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Modelling of Irrigation Water Demand for Sustaining Crop Yield in Saline Environment

Nivedita Singh[1], Shiv Singh Tomar[1], Priyanka Tiwari[2], Mukesh Seetpal[1] and Swapnil Ganveer[3]

[1]School of Agriculture, ITM University, Gwalior (M.P), India
[2]National Institute technology, Kurukshetra, Haryana, India
[3]Foundation for Ecological Security: FES, Balaghat (M.P), India

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ABSTRACT

Increasing the productivity of water and making safe use of poor quality water in agriculture will play a vital role in easing competition for scarce water resources prevention of environmental degradation and provision of food security. The purpose of this study is to cover the crop water demand and supply gap with the management strategies. The comparison of actual water supplies and demand, i.e. crop water demand has been calculated and found that demand is more than supply. The daily reference evapotranspiration for Bhutana distributory is estimated using pan-Montieth method in CROPWAT model and crop-water demand has also been calculated using CROPWAT model. The supply shortfall in total Rabi seasons is 329.5 mm in 2009-10 and 162.2 in 2010-11. This gap is met by pumping ground water. Different scenario is generated after canal supply gap analysis because supply is less and demand is more and at the same, ground water quality is not so good. In some places, there is a problem of salinity or sodicity. Twelve point have been selected for soil sample from different locations of Butana distributory. The result revealed that EC, SAR, RSC varies from 1.5 g/kg, 2.7-20 (mmoles $kg^{-1})^{0.5}$, 0- 8.8 mg/l. The best management strategies such as growing salt tolerant crops varieties and proper irrigation scheduling with effective conjunctive use of multiquality irrigation water, and pre-sowing water management was suggested for various scenarios of deficit canal water supply, poor soil and ground water quality, and water logging conditions for growing more food with less water of good/poor quality. This study will be helpful for engineers, researchers and farmers in taking decision on utilization of ground water, which will minimize their yield losses in scarce water supply and marginal quality of ground water.

Key words : *Poor quality water, Net irrigation requirement, Cropwater requirement, Groundwater quality*

Introduction

Introduction of canal irrigation has increased crop yield and agricultural production in the country for meeting the food grain demand of the burgeoning population leading to the food security of the country. Since, the share of water to agriculture is declining year by year due to the diversion of canal water to other competitive water user sectors, this leads to water scarce situation in irrigated agriculture, particularly, in saline environment. At the same time, climate change is further aggravating the water availability to irrigated agriculture. In efficient water management practices at head reaches and deficit canal supply at tail reaches along with improper conjunctive use of poor quality groundwater are resulting in soil salinization and water logging, respectively, leading in low crop yield in both reaches. Information regarding soil properties is critical for stakeholders attempting to increase nutrients use efficiency and crop productivity (Wani *et al.,* 2014; Yadav *et al.,* 2018; Upadhya *et al.,* 2020) Therefore, more food with less quantum of water in saline environment has to be produced to meet the foodgrain demand of growing population in the country. Out of 4.42 Mha of total geographical area of Haryana state, 80% is under cultivation. The irrigated area constitutes 84% of the cultivated area in the state. The cropping intensity in the state is 181% with total food grains production of over 13 million tones. (https://icar.org.in/files/state-specific/chapter/52.htm). The Food and Agriculture Organization (FAO, 2002) defines modernization as ''a process of rehabilitation of irrigation systems during which substantial modifications of the concept and design are made to take into consideration the changes in techniques and technology and to adapt the irrigation systems to the future requirements of operation and maintenance''.The supply of water is inadequate compared to its growing demand in our country (Bhat, 2014; Deekshithashetty *et al.,* 2021). It also requires that the delivery of water should be made as flexible as possible with ''demand irrigation being the ideal solution''.Several management strategies have been developed for producing optimum crop yield indeficit canal supply and with conjunctive use of poor quality waters (Sharma and Minhas, 2005). Despite this effective and well-adopted method of water distribution, its supply is unreliable and inadequate to meet the crop water demand (Tyagi *et al.,* 1988) and the amounts of water received by the farmers do not correspond with the allocation principle of warabandi. The present study focuses on Demand supply water quality analysis. Some practical or workable management strategies have been suggested based on previous research experience.

Materials and Methods

The long term meteorological data, from 2009-11 recorded by Karnal agricultural weather station was applied to CROPWAT model to calculate the reference evapotranspiration. The calculation of cropwater demand using CROPWAT model (Doorenbos and Pruitt, 1976; Jamshid, 2003; Naheed and Mahmood, 2011; and Smith, 1992). The daily meteorological data includes: 1. Mean air temperature, 2. Maximum and minimum temperature, 3. Dew point temperature, 4. Average relative humidity, 5. Wind speed, 6. Sunshine hours, and 7. Solar radiation. The calculated reference evapotranspiration from penman-montieth method were used in the investigation for further application in the CROPWAT model to calculate the crop water requirement. Crop module (include crop coefficient value, stages of crop, rooting depth of crop, critical depletion, yield response factor and crop height), harvesting date of crop and soil module (include total available soil moisture, maximum rain infiltration rate, maximum rooting depth and Initial soil moisture depletion) and the initial available soil moisture are used for calculation of cropwater demand and irrigation requirement. After that net irrigation requirement was calculated using formula. The net irrigation requirement of both the rabi season year are compared with the actual canal supply data and also collect the ground water sample and analysis has been done. Shortages and excess supplies are identified and best-suited management options are recommended based on the experience reviewer of the system.

Study area

The study area butana distributary is situated in the north- west part of Sonipat district and north of Rohtak district in Haryana . The butana distributary is a part of western Yamuna canal. The butana watershed lies between 28°45' to 29°43'N latitude and 76°53' to 77°44'E longitude with geographical area 231 km^2. Geologically the study area is formed under the fluviate processes of the Indo-Gangetic river system. Soils in the Butana distributary command is, in general, sandy loam in texture. The daily meteorological data of 3 years period Rabi season in the present study were obtained from the meteorological department CSSRI, Karnal, Haryana. Butana command area falls under arid and semi arid region. Fig. 1 shows the study area.

Data Collection

Crop calendar

Wheat and mustard crops are grown in the study area. Both crops are mainly grown during October to April (*Rabi* season). Fig 2 shows the crop calendar.

Canal Supply data

The daily supply data of Butana distributary for 2009, 2010 and 2011 for the present study were obtained from the Irrigation Department, Haryana. Table 1 presents the hydraulic parameter of canal.

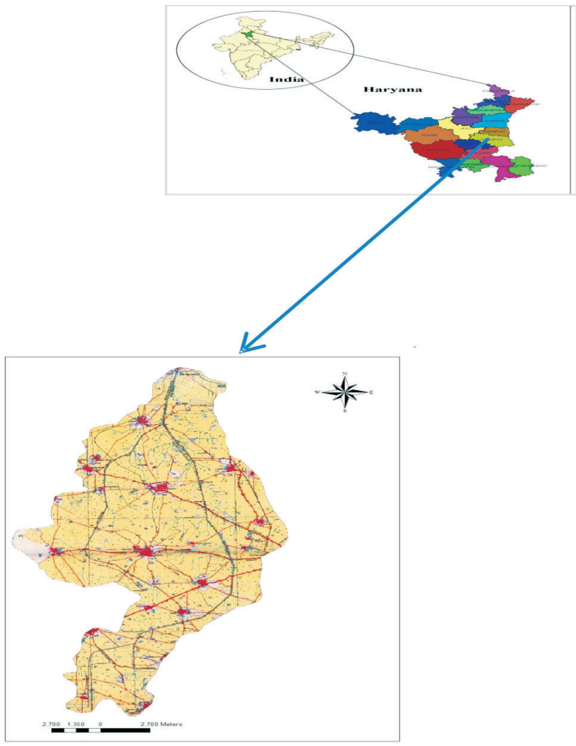

Fig. 1. Location map of the Study area.

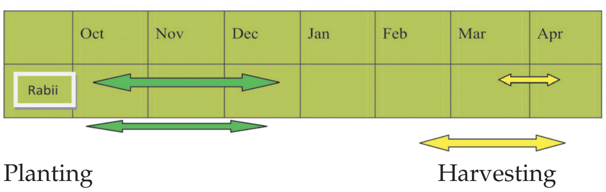

Fig. 2. Crop calendar of Rabi season wheat crop

Data analysis

The net irrigation requirement (NIR) is defined as amount of irrigation water required to be delivered in the field to meet the consumptive requirement of crop as well as other such as leaching, pre-sowing and nursery water requirement (if any) and its shown in equation 1.

$$NIR = \frac{CIR+LR+PSR+NWR}{projectefficiency} \quad .. (1)$$

Where, LR = Leaching requirement, PSR = Pre-sowing requirement, NWR = Nursery water requirement.

Groundwater quality analysis

Soil and groundwater samples collected from farmers fields were analysed for quality using methods as described by Richards, (1954). The formula of SAR and RSC are shown in equation 2 & 3. The relationship usedfor estimation of sodium adsorption ratio, SAR (mmoles $kg^{-1})^{0.5}$ and residual sodium carbonate, RSC mg/l expressed as:

$$SAR = \frac{N_a^+}{\sqrt{\frac{Ca^{++}+Mg^{++}}{2}}} \quad .. (2)$$

$$RSC = (CO_3^{2-} + HCO_3^-) - (Ca^{2+} + Mg^{2+}) \quad .. (3)$$

Where, Na is the sodium, Ca is the calcium, Mg is the magnesium, CO_3^{2-} is the carbonateand HCO_3^- is the bi-carbonate in the irrigation water.

Results and Discussion

Analysis of crop water demand

Cropwater requirement of wheat crop in the study area was 341.8 mm for the year 2009-10 (Rabi season) and 284.2 mm for the year 2010-11, whearas effective rainfall in this periods was 32 mm and 71.8 mm. Irrigation water requirement was calculated by using CROPWAT (Smith, 1992) software. Then, NIR requirement was calculated with the help of equation1 and the NIR was 469 mm in (2009-10) and 392.2 (2010-2011) and the supply was 158.69 mm and 228.26 mm Gap (Deficit supply) has been found by subtraction of NIR and Supply. Deficit supply is presented in Table 2.

This study indicates that water supplies is less as compared to demand (water requirement) by 41.8 to 66.09 %. This gap is managed by pumping Low

Table 1. Hydraulic parameter of canal

Name of the Distributory	Off take R.D	A.F.S Discharge in cusec	Length (feet)	Wheather lift / flow	CCA (acres)	District
Butana Disty.0 to 102900	58332-L Butana branch	227.32	102900	Flow	25604	Sonipat-93100 Rohtak- 9800

Table 2. Demand supply gap analysis

S. No	Year	NIR (Net irrigation requirement)	Supply (Canal water)	Deficit supply, Gap between supply & demand.
1.	2009-10	469.0	158.69	310.31
2.	2010-11	392.2	228.26	163.94

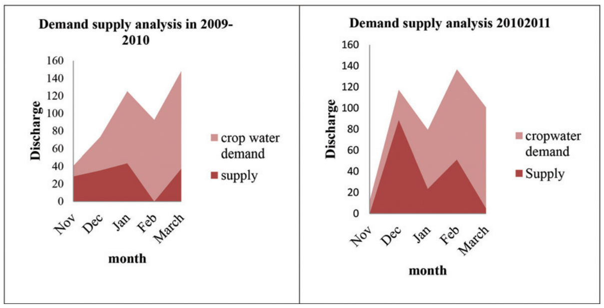

Fig. 3. Demand supply analysis of study area

quality ground water. So, we suggest some management strategies for improving crop yield. Fig. 3 shows the Demand supply analysis.

Groundwater availability

The quality of groundwater shows spatial variation in some places of the study area. The analysis of collected sample revealed that (Table 3) the salinity and alkalinity is significantly higher in the study area (Zaman *et al.*, 2018). The water quality guidelines given by Minhas and Tyagi (1998) were used to categories quality of groundwater in the farmers fields.

Management strategies

Many researchers worked on these technique Keren and Shainberg (1978). Much works had been done in Central soil salinity research institute, Karnal (Mandal *et al.*, 2013). On the basis of these works, we are suggesting some management strategies for crop productivity in saline environment.

1. Growth stage: Germination and early seedling establishment are the most critical stages followed by the phase changes from vegetative to reproductive, i.e. heading and flowering to fruit setting. So, irrigation with saline water should be avoided during initial growth stages.

Crop cultivars

Cropping Sequence

The recommended cropping sequence for saline soils are mustard/paddy-wheat, pearl millet – wheat, cotton – wheat, sorghum (fodder) – wheat. Cotton based cropping sequence are not so beneficial because the yield of winter crops that follows cotton are usually low.

Use of Blended drainage water for irrigation.

Table 4. The salt tolerance varieties.

Crop	Saline environment	Alkali environment
Wheat	Raj 2325, Raj 2560	KRL 1-4, KRL 19

(Source: CSSRI, Karnal)

Table 3. Ground water quality of study area

Site. no.	Distributay	Village (District)	Ground water quality			Problem
			EC (ds/m)	$SAR^{0.5}$ (mmole Kg^{-1})	RSC (mg/l)	
1	Bhutana	Butana Khetlan (Sonipat)	3.4	6.14	0.0	Marginal saline water
2	Bhutana	Butana Kundu (Sonipat)	3.3	20.1	8.8	Highly alkali water
3	Bhutana	Butana Kundu (Sonipat)	8.0	17.4	0.0	High SAR saline water
4	Bhutana	Butana Khetlan (Sonipat)	4.2	3.5	0.0	Saline water
5	Bhutana	Butana Khetlan (Sonipat)	4.4	3.2	0.0	Saline water
6	Bhutana	Khanpur Khurd (Sonipat)	1.9	8.5	2.5	Marginal alkali water
7	Bhutana	Ahulana (Sonipat)	3.0	5.7	0.0	Marginal saline water
8	Bhutana	Ahulana (Sonipat)	7.1	2.7	0.0	Saline water
9	Bhutana	Ahulana (Sonipat)	2.7	2.7	0.0	Marginal saline water
10	Bhutana	Chhichhrana (Sonipat)	4.7	16.6	0.0	High SAR saline water
11	Bhutana	Sanghi (Rohtak)	1.5	9.2	6.3	Alkali water
12	Bhutana	Sanghi (Rohtak)	3.1	20.0	5.8	High alkali water

Table 5. Relative grain yield of wheat with blended drainage water use for post sowing irrigation.

Ec(dS/m) of irrigation water	wheat
0.5 (canal water)	100
Blended drainage water	
4.0	96.2
6.0	92.8
10.0	88.4
14.0	81.4

(*Source:* CSSRI, Karnal)Cyclic/ rotational use of drainage water.

Table 6. Effect of cyclic modes of post- plant irrigation on mean relative yield of wheat.

S.No.	Mode of water application	Wheat Yield (%)
1	4 CW	100
2	CW: DW (alternate)	94.4
3	DW : CW (alternate)	91.3
4	2 CW + 2 DW	94.3
5	2 DW + 2 CW	88.2
6	1 CW + 3 DW	83.6
7	4 DW	73.7

*CW = Canal Water, DW = Drainage water
(Source: CSSRI, Karnal)

Conclusion

This study estimated the demand supply analysis of year 2009-10 and 2010-2011 (Rabi season) and it was found that Gap (deficit supply) is more in 2009-10 as compared to 2010-2011. The gap of water requirements is filled through groundwater abstraction. Different scenarios are generated after canal supply gap because supply is less and demand is more and at the same, groundwater quality is not so good. In some places, there is a problem of salinity or sodicity. So, management of these scenarios is very necessary for sustained crop production. The aim of this study is to suggest the best management strategies for enhancing crop yield of wheat crop in saline environment.

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