International Journal of Research in Agricultural Sciences
Volume 5, Issue 6, ISSN (Online): 2348 – 3997

Determination of Crop Water Requirement of Major Irrigated Crops of Kalu Woreda, Amhara Ethiopia

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Date of publication (dd/mm/yyyy): 02/12/2018

Abstract **– Crop water requirement of major irrigated crops of Kalu woreda was estimated from the available climatic data of the woreda. Climatic data temperature (both maximum and minimum) relative humidity, wind speed and sunshine hour were used to estimate the evapotranspiration rate. Cropwat 8 was run to determine the evapotranspiration of the study area. According to FAO papers the crop water requirement is estimated from the available information both from the study area and from literatures. From this it has been observed that onion requires 236.25mm of water for October planting and 270mm of water for February planting, tomato needs 364.35mm of water for October planting and 432.25mm of water for February planting, cabbage needs 421.65mm of water for October planting and 511.4mm of water for February planting, pepper needs 321.55mm of water for October planting and 376.95mm of water for February planting and finally lettuce requires 230mm of water for October planting and 263.8mm of water for February planting.**

Keywords **– Crop Water Requirement, Evapotranspiration, Irrigation.**

I. INTRODUCTION

Irrigation agriculture is becoming the major activity in most areas of Ethiopia where there is easy access of water. Especially near to local streams, irrigation is practiced to produce vegetable crops for local markets. As part of the country's irrigated agricultural practice irrigation is one of the major activities in pocket areas of Kalu woreda.

Even if the activity is performed intensively in this area during the dry season, several hindering constraints are observed, absence of sufficient land and water and improper water management practices are among others.

In the field observation conducted in these irrigated areas of the woreda, it has been obviously confirmed that among the major problems, absence of proper water management plays a significant role. In the process farmers have limited knowledge and information about how to handle the water management of crops. There is no irrigation scheduling practice in the operation of the crop production activity.

Lack of this information often results in farmers to practice over or under irrigating their fields with consequent loss in yields and production (Mohammed 2006). Over and under irrigation do have a negative consequence both on the soil and crops. If we further look these extremes one can observe that over irrigation results in water lodging, erosion and leaching of nutrients, while under irrigation results in water stress resulting in reduction of yield. Even in pocket areas where the practice is performed, farmers use a simple flooding to irrigate their field. This practice is going on in the area for the past several years.

Water resources of Kalu woreda, a semi arid area of the country, are scarce and limited. It is highly imperative that these resources be used most judiciously to ensure sustain--able agriculture development and productivity. This, in turn requires knowledge of crop water requirements (CWR).

Crop water requirements are defined here as "the depth of water needed to meet the water loss through evapotranspiration (ETcrop) of a disease-free crop, growing in large fields under non-restricting soil conditions including soil water and fertility and achieving full production potential under the given growing environment" (FAO 24).

However even if knowledge of crop water requirement is critically important to improve the production process in the irrigated fields of the study area, as it is clearly outlined this information is still lacking. There is no documented information of the CWR of irrigated crops of the area. Therefore in order to improve the productivity of crops and reduce the negative impact of improper irrigation activity on the soil, the water requirement of major irrigated crops has to be estimated.

There are several methods of estimating the water needs of a crop. But testing the accuracy of the methods under a new set of conditions is laborious, time-consuming and costly, and yet crop water requirement data are frequently needed at short notice for proper management. (FAO 24)

Thus it is clearly important to estimate and generate the crop water requirement data of major irrigated crops with the available information. According to the available resources and urgency of the information it has been intended to estimate the crop water requirement of major irrigate crops with the available meteorological data of the area and hence this project is initiated.

Objectives

The major objectives of this project are.

- To estimate the water requirement of major irrigated crops of the study area.
- To improve the crop water management of the area.
- To recommend appropriate measures which reduces the negative impacts of improper agricultural water management practices.

II. MATERIALS AND METHODS

Due to the difficulty in obtaining accurate field measurements, the prediction methods were applied to determine ET. The ET can be estimated using historical, meteorological and cropping conditions.

In order to estimate the water requirement of major crops in the study area 33 years of meteorological data was used. For areas such as Kalu woreda, where measured data on temperature, humidity, wind and sunshine duration or

radiation are available, an adaptation of crop evaporation estimation method provides the most reasonable results.

Therefore cropwat 8 will be employed to estimate the Eto of the area using the available climatic data.

Since there is no available information for the cropping patterns in the area, agronomic data related to each major irrigated crop such as length of growing period, number of days in each growing stage, Kc and related information used to determine the actual water requirement of major crops in the area were gathered from the available recent sources.

Data Requirements

The following data of the agro-climatic zone of the area were collected from the meteorological station found in Kombolcha town (average data of 33 years from 1985-2017) were used as input for the calculation of ETo.

- Maximum-minimum temperature.
- Relative humidity.
- Wind speed.
- Sunshine hours.

A total of 33 years of ETo was determined for each month and this was reduced to a representative value using a frequency analysis of hydrological procedures and an appropriate statistical procedures including SPSS.

Crop Water Requirements

The evapotranspiration rate of the study area was estimated using CropWat 8 Windows Version. Relevant crop coefficients (Kc) were used to calculate CWR from ETo. These crop coefficients present the relationship between references (ETo) and crop evapotranspiration (ET crop) or ET crop = Kc * ETo. Value of Kc varies with the crop, its stage of growth, growing season and the prevailing weather conditions. ET crop or CWR can be determined in mm per day as mean over the 30 or 10-day periods. However, in this study, CWR was determined over 30-days period. The planting dates were taken from farmers and woreda irrigation experts and length of growing season of each crop was taken from FAO papers and relevant websites.

There are two planting dates for the irrigated crops in the study area, cool season planting done on October and warm season planting done on February. Therefore CRW is estimate for these two cropping seasons.

III. Results and Discussion

Evapotranspiration ETO

From the available meteorological data the ETo of the study area is estimated using cropwat-8 from the available 33 years of meteorological data.

33 years of ETo was calculated and a frequency analysis was run and a representative value was selected. According to the analysis a relatively more frequent value which can represent the area was selected. From literatures it has been observed that for such evapotranspiration studies a value more than 70% frequency can represent the ETo of an area.

Therefore a value having a frequency of 73.53% was selected to represent the study area as follows.

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Eto mm/day	3.69	4.21	4.4	4.62	4.98	5.04	4.42	4.12	4.03	4.01	3.79	3.68

Cropwater Requirement (CWR)

Once we obtained the ETo of the area the cropwater requirement of major irrigated crops of the area was estimated for the two irrigation seasons, October planting and February planting.

Crop water requirement is estimated as follows:

Before proceeding to calculate the total water requirement for each month the Etc of each crop is calculated as follows.

$$Etc = ETo \times Kc$$

Crops water requirement was estimated by multiplying Etc with the number of growing days. The number of days was taken according to Ethiopian months that each month contains 30 days.

$$CWR = Etc \times number\ of\ days$$

Onion

Onion is one of the major irrigated crops in Kalu woreda. As it has been already pointed out there are two cropping periods in the irrigation practices of the area. These are October planting and February planting.

For October planting

The water need of onion is estimated as follows:

Since the crop stays on seedling bed during its initial stage the water requirement in these days is not considered. Therefore the crop stays in seed bed during September and transplanted on October 1st.

CWR based on growth stages

For development stage the crop stays 30days in October and 15 days in November.

Therefore CWR (Dev't Stage) = 30days x 2.81mm/day + 15days x 2.66mm/day= 124.2mm

For mid season stage the crop stays 15 days in November and 5 days in December.

Therefore CWR (Mid season Stage) = 15days x 3.79mm/day + 5days x 3.68mm/day = 75.25mm.

For late season stage the crop stays 10days in December:

Therefore CWR (Late season stage) = 10days x 3.68mm/day = 36.8mm

CWR on Monthly Basis

In October the crop has an Etc of 2.81 for 30days:

Therefore 30days x 2.81mm/day = 84.3mm

In November the crop has an Etc of 2.66mm/day for 15 days and 3.79mm/day for 15 days:

Therefore 15days x 2.66mm/day + 15days x 3.79mm/day = 96.75mm

In December the crop has an Etc of3.68 mm/day for 15 days

Therefore 3.68mm/day x 15 days = 55.2mm

Onion	October		November		December		Total (mm)
ETo (mm/day)	4.01		3.79		3.68		
Growthstage (days)	Devt 45		Mid 20		Late 10		
Kc	0.7		1.0		1.0		
Etc (mm/day)	2.81	2.66	3.79	3.68	3.68		
CWR(mm/G. stage)	124.2		75.25		36.8		236.25
CWR(mm/month)	84.3		96.75		55.2		236.25

For February planting

The same procedure was applied to estimate the CWR of onion for this season planting. The crop stays its initial stage on seed bed and transplanted on February 1st.

CWR based on Growth Stages

For development stage the crop stays 30 days in February and 15 days in March

Therefore CWR (Dev't Stage) = 30days x 2.95mm/day + 15days x 3.08mm/day = 134.7mm

For mid season stage the crop stays 15 days in March and 5 days in April.

Therefore CWR (Mid season Stage) = 15days x 4.4mm/day + 5days x 4.62mm/day = 89.1mm for late season stage the crop stays 10days in April:

Therefore CWR (Late season stage) = 10days x 4.62mm/day = 46.2 mm

CWR on Monthly Basis

In February the crop has an Etc of 2.95 for 30days:

Therefore 30days x 2.95mm/day = 88.5mm

In March the crop has an Etc of 3.08mm/day for 15 days and 4.4mm/day for 15 days:

Therefore 15days x 3.08mm/day + 15days x 4.4mm/day = 112.2mm

In April the crop has an Etc of 4.62mm/day for 15 days

Therefore 4.62mm/day x 15 days = 69.3mm.

Onion	February		March		April		Total (mm)
ETo (mm/day)	4.21		4.4		4.62		
Growthstage (days)	Devt 45		Mid 20		Late 10		
Kc	0.7		1.0		1.0		
Etc (mm/day)	2.95	3.08	4.4	4.62	4.62		
CWR(mm/G. stage)	134.7		89.1		46.2		270
CWR(mm/month)	88.5		112.2		69.3		270

Tomato

Tomato is one of the major irrigated crops in Kalu woreda. As in onion there are two irrigation seasons for tomato also, October planting and February planting. The plant stays in seed bed during its initial stage and transplanted to the cropping field.

For October planting

CWR based on Growth Stages

For development

CWR (Dev't Stage) = 30days x 3.01mm/day + 10days x 2.85mm/day = 118.8mm.

For mid season stage

CWR (Mid season Stage) = 20days x 4.36mm/day + 20days x 4.23mm/day = 171.8mm.

For late season stage

CWR (Late season stage) = 10days x 2.95mm/day + 15days x 2.95mm/day = 73.75 mm

CWR on Monthly Basis

In October:

CWR30days x 3.01mm/day = 90.3mm.

In November :

CWR10days x 2.85mm/day + 20days x 4.36mm/day = 115.7mm.

In December

CWR 4.23mm/day x 20 days + 10days x 2.95mm/day = 114.1mm.

In January :

CWR 15days x 2.95mm/day = 44.25mm

Tomato	October		November		December		January	Total (mm)
ETo (mm/day)	4.01		3.79		3.68		3.69	
Growth stage (days)	Devt 40		Mid 40		Late 25			
Kc	0.75		1.15		0.8			
Etc (mm/day)	3.01	2.85	4.36	4.23	2.95	2.95		
CWR(mm/G. stage)	118.8		171.8		73.75			364.35
CWR(mm/month)	90.3		115.7		114.1		44.25	364.35

February planting

CWR based on Growth Stages

For development

CWR (Dev't Stage) = 30days x 3.16mm/day + 10days x 3.3mm/day = 127.8mm

For mid season stage

CWR (Mid season Stage) = 20days x 5.06mm/day + 20days x 5.32mm/day = 207.6mm

For late season stage

CWR (Late season stage) = 10days x 3.70mm/day + 15days x 3.99mm/day = 96.85 mm

CWR on Monthly Basis

In February:

CWR 30days x 3.16mm/day = 94.8mm

In March:

CWR 10days x 3.3mm/day + 20days x 5.06mm/day = 134.2mm

In April

CWR 5.32mm/day x 20 days + 10days x 3.7mm/day = 143.4mm

In May

CWR 15days x 3.99mm/day = 59.85mm

Tomato	Feb	Mar	Apr	May	Total (mm)
ETo (mm/day)	4.21	4.4	4.62	4.98	
Growth stage (days)	Devt 40	Mid 40	Late 25		
Kc	0.75	1.15	0.8		
Etc (mm/day)	3.16	3.3 5.06 5.32	3.70 3.99		
CWR(mm/G. stage)	127.8	207.6	96.85		432.25
CWR(mm/month)	94.8	134.2	143.4	59.85	432.25

Cabbage

Is one of the major irrigated crops in the study area. As in the other crops there are two irrigation seasons for cabbage also, October planting and February planting. The plant stays in seed bed during its initial stage and transplanted to the cropping field.

For October planting

CWR based on Growth Stages

For development

CWR (Dev't Stage) = 30days x 3.01mm/day + 30days x 2.85mm/day = 175.8mm

For mid season stage

CWR (Mid season Stage) = 30days x 3.87mm/day + 20days x 3.88mm/day = 193.7mm

For late season stage

CWR (Late season stage) = 10days x 3.32mm/day + 5days x 3.79mm/day = 52.15 mm

CWR on Monthly Basis

In October:

CWR 30days x 3.01mm/day = 90.3mm

In November :

CWR 30days x 2.85mm/day = 85.5mm

In December

CWR 30 days x3.87mm/day = 116.1mm

In January

CWR 20days x 3.88mm/day + 10days x 3.32mm/day = 110.8mm

In February

CWR 5days x 3.79mm/day = 18.95mm

Cabbage	October	November	December	January	February	Total (mm)
ETo (mm/day)	4.01	3.79	3.68	3.69	4.21	
Growth stage (days)	Devt 60		Mid 50	Late 15		
Kc	0.75		1.05	0.9		
Etc (mm/day)	3.01	2.85	3.87 3.88	3.32	3.79	
CWR(mm/G. stage)	175.8		193.7	52.15		421.65
CWR(mm/month)	90.3	85.5	116.1	110.8	18.95	421.65

For February planting

CWR based on Growth Stages

For development

CWR (Dev't Stage) = 30days x 3.16mm/day + 30days x 3.3mm/day = 193.8mm

For mid season stage

CWR (Mid season Stage) = 30days x 4.85mm/day + 20days x 5.23mm/day = 250.1mm

For late season stage

CWR (Late season stage) = 10days x 4.48mm/day + 5days x 4.54mm/day = 67.5 mm

CWR on Monthly Basis

In February:

CWR 30days x 3.16mm/day = 94.8mm

In March :

CWR 30days x 3.3mm/day = 99mm

In April

CWR 30 days x 4.85mm/day = 145.5mm

In May

CWR 20days x 5.23mm/day + 10days x 4.48mm/day = 149.4mm

In June

CWR 5days x 4.54mm/day = 22.7mm

Cabbage	Feb	Mar	Apr	May	June	Total (mm)
ETo (mm/day)	4.21	4.4	4.62	4.98	5.04	
Growth stage (days)	Devt 60		Mid 50	Late 15		
Kc	0.75		1.05	0.9		

Cabbage	Feb	Mar	Apr	May		June	Total (mm)
Etc (mm/day)	3.16	3.3	4.85	5.23	4.48	4.54	
CWR(mm/G. stage)	193.8		250.1		67.5		511.4
CWR(mm/month)	94.8	99	145.5	149.4		22.7	511.4

Pepper

Is one of the major irrigated crops in the study area. As in the other crops there are two irrigation seasons for pepper also, October planting and February planting. The plant stays in seed bed during its initial stage and transplanted to the cropping field.

For October planting

CWR based on Growth Stages

For development

CWR (Dev't Stage) = 30days x 2.81mm/day + 5days x 2.66mm/day = 97.6mm

For mid season stage

CWR (Mid season Stage) = 25days x 3.98mm/day + 15days x 3.87mm/day = 157.55mm

For late season stage

CWR (Late season stage) = 15days x 3.32mm/day + 5days x 3.32mm/day = 66.4 mm

CWR on Monthly Basis

In October:

CWR 30days x 2.81mm/day = 84.3mm

In November :

CWR 5days x 2.66mm/day + 25days x 3.98mm/day = 112.8mm

In December

CWR 15days x 3.87mm/day + 15days x 3.32mm/day = 107.85mm

In January

CWR 5days x 3.32mm/day = 16.6mm

Pepper	October		November		December		January	Total (mm)
ETo (mm/day)	4.01		3.79		3.68		3.69	
Growth stage (days)	Devt 35		Mid 40		Late 20			
Kc	0.7		1.05		0.9			
Etc (mm/day)	2.81	2.66	3.98	3.87	3.32	3.32		
CWR(mm/G. stage)	97.6		157.55		66.4			321.55
CWR(mm/month)	84.3		112.8		107.85		16.6	321.55

For February planting

CWR based on Growth Stages

For development

CWR (Dev't Stage) = 30days x 2.95mm/day + 5days x 3.08mm/day = 103.9mm

For mid season stage

CWR (Mid season Stage) = 25days x 4.62mm/day + 15days x 4.85mm/day = 188.25mm

For late season stage

CWR (Late season stage) = 15days x 4.16mm/day + 5days x 4.48mm/day = 84.8 mm

CWR on Monthly Basis

In February:

CWR 30days x 2.95mm/day = 88.5mm

In March :

CWR 5days x 3.08mm/day + 25days x 4.62mm/day = 130.9mm

In April

CWR 15 days x 4.85mm/day + 15days x 4.16mm/day = 135.15mm

In May

CWR 5days x 4.48mm/day= 22.4mm

Pepper	Feb		Mar		Apr		May	Total (mm)
ETo (mm/day)	4.21		4.4		4.62		4.98	
Growth stage (days)	Devt 35		Mid 40		Late 20			
Kc	0.7		1.05		0.9			
Etc (mm/day)	2.95	3.08	4.62	4.85	4.16	4.48		
CWR(mm/G. stage)	103.9		188.25		84.8			376.95
CWR(mm/month)	88.5		130.9		135.15		22.4	376.95

Lettuce

Is one of the major irrigated crops in the study area. As in the other crops there are two irrigation seasons for lettuce also, October planting and February planting. The plant stays in seed bed during its initial stage and transplanted to the cropping field. CWR in the initial stage is not considered here.

For October planting

CWR based on Growth Stages

For development

CWR (Dev't Stage) = 30days x 2.41mm/day + 5days x 2.27mm/day = 83.65mm

For mid season stage

CWR (Mid season Stage) = 25days x 3.79mm/day + 5days x 3.68mm/day = 113.15mm

For late season stage

CWR (Late season stage) = 10days x 3.32mm/day = 33.2mm

CWR on Monthly Basis

In October:

CWR 30days x 2.41mm/day = 72.3mm

In November :

CWR 5days x 2.27mm/day + 25days x 3.79mm/day = 106.1mm

In December

CWR 5days x 3.68mm/day + 10days x 3.32mm/day =

51.6mm

Lettuce	October		November		December	Total (mm)
ETo (mm/day)	4.01		3.79		3.68	
Growth stage (days)	Devt 35		Mid 30		Late 10	
Kc	0.6		1.00		0.9	
Etc (mm/day)	2.41	2.27	3.79	3.68	3.32	
CWR(mm/G. stage)	83.65		113.65		33.2	230
CWR(mm/month)	72.3		106.1		51.6	230

For February planting

CWR based on Growth Stages

For development

CWR (Dev't Stage) = 30days x 2.53mm/day + 5days x 2.64mm/day = 89.1mm

For mid season stage

CWR (Mid season Stage) = 25days x 4.4mm/day + 5days x 4.62mm/day = 133.1mm

For late season stage

CWR (Late season stage) = 10days x 4.16mm/day = 41.6 mm

CWR on monthly basis

In February:

CWR 30days x 2.53mm/day = 75.9mm

In March :

CWR 5days x 2.64mm/day + 25days x 4.4mm/day = 123.2mm

In April

CWR 5 days x 4.62mm/day + 10days x 4.16mm/day = 64.7mm

In May

CWR 5days x 4.48mm/day = 22.4mm

Lettuce	Feb		Mar		Apr	Total (mm)
ETo (mm/day)	4.21		4.4		4.62	
Growth stage (days)	Devt 35		Mid 30		Late 10	
Kc	0.6		1.00		0.9	
Etc (mm/day)	2.53	2.64	4.4	4.62	4.16	
CWR(mm/G. stage)	89.1		133.1		41.6	263.8
CWR(mm/month)	75.9		123.2		64.7	263.8

IV. Conclusion and Recommendation

There are several methods of estimating the water requirement of crops. However because of the limitation on the available information, budget and other facilities in the study area, the information is generated from meteorological data available at the woreda centre.

Crowat 8, the latest software available to estimate the evapotranspiration rate of an area from meteorological data, was used.

According to the analysis of the water requirement of crops it has been observed that, the amount of water each crop requires is within the range of the water requirement of crops in FAO papers.

According to the area of coverage and demand of local market five major irrigated crops were identified in consultation with farmers, the woreda irrigation experts and field observation. The crops considered include onion, tomato, cabbage, pepper and lettuce according to the order of importance.

From the analysis it has been observed that cabbage requires the highest amount of water and lettuce requires the minimum amount of water.

From the results onion stays for a total of four months in the field, about one month in seedling bed and three months in the cropping field. From the available information, for October 1st transplanting it requires a total of 236.25mm of water. October planting is considered as a cool season cropping and the transpiration rate is relatively minimum in comparison to the other seasons.

For February planting onion requires a total of 270mm of water, this season is warm and the evapotranspiration rate is relatively higher.

Tomato requires a relatively higher amount of water than onion, it needs, at Kalu woreda's climatic situation, a total of 364.35mm water for October planting and 432.25mm of water for February planting excluding the water needs for seedling stage.

Cabbage requires the highest amount of water during the growing periods. Excluding the initial stages it needs a total of 421.65mm of water for October planting and 511.4mm of water for February planting.

Pepper is another major irrigated crop in the study area and according to the estimation made, excluding the water requirement of the initial stages, it requires a total of 321.55mm of water during October planting and 376.95mm of water during February planting.

Lettuce is the last crop considered, without the water requirement during the seedling stage it requires a total of 230mm of water during October planting and 263.8mm of water for February planting.

Crop water requirement of crops for October planting

	October	November	December	January	February	Total (mm)
Onion	84.3	96.75	55.2	-	-	236.25
Tomato	90.3	115.7	114.1	44.25	-	364.35
Cabbage	90.3	85.5	116.1	110.8	18.95	421.65
Pepper	84.3	112.8	107.85	16.6	-	321.55
Lettuce	72.3	106.1	51.6	-	-	230

Crop water requirement of crops for February planting

	Feb	Mar	Apr	May	June	Total (mm)
Onion	88.5	112.2	69.3	-	-	270
Tomato	94.8	134.2	143.4	59.85	-	432.25
Cabbage	94.8	99	145.5	149.4	22.7	511.4
Pepper	88.5	130.9	135.15	22.4	-	376.95
Lettuce	75.9	123.2	64.7	-	-	263.8

This information is generated to deliver urgent data that can help farmers to improve their farming practices. As it has been outlined at present farmers have no information on the water needs of crops and this information will provide them with water requirement data from having no information.

The value obtained from climatic data estimation can only provide approximate values. In order to have relatively precise information it needs to be refined further by running field experiments and in addition related activities such as extension work and training should be given for the farmers to put this information to the ground

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