Determination of Crop Water Requirement and Irrigation Scheduling for Banana

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Abstract— Over the last century, the global population has tripled, and water consumption has increased threefold. Water use in India is no exception to this general trend. The main cause of the increase are growing population and rising food demand. In an agrarian economy like India, the importance of water for agricultural productivity hardly needs any emphasis. With increasing scarcity and growing competition for water, judicious use of water in agricultural sector will be necessary. This means that exact or correct amount and correct timing of application should be adopted. In addition, it will need more widespread adoption of deficit irrigation, especially in arid and semiarid 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 improved food security. Irrigation in India includes a network of major and minor canals from Indian rivers; groundwater well based systems, tanks, and other rainwater harvesting projects for agricultural activities. The estimation of “Crop Water Requirement” is essential for irrigation planning and management. The increasing demand and scarcity of water makes it important to use the available water in the most economic way. The accurate determination of irrigation schedule is a time-consuming and complicated process. The introduction of computer programs, however, has made it easier and it is possible to schedule the irrigation water supply exactly according to the water needs of the crops. Ideally, at the beginning of the growing season, the amount of water given per irrigation application, also called the net irrigation depth, is small and given frequently. This is due to the low evapotranspiration of the young plants and their shallow root depth. During the mid-season, the irrigation depth should be larger and given less frequently due to high evapotranspiration and maximum root depth. Thus, ideally, the irrigation depth and/or the irrigation interval (or frequency) vary with the crop development. “Irrigation Scheduling” is necessary to improve the overall efficiency of irrigation projects. Correct assessment of crop water requirement under superior condition is an essential element in order to determine the amount of water required and time of irrigation. The objective of this study is to estimate the crop water requirement and irrigation scheduling using “CROPWAT” for Banana. The CROPWAT is based on penman-monteith method. The study area is Dhandhoda station of Vadodara district in Gujarat, India. Various soil data, i.e. type of soil, infiltration rate, water holding capacity are determined by field experimentation. Climatological data of ten years (2005 to 2014) are used for this study. Irrigation scheduling is carried out for various scenarios as Irrigation at critical depletion, Irrigation at fixed depletion (40 mm). Irrigation at fixed intervals per stage (7 to 10 days). Irrigation at user defined intervals (40/50/60/70/80/90/100 days). The study reveals that out of four scenarios studied, the critical depletion scenario is the best one as the yield reduction is minimum. Crop water requirement for Banana varies from 936.6 mm to 745.6 mm over a period of ten years. Crop water requirement of Banana crop for the year 2014 is 853.8 mm and as per irrigation scheduling carried out by Critical depletion scenario, the total depth of irrigation is 878.8 mm with 0.1 percent yield reduction. It is recommended to irrigate the field as per critical depletion scenario as it applies water before the crop goes under water stress and hence it gives maximum yield.

Key words: Banana, Crop Water Requirement, CROPWAT, Irrigation Scheduling, Minimum Yield Reduction

I. INTRODUCTION

India has made immense progress towards food security. Indian population has tripled, and food-grain production more than quadrupled. There has been a substantial increase in available food-grain per capita. The main cause of the increase are growing population and rising food demand. With increasing scarcity and growing competition for water, judicious use of water in agricultural sector will be necessary. This means that exact or correct amount and correct timing of application should be adopted.

Reference crop evapotranspiration (ETo) is one of the basic components of the hydrologic cycle and is essential for estimating crop water requirements. CROPWAT is meant as a practical tool to help agrometeorologists, agronomists and irrigation engineers to carry out standard calculations for evapotranspiration and crop water use studies, and more specifically the design and management of irrigation schemes.

Banik et al. (2014) carried out the study by CROPWAT model were compared between plain and hilly region for rice and wheat crop to meet the irrigation demand of crops. They concluded that Irrigation requirement of rice and wheat crop is more for the plain region as compared to the hilly region. Simulation study was conducted by Vashishth and Sapute (2015) with the objectives of determining irrigation water requirement and irrigation scheduling of directed seeded rice (DSR) and wheat irrigated by sprinkler irrigation system. They concluded that Irrigation should be done at the critical depletion to achieve 0% yield reduction of wheat and maximum rainfall efficiency. In this study, Crop Water Requirement of Banana crop is determined and irrigation scheduling is carried out by various scenarios.

Shah et al. (2016) carried out the study to determine the crop water requirements and irrigation scheduling for Wheat and Cabbage crops, for the area which is selected near Water Resources Engineering and Management


Institute in Samiala of Vadodara district in Gujarat, India. They concluded that Irrigation should be done at the critical depletion to achieve minimum yield reduction of crops.

II. STUDY AREA AND DATA COLLECTION

The study area is Dhandhoda station of Vadodara district in Gujarat, India. Geographical location of Dhandhoda is 22.32 degree North (Latitude) and 73.96 degree East (longitude) at an elevation of 134 meters.

The area comes under Agro climatic Zone III. The climate is semi-arid.

A. For Crop Water Requirements (CWR)

Daily climatic data (maximum and minimum air temperatures, Relative humidity, wind speed, sunshine hours).

B. For Irrigation Scheduling
- Soil type
- Infiltration Rate
- Soil Moisture Holding Capacity

III. METHODOLOGY

The study is carried out by using CROPWAT software which calculates the crop water requirement and Irrigation scheduling for the Banana. The result of the study will be useful in calculation of agricultural water demand of the study area.

A. Cropwat

Computer model simulation is an emerging trend in the field of water management. CROPWAT is a powerful simulation tool which analyzes complex relationships of on-farm parameters such as the crop, climate, and soil, for assisting in irrigation management and planning. CROPWAT is one of the models extensively used in the field of water management throughout the world. CROPWAT facilitates the estimation of the crop evapotranspiration, irrigation scheduling and agricultural water requirements with different cropping patterns for irrigation planning.

Reference Crop Evapotranspiration (ET0) values calculated using the Penman-Monteith equation.

B. Penman-Monteith Approach

From the Penman-Monteith equation and the equations of the aerodynamic and surface resistance, the FAO Penman-Monteith method to estimate ET0 is expressed as:

\[
ET_0 = \frac{0.408 (R_n - G) + \frac{900}{T} + 0.03 \Delta (e_s - e_a)}{\Delta + 0.03 (e_s - e_a)} \quad (1)
\]

Where:
- \(ET_0\) = reference evapotranspiration [mm day-1],
- \(R_n\) = net radiation at the crop surface [MJ m$^{-2}$ day$^{-1}$],
- \(G\) = soil heat flux density [MJ m$^{-2}$ day$^{-1}$],
- \(T\) = mean daily air temperature at 2 m height [°C],
- \(U_2\) = wind speed at 2 m height [m s$^{-1}$],
- \(e_s\) = saturation vapour pressure [kPa],
- \(e_a\) = actual vapour pressure [kPa],
- \(e_s - e_a\) = saturation vapour pressure deficit [kPa],
- \(\Delta\) = slope vapour pressure curve [kPa °C$^{-1}$],
- \(\gamma\) = psychrometric constant [kPa °C$^{-1}$].

C. Crop Coefficient (Kc)

The Crop coefficient (Kc) integrates the effect of characteristics that distinguish a specific crop from the Reference crop. According to the Crop coefficient approach, Crop evapotranspiration under standard conditions (ETc) is calculated by multiplying the Reference evapotranspiration (ET0) by the suitable Kc.

Kc is influenced mostly by crop type and to a minor extent by climate and soil evaporation. Moreover, the Kc for a given crop varies over the crop growing Stages, since ground cover, Crop height and leaf area change as the crop develops.

D. Crop Coefficient Curve

With reference to seasonal crops, the total growing period can be divided in four distinct growth stages:
- Initial stage: It runs from Planting to approximately 10% ground cover.
- Development stage: This stage runs from 10% ground cover to effective full cover, which usually occurs at the initiation of flowering.
- Mid-season stage: This period runs from effective full cover to the start of maturity, often indicated by the beginning of the ageing, yellowing or senescence of leaves, leaf drop, or the browning of fruit.
- Late season stage: This period runs from the start of maturity to harvest or full senescence.

E. Crop Evapotranspiration (ETc)

Crop evapotranspiration is calculated by multiplying ET0 by Kc, a coefficient expressing the difference in evapotranspiration between the cropped and reference grass surface.

\[ETc = Kc \times ET0\]

The effect of both crop transpiration and soil evaporation are integrated into a single crop coefficient.

The amount of water required by the crop during whole season is defined as crop water requirement.

F. Irrigation Scheduling

Irrigation is required when rainfall is insufficient to compensate for the water lost by evapotranspiration. The primary objective of irrigation is to apply water at the right time and in the right amount. Irrigation Scheduling is carried out using following scenarios.
1) Irrigation at critical depletion,
2) Irrigation at fixed depletion,
3) Irrigation at user defined intervals.
4) Irrigation at fixed interval per stage.

IV. RESULTS AND ANALYSIS

A. Station: Dhandhoda for year 2014

1) Crop Water Requirements

Fig.1 shows computation of crop water requirement of Banana. The results show that a total Irrigation requirement of Banana is 853.8 mm.
B. Irrigation Scheduling: At Critical Depletion

Irrigation is applied at critical depletion and it refills soil to field capacity. Field efficiency is considered as 70%. Fig. 2 shows computation of Irrigation scheduling. As per irrigation scheduling carried out by CROPWAT it shows that gross irrigation requirement is 1255.5 mm and net irrigation requirement is 878.8 mm. Fig. 3 shows the irrigation scheduling for Banana.

C. At Fixed Interval per stage

Irrigation is applied at fixed interval per stage and it refills soil to field capacity. Field efficiency is considered as 70%. Fig. 4 shows computation of Irrigation scheduling. As per irrigation scheduling carried out by CROPWAT it shows that gross irrigation requirement is 1178.6 mm and net irrigation requirement is 825 mm. Fig. 5 shows Irrigation scheduling.

D. At Fixed depletion

Irrigation is applied at fixed depletion and it refills soil to field capacity. Field efficiency is considered as 70%. Fig. 6 shows computation of Irrigation scheduling. As per irrigation scheduling carried out by CROPWAT it shows that gross irrigation requirement is 870.9 mm and net irrigation requirement is 609.7 mm. Fig. 7 shows irrigation scheduling.
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E. At User defined interval

As per irrigation scheduling carried out by CROPWAT it shows that gross irrigation requirement is 914.5 mm and net irrigation requirement is 640.2 mm. Fig.9 shows of Irrigation scheduling.

Table 1: 10 Years Result Of Dhandhoda Station for Crop Water Requirement and Irrigation Depth Applied

At Dhandhoda looking to the crop water requirement and irrigation depth applied for year 2005-2014, it has been found that the minimum crop water requirement is 745.6mm in 2005 and maximum crop water requirement is 936.6mm in 2009.

Similarly the irrigation depth applied minimum is 769.7mm in year 2005 and maximum is 956.6mm in 2006. The deviation of maximum and minimum crop water requirement as well as irrigation scheduling is observed to be 20%.

V. CONCLUSIONS

- Crop water requirement of Banana crop is 853.8 mm.
- As per irrigation scheduling carried out by Critical depletion scenario, the irrigation Requirement is 878.8 mm with 0.1 percent yield reduction.
- As per irrigation scheduling carried out by User defined Interval scenario, the irrigation Requirement is 640.2 mm with 27.1 percent reduction.
- As per irrigation scheduling carried out by fixed depletion Scenario, the irrigation requirement is 609.7 mm with 34 percent reduction.
- As per irrigation scheduling carried out by fixed interval per stage Scenario, the irrigation requirement is 825 mm with 7.5 percent reduction.
- As per scheduling carried out at critical depletion, water applied (i.e. 878.8 mm) is nearer to crop water requirement (i.e 853.8 mm) and yield reduction is 0.1

REFERENCES