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Irrigation water requirement modelling using CROPWAT model: Balangir district, Odisha

Shreya Nivesh, Pradeep Singh Kashyap and Bhagwat Saran

Abstract
Present study deals with the determination of crop irrigation requirement of major cultivated crops in Balangir district, Odisha, India. The main crops include Paddy, Pulses, Cotton, Sesame, Groundnut and Mango. The irrigation water requirements and scheme water supply for each crop in the district were determined by using CROPWAT 8.0 model. Reference evapotranspiration was calculated using Food and Agriculture Organization-Penman Montieth equation. The effective rainfall was calculated using USDA S.C. method. Modelling results showed that actual irrigated area in the district is 17794 km^2 and net irrigation demand for the actual irrigated area is 0.9 BCM. This study might be useful to prevent over or under irrigation and planning water management strategies in the district.

Keywords: CROPWAT, reference crop evapotranspiration, crop evapotranspiration, irrigation water requirement, effective rainfall

1. Introduction

Over the past decade, many countries around the world have witnessed serious water shortages particularly in India. Population growth, Industrialization, extended drought, climate change and environmental concerns are the major limiting factors threatening food security in developing countries. Agriculture is the largest water consumer in India utilizing more than eighty-one percent water. Water for agriculture is becoming increasingly scarce in the light of growing water demands from different sectors. The need for increase in food production to match population growth is becoming a major concern to all the governments of the world. The dependence on water for food production has become a critical constraint to enhance food productivity. Irrigation practice, therefore becomes a most reasonable option as it is able to assist agriculture in areas with minimum rainfall and erratic rainfall distribution pattern. For better management of available resources and agricultural productions, it is necessary to understand irrigation water requirement and present level of water supplies. Methods based on ratio of irrigation water to cumulative pan evaporation (Aiyelaagbe and Ogbonnaya, 1996) [2], open pan evaporation rate (Singh, 1987; Manjunath *et al*., 1994) [17, 11] and soil moisture depletion (Home *et al*., 2000) [9] have been widely used for scheduling irrigation. However, these methods are expensive and tedious. Food and Agriculture Organization recommend using CROPWAT software to better estimate crop water requirement. CROPWAT has been widely used for predicting, reference crop evapotranspiration, crop evapotranspiration, irrigation scheduling and cropping patterns (George *et al*., 2000; Andranistakis *et al*., 2000; Feng *et al*., 2007; Kang *et al*., 2009; Nazeer, 2009; Mimi and Jamous, 2010; Song *et al*., 2016; Tan and Zheng, 2017; Abirdew et *al*., 2019; Ewaid et *al*., 2019; Moeski et *al*., 2019) [8, 4, 7, 10, 14, 12, 19, 20, 1, 5, 13]. Hence in this paper an attempt has been made to compute irrigation requirement of major crops in the Balangir district and to develop scheme water supply under different management conditions using CROPWAT 8.0 model.

2. Materials and Methods

2.1 Study area

The study area selected for the present study is Balangir Distict, also called as Bolangir district and situated in the western part of the state Odisha, India. The watershed lies within the geographical coordinates of 20° 42′ 08.15″ N latitude and 83° 28′ 49.43″ E longitude at an average altitude of 142m. Total geographical area of the district is 6790 km^2 and the average annual rainfall is 1290 mm. The total population of the district is 16.48 lakh and soil which are predominant in this area are Red and Black soils.

2.2 Methodology
For this study Food and Agriculture Organization-CROPWAT 8.0 model is used. CROPWAT was developed by department of Land and Water Resources of FAO. CROPWAT 8.0 is a computer program that integrates several models necessary to predict crop water requirement (CWR), irrigation water management and irrigation scheduling (Smith, 1991) [18]. CWR depends on climatic conditions, crop area and type, soil type, growing season and crop production frequencies (George et *al*., 2000) [8]. It follows FAO approved Penman-Montieth method to estimate reference evapotranspiration (ET_o), crop evapotranspiration (ET_c) and irrigation water management (FAO, 1998; Smith, 1991) [6, 18]. It is to be noted that ET_c represents amount of water that crop losses due to evapotranspiration while, CWR represent amount of water to be applied. Modelling of crop evapotranspiration and irrigation water requirements were carried out using climatic, crop and soil data. The model required the following data for estimating irrigation water requirements.

2.3 Crop irrigation requirement estimation
In calculating the reference evapotranspiration (ET_o), the study utilized 15 years of monthly maximum and minimum temperature, relative humidity, sunshine hour and wind speed data extracted from the New_LocClim (local climate estimator). The ET_o was calculated using FAO Penman-Montieth equation (Allen et *al*., 1998) [3]. Equation can be represented as:

$$ET_O = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1+0.34u_2)} \quad \text{.......... (1)}$$

where, ET_o = reference evapotranspiration (mm/day); R_n = net radiation at the crop surface (MJ/m^2/day); G = soil heat flux density (MJ/m^2/day); T= mean daily air temperature at 2 m height (°C); u_2 = wind speed at 2 m height (m/sec); e_s = saturation vapour pressure (kPa); e_a = actual vapour pressure (kPa); e_s - e_a saturation vapour pressure deficit (kPa); Δ = slope of vapour pressure curve (kPa °C^{-1}); γ = psychrometric constant (kPa °C^{-1}).
Effective rainfall was calculated using USDA-SCS method as described in FAO publications (Sheng-Feng et *al*., 1998) [16]. For equation can be represented as:

$$P_{eff}=P_{tot}(125-0.2*P_{tot})/125 \text{ for } P_{tot}<250\text{mm} \quad \text{........(2)}$$
$$P_{eff}=125 + 0.1P_{tot} \text{ for } P_{tot} > 250 \text{ mm} \quad \text{........(3)}$$

where, P_{eff} = effective rainfall (mm); P_{tot} = total rainfall (mm)
The major cultivated crops in this study area are Paddy, Mung, Cotton, Maize, Cotton, Sesame, Maize, Groundnut, Mango, Onion, Sweet Potato and Capsicum. The salient details of the crops considered for the study area are as per FAO. Crop coefficient values are taken from available published data. ET_o is multiplied by an empirical crop coefficient (K_c) to produce an estimate of crop evapotranspiration (ET_c)

$$ET_c=K_c*ET_o \quad \text{.......(4)}$$

where, ET_c = evapotranspiration of a specific crop (mm/day); Kc = crop coefficient; ET_o = reference evapotranspiration (mm/day).
The major soils of the district are mixed Red and Yellow, Red and Black, Black, Laterite and Lateritic. The salient details of the soils considered for the study area are as per FAO publications.

3. Results and Discussion
The reference evapotranspiration (ET_o) for the district was calculated from Penman-Montieth equation using agroclimatic data. The ET_o ranged from 2.8 mm/day to 7.7 mm/day and it was found maximum in the month of May and minimum in the month of January (Fig. 1). The results show that ET_o was lowest during rainy season to higher during summer season.

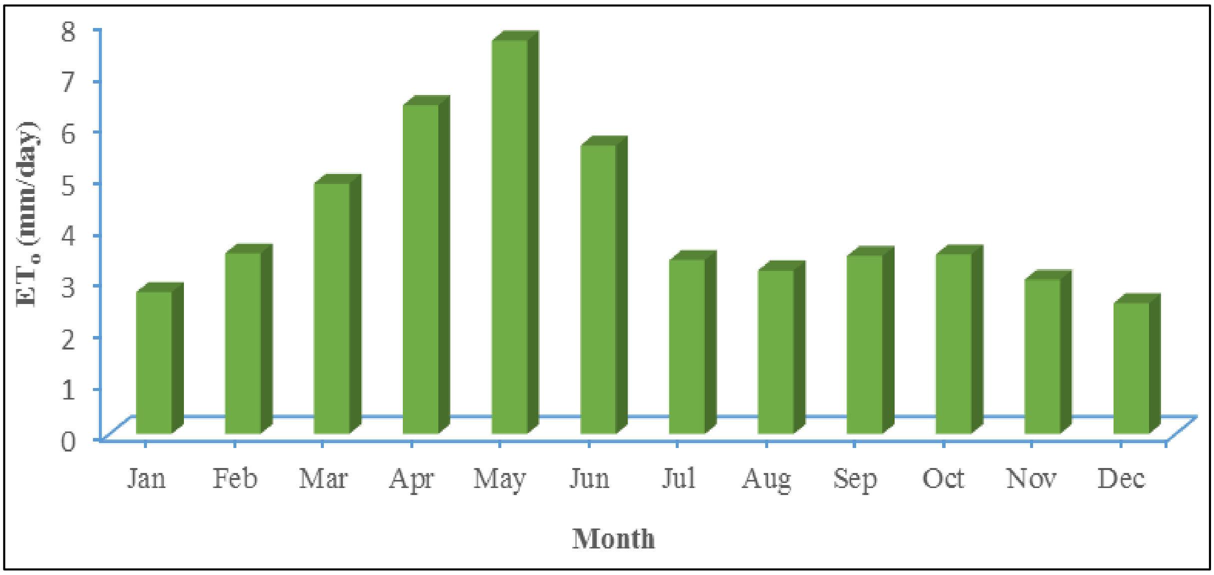

Fig 1: Monthly reference evapotranspiration at Balangir district.

The effective rainfall (P_{eff}) for the district was calculated using USDA-SCS method and it ranged from 3.0 mm to 162.6 mm. The results show that P_{eff} was lowest during winter season to higher during rainy season (Fig. 2).

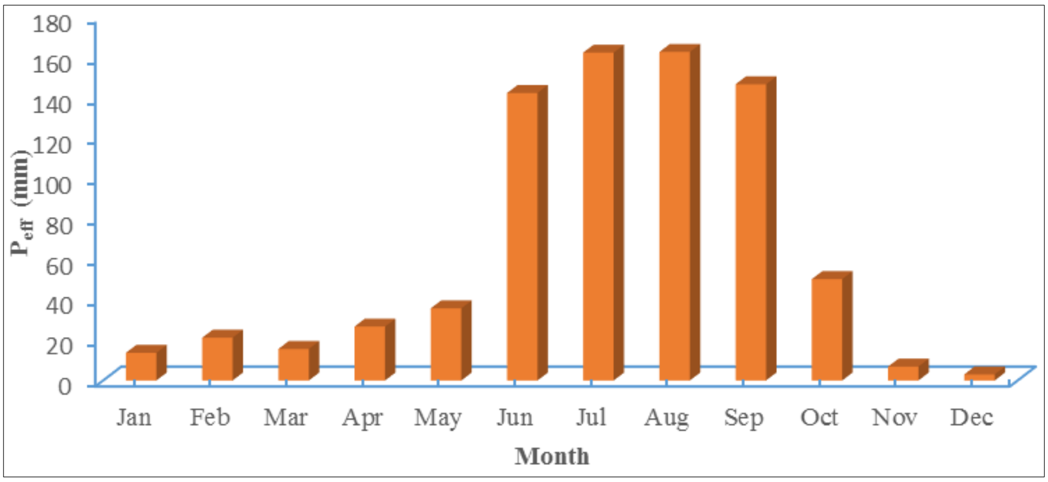

Fig 2: Monthly effective rainfall at Balangir district.

For the measure cultivated crops in Balangir district irrigation requirement (IR) varied from 29 mm to 830 mm. The results show that for mango crop irrigation requirement was found to be maximum in summer season and minimum in winter season (Fig. 3).

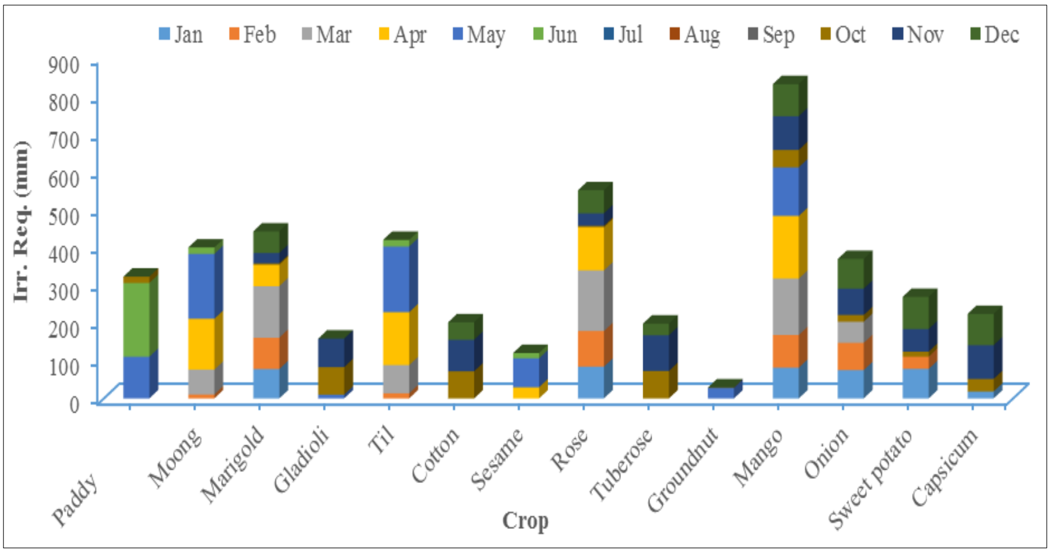

Fig 3: Irrigation requirement for major crops at Balangir district.

The net scheme irrigation requirement calculated using CROPWAT 8.0 model for the Balangir district was found to be maximum in the month of June i.e., 97.1 mm/month and nil for the months of July, August and September.

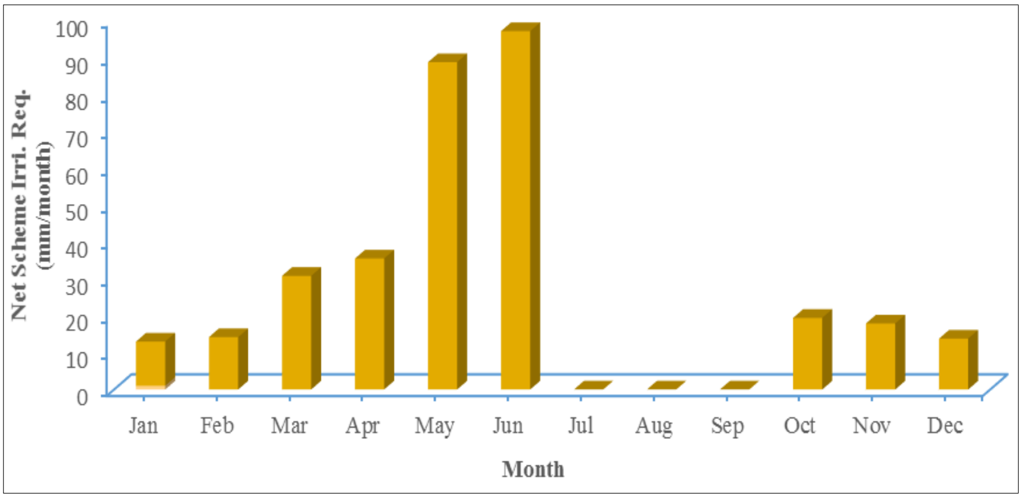

Fig 4: Net scheme irrigation requirement for major crops at Balangir district

Total actual irrigated area and net irrigation demand for actual irrigated area was found to be 17794 km^2 and 852 Mm^3 respectively (Fig. 5). Actual area was irrigated maximum in the month of May and nil in the months of July and August. Net irrigation demand for the actual irrigated area was found maximum in the month of May and nil in July, August and September.

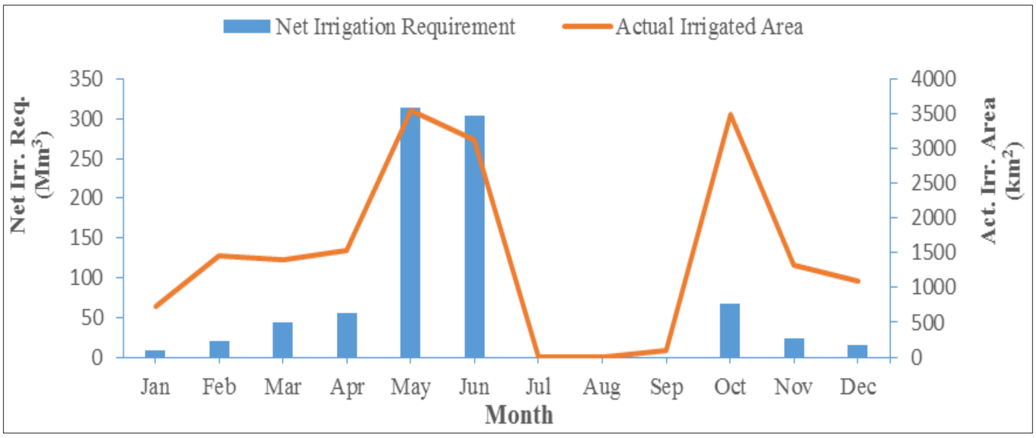

Fig 5: Actual irrigated area and net irrigation requirement at Balangir district

4. Conclusions

An attempt has been made to compute irrigation water requirements of major crops in the Balangir district, Odisha using CROPWAT 8.0 model. Results revealed that total irrigation requirement for major crops of the district was 4524 mm/year and net scheme water supply was 852 Mm^3/year. The results obtained from the study can be used as a guide by farmers for selecting the amount and frequency of irrigation water for the main crops.

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