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Water Demand Analysis and Irrigation Requirement for Major Crops at Holetta Catchment, Awash Subbasin, Ethiopia

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ABSTRACT
The water demand and irrigation requirement of Holetta Catchment is not fully studied. In addition to this, due to scarcity of the available surface water and increase in water demand for irrigation, the major users of the river are facing a challenge to allocate the available water. Therefore, the aim of this research was to investigate the water demand of the major users of Holetta River and to study the irrigation requirement for major crops at Holetta catchment using questionnaire survey, statistical methods, and CropWat model. Structured questionnaire was used to identify information such as the number of Holetta River users, major crops grown by irrigation and the total area coverage. The major users are Holetta Agricultural Research Center (HARC), Tesdey Farm and Village Farmers. CropWat model was used to calculate the irrigation water requirement for major crops. Based on the result of CropWat model and survey analysis, the total irrigation requirement of all three users of Holetta River was 0.305, 0.575, 0.995, 0.865, and 0.332 MCM for January, February, March, April, and May respectively. The analysis also indicated the total water demand of all three major users of Holetta River during the irrigation season from January to May. The total water demand was 0.313, 0.583, 1.004, 0.873 and 0.341 million cubic meters (MCM) for January, February, March, April, and May respectively. The available river flow from January to May was 0.749, 0.419, 0.829, 0.623 and 0.471 MCM respectively. From the five months, the demand and the supply showed a gap during February, March and April. The total shortage of supply during these months was 0.59MCM. During these months, there was also conflict between users at diversion and water allocation. Therefore, in order to solve water shortage, alternative source of water supply like ground water and water harvesting technologies should be studied and integrated water management system should be implemented. In addition to this, to improve the efficiency of irrigation water, different irrigation methods like drip irrigation should be improved in the area.
Keywords: Water demand, Holetta River, CropWat model, Water use

1. Introduction

Ethiopia has 12 river basins and Awash River basin is one of them. Holetta River is one of the rivers found in the upper part of Awash basin and facing challenges of runoff variability and scarcity of water availability during the dry season.

The Holetta River is the main source of surface water in the study area and it is a perennial river having three major users. These are Holetta Agricultural Research Center (HARC), Tesdey Farm, and Smallholder farmers. Holetta Agricultural Research Center is founded in 1963 and it is one of the potential users of Holetta River. In early time, the HARC uses the Holetta River only for fruits and horticulture, but starting from 2011; HARC is improving the facility of irrigation in the center to expand the irrigation coverage. Tsedey farm is a private company, which use Holetta River for irrigation purpose. The farm mostly produces potato and vegetables like cabbage. The other major users of Holetta River are the smallholder farmers around the river. These farmers use the river for traditional irrigation purposes. The major products of the farmers are vegetables and crops like potato, cabbage, and tomato. In addition to increasing water demand in the area, there is no facility to store the water in the rainy season for future use in the dry season.

Holetta River is one of the rivers that face competition among users. The competition for water among the major users of Holetta River is increasing due to socio-economic development and population growth in the catchment. Furthermore, the water demand and management system of Holetta River catchment not fully assessed. In addition to this, due to scarcity of the available surface water and increase in water demand for irrigation, the major users of the river are facing a challenge to allocate the available water. Due to all the above reasons, the competing users start to face conflicts when allocating the available water. With growing demands on limited water resources, effective allocation and management of stream flow and reservoir storage have become increasingly important. Therefore, this research mainly focuses on estimating the water demand of the three major users of Holetta River and assessing the irrigation requirement in the catchment.

2. Theoretical background

2.1. Global Water Management and Allocation Issues

Integrated Water Resource Management is a way of analyzing the change in demand and operation of water institutions that evaluates a variety of supply side and demand side management measures to determine the optimal way of providing water services. Demand side management includes any measure or initiative that will result in the reduction in the expected water usage or water demand. Supply side management includes any measure or initiative that will increase the capacity of a water resource or water supply system to supply water (Buyelwa, 2004).

The growing pressure on the world's fresh water resources is enforced by population growth that leads to conflicts between demands for different purposes. The main concern on water use is the conflict between the environment and other purposes like hydropower, irrigation for agriculture and domestic, and industry water supply, where total flows diverted without releasing water for ecological conservation. Consequently, some of the common problems related to water faced by many countries are shortage, quality deterioration and flood impacts. Hence, utilization of integrated water resources management in a single system, which built up by river basin, is an optimum way to handle the question of water (Tessema, 2011).

2.2 Description of CROPWAT Model

CropWat is a decision support system developed by the Land and Water Development Division of Food and Agriculture Organization (FAO) for planning and management of irrigation (FAO, 1992). CropWat is a practical tool to carry out standard calculations for reference evapotranspiration, crop water requirements, and crop irrigation requirements, and more specifically the design and management of irrigation schemes. For this study, CropWat 8.0 was used. CropWat 8.0 is a computer programme for the calculation of crop water requirements and irrigation requirements from existing or new climatic and crop data. Furthermore, the program allows the development of irrigation schedules for different management conditions and the calculation of scheme water supply for varying crop patterns. In CropWat8.0, the calculation of crop water requirements is carried out per decade.

2.2.1. Crop Water Requirement

The amount of water required to compensate the evapotranspiration loss from the cropped field is defined as crop water requirement. Although the values for crop evapotranspiration and crop water requirement are identical, crop water requirement refers to the amount of water that needs to be supplied, while crop evapotranspiration refers to the amount of water that is lost through evapotranspiration. The irrigation water requirement represents the difference between the crop water requirement and effective precipitation. The irrigation water requirement also includes additional water for leaching of salts and water to compensate for non-uniformity of water application. For the calculations of the Crop Water Requirements (CWR), the crop coefficient approach is used (FAO, 1998).

2.2.2. Crop Coefficient Approach

Crop evapotranspiration can be calculated from climatic data and by integrating directly the crop resistance, albedo and air resistance factors in the FAO Penman-Monteith approach. As there is still a considerable lack of information for different crops, the Penman-Monteith method is used for the estimation of the standard reference crop to determine its evapotranspiration rate, i.e., reference evapotranspiration (ETo). Experimentally determined ratios of ETc/ETo, called Crop coefficient (Kc), are used to relate crop evapotranspiration under standard conditions (ETc) to ETo. This is known as the crop coefficient approach.

$$ETc = Kc * ETo \quad .... \quad \text{Equation 1}$$

Radiation, air Temperature, Humidity and Wind speed are all incorporated into the ETo estimate. Therefore, ETo represents an index of climatic demand, while Kc varies predominately with the specific crop characteristics and only to a limited extent with climate and soil evaporation. This enables the transfer of standard values for Kc between locations and between climates. This has been a primary reason for the global acceptance and usefulness of the crop coefficient approach and the Kc factors developed in past studies. The reference ETo is defined and calculated using the FAO Penman-Monteith equation (FAO, 1998). The crop coefficient, Kc represents an integration of the effects of four primary characteristics that distinguish the crop from reference grass. These characteristics are crop height, Albedo of the crop soil surface, canopy resistance, and evaporation from soil, especially exposed soil (FAO, 1998).

2.2.3. Effective Rainfall

For agricultural production, effective rainfall refers to the portion of rainfall that can effectively be used by plants. This shows not all rain is available to the crops as some is lost through runoff and deep percolation. How much water actually infiltrates the soil depends on soil type, slope, crop canopy, storm intensity, and the initial soils water content. During the rainy season in tropical and some semi-tropical regions, a great part of the crop's water needs are covered by rainfall, while during the dry season, the major supply of water should come from irrigation. How much water is coming from rainfall and how much water should be covered by irrigation is, unfortunately, difficult to predict as rainfall varies greatly from season to season. In order to estimate the rainfall deficit for irrigation water requirements, a statistical analysis needs to be made from long-term rainfall records (FAO, 1998).

3. Materials and Methods

3.1. Description of Study Area

The study was conducted at Holetta catchment, which is located in the upper part of Awash River basin, Ethiopia. The study area lies at an altitude of 2069 - 3378 meters above sea level and located at a latitude range of $8^0$56'N to $9^0$13'N and longitude range of $38^0$24'E to $38^0$36' E. It is a catchment with drainage area of 403.47 km^2. The annual rainfall of the study area ranges between 818-1226 mm. The climate of the study area is described with the air temperature ranging from 6^0C to 23^0C with the mean of 14 ^{0}C. Figure 1 showed the location of Holetta catchment.

Holetta town is the major settlement in the catchment of the Holetta River, which is the capital of the *Wolmera Genet* area and 45 km in the west direction from Addis Ababa. The total length of streams in the catchment is about 45.51 km. About 5km north of Holetta town is the conjunction of the Holetta and the *Mintile* River, which originates in the mountains. At the end, the Holetta River will join with Awash River at *IluWoreda*. In addition to HARC and Tsedey Farm, smallholder farmers in four *kebele*'s in the downstream use the river for irrigation which were considered as the major users of the river. These are *MediGudina, DewanaLafto, Tulu WatoDalecha* and *HamusGebeya*. Farmers in these kebeles grows cereals under rain-fed agriculture from June to November for subsistence. Potatoes and tomatoes are the dominant irrigated horticultural crops grown in the area.

3.1.1 Climate

The central and most of the eastern part of the country have two rainy periods and one dry period. These seasons are known locally as the main *Kiremt* rains from June to September, small *Belg* rains, from February to May, and dry *Bega* season from October to January. The annual rainfall of the study area ranges between 818-1226 mm, with a bimodal pattern of main rainy season during June to September and short rainy season during January to May.

There is relatively intensive rainfall during June to August with the highest mean monthly rainfall recorded in July - 243 mm. The months with the lowest rainfall are November and December (figure 2). The maximum temperature ranges from 20^0C to 25^0C and it reaches to the mean maximum temperature in February and May. The minimum temperature ranges from 2.5^0C to 10^0C and it reaches to the lowest minimum temperature in November and December. The mean monthly relative humidity value varied from 45 to 85% (figure 2).

3.1.2. Land use/ Land cover

The major land use and land cover types of the catchment are agriculture land, forest, pastureland, settlement, and water bodies. Forests and woodlands occur on the better-drained soils of mountains and sides of the valleys, and grasslands occupy areas of heavy clay soil of the valley bottom.

3.1.3. Soil Classification

The soil type in the study area is classified as vertisols, cambisols and nitisols. However, the dominant are vertisols and nitisols. Vertisols occur on smooth plains and on rolling topography of the plateau. They are characterized by their high clay content and have in general a good natural fertility. Due to clay mineralogy they are very hard and crack when dries; sticky and plastic when wet. Nitisoil generally occur on steeper hill slopes of the plateau and in the upper parts of the Holetta catchment. These soils contain more than 35% clay. The high clay content of Nitisoils result in somewhat better chemical and physical properties than other tropical soils related to the soil depth, stable structure and high water holding capacity permeability (Kramer, 2000).

3.2. Data Collection

All meteorological data (rainfall, temperature, relative humidity, wind speed, and sunshine hour) were collected from National Meteorology Agency and Holetta Agricultural Research Center. River flow data and GIS data (topographic, land use/cover data and map, soil map) were collected from Ministry of Water and Energy.

Primary data of crop type and area coverage were collected from major water users of Holetta River. To collect these primary data, 100 respondents were randomly selected and interviewed using structured questionnaire. In order to determine the sample size, the following formula was used (Cochran, 1977).

$$n = \frac{(Z^2 pq)/d^2}{1+\frac{1}{N}\left[((Z^2 pq)/d^2)-1\right]} \qquad \text{..................... Equation 2}$$

Where, n= is the desired sample size

N = the number of sample size when the population is less than 1000

Z = 95% confidence limit i.e. 1.96
P = 0.1(proportion of the population to be included in the sample i.e. 10%)
q =1-P =1- 0.1, =0.9
N = total number of population
d = margin of error or degree of accuracy desired (0.05)

Over all 100 respondent were interviewed, 60 of them were from farmers, 10 from Holetta Agricultural Research Centre, 10 from Tsedey farm , 10 from *Kebele* and 10 from Welmera woreda Agricultural office .Then, the questionnaire was analyzed with Excel software and simple statistical description method was used. The majority of downstream users of Holetta River were from four *Kebele*s. These are *MediGudina, DewanaLafto, Tulu WatoDalecha* and *HamusGebeya*. For detail questionnaire survey only one *kebele* was selected which is *MediGudina*.

Water demand for livestock and human consumption was estimated by multiplying the number of user by standard consumption

$$CR = \frac{N * q * t}{1000} \quad \text{................ Equation 3}$$

Where, CR is human and livestock consumptive requirement (m^3);
N is the user size (number); q is the consumptive rate (lt/day) and,
t is the number of days

3.3. CropWat Model Input

Calculations of the crop water requirements and irrigation requirements were carried out with inputs of climatic, crop and soil data. The model required the following data for estimating crop water requirements (CWR).

3.3.1. Climatic Data

In order to calculate the reference evapotranspiration, CropWat model use 11 years (1994 -2004) of monthly maximum and minimum temperature, relative humidity, sunshine hour, and wind speed data that was collected from Holetta station.

3.3.2. Rainfall Data

Effective rainfall was calculated based on 11 years monthly rainfall data collected from Holetta station. The annual rainfall in the catchment ranges 818 -1226 mm. The average maximum monthly rainfall is 243mm, which occurred in July, and the minimum is zero occurred in December.

3.3.3. Cropping Pattern Data

A Cropping pattern data includes planting date, crop coefficient data files (including Kc values, stage days, root depth, depletion fraction) and the area planted (0-100% of the total area).A survey was carried out in the study area to assess the crops grown under irrigation. The present cropping pattern data was assessed through field observations, interviews with farmers, HARC, and Tsedey farm. Additional information was taken from Agricultural office, *kebele* Administration and FAO Irrigation and Drainage paper 33 (FAO, 1986). Essential information collected from the above sources includes (i) Crop type and crop variety, (ii) Planting date, (iii) Crop coefficient (Kc), (iv) Field irrigation methods, (v) Rooting depth, (vi) Allowable depletion levels, (vii) Critical depletion fraction (p) and (viii) Length of individual growth stages. The Crop module requires crop data over the different development stages: initial, development, mid and late stages (FAO, 1986).

3.3.4. Soil Data

Soil data includes total available soil moisture, maximum rooting depth, initial soil moisture depletion (percentage of total available moisture), and maximum infiltration rate. The above data of soil collected from the soil survey carried out at HARC and FAO Irrigation and Drainage paper 33 (FAO, 1986).

4. Results and Discussions

The survey form was used to identify information which includes the number of Holetta River users, major crops grown by irrigation, the total area coverage and the competition among users in the catchment.

According to the collected data, majority of users have been using the river more than ten years and 51.67% of the users use the river for 30- 50 years. All the farmers respondent reply that they use the Holetta River for irrigation, livestock and human consumption but the main use of the river is for irrigation. Holetta Agricultural Research Center and Tsedey Farm use the river only for irrigation purpose.

The major crops grown are potato, tomato, cabbage, carrot, onion, and lettuce. The farmers respond showed that the three major crops are potato with 96.67%, cabbage with 91.67% and tomato with 56.67%. They use furrow irrigation to grow these crops during the off-season mainly from January to June. The total area of irrigated farm by each farmer is about 0.25 hectares. The survey also indicated that the major crops for HARC are potato, cabbage, barely, and apple. Potato, tomato, and cabbage are the major crops for Tsedey farm. Figure

3 explained the major crops grown by the three users of Holetta River.

All the farmers respond that the only source of water for irrigation is the river and there is no any other alternative except springs and wells for domestic consumption. About 63.33 % of the farmers agreed that there is conflict between the users. On contrary, 36.67 % of the farmers replied that there is no conflict. HARC and Tsedey Farm respondents believed that there is a conflict between users of Holetta River. They also mentioned that this conflict mostly occurs at the turning points and during allocation of the water. The respondent replied that there is an irrigation committee to settle this conflict but there is no coordinated and well-structured irrigation committee and water management system in the area.

During the survey, attempts were made to collect information about the number of households and livestock that use Holetta River. According to the survey from Agricultural office and *kebele*, about 371 households use the river for irrigation purpose and 300 households use for human consumption. The most important livestock in the study area were ox, cow, sheep, goat, horse and donkey. According to the survey, the approximate number of livestock was summarized in table 1.

4.1. CROPWAT Model Analysis

Reference evapotranspiration, effective rainfall, crop pattern data, and soil data were used CropWat model analysis. The major crops identified from the survey analysis were used in the calculation of crop water requirement.

4.1.1. Reference Evapotranspiration

First monthly maximum and minimum temperature, relative humidity, sunshine hour, and wind speed data (1994-2004) was fitted in CropWat model. Then, the model calculated crop evapotranspiration values based on the FAO Penman-Montieth equation. Figure 4 showed the calculated reference evapotranspiration. The reference evapotranspiration starts to rise at January and it will reach to a maximum point 4.52 at mid of March. During February, March, April and May the reference evapotranspiration is above 4.0 but for the rest of the months it is below 4.0 (figure 4).

4.1.2. Effective Rainfall

To account for the losses due to runoff or percolation, a choice was made from the four methods given in CropWat 8.0 (Fixed percentage, dependable rain empirical formula, USDA Soil Conservation Service). Rainfall data from 1994-2004 was taken to calculate effective rainfall and dependable rain empirical formula has been used. Figure 5 showed the rainfall and effective rainfall graph calculated by CropWat model.

4.1.3. Crop and Soil Data

Crop water requirement and irrigation requirements were calculated only for the major crops in the study area. The major crops are Potato, Cabbage, Apple and Barely for Holetta Agricultural Research Canter; Potato, Cabbage and tomato for Tsedey farm and farmers. The development stages, Kc factor and root depth of each crop was taken from FAO Irrigation and Drainage paper24 (FAO, 1992) and FAO Irrigation and Drainage paper 33 (FAO, 1986). Table 2 showed the summary of growing period, soil water depletion level, Kc value, and root depth for major crops grown in the area.

The soil data required by the CropWat model includes, total available soil moisture, maximum rain infiltration rate, maximum root depth, initial soil moisture depletion and initial available soil moisture. The soil data used in the model was the same for all crops except the maximum root depth.

4.1.4. Crop Water Requirement and Irrigation Requirement

In order to estimate the water demand for agricultural use/ irrigation for each crop, evapotranspiration, effective rainfall, data of crop type, area coverage and soil data were fitted in CropWat model. The water demand of irrigation is assumed to occur during the growing season. All calculation procedures as used in CropWat 8.0 are based on the FAO Irrigation and Drainage paper 56 (FAO, 1998). The crop water requirement (CWR) and irrigation requirement (IR) of each crop for the entire growing period was summarized in table 3 and 4. Table 3 described the total crop water requirement and irrigation requirement for each crop and table 4 showed the irrigation requirement for a month of January to May.

4.2. Water Demand Analysis

The result of CropWat model and survey analysis was used as an input for the calculation of water demand. The CropWat calculated the irrigation water requirement of the major crops in the area. The survey analysis indicated the area coverage and number of users of Holetta River.

Based on the result of CropWat model and survey analysis, the irrigation water demand for the three major users of Holetta River was calculated. The period was taken only for the dry seasons, from January to May. Table 5 showed the monthly irrigation requirement of each major crop in million cubic meters (MCM) for HARC. Table 6 described the monthly irrigation requirement of each major crop for Tsedey farm and table 7 described the monthly irrigation requirement of each major crop for smallholder farmers at one *kebele*.

The three other *kebele* farmers only differ based on the area of irrigated land. *DewanaLafto Kebele* has 94 ha of irrigated land, *Tulu WatoDalecha* has 150 ha and *HamusGebeya* has 218 ha. Therefore, the irrigation requirement for these kebele's was summarized and it was 0.286, 0.543, 0.946, 0.824 and 0.317 for the months of January, February, March, April and May (table 8).

Then, the total monthly irrigation requirement (IR) for all the three major users was added and summarized. Based on the analysis, the total irrigation water demand of all three users was 0.305, 0.575, 0.995, 0.865, and 0.332 MCM for January, February, March, April, and May respectively (table 9).

Tsedey farm and HARC use the river only for irrigation purpose but the farmers' further use the river for human consumption and livestock. Therefore, the water demand for human consumption and livestock was calculated for the farmers.

The monthly human consumption and monthly livestock consumption at the *Kebeles* was calculated using equation 3. The total human consumptive requirement was 0.0028, 0.0025, 0.0028, 0.0027, and 0.028 MCM for January, February, March, April, and May respectively (table 9). According to the result, the total livestock consumptive requirement was 0.0059, 0.0053, 0.0059, 0.0057, and 0.0059 MCM for January, February, March, April and May respectively (table 9).

Monthly value of irrigation requirement, human consumptive requirement and livestock consumptive requirement was added in order to get the overall water demand of the three major users of Holetta River. Finally, the total water demand requirement of each month for all the three users was summarized. The total water demand of all three major users was 0.313, 0.583, 1.004, 0.873 and 0.341 MCM for January, February, March, April, and May respectively (table 9). The available river flow from January to May was 0.749, 0.419, 0.829, 0.623 and 0.471 MCM respectively. From the five months, the demand and the supply showed a gap during February, March and April. The total shortage of supply during these months was 0.59MCM. During these months, there was also conflict between users at diversion and water allocation.

The overall analysis of this study showed that there is gap between water supply and demand at Holetta catchment. There is also high conflict among users due to water shortage and lack of well structured irrigation committee and water management system. The other problem in the catchment is use of traditional irrigation system which waste water and decrease water use efficiency. Therefore, in order to solve water shortage, alternative source of water supply like ground water and water harvesting technologies should be studied and different agricultural water management options should be implemented. In addition to this, to improve the efficiency of irrigation water, different irrigation methods like drip irrigation should be developed in the area and irrigation scheduling should be practiced.

Other studies also showed similar result concerning problems on water management, shortage of water supply and conflict among water users. Water demand driven by the rapid increase of population and increasing demand for agricultural irrigation is one of the challenges in water allocation. This quick rate of growth brings severe consequences that result from high stresses on water resources and their unprecedented impacts on socio-economic development. Water scarcity is also one of the problems in the river basins. The major reasons are high water demand from population growth, degraded water quality and pollution of surface and groundwater sources, and the loss of potential sources of fresh water supply due to old and unsustainable water management practices. Conflicts often arise when different water users of the river compete for limited water supply (Lizhong, 2005).

Water scarcity is more than just a question of availability. It is a deeply divisive international issue that some, including the vice president of the World Bank, have warned will be the source of the world's next deadly wars (Vaughn.J, 2007). In northern Africa, several types of water crises are interconnected. Drinking water is often in short supply, rainfall is limited and unpredictable, and the existing infrastructure leads to evaporation and immense losses of water. The residents in some urban areas receive water only once every three days. The United Nations estimates that, in other parts of the continent, patterns of unsustainable use of water, poor management, pollution, increasing consumption, and rapid population growth are responsible for numerous conflicts. The UN estimates that by 2025, one out of two Africans will be living in countries facing water scarcity (Vaughn.J, 2007).

5. Conclusion

The study identified the three major users of Holetta River that is Holetta Research Center, Tsedey Farm and smallholder farmers. Based on the analysis, the total irrigation requirement of all three users was 0.305, 0.575, 0.995, 0.865, and 0.332 MCM for January, February, March, April, and May respectively. In addition to irrigation, the smallholder farmers use the river for livestock and human consumption. Therefore, the study included the water demand for livestock and human's use. According to the result, livestock consumptive requirement was 0.0059, 0.0053, 0.0059, 0.0057 and 0.0059 MCM for January, February, March, April and May respectively. The human consumptive requirement was 0.00279, 0.0025, 0.00279, 0.0027, and 0.00279 MCM for January, February, March, April, and May respectively. Overall, the water demand in the area was 0.313, 0.583, 1.004, 0.873, and 0.341 for January, February, March, April, and May respectively. The available river flow from January to May was 0.749, 0.419, 0.829, 0.623 and 0.471 MCM respectively. From the five months, the demand and the supply showed a gap during February, March and April. The total shortage of supply during these months was 0.59MCM. During these months, there was also conflict between users at diversion and water allocation. The survey analysis showed that about 63.33 % of the farmers agreed on the occurrence of conflict between users of Holetta River. On contrary, 36.67 % of the farmers replied that there is no conflict. HARC and Tsedey farm respondents believed that there is a conflict between users of Holetta River. They also mentioned that this conflict mostly occurs at the turning points and during allocation of the water. The respondent replied that there is an irrigation committee to settle this conflict but there is no coordinated and well-structured irrigation committee and water management system in the area. Furthermore, there is no rules and regulation to use the river properly and to manage the catchment.Therefore, in order to solve water shortage, alternative source of water supply like ground water and water harvesting technologies should be studied and integrated water management system should be implemented. In addition to this, to improve the efficiency of irrigation water, different irrigation methods like drip irrigation should be improved in the area.

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Table 7.Summary of livestock which users Holetta River

Type of livestock	Number
Ox	154
Cow	250
Sheep	500
Goat	200
Horse	33
Donkey	34

Table 8.Summary of crop and soil data for the major crops at Holetta catchment

No	Crop	Planting Date	Total growing period/days	Kc				Soil water depletion	root depth (cm)
				Initial	Dev't	Mid stage	Late stage		
1	Potato	15/01	110	0.5		1.15	0.75	50%	60
				25	30	35	20		
2	Cabbage	15/01	105	0.7		1.05	0.95	35%	50
				25	35	30	15		
3	Tomato	15/01	145	0.6		1.15	0.8	40%	100
				30	40	45	30		
4	Apple	15/06	365	0.6		0.95	0.75	50%	150
				30	120	170	45		
5	Barely	15/01	120	0.3		1.15	0.25	100%	110
				15	25	50	30	critical	

depletion

Table 9.Estimation of total crop water requirement and irrigation requirement

crop	CWR (mm)	Effective rain(mm)	Net IR (mm)
potato	440.1	78.3	360.9
cabbage	425.4	73.5	350.6
tomato	600.8	116.8	480.8
apple	668.7	103.6	565
barely	466.2	86.7	378.7

Table 10.Estimation of irrigation water requirement (mm/month) for each crop

Month	Potato	cabbage	tomato	barely	apple
January	32	45.3	38.7	19.1	125
February	69.7	82.5	68	95	114.5
March	138.1	122.7	122.5	144.3	121.7
April	110.8	100.3	122.7	104.9	102.5
May	10.2		118.3	15.4	101.3

Table 11.Monthly irrigation requirement (MCM) for each major crop of HARC

Crop Type	Area(ha)	total IR(MCM)				
		January	February	March	April	May
potato	6	0.0019	0.0042	0.0083	0.0066	0.0006
cabbage	3	0.0014	0.0025	0.0037	0.0030	
apple	6	0.0075	0.0069	0.0073	0.0062	0.0061
barely	5	0.0010	0.0048	0.0072	0.0052	0.0008
total	**20**	**0.0117**	**0.0183**	**0.0265**	**0.0211**	**0.0075**

Table 12.Monthly irrigation requirement (MCM) for each major crop of Tsedey farm

Crop type	Area(ha)	Total IR(MCM)				
		January	February	March	April	May
potato	7	0.0022	0.0049	0.0097	0.0078	0.0007
cabbage	5	0.0023	0.0041	0.0061	0.0050	
tomato	6	0.0023	0.0041	0.0074	0.0074	0.0071
total	**18**	**0.0068**	**0.0131**	**0.0232**	**0.0201**	**0.0078**

Table 13.Monthly irrigation requirement (MCM) for each major crop of smallholder farmers

Crop type	Area (ha)	Total IR(MCM)				
		January	February	March	April	May
potato	92.75	0.0297	0.0646	0.1281	0.1028	0.0095
cabbage	92.75	0.0420	0.0765	0.1138	0.0930	
tomato	92.75	0.0359	0.0631	0.1136	0.1138	0.1097
total	278.25	**0.1076**	**0.2042**	**0.3555**	**0.3096**	**0.1192**

Table 14.Total monthly irrigation requirement (MCM) for the four kebele smallholder farmers

	Total IR (MCM)				
Kebele	**January**	**February**	**March**	**April**	**May**
MediGudina	0.108	0.204	0.356	0.310	0.119
DewanaLafto	0.036	0.069	0.120	0.105	0.040
Tulu watoDalecha	0.058	0.110	0.192	0.167	0.064
HamusGebeya	0.084	0.160	0.279	0.243	0.093
Total	**0.286**	**0.543**	**0.946**	**0.824**	**0.317**

Table 15.Overall summary of total water demand at Holetta Catchment

	January	**February**	**March**	**April**	**May**
Total Irrigation requirement (IR) for the three users (MCM)	0.3048	0.5747	0.9955	0.8648	0.3321
Human consumptive requirement CR (MCM)	0.0028	0.0025	0.0028	0.0027	0.0028
Livestock consumptive requirement CR (MCM)	0.0059	0.0053	0.0059	0.0057	0.0059
Total (MCM)	**0.3130**	**0.5830**	**1.0040**	**0.8730**	**0.3410**

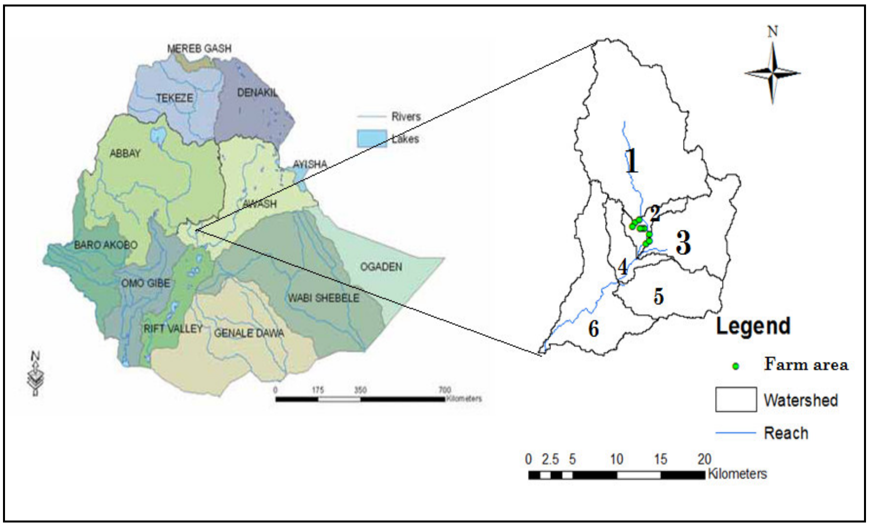

Figure 7.Location of Holetta catchment

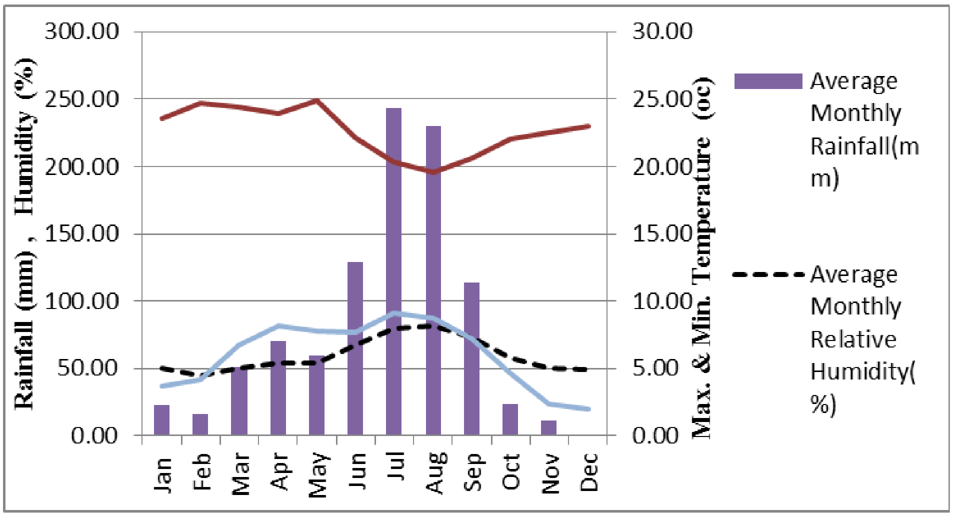

Figure 8.Average Rainfall, Temperature and Relative humidity of Holetta catchment (1994 -2004)

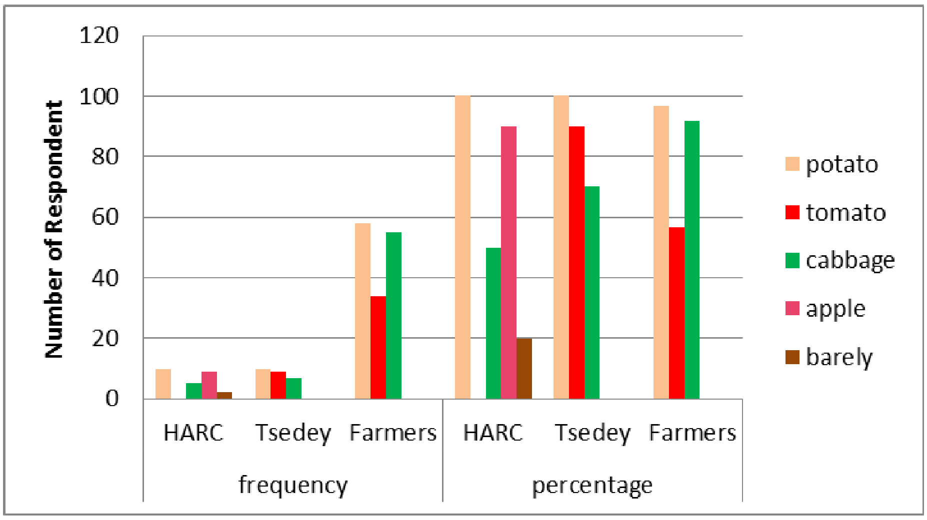

Figure 9. Summary of major crops for the three users of Holetta River

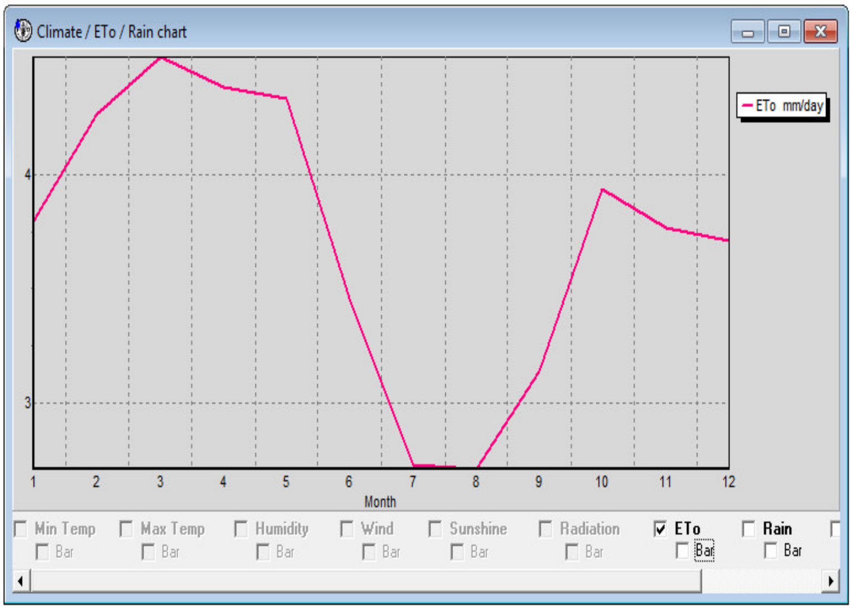

Figure 10.Reference Evapotranspiration (ETo) used by CropWat 8.0

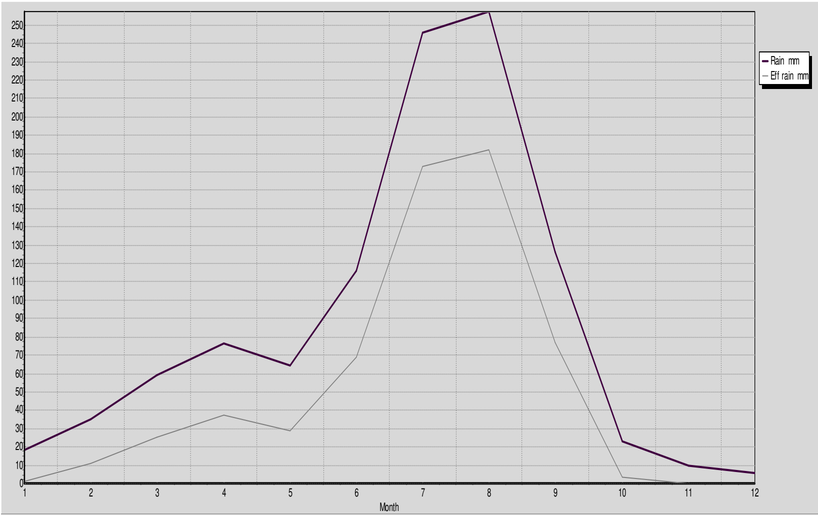

Figure 11.Rainfall Vs Effective rain calculated by CropWat 8.0