

Determination of Crop Water Requirements and Irrigation Scheduling Using CROPWAT: A Case Study of Waghodia Region

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ABSTRACT: In regions where water resources are limited, there, determination of crop water requirement is one of the key parameters for precise irrigation scheduling. This study was carried out to determine the crop water requirements and irrigation scheduling for rabi and hot weather crops, for the Waghodia region at Vadodara. Crop Water Requirement of each crop was determined by CROPWAT model which is developed by the Food Agricultural Organization (FAO), using 7 years climatic data. CROPWAT is a computer programme for the calculation of crop water requirements and irrigation requirements from existing or new climatic and crop data. The irrigation requirement of a crop is the amount of water to be supplied by irrigation to a disease-free crop growing in a large field with adequate soil water, fertility and achieving food production potential under the prevailing soil and climatic conditions. To determine the crop water requirements (CWR), reference crop evapotranspiration (ET_o) and crop factor (K_c) are used. The reference crop evapotranspiration (ET_o) has been determined using meteorological data. Irrigation scheduling is the process of determining the time to irrigate and how much water is to be applied in each irrigation. For efficient utilization of water, irrigation scheduling is required. Irrigation schedules are considered to either fully or partially provide the estimated water requirements of the crop. For the area under study, it has been seen that the irrigation requirements for wheat, maize, potato and castor bean are 264.8mm, 236.9mm, 363.5mm and 465.6 respectively. For these crops the irrigation scheduling has been carried out which shows the amount of water to be supplied at a specific period of time to these crops. To find out irrigation scheduling two approaches are used. One is irrigating at critical depletion and the other is irrigating at fixed interval per stage.

KEYWORDS: Crop Water Requirement, Irrigation Scheduling, CROPWAT

I. INTRODUCTION

Water is a life line for human being. Life is impossible for humans as well as both animals and plants, without water. About 70% of earth is covered by water but there is only little quantity of pure water is available and can be usable. So Water is as essential as air and sunlight. The growth of world population is continuously increasing which places new demands on water resources every day.

In future judicious use of water in agricultural sector will be necessary because day by day water scarcity is increasing and that can be achieved by applying exact or correct amount of water on exact or specific time. In addition, it will need more widespread adoption of deficit irrigation, especially in an arid and semi-arid regions. Recent advances in new irrigation technologies will help to identify irrigation scheduling strategies that minimize water demand with minimal impacts on yields and yield quality, leading to improve food scarcity.

The largest amount of water is used in agricultural practices and hence effective use of water can conserve more water which can be use later on in water crises. Accurate planning and delivery of the necessary amount of water in time and space can conserve water. Moreover, implementation of sound irrigation water management practices is necessary to overcome excessive irrigation to eliminate many associated problems. In this context methods to quantify accurate irrigation water requirement play a key role in the conservation and management of water resources. For agricultural practices in an arid and semi-arid climates, planning and management of water is most important. For better management and conservation of agricultural water, it is prerequisite to understand the crop water requirement. One of

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

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Vol. 7, Issue 2, February 2018

the most important component in the water balance is evapotranspiration (ET). In this study, calculation of ET is based on the average meteorological data and some standard FAO parameters.

The objectives of this study were:

- To calculate and analyse crop water requirement
- To use CROPWAT irrigation scheduling model for evaluating the crop water requirement and irrigation scheduling.

CROPWAT is helpful to agro scientists, agro researchers and water resources engineers as a practical tool to carry out standard calculations for evapotranspiration and management of irrigation schemes. Plants use water for cooling purposes and the driving force of this process is prevailing weather conditions. Under the same climate and atmosphere, different crops have different water use requirements

Irrigation scheduling makes sure that water is consistently available to the plant and that it is applied according to crop requirements.

Proper irrigation will lead to increase in prosperity and water use efficiency by:

- Maximizing crop yield and quality
- From deep percolation water lost can be minimize;
- Optimizing pumping costs.

To effectively schedule irrigation applications, four key pieces of information need to be known:

- soil texture
- water holding capacity of the soil
- soil moisture content
- crop water use at the specific development stage.

Another factor like, knowing the allowable depletion of the crop, that is how much water can be removed from the soil profile prior to stressing the crop should be considered within a scheduling program.

The limitations of an irrigation system can impact a scheduling program, so it is necessary to be aware of how much water can be applied efficiently to the crop in the specific time duration.

II. STUDY AREA

The area selected for the present study is the catchment area of the Waghodia region which is located in Vadodara. The entire Gujarat is divided into various Agro climatic zones and Vadodara district is covered in Agro climatic zones-3. Geographical location of Vadodara District is 22.30° North (Latitude) and 73.19° East (Longitude) at an elevation of 39 meters (123 feet). The city is located on the fertile plain between the Mahi & Narmada Rivers. Vadodara is divided by the Vishwamitri into two physically distinct eastern and western regions. Vadodara District is the 18th largest city in India with an area of 148.95 km² and a population of 4.1 million according to the 2010-11 census. The city is located in central Gujarat and sits on the bank of the river Vishwamitri. The Vishwamitri commonly dries up in the hot weather.

III. MATERIALS AND METHODS

- **Stages of growth** : Four stages of plant growth were used in determining water requirement of the crop. The crop growth stages include initial stage, development stage, mid-season and late season stage.
- **Estimation of water requirement** : Crop water requirement is determined from the interrelationships of the ET, Soil Type, bulk density of the soil, field capacity and permanent wilting point of the soil and the effective root zone

International Journal of Innovative Research in Science, Engineering and Technology

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Vol. 7, Issue 2, February 2018

of the project site. The crop evapotranspiration (ETc) was estimated by FAO Penman-Monteith equation which is as defined below :

$$ET_c = K_c (ETo)$$

Where,

ETc = Crop Evapotranspiration

ETo = Reference Crop Evapotranspiration

Kc = Crop Factor / Crop coefficient

The CROPWAT programme developed for the FAO Penman-Monteith method (FAO -2005) was utilized for estimating the crop water requirement and irrigation scheduling of each of the crops studied. The climatic data like Min-Max Temperature, Relative Humidity, Wind Speed and Sunshine hours are used for the calculations.

- **Irrigation Scheduling :** There are two approaches used to determine the irrigation scheduling.

- 1) Irrigate at critical depletion
- 2) Irrigate at fixed interval (15days) per stage

IV. RESULTS AND DISCUSSION

The trend analysis for seven year data is carried out. The CROPWAT Software is generated for predicting the Crop Water Requirements of the different types of Crops like Wheat, Maize, Castor Beans and Potato and for that Metrological parameters like Maximum Temperature, Minimum Temperature, Wind Speed, Relative Humidity, Sunshine Hours are used.

The metrological parameters are considered as input and Reference Crop Evapotranspiration is considered as output. The data sets are converted on daily basis.

The trends over study period of 7 year of all the meteorological parameters are observed in all months in daily basis with the help of CROPWAT.

TABLE 1: IRRIGATION REQUIREMENT

CROP	ETO (MM/DAY)	Kc	ETC (MM/DEC)	IRR.REQUIRED (MM/DEC)
WHEAT	2.85	10.82	264.8	264.8
MAIZE	2.78	10.06	236.9	236.9
POTATO	3.59	9.9	363.5	363.5
CASTOR BEANS	4.17	14.46	621.5	465.6

Results show that for Wheat, Maize, Potato and Castor beans, crop evapotranspiration (ETc) and crop water requirement (CWR) are 264.8, 236.9, 363.5, 621.5 and 264.8, 236.9, 363.5, 465.6 respectively for the year 2001 to 2007 (Table : 1). From the values of the Crop water requirement by CROPWAT, it can be shown that for the crop of Wheat, Maize, potato and Castor bean, the irrigation requirements are completely satisfied.

TABLE 2: IRRIGATION SCHEDULING FOR WHEAT (AT CRITICAL DEPLETION)

Date	15-Nov	12-Dec	03-Jan	22-Jan	07-Feb	22-Feb	12-Mar
Day	3	30	52	71	87	102	End
Gross Irrigation, mm	66.2	65.7	64.9	64.1	65.5	64.7	0

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Vol. 7, Issue 2, February 2018

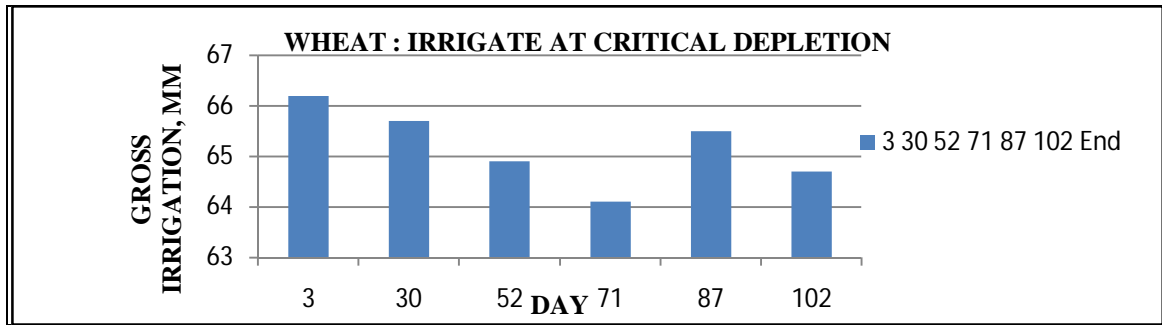


Fig. 1 Irrigation Scheduling for wheat

TABLE 2.1: IRRIGATION SCHEDULING FOR WHEAT (AT FIXED INTERVAL)

Date	27-Nov	12-Dec	27-Dec	11-Jan	26-Jan	10-Feb	25-Feb	12-Mar
Day	15	30	45	60	75	90	105	End
Gross Irrigation, mm	230	36	43.3	47	53.3	65.4	60.2	0

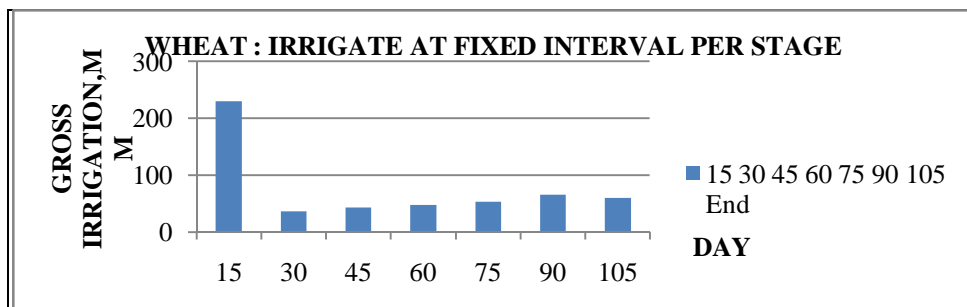


Fig. 1.1 Irrigation Scheduling for wheat

Here, in this study canal based irrigation system is taken and scheduling is done by two approaches (1) irrigate at critical depletion and (2) irrigate at fixed interval per stage. By comparing results and graphs of both approaches, we come to know that option 1 is better for wheat as it shows less irrigation requirement i.e. 391.1mm as compared to other option i.e. 535.2mm where in both cases yield reduction is zero.

TABLE 3: IRRIGATION SCHEDULING FOR MAIZE (AT CRITICAL DEPLETION)

Date	18-Oct	23-Nov	15-Dec	04-Jan	23-Jan	13-Feb	16-Feb
Day	4	40	62	82	101	122	End
Gross Irrigation, mm	64.2	64.5	66	63.9	66.1	64.2	0

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Vol. 7, Issue 2, February 2018

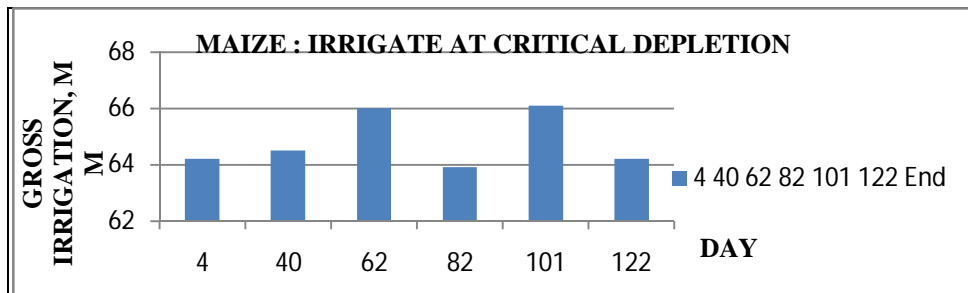


Fig. 2 Irrigation Scheduling for maize

TABLE 3.1: IRRIGATION SCHEDULING FOR MAIZE (AT FIXED INTERVAL)

Date	29-Oct	13-Nov	28-Nov	13-Dec	28-Dec	12-Jan	27-Jan	11-Feb	16-Feb
Day	15	30	45	60	75	90	105	120	End
Gross Irrigation, mm	182.8	24.6	38	45.9	47.2	49.8	52.8	45.3	0

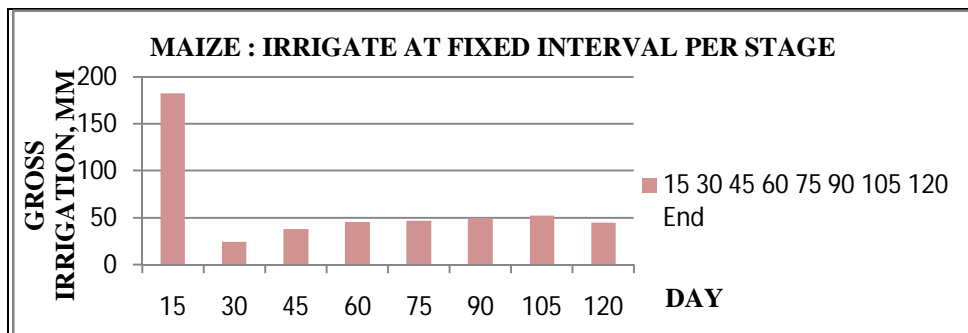


Fig. 2.1 Irrigation Scheduling for maize

Here, in this study canal based irrigation system is taken and scheduling is done by two approaches (1) irrigate at critical depletion and (2) irrigate at fixed interval per stage. By comparing results and graphs of both approaches, we come to know that option 1 is better for maize as it shows less irrigation requirement i.e. 388.9 mm as compared to other option i.e. 486.4 mm where in both cases yield reduction is zero.

TABLE 4: IRRIGATION SCHEDULING FOR POTATO (AT CRITICAL DEPLETION)

Date	05-Jan	23-Jan	08-Feb	19-Feb	28-Feb	08-Mar	16-Mar	23-Mar	30-Mar	06-Apr	14-Apr	22-Apr	29-Apr
Day	1	19	35	46	55	63	71	78	85	92	100	108	End
Gross Irrigation, mm	44.4	35.9	42.7	46	48.7	45.6	48.7	45.6	48.5	46.6	49.3	45.8	0

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Vol. 7, Issue 2, February 2018

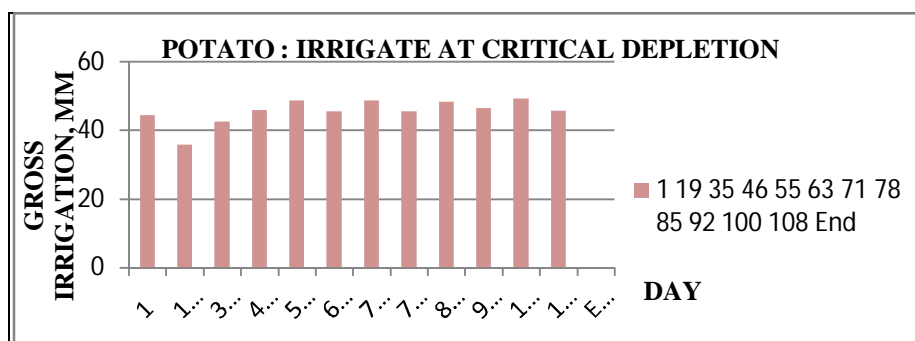


Fig. 3 Irrigation Scheduling for potato

TABLE 4.1: IRRIGATION SCHEDULING FOR POTATO (AT FIXED INTERVAL)

Date	19-Jan	03-Feb	18-Feb	05-Mar	20-Mar	04-Apr	19-Apr	29-Apr
Day	15	30	45	60	75	90	105	End
Gross Irrigation, mm	81.1	36.2	59.1	82.1	91.9	101.5	91.9	0

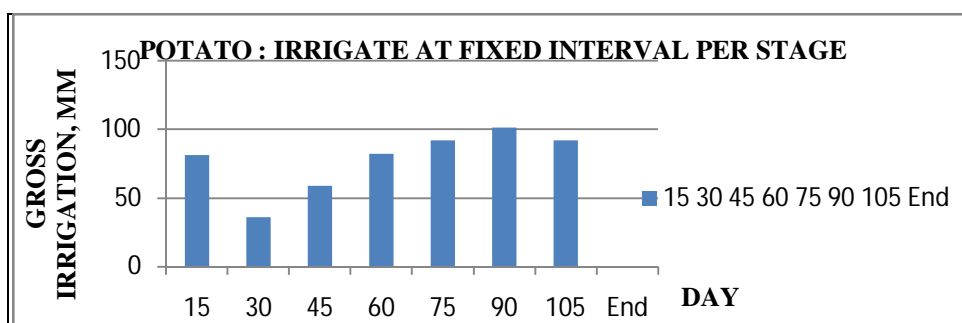


Fig. 3.1 Irrigation Scheduling for potato

Here, in this study canal based irrigation system is taken and scheduling is done by two approaches (1) irrigate at critical depletion and (2) irrigate at fixed interval per stage. By comparing results and graphs of both approaches, we come to know that option 2 is better for potato as it shows less irrigation requirement i.e. 543.8 mm as compared to other option i.e. 547.8 mm where in both cases yield reduction is zero.

TABLE 5: IRRIGATION SCHEDULING FOR CASTORBEAN (AT CRITICAL DEPLETION)

Date	01-Mar	30-Mar	15-Apr	26-Apr	04-May	12-May	19-May	27-May	04-Jun	12-Jun	20-Jun	19-Jul	27-Aug
Day	1	30	46	57	65	73	80	88	96	104	112	141	End
Gross Irrigation, mm	59.8	60.6	62.5	63.4	58.8	63.8	59	64.8	60.1	60.9	59.3	60.2	0

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Vol. 7, Issue 2, February 2018

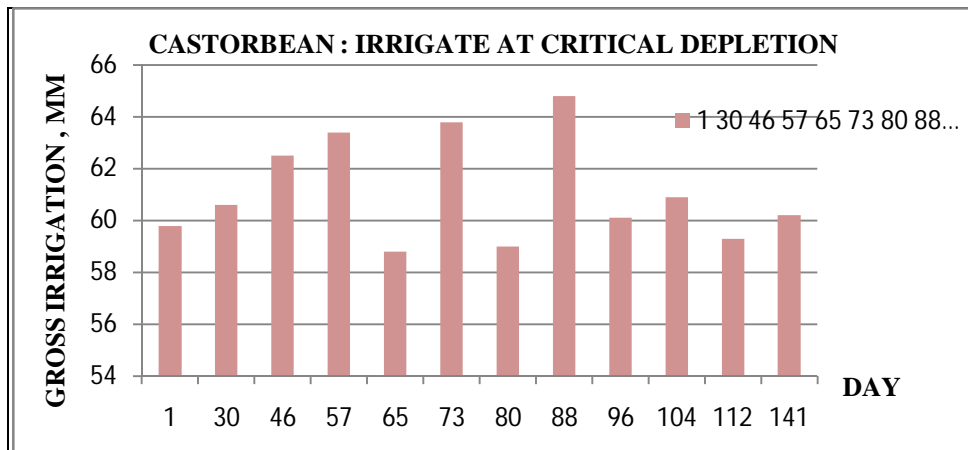


Fig. 4 Irrigation Scheduling for castor bean

TABLE 5.1: IRRIGATION SCHEDULING FOR CASTORBEAN (AT FIXED INTERVAL)

Date	15-Mar	30-Mar	14-Apr	29-Apr	14-May	29-May	13-Jun	28-Jun	13-Jul	28-Jul	12-Aug	27-Aug
Day	15	30	45	60	75	90	105	120	135	150	165	End
Gross Irrigation, mm	182.6	34.2	57.6	88.9	119.3	122.1	112.8	28.3	31.6	47	7	0

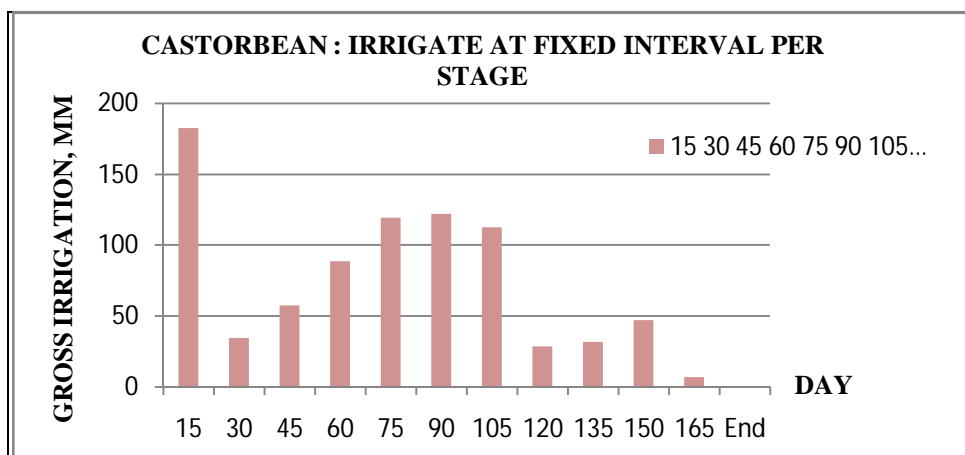


Fig. 4.1 Irrigation Scheduling for castor bean

Here, in this study canal based irrigation system is taken and scheduling is done by two approaches (1) irrigate at critical depletion and (2) irrigate at fixed interval per stage. By comparing results and graphs of both approaches, we come to know that option 1 is better for castor bean as it shows less irrigation requirement i.e. 733.2 mm as compared to other option i.e. 831.4 mm where in both cases yield reduction is zero.

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V. CONCLUSIONS

In canal irrigated area precisely calculated crop water requirement will lead the conservation of water in the command area. That main help in reducing problem of water logging in canal irrigated area then applied to irrigation management model which could exactly evaluate the agricultural water requirements. This study shows a more important intimation that the CROPWAT irrigation management model could be used to effectively and efficiently to estimate the agricultural water requirements of different types of crops. From the result, we can conclude that option 1 is better for wheat, maize and castor bean than other option and for potato 2nd option is better than other option as is shows optimum irrigation scheduling with no yield reduction and can conserve more water.

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