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Crop water requirement and irrigation schedule for major crops of Indo–gangetic plain using CROPWAT model

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ABSTRACT

In view of increasing groundwater pumping to meet irrigation demand of major crops there is a need to use groundwater efficiently. A study was conducted at *Rasoolpur jatan* village of Muzaffarnagar district to determine the crop water requirement (Et_c) and irrigation scheduling of sugarcane, maize and wheat using CROPWAT 8.0 model. In the study area, reference evapotranspiration (ET_o) varied from 1.89 to 7.33 mm day^{-1} similarly effective rainfall (R_{eff}) varied from 0 to 148.4 mm. At the initial stage ET_c of maize and wheat were found to be lower (28.8 mm and 36.4 mm) and for sugarcane it was maximum (50.6 mm). During the mid–season stage water requirement (ET_c) for wheat was minimum (141.4 mm) and maximum for sugarcane (1098.9 mm). The peak water requirement was 9.27 mm day^{-1} with application efficiency of 60%. The average crop water demand estimated for sugarcane, maize and wheat were 1580 mm, 387.7 mm and 315.4 mm whereas net irrigation requirement (NIR) were 1072 mm,138.2 mm and 192.1 mm, respectively. Proper irrigation scheduling can save 20.05 ha–m and 2.64 ha–m of groundwater in sugarcane and wheat. The study shows that R_{eff} was not sufficient to meet the water requirement of sugarcane, maize and wheat crops. Hence irrigation is needed to meet water requirement of crops and appropriate scheduling practice may be followed in the study area to reduce the load on the groundwater.

1. INTRODUCTION

In India, water availability in agriculture sector is decreasing day by day. Due to growing water demand by different sectors water resource including surface as well as subsurface water is becoming increasingly scarce (Adeniran *et al.,* 2010). In India agriculture sector is the highest water consuming sector (81%) therefore more judicious use of water in agriculture should be sovran precedence (Surendran *et al.,* 2013). For efficient and productive utilization of available water resources, one should have a better knowledge of crop, climate and soil (Ewaid *et al.,* 2019). To maintain biodiversity and economic growth of any country, water is considered as the most important sources (Donald, 1968). The crop productivity other than sugarcane in UP remains nearly constant or lower than the national average. The main limiting component for higher productivity in this region is the soil moisture stress during summer season (Surendran *et al.,* 2015).

The lack of modern and location–specific irrigation methods and information regarding when to irrigate and how much quantity to be applied are the main causes for lower irrigation efficiency in the country (Surendran *et al.,* 2015). Detail information related to soil and climate data are not known to farmers. Existing traditional irrigation methods have low irrigation efficiency. Uneven distributions of rainfall, low water holding capacity of soil as well as low irrigation efficiency have great influence on irrigation water requirements (Kumar, 2017). Crop water requirement (ET_c) have definite bearing on surface as well as sub surface water resources as these resources are used to meet the irrigation need of crops (Ewaid *et al.,* 2019). Therefore, accurate information is essential for effective planning on water management.

Crop water demand and irrigation requirements of some major crops in study area were determined using rainfall and evapotranspiration (ET) through United State Department of Agriculture (USDA) and Penman Monteith method. ET_o is a key component for appropriate irrigation planning and regional water balance studies (Kumar, 2017). The reference evapotranspiration (ET_o) plays a vital role in hydrological studies as it is used for estimating net irrigation requirement (NIR) of crops (Rowshon *et al.,* 2013; Mehta and Pandey, 2015; Doorenbos and Pruit, 1975). Type of crop, different crop growth stages and type of soil as local factors are the various parameters that affect the crop water demands (Gadge *et al.,* 2011).

According to an estimate by Central Ground Water Board, Government of India, the annual replenishable ground water resource for the entire country is 432 billion cubic metre (BCM) out of which the net annual ground water availability is 393 BCM. The annual ground water draft is 249 BCM in which 221.5 BCM is used for irrigation. The net ground water availability for future is 173.25 BCM (CGWB, 2019). The present stage of groundwater development in the country is 63.33%. Groundwater availability is non–uniform in space and time. Sugarcane is a cash crop mainly cultivated for sugar in tropical and subtropical agro–climatic conditions of India. In the major sugarcane growing region, more than 80% of sugarcane area is irrigated by groundwater through deep–well pumping. In these regions of the country, the annual groundwater draft is higher than the net annual ground water availability. Hence, the groundwater table is lowering approximately @ 1.0 m $year^{-1}$ due to over exploitation. At the current level of water consumption for sugarcane (25,000 KL ha^{-1}), the major sugarcane–producing state including Uttar Pradesh, Maharashtra and Karnataka may not possibly sustain their sugarcane production in future (Dingre and Gorantiwar, 2020). Long term data on rainfall analysis of study area demonstrated that crops failure and declining water table is due to prolonged dry spells (Sharma and Dubey, 2013).

Rasoolpur Jatan village of Shahpur block is a major grower of sugarcane and irrigation being done through open channel to sugarcane using substantially excess water than required. This is mainly due to the beliefs among farmers that more the water is applied to sugarcane, more yield is obtained. Of course, this is not true; therefore there is a need to provide the information to farmers on precise water measurement. Due to excess groundwater pumping water table is declining very fast and many pockets come under dark zone to over exploited state in the study area. In this situation, the productivity of high–water–requirement crops like sugarcane can only be sustained by using water saving technologies. So the sole reason to conduct this study is to improve the use efficiency of irrigation water with appropriate scheduling practice. Irrigation scheduling determines when to irrigate and how much quantity to be given (Afandi *et al.,* 2010). For scheduling of any crops exact quantity of water and correct timing of application is very much essential component (Bhat *et al.,* 2017). For estimation of ET_o various approaches have been used (Jensen *et al.,*1990) including use of lysimeter, water balance method and use of meteorological data for estimation of ET_o (Choudhury *et al.,* 2013). Climatic parameters and plant characteristics affects the ET demand (Priya *et al.,* 2014). Keeping this in view, the present field experiment was conducted to reduce excess groundwater pumping with appropriate scheduling practice of sugarcane, maize and wheat in Shahpur block of western Uttar Pradesh.

2. MATERIALS AND METHODS

Study Area

The study was carried out for Rasoolpur Jatan village located in Shahpur block, Muzaffarnagar district, Uttar Pradesh (Fig. 1) which represents agro–ecological zone IV (Mandal *et al.,* 2016). The climate is characterized as hot dry sub–humid. The average annual rainfall in the area is 883 mm. Major portion of annual rainfall occurs in the month of July to October. The average minimum and maximum temperature ranges between 7.3^{o}C to 13.5^{o}C and 18.5^{o}C to 28.6^{o}C, respectively during winter whereas in summer average minimum and maximum temperature ranges between 13.5^{o}C to 24.6^{o}C and 30^{o}C to 41^{o}C, respectively. The highest and lowest temperatures in the district are generally recorded during the month of June and January, respectively. The sunshine hours are minimum in January and maximum in May. The average annual sunshine is 9.3 hrs and average annual radiation is 20.2 MJ $m^{-2}day^{-1}$. The soil texture of the Rasoopur Jatan is given in the Table 1.

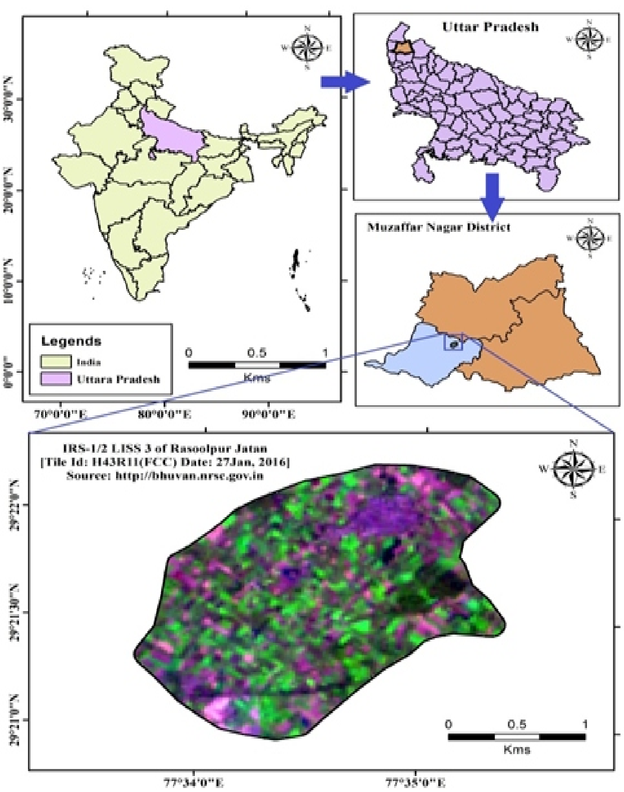

Fig. 1. Location map of study area

Sugarcane, wheat and maize are the major crops and main source of irrigation in the village is groundwater. The cropping intensity and irrigation intensity of the study area is 142% and 135%, respectively. The contribution of groundwater in irrigation is around 89%. The present groundwater level in the study area varies between 20.84 m bgl to 25.14 m bgl whereas the present stage of groundwater development in the study area is 96.75%. Due to indiscriminate use of groundwater in the study area water level is declining rapidly (CGWB, 2017). The monthly variation of ET_0 is shown in Fig. 2 depicting variation of climatic parameters.

CROPWAT 8.0 Model Description and Input Data

In this study, CROPWAT 8.0 model developed by FAO was used to calculate ET_o, ET_c and irrigation scheduling for crops. The input parameters for this model includes a) climatic data [daily or monthly rainfall (mm), daily or monthly maximum and minimum temperature (°C), humidity (%), wind speed (km hr^{-1}) and total solar radiation (h)] b) soil data [soil type, moisture holding capacity, infiltration rate of soil, soil moisture depletion] and c) crop data [planting date, harvesting date, crop coefficient (K_c), crop growth period in different stages of crop, rooting depth, yield response factor]. For this study rainfall data for thirty six years (1980–2015) were collected from the India Meteorological Department (IMD). The crop coefficient values (Table 2) for some major crops such as sugarcane, wheat and maize were taken from the FAO–56 manual (Allen *et al.,* 1998). Planting and harvesting data were collected during the experiment. The soil in the Rasoolpur Jatan village is loam (medium) type as per FAO standards.

Table: 1
Soil texture at Rasoolpur Jatan village, Muzaffarnagar district

S.No.	Textural class	Sand (%)	Silt (%)	Clay (%)
1	Loam	48.0	41.6	10.4
2	Loam	51.2	32.8	16.0
3	Loam	49.6	29.6	20.8

Reference Evapotranspiration (ET_o)

ET_o is one of the important parameters required for crop planning and irrigation strategies (Mehta and Pandey, 2015). Among various methods of ET_o estimation, Penman–Monteith method is most widely used around the globe (Kumar, 2017; Sravya *et al.,* 2019) and given in eq. 1.

$$ET_O = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T_a + 273} U_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34U_2)} \quad ...(1)$$

Where, ET_o = 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_a = mean daily air temperature at 2 m height (°C), U_2 = wind speed at 2 m height (ms^{-1}), e_s = saturation vapor pressure (kPa), e_a = actual vapour pressure (kPa), e_s–e_a = saturation vapor pressure deficit (kPa), Δ = slope vapor pressure curve (kPa°C^{-1}), γ = psychrometric constant (kPa°C^{-1}).

Crop Water Requirement (ET_c)

Evaporation and transpiration phenomenon takes place simultaneously, These two processes combined together called ET. The ET_o is defined as water loss from a hypotheti-

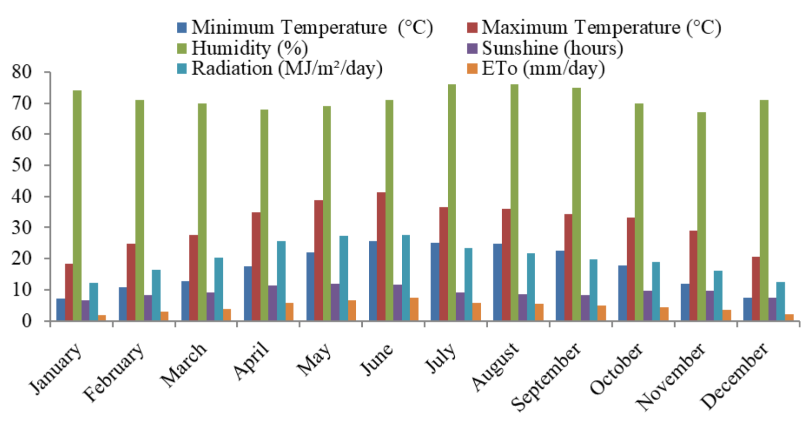

Fig. 2. Variation of temperature, humidity, sunshine, radiation and ET_o at Rasoolpur Jatan village, Muzaffarnagar district

Table: 2
Stage wise crop coefficient (K_c), crop duration and height of different crops at Rasoolpur Jatan village

Crops	Kc_{ini}	Kc_{mid}	Kc_{end}	Rooting depth (m)	Crop duration (days)	Mean crop height (m)
Sugarcane	0.40	1.25	0.75	1.50	320	3
Maize (*kharif*)	0.30	1.20	0.35	1.00	95	2
Wheat	0.70	1.15	0.25	0.90	120	1

Kc_{ini} = Initial stage crop coefficient, Kc_{mid} = Mid–stage crop coefficient, Kc_{end} = End stage crop coefficient

cal green grass cover which is disease free and under well watered condition with a crop height of 0.12 m, canopy resistance (70 s m^{-1}) and albedo (0.23). Knowledge about variability in crop evapotranspiration (ET_c) is essential for realistic assessment of crop water footprint (Mali *et al.,* 2015). The ET_c was calculated with the help of K_c as given in the eq. 2.

$$ET_c = K_c \times ET_o \qquad \dots (2)$$

Where, ET_c = crop evapotranspiration / crop water requirement (mm day^{-1}); ET_o = reference evapotranspiration (mm day^{-1}); K_c = crop coefficient.

To know the ET_c of sugarcane, March 28 to February 10 duration was considered for estimation of ET_c while for Maize, July 05 to November 06 period was selected and similarly for wheat, November 22 to March 31 period was selected.

Effective Rainfall (R_{eff})

In present study, USDA approach was used to estimate R_{eff} (FAO, 2009). It gives the relation between R_{eff} and mean rainfall for different values of ET_c.

Net Irrigation Requirement (NIR)

The ET_c is first satisfied by rain and only the remaining quantity is given as irrigation. Considering water for land preparation, ET_c and R_{eff}, the NIR is calculated (Kumar, 2017). NIR is the volume of water which is delivered to the crop field and available for the plant to use. As per their growing period NIR is calculated for different crops by using the eq. 3.

$$NIR = ET_c - R_{eff} \qquad \dots (3)$$

Where, NIR = net irrigation requirement (mm); ET_C = potential crop evapotranspiration (mm day^{-1}); R_{eff} = effective rainfall (mm).

The NIR of the selected crops was calculated by summing the monthly NIR of selected crops.

3. RESULTS AND DISCUSSION

The occurrence of rainfall affected the depth of irrigation in different growth stages. The Et_c, R_{eff} and irrigation requirement of sugarcane, maize and wheat is shown in Table 3.

The water requirement of sugarcane during its initial stage continuously increased and varied between 1.77 mm day^{-1} to 2.30 mm day^{-1}. During developmental stage and mid–season stage, the water requirement (ET_c) of sugarcane increased continuously and varied between 2.50 to 7.90 mm day^{-1}, and 3.78 mm day^{-1} to 9.27 mm day^{-1}, respectively. The water requirement reached to its maximum during the mid–season stage. In the late–season stage ET_c decreased continuously till the end of crop season and varied between 1.67 mm day^{-1} to 3.11 mm day^{-1}. The ET_c for initial, development, mid–season and late season of sugarcane were 50.6 mm, 264.7 mm, 1098.9 mm, and 165.8 mm, respectively. Invariably, grand growth stage was identified as high water requirement stage due to its long duration. This followed by tillering stage and maturity stage. Thus total depth of water required for sugarcane is 1580 mm. The ET_c varies considerably from place to place depending on weather conditions, texture of soil and duration of the crop. Numerous approaches have been used by different researchers to measure or estimate ET_c (Silva *et al.,* 2012; Win *et al.,* 2014; Anderson *et al.,* 2015; Cardoso *et al.,* 2015). Nevertheless, its estimate largely depends upon type of approach used by researchers. Using water balance method, Dingre and Gorantiwar (2020) reported ET_c of sugarcane as 1318−1426 mm including annual R_{eff} in semi−arid region of Maharashtra state, India. Likewise, Win *et al.* (2014) at Myanmar and Cardoso *et al.* (2015) at tropical Brazil reported ET_c as 1369.84 mm and 1438.23 mm, respectively. Omary and Izuno (1995) in south Florida, USA used a novel way of measuring actual sugarcane evapotranspiration by monitoring daily changes in the height of the water table and estimated annual ET_c of sugarcane as 1060 mm. Anderson *et al.* (2015) measured ET_c at two irrigated sugarcane fields (1191 mm and 1389 mm) of Maui, Hawaii, USA in contrasting climates by eddy covariance towers. They used the short (ET_0) and tall (ET_r) vegetation versions of the American Society for Civil Engineers (ASCE) equation. The only field water balance study reported ET_c as 1686.7 mm for tropical condition of Brazil (Silva *et al.,* 2012). Thus, on an annual basis, the ET_c ranges from 950 mm to 1700 mm depending on the location from different parts of the world. Therefore, ET_c amounting 1580 mm derived by Penman–Monteith method in this study seems to be appropriate for dry sub–humid conditions.

Similarly for wheat, ET_c during its initial stage varied between 1.78 mm day^{-1} to 2.12 mm day^{-1}. During second phage (development stage), ET_c of wheat decreased and varied between 1.6 mm day^{-1} to 2.09 mm day^{-1}, whereas in mid stage, the water demand increased and varied between 2.07 mm day^{-1} to 3.76 mm day^{-1}. Maximum water requirement reached during the mid–stage. ET_c decreased in the late–season and varied between 1.77 mm day^{-1} to 3.76 mm day^{-1}. The crop water needs for wheat was found lesser in the

Table: 3
Crop water requirement, effective rainfall and irrigation water requirement of different crops

Crops	Total ET_c (mm)	Effective rainfall (mm)	Irrigation water requirement (mm)
Sugarcane	1580	508	1072
Maize (*kharif*)	387.7	249.5	138.2
Wheat	315.4	123.3	192.1

initial and development stage as compared to mid and late season stage. During the four different stages, ET_c for wheat were 36.4 mm, 57.5 mm, 141.4 mm, and 80.1 mm, respectively. Invariably, grand growth stage identified as high water requirement stage due to its long duration. This followed by maturity stage and tillering stage. Thus ET_c for wheat was found to be 315 mm. Kumar (2017) reported that the total seasonal ET_c for wheat varied between 212.9 mm and 243.3 mm at Sabour and Patna, respectively. Since Sabour comes in III A zone and Patna in III B zone there was large difference between total ET_c of wheat crop at both the locations. Tyagi *et al.* (2000) reported the average measured seasonal crop ET amounts of 336 mm for wheat considerably lower than reported for studies conducted at other places in India. The difference in crop ET values of these crops between Karnal and other places in India may be due to difference in approach including measurement of crop ET by sensitive lysimeters at Karnal. For West Bengal, the seasonal ET_c of winter wheat was between 238.2 mm and 261.95 mm (Bandyopadhya and Mallick 2003). Mehta and Pandey (2016) recorded probably highest winter wheat ET of 501.2 mm from central Gujarat witnessing higher temperature. Thus the wheat evapotraspiration ranges from 210 mm to 510 mm depending upon the location from different part of India and its growing period.

During its initial stage, maize water requirement varied between 1.74 mm day^{-1} to 1.89 mm day^{-1}. In the development stage, ET_c of maize increased continuously and varied between 2.07 mm day^{-1} to 4.72 mm day^{-1}, whereas during mid–stage, water demand increased and varied between 5.59 mm day^{-1} to 5.98 mm day^{-1}. During the mid–season stage water requirement was maximum. In the late–season stage ET_c decreased continuously towards the end of crop season. In this stage ET_c varied between 1.59 mm day^{-1} to 4.21 mm day^{-1}. The ET_c of maize crop during four different stages were 28.8 mm, 64.5 mm, 185.7 mm, and 108 mm, respectively. Thus total depth of water required for maize was 387.7 mm. Kumar (2017) reported that ET_c for *kharif* maize crop was 291.6 mm at Sabour and 318.7 mm at Patna. Likewise, Mehta and Pandey (2016) reported *kharif* maize having the highest ET_c of 445.4 mm. Thus ET_c was found to vary not only with the crops, its stage and duration, but also with the season as well. Kumari *et al.,* (2017) in western UP found that 450 mm of water is required for *kharif* maize. Thus it is found that ET_c for *kharif* maize varies between 290 mm to 450 mm and the information generated can be used in scheduling irrigation for different crops in India.

Irrigation Schedule for Different Crops

Water is supplied to the farmer's fields through very poorly maintained distribution systems that is made of earthen channels suffer substantial water loss due to leakage, seepage and deep percolation (Al–Ansari and Knutsson, 2011). Optimization of irrigation water requires scientific irrigation scheduling practices. Irrigation scheduling helps to meet water demands of crops and avoid over or under application of water (Montoro *et al.,* 2012). Table's 4 to 6 and Fig's 3 to 5 illustrate the schedules of irrigation for the sugarcane, maize, and wheat crops.

The total available moisture (TAM) and readily available water (RAM) is the portion of TAM that crop can take from their root zone without facing any water stress as shown in the above Fig's 3, 4, and 5 (Some *et al.,* 2006). Table's 4, 5, and 6 indicate the irrigation scheduling for sugarcane, wheat and maize, respectively. From the above results, it is clear that for proper germination, first irrigation was needed at the beginning of sugarcane transplanting. In the initial stage, it required gross irrigation of 200 mm at 60% application efficiency. During the development stage

Table: 4
Irrigation schedules for sugarcane

Crop	Stages	Net Irrigation (mm)	Gross Irrigation (mm)	Flow ($l\ s^{-1}ha^{-1}$)
Sugarcane	Init	60	100	0.68
	Init	60	100	1.65
	Dev	65	108.3	0.9
	Dev	65	108.3	1.79
	Dev	65	108.3	1.79
	Dev	70	116.7	1.35
	Dev	70	116.7	2.25
	Dev	70	116.7	2.25
	Dev	70	116.7	2.25
	Mid	70	116.7	2.25
	Mid	70	116.7	1.93
	Mid	60	100	0.26
	Mid	60	100	0.72
	Mid	50	83.3	0.21
	Mid	50	83.3	0.8
	Mid	40	66.7	0.37
	Mid	40	66.7	0.55
	End	37	61.7	0.45
	End	-	-	-

Table: 5
Irrigation schedules for wheat

Crop	Stages	Net Irrigation (mm)	Gross Irrigation (mm)	Flow ($l\ s^{-1}ha^{-1}$)
Wheat	Init	-	-	-
	Init	49.7	82.8	0.39
	Mid	71.8	119.6	0.62
	Mid	70.7	117.8	0.60
	End	-	-	-

Table: 6
Irrigation schedules for maize (*kharif*)

Crop	Stages	Net Irrigation (mm)	Gross Irrigation (mm)	Flow ($l\ s^{-1}ha^{-1}$)
Maize	Init	34.7	57.8	0.23
	Mid	103.5	172.5	0.68
	End	-	-	-

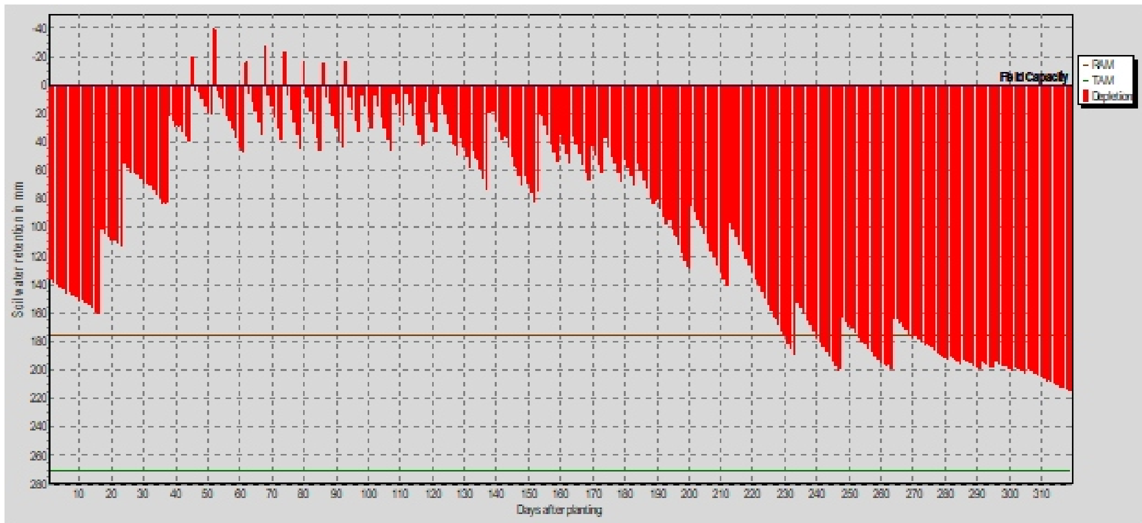

Fig. 3. Irrigation schedules for sugarcane

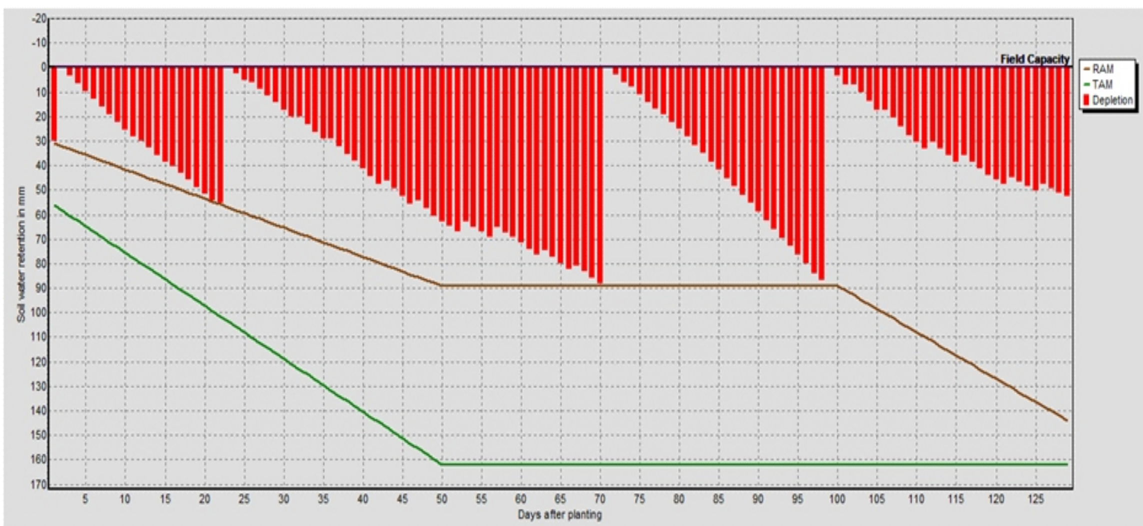

Fig. 4. Irrigation schedules for wheat

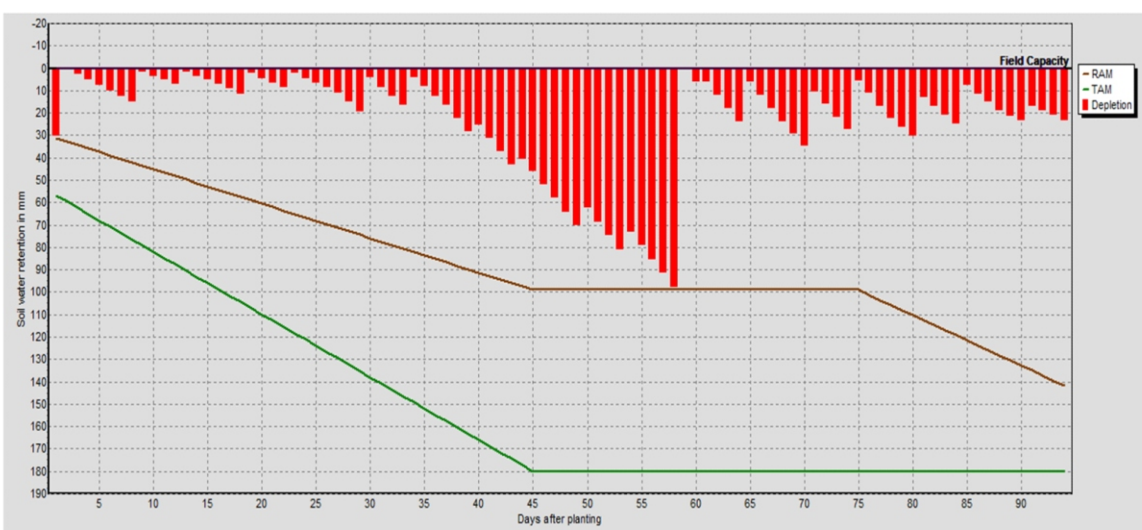

Fig. 5. Irrigation schedules for Maize (*kharif*)

the gross irrigation amount varied from 108.3 mm to 116.7 mm. Similarly, it was found that its irrigation requirement was high at the start of mid–season stage and gradually decreases. Mehanuddin *et al.* (2018) reported that sugarcane crop in the developing stage requires net irrigation of 196.7 mm (gross irrigation of 281.0 mm) and at the 109th day of mid stage it requires net irrigation of 196.8 mm (gross irrigation of 281.1 mm) at the 155th day of the mid stage it requires net irrigation of 199.4 mm (gross irrigation of 284.9 mm) in Shimoga, Karnataka. The total NIR of sugarcane was 640.4 mm at 70% application efficiency, much less than our estimation of 1072 mm at 60% application efficiency due to difference in water application efficiency, climatic differences and number of rainy days at both the places. For the wheat crop in *rabi* season first irrigation was required on 22nd day after sowing. For the first irrigation, the NIR was 49.7 mm. Similarly second and third irrigation were scheduled on 70th and 97th day after planting. During this stage net irrigation of 71.8 mm and 70.7 mm were computed to reach its maturity stage. Kumar (2017) reported that the net irrigation water requirement for *rabi* wheat varied between 173.7 mm and 240.5 mm and for *kharif* maize it varied between 67.5 mm and 164.1 mm at Sabour and Patna, respectively. In the *rabi* season, crop water demand and irrigation requirement of wheat were more because of limited R_{eff}. Mehanuddin *et al.* (2018) reported that for maize crop in *kharif* season, there is no need to supply water through irrigation, since rainfall was sufficient to meet the irrigation requirement but in our study it was found that maize required net irrigation of 34.7 mm and 103.5 mm in the initial and mid–season stage, respectively due to insufficient rainfall in *kharif* season. Second irrigation was scheduled on 58th day. The highest irrigation water required in grand growth stage for sugarcane and wheat due to long duration and the lowest irrigation water was required for the maturity stage. Bhat *et al.* (2017) using CROPWAT model, reported the irrigation requirement of *kharif* maize to be 288.2 mm in Kashmir. It may be due to lower available moisture in the soil during the crop period. Thus we can see that irrigation requirement depending on the location, due to varying climatic conditions.

The present land use in the study area included 289.66 ha under double / triple crop, 5.02 ha current fallow, 0.70 range land and 19.96 ha as orchards. The area under sugarcane, wheat, and rice crop were 213.3 ha, 80.0 ha, and 46.6 ha, respectively which were irrigated through groundwater. As per irrigation schedule using CROPWAT model, gross irrigation requirement of sugarcane, wheat and maize were found as 1786.7 mm, 320.2 mm, and 230 mm, respectively. A survey with farmers reveals that they are giving 3 to 4 number of irrigations to wheat, 16 to 18 number of irrigations to sugarcane thus applying 1880 mm water to sugarcane and 353 mm water to wheat through traditional irrigation methods. It is clear from above that farmers are applying more water to the crops and groundwater is the only source of irrigation in the study area hence water table is declining very rapidly due to excessive pumping. Passioura (2006) reported that irrigation scheduling not only improve timing of water applications but also enhance the ratio of yield to consumptive use (water productivity) by improving gravity fed open channel irrigation systems to pipe irrigation and pressurized drip or sprinkler systems. Therefore, it is the need of hour to change the cropping pattern as reducing the sugarcane area and replacing it with other less water demanding crop and replace the traditional open channel irrigation with pipe network and micro irrigation system that will also arrest the declining water table and enhancing the productivity with the available water resources. Thus for the sustainable utilization of groundwater resources proper irrigation scheduling will help farmers to shift from high water demand crop to less water demand crops. Irrigation scheduling helps avoiding excess use of water and excess running of pump.

4. CONCLUSIONS

In this study, an attempt has been made to calculate ET_o, ET_c and NIR of three crops such as sugarcane, wheat and maize using CROPWAT 8.0 model. The ET_c, NIR and K_c values changes with the crop growth stages. The crop water demand estimated for sugarcane, maize and wheat were 1580 mm, 387.7 mm, and 315.4 mm, respectively. Among the three major crops sugarcane has highest ET_c. The gross irrigation requirement for sugarcane, wheat and maize with scientific scheduling practice were calculated as 1786.7 mm, 320.2 mm, and 230.3 mm, respectively. In sugarcane and wheat 94 mm and 33 mm of irrigation water can be saved per hectare. R_{eff} is not sufficient to fulfill the ET_c for sugarcane, maize and wheat due to erratic and inadequate distribution of rainfall. Therefore to meet the crop water demand additional irrigation through groundwater is necessary. The outcomes of this study can be useful in raising awareness among farmers about use of efficient irrigation methods and save water, time, energy and money.

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