dependent on the full participation of the beneficiaries in all aspects of the project implementation. The

participatory approach will create a sense of responsibility and ownership and greatly contributes to the success of the irrigation schemes constructed in previous years.

Keywords: Irrigation Water Management, Irrigation Crop Production, Cropping Pattern, Crop Water Requirement, Irrigation Schedule.

INTRODUCTION

1.1 General

Irrigation development plays an essential role in stabilizing crop production by either supplementing or replacing the need for natural precipitation. Irrigation makes agriculture more confidential. It stabilizes crop production by protecting against drought and by increasing crop yields, increases their income and crops that improve their diet Ebissa G. K. (2017).

Eighty-five percent of the population of Ethiopia depends directly on agriculture for their livelihoods, while many others depend on agriculture-related cottage industries such as textiles, leather, and food oil processing. Agriculture contributes up to 50 percent of gross domestic product (GDP) and up to 90 percent of foreign exchange earnings through exports (Davis *et al.*, 2009). It is widely believed that Ethiopia has ample resources for agriculture. The country has 111.5 million hectares of land. While74 million hectares are arable, only 13 million hectares are currently being used for agricultural activities (Abate, 2007).Water resources are also plentiful in many parts of the country. Referring to the 2007 Housing and Population Census of Ethiopia Abate (2007) pointed out that there were about 12 million farm households providing human resources for agriculture and related activities. Ethiopia's livestock resources are among the top in the world, at least in terms of quantity. The country also has a high level of biodiversity, with several different economically important crops indigenous to the country.

Despite the huge potential of the area, existing traditional farming practice is not in harmony with the needs and requirements of developing a productive and sustainable agriculture in Ethiopia. The food security situation has continued to deteriorate because of various factors including shortage of rain fall, high population growth, deforestation, soil degradation, pest out break and other related factors are threatening food security situation of the area. Although the initiation of farmer's traditional surface irrigation practice is appreciated, it is not in a position to provide sustainable supply source and effective utilization of water. Therefore, the development of Nanno Small Scale Irrigation Project diversion irrigation is expected to contribute towards alleviating these problems thereby increasing food supply and income source to the community and also at local and regional levels (Ebissa G. K. et al 2017). Fortunately, Ethiopia is lucky in that it has got ample source of surface and subsurface water for which it is known as "The Water Tower of East Africa." Moreover; the irrigation potential is estimated to be about 4.25 million hectare of which only 5.8% is irrigated.(source: Study carried out by International Water Management Institute-IWMI). Nowadays, implementation of small and medium scale irrigation schemes is being given priority in the water sector development strategy of Ethiopia.

1.2 Objectives

The aim of this paper is (1) To evaluate the existing agricultural situation of the area including crops grown, the cropping pattern and farming practice, (2) To propose the necessary interventions and ensure the possible increase in productivity, (3) To investigate the suitability of soil, climate and water to irrigated agriculture, (4) To estimate crop water requirements, (5) to estimate input requirements of irrigated crops, (6) Estimate of monthly potential Evapo-transpiration and rainfall deficit, (7) Estimation of incoming floods to the diversion and the outflow design flood, and in General to assess Irrigation water management and crop production.

1.3 Study Methodology

The methodology used in this development study was aimed at plainly defining and describing the agronomic situation of the area and out lining the major crop production constraints and developing recommendation for implementation.

Primary and secondary data were collected from the Kebele development agents, farmers and Wareda agricultural and development office using checklists through group discussion and key informant interview on crop production, cropping pattern, farming practice and production constraints. Four soil profiles were dug to a possible soil depth at representative sites in the command area and samples were collected at two different depths to catch different root depths of various crops. Crop water requirements of crops are computed using crop wat 4 windows model.

Hydrological data are essential in the design of the diversion weir, main canal, intake head works, flood protection works and irrigation system. Some of the relevant parameters required at project locations are minimum flow, the mean and maximum flows of the river, the sizing of the weir and catchment characteristics. This study used key informant interviews with community representatives. Secondary data are collected from government offices, National Meteorological Service Agency and Central Statistical Agency. Climatic data were obtained from Bonga branch of the National Meteorological Service Agency. Data obtained from various sources were analyzed using descriptive statistical analysis.

2 DESCRIPTION OF THE PROJECT AREA

2.1 Location

Gondoro river diversion irrigation project is found in Southern Ethiopia nation, nationality and people's regional state, Kefa administrative zone of Adiyo woreda at Yecha kebele. It is found on 64 km away from the zone town, Bonga. The project area is situated at 4.5km far from woreda town, Kaka, from which 2.5km is all weather road and the rest 2km is only dry weather road.

2.2 Catchments characteristics

Generally, the hydrology of the visited site (Gondoro) is dominantly characterized by ephemeral stream typical of narrow valley bottoms with high erosive floods that are often seen damaging culverts and road embankments, and changing the stream course (field observations). The surrounding area of the wier sites is typical of thick alluvial deposit with easily erodible channel bed and banks. Therefore, the dominant hydrology of the sites appears to be flash flood hydrology with extreme short lived high energy. All the sites are un-gauged and require special hydrological treatment combined with careful watershed characterization and parameter generation. Therefore, it has to be underlined that the degree of freedom in generation of runoff from un-gauged catchments is unlimited and requires some degree of control through regional investigation and characterization.

The channel x-section appears to be unerodible with basalt rock bed and filled with mixed bed sediments of bolder and sand. At the time of visit in February 25, 2012, the approximate lean flow could be in the range of ***58.7 l/s.*** The catchment upstream of the weir site appears to be covered partly with high forest land and partly with rain fed agriculture and woodland mixed with thick erodible over burden.

The size of the watershed that contributes runoff to Gondoro weir site, as determined from aerial photograph (scale. 1:50,000), is 10.5 km2.

The type and volume of runoff resulting from catchment area are mainly influenced by climatic and geographic factors. Even though the Geographic factors include both watershed characteristics in determine the time of concentration, Tc, and the curve numbers, like land use /cover/, slope of watershed, soil type, and size of the watershed have been given due emphasis. Land use and soil map used for the approximation of the data is found from the global approximation method

2.3 Climate

Since Ethiopia is situated in the north-eastern part of Africa, it is influenced from the northeast, to the southeast and southwest (West African) winds bringing moisture from the Indian and Atlantic Ocean. In the northern hemisphere summer, moisture laden winds gradually penetrate into the countries as the African sector of the Inter-Tropical Convergence

Zone (ITCZ) progresses northward. The July ITCZ patterns are presented in Figure 2.1.

The main synoptic features that affect the Ethiopian rainfall including the project area are presented by Table 2.1. The project area receives its main rainfall from May to September. The orographic influence on rainfall depth values is also marked in the mountainous area that prevails in the area under study.

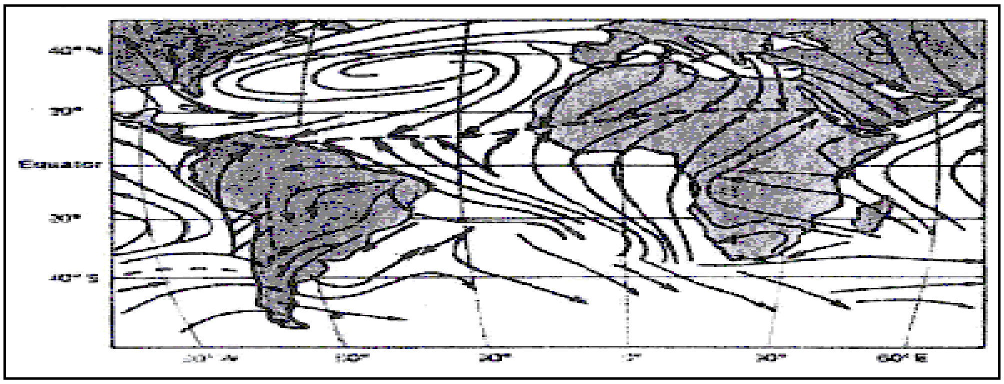

Figure 0-1: Mean Position of ITCZ in July and average winds near the surface

The nearby meteorological stations around the project area are at Bonga and Jimma. Bonga station is assumed to represent metorological parameters required for the estimation of evapotranspiration (Temperature, Relative Humidity, Windspeed and Sunshine Hours). For one thing, it is only about 64km from the project area and at similar altitude. Whereas the average altitude of the command area is 1958m a.s.l, the elevation of Bonga is 2000 m a.s.l.

Table 0-1: Main synoptic features affecting Ethiopian rainfall

	Major synoptic features affecting rainfall over Ethiopia			
Season	**ITCZ (south Atlantic ocean effect / El Nino, SOI)**	**North Indian Ocean effect**	**Low level Jet and Tropical easterly Jet**	**Remarks**
June – Sept (main rainy season)	**ITCZ** moves northwards to red sea. most of ethiopia receives rains	SST condition influence the main rains	Active and moves northwards	South and southeastern parts of Ethiopia do not receive rains.

Feb – May (small rainy season)	ITCZ is in south Ethiopia bringing rains to south and southwestern Ethiopia.	Moisture source for eastern, southeastern, and some central highlands part of Ethiopia receives useful rains.	Moves northwards	As important as the main rain season for eastern and northeastern Ethiopia
Oct – Jan ("dry season")	ITCZ is located further south and brings rain for extreme south and southeastern Ethiopia.	Occasionally causes some untimely rainfall in most part of Ethiopia	Weak and migrate southwards	Crop harvesting time in most of Ethiopia

2.4 Rainfall

The Annual Maximum rainfall data record extending between 1985 to 2007 is analyzed. Out of the total 288 monthly records, there are only 3 months (less than 1%) missing data. The data source is the National Meteorological Services Agency (NMSA). The missing monthly data can be filled using statistical techniques. However, only the recorded data has been used to determine the dependable rainfall. The average annual rainfall at Bonga Station is about 1799 mm. The variability of annual rainfall as explained by coefficient of variation is about 11 %.

The average annual rainfall over the command area is about 1650mm (as seen in the isoheytal map, Fig. 1.1), whereas that of Bonga is 1799mm. Hence, the monthly rainfall values of Bonga are adjusted by a factor of F = 1650/1799 = 0.92 to arrive at the mean monthly and dependable rainfall values for the command area.

The monthly rainfall distribution as shown in Figure 2.2 has uni-modal characteristics with better rainfall distribution from May to September. Rainfall over the watershed is mono-modal; nearly 80 % of the annual rainfall occurs from March to October.

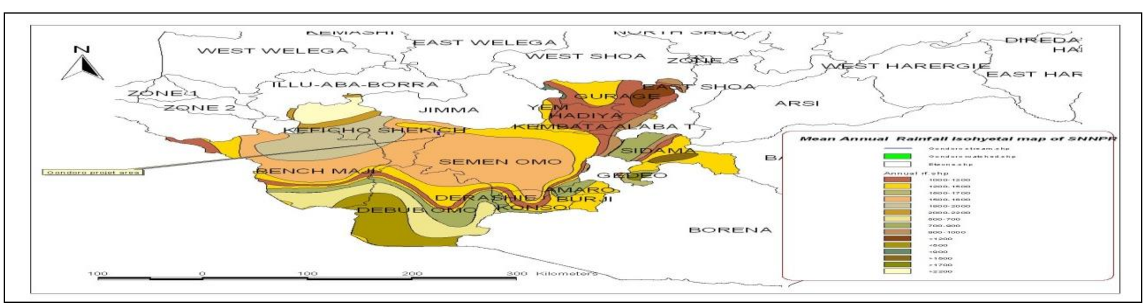

Figure 0-2: Gondoro Catchment & Isoheyts of Annual Rainfall Map

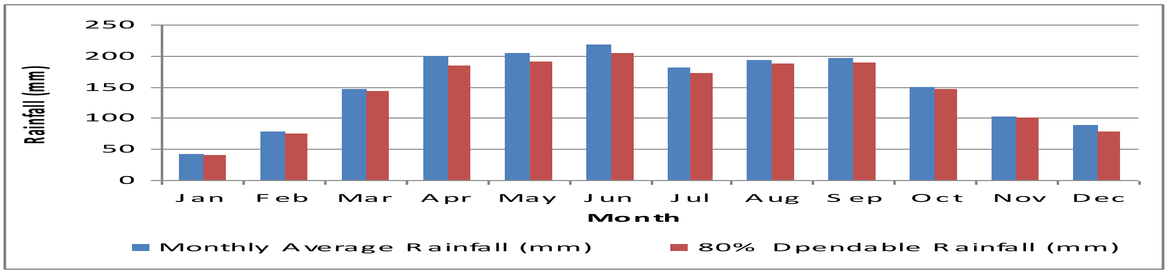

Figure 0-3: Average and 80% dependable rainfall for the project area

Rainfall coefficient (RC) which is defined as the ratio of mean monthly rainfall to rainfall module (one-twelfth of the annual total) is shown in Table 2.2.

Rainfall coefficients:

- Less than 0.6 represent a dry month;
- Greater than 0.6 represent a rainy month;
- 0.6 - 0.9 represent small rain;
- 1.0 - 1.9 represent big rains with moderate concentration;
- 2.0 - 2.9 represent big rains with high concentration.

Table 0-2: Monthly Rainfall and Rainfall coefficients

Month	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	*Total*
mean	41	78	146	199	204	218	182	194	197	150	102	88	1799.0
80% monthly dep. R.F.	39.2	74.0	143.6	184.7	190.5	204.0	171.6	188.1	189.6	145.6	100.4	78.3	
Coeff. Of Correlation	1.0	0.9	1.0	0.9	0.9	0.9	0.9	1.0	1.0	1.0	1.0	0.9	
RC (mean)	0.4	0.7	1.3	1.7	1.8	1.9	1.6	1.7	1.7	1.3	0.9	0.8	

Accordingly, March to Octoer represent big rainfall with moderate concentration whereas months with Small of rainfall are in November and February. There is one dry month which is in January with RC of less than 0.6.

The ERA (2003) IDF curves (10 to 120 minutes duration of rainfall) for different regions of Ethiopia were adopted in the current study. Figure 2.3 shows these

Irrigation by stream diversion is required if crop production is envisaged in the long period of October to March.

Rainfall Intensity

regions. The Gondoro diversion project site is located in Region B1 and the corresponding IDF curves for the region are given in Figure 2.4. These curves will be used to estimate design floods for farm structures such as cross drainage works.

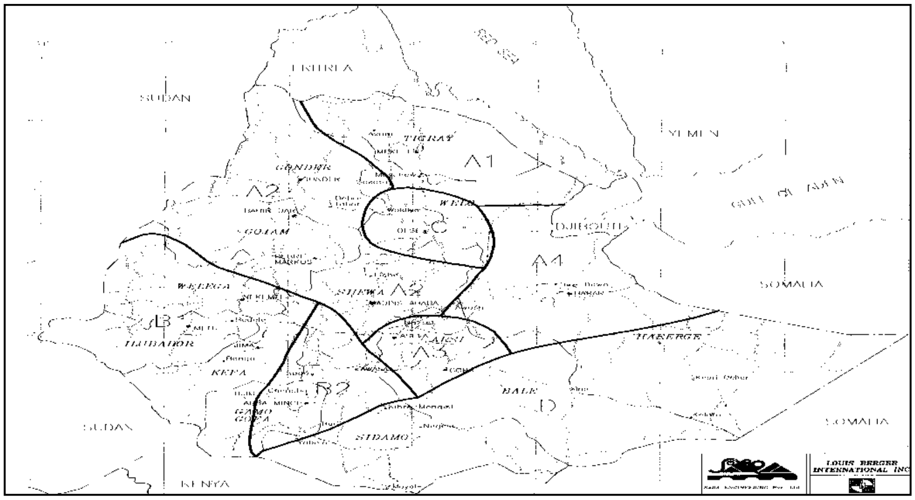

Figure 0-4: Rainfall Regions (ERA, 2003)

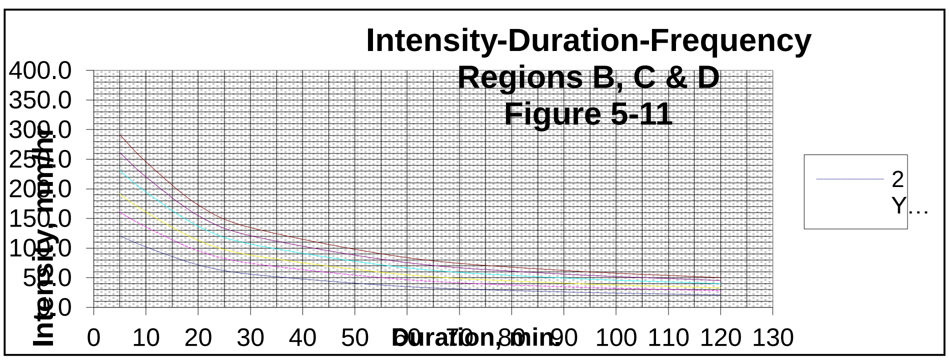

Fig 2 The ERA (2003) IDF curves

2.5 Temperature

Temperature is an important weather element which indicates the relative degree of molecular activity, or heat, of a substance. Several factors influence temperature of the area latitude, altitude, distance from large water bodies, direction of prevailing wind, etc. Maximum temperature usually occurs on day time and minimum temperature during knight. Temperature is normally decreasing with increasing altitude. Maximum temperatures during the day are important factors to determine potential evapo-trReplypiration. Recording minimum temperature is useful to identify the occurrence of frost, which damages the growth of plants.

The average altitude of the project area is similar to the altitude of Bonga. Hence, the temperature of the project area is estimated from Bonga station. Therefore, the mean, maximum, and minimum annual temperatures of the project area as shown in Table 2.3 are 19.7, 27.4, and 11.5^{o}C respectively. Maximum temperatures occur in the months February-May and minimum temperatures June - September.

Table 0-3: Estimated Monthly Average Temperatures of the Project Area

Element	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Yearly Average**
Tmin	10	11	11.9	12.7	12	12.4	12.4	12.4	11.7	11	10.3	10.3	11.5
Tmax	29	29.7	29.2	28.1	27	25.9	24.3	24.6	25.8	27.8	28.1	28.4	27.36
Tavg	19.9	20.6	20.8	20.7	20	19.3	18.5	19.1	18.7	19.3	19.4	19.6	19.68

2.6 Wind Speed

Wind movements create turbulence and replace air at the water surface with less moist air and increase evaporation. Hence, the higher the wind speed is the more the evaporation. The nearest climatic station with wind speed data is Bonga Station. Monthly wind speed variation is from 0.8 - 2.1 m/sec; the yearly average is only 0.9 m/sec. Table 2.4 shows the average monthly wind speed at Bonga meteorological station which has been adopted for the project site.

Table 0-4: Average Monthly Wind Speed at 2m (m/sec) at Bonga station

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly Average
1.1	1.2	2.1	1.5	1.3	1.2	1.1	1.2	1	1.1	0.9	0.8	1.21

2.7 Sunshine duration

Solar radiation provides nearly all of the energy that reaches the earth surface. Daily sunshine hour's duration is thus a factor to determine radiation and the potential evapo-trReplypiration. The longer the sunshine hour is the more the evapo-trReplypiration. There is no sunshine hours data at the project area, hence the Bonga Station data is considered. The average daily duration of sunshine hours at Bonga is 6.0 hours. Sunshine hours duration is maximum in the dry season, November to January, and minimum in the rainy season May to September. The maximum sunshine hours duration of 8.0 hours occurs in December where as the minimum of 3.1 hours occurs in July. Mean daily sunshine hours duration is shown in Table 2.5.

Table 0-5: Mean Daily Sunshine Hours Duration at Bonga

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly Average
7.6	6.6	6.4	6.6	6.0	4.9	3.1	3.6	4.9	6.8	7.6	8.0	6.0

2.8 Relative humidity

Relative humidity, the water vapour contained in the atmosphere, is expressed as the percentage of the ratio of actual to saturation vapour pressure. More evaporation takes place in a dry air than in air with high relative humidity. The relative humidity data for the project area is also taken from Bonga station. The average relative humidity data at Bonga as shown in Table 2.6 varies from about 85% in July and September to 56% in March. Relative humidity is the maximum in July, August & September. The yearly average is 74%.

Table 0-6: Average Relative Humidity at Bonga in %

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly Average
66	69	56	71	75	80	85	85	85	80	73	64	74

3. RESULTS AND DISCUSSION

3.1 Potential Evapotranspiration (PET)

Potential evapotranspiration is the evapotranspiration when the ground is fully covered by vegetation and abundant moisture is available in the root zone. The PET is calculated by the Penman-Monteith method using FAO CROPWAT version 4.3 program. The input data are Maximum & Minimum Temperature, Relative Humidity, Wind Speed, and Sunshine duration. The results, on monthly basis, are shown in Table 2.7 and 2.8. The average annual PET of the project area is 1217 mm

.

Table 0-7: Output of CROPWAT 4.3 for the Project Area

Country :	Ethiopia			Station	: Bonga		
Altitude:	2000 meter(s) above M.S.L.						
Latitude:	7.3 Deg. (North)			Longitude	: 36.5 Deg. (East)		
Month	MaxTemp	MiniTemp	Humidity	Wind Spd.	SunShine	Solar Rad.	ETo
	(deg.C)	(deg.C)	(%)	(Km/d)	(Hours)	(MJ/m2/d)	(mm/d)
Jan.	29	10	66	95	7.6	11	1.95
Feb.	29.7	11	69	103.7	6.6	12.4	2.6
Mar.	29.2	11.9	56	181.4	6.4	15.1	4.07
Apr.	28.1	12.7	71	129.6	6.6	17.9	3.97
May	27	12	75	112.3	6	18.6	3.99
Jun.	25.9	12.4	80	103.7	4.9	17.5	3.69
Jul.	24.3	12.4	85	95	3.1	14.6	3.05
Aug.	24.6	12.4	85	103.7	3.6	14.3	2.95
Sept.	25.8	11.7	4.9	86.4	4.9	14.1	3.34
Oct.	27.8	11	80	95	6.8	13.6	2.57
Nov.	28.1	10.3	73	77.8	7.6	11.6	1.86
Dec.	28.4	10.3	64	69.1	8	10.5	1.46
Average	27.3	11.5	67.4	104.4	6	14.3	2.96

Table 0-8: Monthly PET at the Project Area (mm)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly Total
118	109	136	123	114	.7 99	90	96	99	115	108	109	1217

Climate classification

According to Thornwaithe method of climate classification, where the precipitation is analyzed month by month is just adequate to supply all the water that would be needed for maximum evapotrReplypiration in the course of a year, the moisture index is considered to be Zero. The moisture index, Im, is calculated from rainfall and PET data as follows:

$$Im = 100*(s - d)/n \ (\%)$$

Where,

Im = moisture index
s = moisture surplus (rainfall – PET), yearly total
d = moisture deficiency (PET – rainfall), yearly total
n = PET, yearly total

Gemechu D. (1977), Aspects of Climate and Water Budget in Ethiopia, give ranges of Im to define climatic types or moisture regions by quoting Barry and Chorley (1968) as follows.

Im	Climatic (Moisture) Region
Over 100	Perhumid
20 to 100	Humid
0 to 20	Moist Subhumid
-33 to 0	Dry Subhumid
-67 to -33	Semi Arid
-100 to -67	Arid

The monthly moisture surplus and deficit for the project area is shown in Table 2.8.

Table 0-9: Moisture Surplus and Deficit at the Project Area

Element	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly Total
Rain	41	78	146	199	204	218	182	194	197	150	102	88	1799
PET	118	109	136	123	115	99	90	96	99	115	108	109	1217
Rain - PET	-77	-31.2	9.6	76	89	119	92.1	97.9	98	35.3	-6	-20.5	

Yearly Moisture Deficiency, d = 134.7 mm
Yearly Moisture Surplus, s = 616.9 mm

For the project area, Im, as calculated by the above procedure is 0.396; which results in a Moist Sub humid climate. The moisture surplus is only during the Kiremt (March-October) season; the moisture in other months is not enough for crop production. Hence, irrigation is a requirement for crop production in the dry season (*November to February.)*

3.2 Crop Production In The Project Area

3.2.1 Rain Fed Crop Production

3.2.1.1 Existing Cropping Pattern

In the kebele agriculture is mainly dependant on rainfall and it is dominated by the production of sol crop maize, tef, wheat, barley, F.bean, sorghum and coffee. Banana and Enset are grown in most of the households around there homestead and it is a main source of food and cash income for the house holds. The system of production is traditional one in which plowing, harvesting and threshing is done by human and animal power only. Crops grown in the command area are Maize, tef, sorghum, wheat, barley and F. bean. Previous years Cropping pattern of the kebele for their total cultivated land is shown below

.

Table 4: Existing cropping pattern of the kebele

Crop	Coverage(ha)	%	Productivity(qt/ha)
Cereals			
Maize	117.75	12.11	65-70*
wheat	75.5	7.76	14
Tef	165.25	17.00	15
Barley	42.625	4.38	32
Sorghum	28.75	2.95	25-30
Millet	12.5	1.28	18
Pulse			
F. Bean	26.75	2.75	25
Fieldpea	27.625	2.84	22
Vegetable and fruits(Banana, Onion, Enset, carrot, cabbage)and Coffee	475.25	48.89	na
Total	972	100	

- *Na- Data not available, *Improved seed with fertilizer*

Table 5: Crop calendar for major crops

Crop	Land Preparation	Sowing date	Weeding date	Harvesting data
Maize	Jan – March	Mar – May	Apr-May	Aug -Sep

Tef	May-Jun	July12- Aug15	Aug	Oct- Nov
Wheat	Mar- Jun	July1- 30	Aug	Dec
Barley	May - July	July 15- Aug 30	September	Nov15-Dec
Sorghum	Feb- Mar	Apr- May	Jun- Oct	November
F.bean	May-Jun	Jun15- July30	September	October(end)

Source: kebele development office & field survey

3.2.2 Production Factors

Land

The maximum land holding of a household extends up to 10 hectare. The lowest land holding is 0.5 hectare and average landholding of the kebele is 3.5 hectare. The average land holding size of the households is decreasing through years as compared to the previous years. This land holding may decrease more due to the annual increment of rural population. In such situation to satisfy additional food requirement, higher yields would only achieved by through the application of irrigation water and use of appropriate farm management including the introduction of improved farm inputs and implements as well as better cultivation technique.

Animal Power

Oxen are the most commonly used draft power in the kebele. Donkeys and horses are also another source of animal power for transporting agricultural products to the market and for any other purpose. 75% of the household possess one and above oxen, and only 15% of the household has no any ox.

Table 6: Number of oxen per household at the kebele

No.	No. of oxen	No.of Households	%
1	No. of HH who posses nil ox	55	15.4
2	No. of HH who posses one ox only	86	24.08
3	No. of HH who posses two oxen	135	37.81
4	No. of HH who posses three oxen	74	20.72
5	No. of HH who posses four and above	7	1.96
	Total	357	100

Source: kebele development office

Input

Major inputs used in the area are fertilizers and improved seeds. Fertilizer is applied for crops mainly for maize, wheat and tef. Improved seed is used for maize and wheat only. Application of inputs (fertilizer and improved seed) is increasing from time to time. The basis for this is farmer’s attitude on fertilizer and improved seed is changed, farmers realize the yield obtained from improved technologies is by far better than from the conventional one.

In the 2009/10 cropping season a total of 300.5qt DAP and Urea and 49.25qt of improved seed was utilized by the kebele. Whereas in the 2010/11 cropping season a total of 555 qt DAP and Urea and 180.5 qt improved seed was used.

The major problems in input use in the kebele are;

- Lack of on time delivery of inputs
- Lack of accessible roads up to the kebele
- Different varieties of improved seeds are not delivered
- High input price
- Lack of skilled manpower

Table 7: Existing man days and oxen days for major crops

		Tef	Wheat	Maize	F. bean	Sorghum	Barley
Land preparation	Man	16	12	12	8	12	12
	oxen	16	4	12	8	12	4
Sowing		20	8	4	4	4	8
		-	4	4	4	4	4
Weeding/cultivation		60	60	24	16	50	40
		-	--	4	-	-	--
Bird scaring		-	--	4	-	-	--
		-	--	-	-	-	--
Harvesting		24	40	12	10	20	12
		-	--	-	-	-	--
Threshing		-	12	45	20	4	8
		-	12	-	-	8	12
Total		120	132	97	58	90	80
		16	20	*20*	*12*	*24*	20

Source: field survey and kebele development office

Farming Practice

Land Preparation:-Land preparation is done by using the traditional way of plow drawn by two oxen. The number of plowing vary from one crop to another, within a given crop also the frequency of plowing vary due to the presence or absence of enough labor and animal power.

Sowing and weeding/ cultivation:-The method of sowing for most of the crops is by broad casting. After the crop has sown, weeding is practiced to decrease the competition of weeds for nutrients, light and moisture. Therefore, weeding is practiced through hand weeding, for maize there is a traditional practice called ‘shelshalo’. They also use 2,4D for most of the crops.

Harvesting and Threshing:-Harvesting is done by hand picking and with the help of sickles; this is done when the crop reach at maturity. The harvested crop is collected and transported to winnowing area and left for some time to decrease the moisture content of the grain. When it becomes dry they run over animals to separate the grain from its cover.

Table 8: Frequency of plowing and weeding for major crops

Crop	Frequency of plowing	Frequency of weeding
Tef	4	1-2
Maize	3-4	2(one Shelshalo)
Wheat	4	2
F. bean	2	-
Sorghum	2	1-2(and 2,4D)
Barley	3-4	2

Source: *field survey and kebele development office*

3.2.3 Cropping System

The dominant cropping system practiced in the kebele is sol cropping of tef, maize, F.bean, wheat, Barley and sorghum. Mixed cropping of maize with cabbage, is practiced in the project area to a limited extent. Farmers rotate crops with their limited options.

Therefore, the common crop rotations practiced by the farmer in the area are-

Maize --- Tef
Maize --- Wheat/Barley
Wheat --- F.bean/F.pea

3.2.4 Agricultural Extension

Like any other areas of the region, the agricultural extension system in the woreda is agricultural training and advisory extension system. Two types of extension approaches/ packages are under implementation (minimum and family package). Agricultural extension has been given by the development agents. The development agents supervise the farmers and give technical support about the preparation of compost, fertilizer application, making terrace, forage production. ….In the Kebele there are development agents having different profession (cooperative, plant science and natural resource).

3.2.5 Crop Protection

In addition to the other factors, which has great impact on crop production, a significant amount of yield is lost due to pests, these pests include insect pests, diseases, weeds and rodents causing losses at both the pre harvest and post harvest stages.

The types of crop pests are different depending on the type of host crop. So, important crop insect pests, diseases and weeds and the existing control measures are mentioned below.

Table 9: Major crop pests of main crops

Crop	Insect pests	Diseases	Control measure
Maize	Stalk borer, weevils, monkeys	-	- Field sanitation - adding ash to the field - Animal urine
F.bean	African ballwormWeevils, aphids	- Bacterial wilt - root rot	
Sorghum	Weevils,	-	
Tef	shoot fly, beetles	-	
Wheat	Barley fly	Rust, smut	
Barley	Barley fly	Rust, smut	

Source: field survey and kebele agricultural office

In addition to insect pests and diseases, weeds are also causing a significant yield loss, through competition for nutrients, light and moisture, as a host plant for insect pests and diseases, and used as an oviposition site. Weeds are great problems to the farmers due to its high demand for labor to remove the weed. The dominant weeds present in the farmland area are, cucrbits, Cyprus spps, Eragrosties cilianensis, and others. The farmers control these weeds by hand weeding and apply 2-4 D.

3.2.6 Major Constraints of Agriculture

- Lack of varieties of improved seed
- Erratic nature of the rain fall
- Crop insect pest, disease and weed infestation
- In accessibility of most of the kebeles to deliver inputs.
- Lack of trained manpower at Woreda as well as kebele level

3.3 *Traditional Irrigation*

There is no well practiced traditional irrigation in the project site. However, elementary schools found in the village divert Gondoro River traditionally and use it to produce vegetable crops and coffee seedlings. But some few farmers able to produce few vegetable crops fetching water using cans from the canal.

3.4 *Irrigation Crop Production*

3.4.1 Rational and Objectives

Crop production in the project area is mainly relying on rainfall only one major production season per year. In the project area agriculture comprises both crop and livestock production. Grain is produced under rain fed condition using the traditional ox- drawn plow by smallholder farmers at subsistence level. Few farmers use a low input and most of the farmers do not use inputs. Farmers use low yielding local crop varieties with very small amounts of agro-inputs. Crop production is severely affected by the utilization of back ward farming practices, less diversified crops, and incidence of different crop pests. All these lead to very low crop yields and low standard of living.

On top of the above facts, there is a need to supplement the rain fed production with irrigation and cultivate the land under full irrigation during the dry season by providing different crop types in order to meet the objective of increasing household income, provide food throughout the year for the family, and generally increase the living standard of the people.

Implementation of Gondoro irrigation project is aimed at increasing crop production as well as income of farmers in the project area through the application or use of improved technologies and agricultural inputs and by applying irrigation water from Gondoro river diversion to supplement the rain fed production and for the dry season irrigation for about 80 ha of land.

The objectives of Gondoro irrigation project are:

- Develop 80 hectares of land for full and supplemental irrigation.
- Recommend cropping pattern for irrigated farming
- Determine input requirement for the proposed scheme
- Realize higher crop yields and raise the household income of the beneficiaries.

3.4.2 Proposed Cropping Pattern

The proposed cropping pattern for the project area in the wet season includes Maize, tef, wheat, Barley and F.bean. During the dry season onion, garlic, cabbage, maize, carrot and fruit trees mainly coffee are proposed. The wet season cropping calendar ranges from May to November. Planting of the dry season cropping staggered from December to January targeting the market demand household food scarcity, and allowing enough time for the land preparation to the proceeding crop.

The above crops are selected based on farmers preference, value of the crops, labor required for production, feeding habit of the people and environmental requirements of the crops (suitability of the soil and the prevailing climate).

Table 10: Proposed cropping pattern

	%	**Area(ha)**
Wet season		
. Maize	10	8
. Tef	45	36
. F.bean	5	4
. Wheat	20	16
. Barley	10	8
. Fruit trees	10	8
Dry season		
. Onion	30	24
. Garlic	30	24
. Cabbage	10	8
.Carrot	5	4
.Maize	15	12
. fruit trees	10	8
Total	100	80

The cropping pattern is revised according to the market demand, farmer's diet change and other factors.

The proposed cropping pattern has advantageous for by bringing a certain level of annual income, changes the feeding habit of the family by providing different nutritional contents, improves efficient use of natural resources and ultimately secure household food security.

Table 11 Crop calendar for proposed crops.

Crop	Land preparation	Planting Time	Harvesting Time
Wet Season			
Maize	April-May	May	October
Tef	May-June	July	November
F.bean	May- June	June	October
Wheat	June	June-July	October
Barley	June	July	October
Dry Season			
Onion	Nov- Dec	Late December	Early April
Garlic	Nov- Dec	late December	April
Cabbage	December	Jan	April
Carrot	Nov - Dec	late December	March
.Maize	December	Jan	Early May

3.4.3 Irrigation System and Method

Irrigation is supplementing rainfall for crop production by bringing surface water or ground water from a surface to fields. Artificial supply of water is needed for ensuring a regular supplement of water during the wet season and providing irrigation during the dry season. Gondoro irrigation project has an irrigation system of diverting Gondoro River. The method of irrigation proposed is furrow, which is suitable for soils of regular topography and medium and heavy soils, reduces the losses due to evaporation, and minimizes the puddling hazard in heavy soil.

Table 12: Method of irrigation for proposed crops

Crop	Method of irrigation
Maize	Furrow, border
Onion	Furrow
Garlic	Furrow
Cabbage	Furrow
Carrot	furrow
Fruit trees	Ring (basin)

3.4.4 Irrigation Scheduling

Field irrigation schedules are based on the field water balance and are expressed in depth and interval of irrigation. Too frequent small application of water tend to reduce irrigation efficiency and also time consuming for the farmer, delayed irrigation on the other hand particularly when the crop is sensitive to water stress could affect yields which cannot be compensated for by subsequent over watering. Therefore, correct time of irrigation application has great importance for the crop as well as to use effectively the scarce water.

Table 13: Irrigation water requirement (mm/month)

Crop		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wet Season													
Tef								0	0	0	0	0	
Maize						0	0	0	0	0			
wheat								0	0	10.96	2.13		
Barley								0	0	6.33	6.1		
F.bean							0	0	0	9.66	4.06		
Dry sSeason													
Onion		19.15	51.61	61.31	20.51								
Garlic		69.35	77.83	53.99	8.23								12.33
Maize		7.81	43.66	67.58	36.78	0							
Carrot		26.87	67.56	56.7									5.59
Cabbage		20.27	52.42	62.24	11.89								
Fruit		104.37	99.24	78.74	40.25	1.41	0	0	0	1.79	31.33	68.42	91.01

Table 14: Net irrigation requirement (mm/month)

Crop	%	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
							Wet Season						
Tef	45							0	0	0	0	0	
Maize	10					0	0	0	0	0			
wheat	20							0	0	2.19	0.42		
Barley	10							0	0	0.63	0.61		
F.bean	5						0	0	0	0.48	0.2		
							Dry Season						
Onion	30	12.61	25.04	18.73	1.35								2.83
Garlic	30	20.81	23.35	16.20	2.47								3.70
Maize	15	1.17	10.14	10.14	5.52	0.00							
Carrot	5	1.34	3.38	2.84									0.28
Cabbage	10	2.03	5.24	6.22	1.19								
Fruit	10	10.44	9.92	7.78	4.03	0.14	0.00	0.00	0.00	0.18	3.13	6.84	9.10
NIR		48.39	77.07	61.91	14.55	0.14	0	0	0	3.48	1.23	6.84	15.91
GIR		96.788	154.146	123.814	29.1	0.28	0	0	0	6.96	2.46	13.68	31.82
Duty for 12hr		0.7	1.2	1.0	0.2	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.2

Table 15: Irrigation interval and depth of application for proposed crops

Crop	Crop evapotranspiration (mm/season)	Irrigation water requirement (mm/season)	Maximum ETC (mm/day)	Fraction of available soil water(p)	Total available soil water mm/depth(sa)	Rooting depth d(m)	Depth of application p.sa.d/Ea (mm)	irrigation interval I=p.sa.d/Etcrop days
Onion	432.67	207.84	4.78	0.25	200	0.4	40	4
Maize	502.05	155.84	4.85	0.6	200	1	240	25
Garlic	528.68	221.72	4.57	0.25	200	0.4	40	4
Cabbage	345.23	146.81	4.57	0.45	200	0.4	72	8
Carrot	343.91	156.73	4.57	0.35	200	0.7	98	11
Fruit trees	1533.91	516.56	5.22	0.5	200	1.3	260	25

Soil type: Silt clay loam
Total available soil water (sa): 200mm/m

3.4.5 Irrigation Water Management

The method of irrigation proposed for the project is furrow and the alignment should be across the slope but with some gradients. Thus, water can move through. The crop has to be sown in rows with layout furrows so water application and other agronomic practices can be easily done.

By considering farmers experience for irrigation and management of the canals and to reduce loss of water during excessive time of application twelve hours daytime irrigation is proposed.

3.4.6 Organizational Aspects of the Project

A permanent solution for all irrigation water management problems is to involve participation of farmers for water distribution right from the stage of release of water from the headwork up to its uptake by the plant and make them responsible for maintenance of the irrigation system. Participation of farmers in irrigation water management implies a significant role for them in decision-making.

The farmers' participation should be through legal bodies by establishing water users association, which has a supreme committees and sub committees organized, based on neighboring farms or blocks.

The main committee should include farmers, development agents and kebele administrative council. The committee can control and manage the irrigation scheme by deciding seasonal water allocation water balance and operational plan, Controls outlets and structures, ensure equitable distribution of water to all the farmers, repair and maintain the irrigation system during damage and develop by-laws and execute accordingly. The subcommittee also has a duty of preparing timetable for irrigation, control water distribution and cleaning canals within their blocks.

In addition to this farmers should be organized into cooperatives so that they can get inputs through their cooperative. The cooperative also help them to search better price for their produce.

3.4.7 Extension and Research Demonstration

Despite of the fact that, there is an already existing extension system in different agricultural activities it is not effective as of its stage. So, to identify and overcome production problems at the farm level there should be a strong linkage between farmers, researchers and extension staff. The primary extension technique would be participatory technology development, supplemented and supported through a variety of other modern extension systems. Moreover it is better to use the elementary school situated in the midst of the village as a demonstration site since it is already started this work by producing through traditional irrigation.

3.4.8 Crop Protection

To have effective crop protection practice at household level as well as in the Kebele the following activities should be done, i.e.

- Identifying traditional pest control measures practiced by farmers and use this as part of the pest control measures;
- Supply the necessary crop protection inputs on time,
- Pest monitoring at different pest development stage,

- Training of farmers, development agents and woreda experts on integrated pest management,
- Conduct on farm demonstration trail of pest control techniques,
- Improve post harvest handling of crops and use biological control measures not to affect the environment and crop quality.

3.4.9 Input Requirement

The main agricultural inputs are fertilizer, improved seed and chemicals

Table 16: Input requirements for proposed crops

Crop	Seed rate (kg/ha)	Fertilizer (kg/ha)		Pesticide	Herbicide
		DAP	Urea		
Maize	25-30	100	100	Enosulfan5% dust 7.8kg/ha 2.5 kg/ha mancozeb - 3.5 kg/ha Ridomil	1lt, 24-D
F.bean	100-120	-	-		
Tef	20 - 30	100	50		
Wheat	150 -175	100	125		
Barley	125	50	100		
Onion	4-5	100	100		
Garlic	1200	-	200		
Carrot	4.5	175	-		
Cabbage	0.6	250	150		
Fruit trees/Coffee	250 seed ling	100/year	80/year		

Table 17: Man and oxen days per hectare required for proposed crops

	Man days	oxen days
West season		
Maize	102	20
F. bean	64	22
Tef	125	30
Wheat	130	30
Barley	110	16
Day season		
Onion	150	20
Garlic	160	26
Carrot	236	20
Maize	226	25
Cabbage	236	20
Fruit trees/coffee	280	10

3.4.10 Yield Projection

To build the yield of the proposed crops throughout the project year references are used on results obtained from research centers, on farm trials and demonstration sites, existing yield of the farmer and the ability to adopt and practice the proposed agricultural practices and so on. The yield of the proposed crops increases with a smaller rate at the start and increases when the extension services become strong and farmers' awareness for technologies escalates

.

Table 18: Yield build up of irrigated crops (qt/ha)

Crop	Implementation year				
	1	2	3	4	5
Maize	30	40	50	60	60
F. bean	12	16	20	22	25
Wheat	30	35	40	45	48
Barley	24	30	36	40	43
Tef	13	16	20	20	20
Onion	150	200	250	300	300
Garlic	20	30	40	45	45
Carrot	55	60	80	90	100
Cabbage	80	110	120	130	140
Fruit trees/coffee	12	15	17	17	17

3.4.11 Anticipated Benefits

The implementation of the project will provide irrigation water to an area of 80 hectares. Farmers' in the project area able to cultivate double cropping under summer season with supplementary irrigation and during the dry season full irrigation. This will increase total production and productivity of the area. Planting of horticultural crops and high value crops makes the beneficiaries to get high income and different nutritional content crops. Moreover, helps to secure food availability for the household throughout the year.

The practice of irrigation will create additional employment opportunities for the beneficiaries as well as for the people outside the command area. A part from the scheme's beneficiaries, many other families in the surroundings will benefit from increased food production and possible labor opportunities in the irrigated fields.

Crop failure due to late set or early withdrawal of the rainfall will be considerably reduced through the provision of supplementary irrigation of wet season crops. This will boost crop yields and offset food deficit in the area. The project will also encourage crop diversification based on market demands in and out of the Wareda.

New farming practices and improved technology will be provided through the extension services of the project. More importantly, apart from the benefits it provides to the beneficiaries, the project will also serve as a demonstration site for irrigation practices to the surrounding farmers.

3.4.12 Implementation Schedule

Increasing yield of agricultural products is one of the challenges of developing countries with the growing population. So, there should be a mechanism to increase the productivity of a unit of land by applying most effective technologies developed by farmers, researchers, or any other body. Along with this, training of farmers and agricultural development staff should be under taken to back up the practical and theoretical expertise of improved technologies. So that, training should be given for farmers before the starting of irrigation crop production in different technical and management practices, development agents and extension staff should also be trained. To make the project sound, inputs are also delivered on time and with enough amounts.

Table 19: Implementation schedule

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Training of farmers				■	■						■	■
Training of DAs'	■	■										
Training of WARD experts	■	■	■									
Input supply			■	■	■					■	■	■

3.4.13 Resource Required

As part of the resource required there are human and physical resources required. For the kebele there are three development agents with different discipline, and there are also woreda experts in each field who work in all the kebeles.

Concerning materials required for the household, since they are planning to cultivate vegetables, there is an intensive work of land preparation, cultivation and watering. So the materials required by the family are given below.

Table 20: Farm tools required per hectare

Farm tools	Requirement per ha
Sickle	4
Spade	8
Hoe	4
Rake	12

4. CONCLUSION

In general, as a conclusion the agro-climatic condition of the project site, the suitability of the soil for crop production, physical feature of the command area and the availability of irrigation water are suitable for development of irrigation.

Despite the above facts, the sustainability of the project is very much dependent on the full participation of the beneficiaries in all aspects of the project implementation. The participatory approach will create a sense of responsibility and ownership and greatly contributes to the success of the irrigation schemes constructed in previous years.

The objective of the project will only achievable when:

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

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

ACKNOWLEDGMENTS

I am most grateful to Almighty **God** for blessing, protecting and giving me enough mental and physical strength to make this thesis possible. I must acknowledge and thank all those people who have supported me and had their contributions throughout this period.

Ebissa G. K. (M. Tech)

REFERENCES

[1] Abate H. (2007), Review of Extension Systems Applied in Ethiopia with Special Emphasis to the Participatory Demonstration and Training Extension System, Rome: FAO.

[2] Admasu Gebeyehu, 1988: Regional Analysis on Some Aspects of Stream flow Characteristics in Ethiopia. (Unpublished Draft Report). August 1988.

[3] ARARI, 2005. Crop production guideline for development agents, Vegetable and Fruit crops (Amharic). Bahir dar

[4] Awulachew, S.B. et al. 2007, Water resources and irrigation development Ethiopia, Ethiopia working paper 123, Addis Ababa, International Water Management Institute.

[5] Banihabib, M. E., Valipour, M., and Behbahani, S. M. R. (2012). “Comparison of autoregressive static and artificial dynamic neural network for the forecasting of monthly inflow of Dez reservoir.” J. Environ. Sci. Technol., 13(4), 1–14.

[6] Beltrando, G., Camberlin, P., 1993. Inter annual variability of rainfall in the eastern horn of Africa and indicators of atmospheric circulation. Int. J. Climatol. 13, 533-546.

[7] Camberlin, P., 1997. Rainfall anomalies in the Source Region of the Nile and their connection with the Indian Summer Monsoon. *Journal of Climate, Vol. 10, pp. 1380 - 1392.*

[8] Continental consultants,1996. Irrigation agronomy in SAERAR micro irrigation schemes. Vol. VIII

[9] Davis, K, B. Swanson, and D. Amudavi. (2009), Review and Recommendations for Strengthening the Agricultural Extension System in Ethiopia. International Food Policy Research Institute (IFPRI).

[10] Ebissa G. K., Dr K. S. Hari Prasad , and Hitesh Upreti (2017), “ Hydrology Final Report on Gondoro Small Scale Irrigation Project”, International Journal of Scientific and Engineering Research (IJSER), Vol. 8, No 4, April, pp. 1284-1306

[11] Ebissa G. K.(2017), “Geological study of Gondoro small scale Irrigation project’’, International Journal of Engineering Development and Research (IJEDR),, Vol. 5, No 2, May, pp. 1148-1156

[12] Ebissa G. K.(2017), "Agronomy Study on Small Scale Irrigation Project", International Journal of Engineering Development and Research (IJEDR), Vol. 5, No 2, , May, pp.1157-1167

[13] Ebissa G. K. (2017), "Hydrology of Small Scale Irrigation Project", International Journal of Engineering Development and Research (IJEDR), Vol.5, Issue 2 , May, pp.1176-1198

[14] Ebissa G. K.(2017), "Estimation of Open Channel Roughness by using Gradual Varied Flow Profiles", International Journal of Science and Research (IJSR), Vol. 6, No 5, May, pp. 1295 – 1304

[15] Ebissa G. K. (2017), "Environmental Impact Assessment and their Mitigation measures of Irrigation Project, International Journal of Innovative Science and Research Technology (IJISRT), Vol. 2, No 5, May, pp: 186-193.

[16] Ebissa G. K. (2017), "Hydrologic Analysis and peak discharge determination", International Journal of Engineering Development and Research (IJEDR), Vol.5, No 2, May pp.1258-1286.

[17] ERA (Ethiopian Roads Authority), 2002: Drainage Design Manual, Hydrology.

[18] Estevez, J., Gavilan, P., and Berengena, J. (2009). “Sensitivity analysis of a Penman–Monteith type equation to estimate reference evapotranspiration in southern Spain.” Hydrol. Process., 23(23), 3342–3353.

[19] FAO, 1996. Irrigation and drainage paper. Vol-24.Rome.

[20] FAO, 1996. Irrigation and drainage paper. Vol-33.Rome.

[21] FAO (1998): CROPWAT for Windows, User-Guide, Version 4.3.

[22] Food and Agriculture Organization, homepage. www.fao.org (01-01-2008)

[23] FAO (Food and Agricultural Organization of the United Nations) (2014), Food and Agriculture organization of the United Nations, Global information and Early warning system country brief. December 2014.

[24] Fiddes D, 1977: Flood estimation for small East African rural catchments, Proceeding Institution of Civil Engineers, Part 2, 63, 21-34 (1977)

[25] Haile, T., 1986. Climatic variability and support feedback mechanism in relation to the Sahelo-Ethiopian droughts. M.Sc. Thesis in Meteorology, Department of Meteorology, University of Reading, U.K. pp.119-137

[26] Haile, A.M. 2007, A tradition in transition, water management reforms and indigenous spate irrigation systems in Eritrea. Leiden, Taylor and Francis/Balkema. Ph. D. thesis. Wageningen University.

[27] K. Subramanya (2006), Engineering Hydrology, Second Edition, Tata McGraw Hill; New Delhi

[28] Mersha, E., 1999. Annual rainfall and potential evapotranspiration in Ethiopia. Ethiopian Journal of Natural Resources 1(2): 137-154.

[29] MOWR 2004, National water development report for Ethiopia, United Nations Educational, Scientific, and Cultural Organization World Water Assessment Program**.**

[30] Mutreja, K.N. (1986) Applied Hydrology. 959 p. Tata McGraw Hill.

[31] NMSA (National Meteorology Service Agency), 1996. Climatic and Agro climatic Resources of Ethiopia. Vol. 1, No. 1. National Meteorology Service Agency of Ethiopia, Addis Ababa.137 pp.

[32] Rahimi, S., Gholami Sefidkouhi, M. A., Raeini-Sarjaz, M., and Valipour, M. (2014). "Estimation of actual evapotranspiration by using MODIS images (A case study: Tajan catchment)." Arch. Agron. Soil Sci., 1.

[33] R.D Misra and M. Ahmed.1987. Irrigation agronomy manual. India.

[34] Shaw, Elizabeth M., 1988: Hydrology in Practice. International Van Nostrand Reinhold.

[35] Schrader, F., et al. (2013). "Estimating precipitation and actual evapo transpiration from precision lysimeter measurements." Procedia Environ. Sci., 19, 543–552.

[36] S.K. Garg (2005), Hydrology & Water Resources Engineering; 13th revised edition ; New Delhi

[37] Taddesse, T., 2000. Drought and its predictability in Ethiopia. In: Wilhite, D.A. (Ed.), Drought: A Global Assessment, Vol. I. Routledge, pp. 135-142.

[38] Tesfaye, K., 2003. Field comparison of resource utilization and productivity of three grain legumes under water stress. Ph.D. thesis in Agro meteorology, Department of Soil, Crop and Climate Sciences, University of the Free State, South Africa.

[39] Teshome, W. 2003, Irrigation practices, state intervention and farmers' life-worlds in drought-prone Tigray, Ethiopia. Ph. D. thesis. Wageningen University.

[40] Tian, H., Wen, J., Wang, C. H., Liu, R., and Lu, D. R. (2012). "Effect of pixel scale on evapotranspiration estimation by remote sensing over oasis areas in north-western China." Environ. Earth Sci., 67(8), 2301–2313.

[41] Tian, F., Qiu, G., Yang, Y., Lu, Y., and Xiong, Y. (2013). "Estimation of evapotranspiration and its partition based on an extended three temperature model and MODIS products." J. Hydrol., 498, 210–220.

[42] Tilahun, K, 1999. Test homogeneity, frequency analysis of rainfall data and estimate of drought probabilities in Dire Dawa, Eastern Ethiopia. Ethiopian Journal of Natural Resources 1(2) 125-136.

[43] US Army Corps of Engineers (1993). Hydrologic Frequency Analysis, Engineer Manual 1110-2-1415.

[44] USDA Soil Conservation Service (1972) National engineering handbook: section 4. Hydrology, Chapters 4–10 USDA-SCS, Washington, DC

[45] Valipour, M. (2014a). "Analysis of potential evapotranspiration using limited weather data." Appl. Water Sci., in press.

[46] World Bank (2008), Ethiopia at a glance. Washington, D.C.: World Bank.

[47] Xu, C. Y., and Chen, D. (2005). "Comparison of seven models for estimation of evapotranspiration and groundwater recharge using lysimeter measurement data in Germany." Hydrol. Process. 19(18), 3717–3734.

