Vol. 19, No. 1, pp. 115-126 (2019)
Journal of Agricultural Physics
ISSN 0973-032X
http://www.agrophysics.in

Research Article

Irrigation Scheduling of *Rabi* Crops Using CROPWAT Model in Bina Command Area, Sagar District, Madhya Pradesh

ANSHU GANGWAR[1], VIKAS KUMAR RAI[2]*, T.R. NAYAK[3], R.M. SINGH[4] AND ASHISH RAI[5]

[1]*Krishi Vigyan Kendra (DRPCAU, Pusa), Piprakothi, East Champaran, Bihar*
[2]*Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar*
[3]*Central India Hydrology Regional Centre, National Institute of Hydrology, Bhopal, Madhya Pradesh*
[4]*Dept. of Farm Engineering, IAS, Banaras Hindu University, Varanasi, Uttar Pradesh*
[5]*Krishi Vigyan Kendra (DRPCAU, Pusa), Parsauni, East Champaran, Bihar*

ABSTRACT

Water is becoming a scarce resource as a result of the growing demand for various purposes such as hydropower, irrigation, and water supply etc. With growing population, the demand of water for various purposes is ever increasing. On the other hand, the availability of water is limited in space and time. A systematic and scientific planning for its optimal utilization is highly imperative. Use of modern techniques in irrigation system will go a long way in economizing consumption and saving of water which will bring greater areas under command and will ultimately result in more agricultural yield. Water requirements and irrigation scheduling are determined for major crop using the CROPWAT 8.0 model. In the present study irrigation scheduling is suggested for various soil types in Bina command area for *Rabi* season crop based on characteristics such as water holding capacity, evapotranspiration losses etc. Results showed that the maximum net irrigation water required in Khurai canal command area (49.76 MCM) followed by Kanjia Sub branch canal command area (38.33 MCM), while it is minimum for Bina main canal command area and found 9.76 million cubic meter (MCM). Hence, the study may help to obtained maximum water use efficiency and optimal use of resource available in the command areas for maximum crop production.

Key words: Irrigation scheduling, Water-use efficiency, Soil type, CROPWAT

Introduction

In India, water is a very important factor for crop production. Due to the rapid growth of population in the country, an intense development of irrigated agriculture requires throughout the country. Increasing crop production with limited water resources has been an enormous challenge for India's agriculture sector over the past several decades (Chakraborty *et al.,* 2018). The present level of efficiency of major and medium irrigation project has been assessed to be about 30% (MOWR, 2011). However, low overall efficiency offers an opportunity for meeting the increasing water demands by improving the performance of the existing irrigation projects. Government of India is continuously spending considerably very high efforts in terms of money on planning, creation, and management of irrigation facilities to realize the untapped potential and to achieve the goal of sustainable agricultural crop production. The intensive irrigation practices

*Corresponding author,
Email: vikas.soils@rpcau.ac.in

without proper water management strategies are causing over-exploitation of groundwater and thus decline of water table in some areas, whereas other areas are witnessing salinity and water logging problems. In agricultural water management, significant improvements can be achieved by adopting the suitable monitoring and scheduling tools to ensure that farmers are using water efficiently and that each of them uses only the volume of water assigned. Otherwise, excessive irrigation may lead to water logging conditions (Chowdary *et al.,* 2008). For irrigation planning purposes, rainfall monitoring (i.e. time and amount), crop monitoring (i.e. critical crop growth stages, crop duration, height of crop etc.), soil monitoring (i.e. infiltration rate of soil, water holding capacity, initial moisture depletion etc.) and water balance techniques (i.e. evapo-transpiration, infiltration etc.) are important approaches. The objective of a proper irrigation scheduling is to provide the optimum amount of water before harmful stress occurs. In this manner, it is very essential to characterize a precise strategy when designing an irrigation system framework. To solve this problem, estimation of crop water requirement helps to determine the proper irrigation schedule that how much water to use at a given time so that crops are produced economically by which we can planned and managed the water resources in a sustainable manner. A number of compu-terized simulation models are available to estimate the crop water requirements and net irrigation requirements for proper irrigation scheduling.For this purpose, CROPWAT 8.0 model, a decision support system could play a useful role which was developed by FAO is also being used by several researchers (Karim *et al.,* 2013, Singh *et al.,* 2014, Gangwar *et al.,* 2017; Verma *et al.,* 2019) that also helps to design an irrigation schedule or recognize water deficit in case of irrigated or rain fed conditions (FAO, 1992; Setegn *et al.*, 2011). For proper planning and management of irrigation in any area, its scheduling plays a significant role and an essential component of any major and medium irrigation projects as well asfor optimal crop production. For optimum irrigation scheduling, comprehensive informationof the soil moisture condition, crop water requirement, and yield reduction potential under water-stressed conditions is essential to maximize profits and optimize the use of water along with energy (Zegbe *et al.,* 2003; Kang *et al.,* 2002). In the present study irrigation scheduling was done for wheat, gram-pulses and mustard crops in *Rabi* season of the Bina command area lies in Sagar district of Madhya Pradesh, India, by using CROPWAT 8.0 model based on a daily soil-water balance using various user-defined options for water supply and irrigation management conditions.

Materials and Methods

Description of study area

The Bina command area selected for the study is located at the longitude of 78°02' to 78°25' E and latitude of 23°47' to 24°27' N at the altitude of 481 m above mean sea level in Sagar district of the Madhya Pradesh. The Bina command comes under Survey of India (SOI) toposheet NO. 54L3, 54L4, 54L7, 54L8 and 55I5 with 1: 50,000 scale. Proposed Chakarpur dam will be the major source in this command which is situated on Bina River. The area experiences sub-humid sub-tropical monsoon type of climate, characterized by hot summers (41°C) and mild winters (12°C). The command area receives an average annual rainfall of 1156.5 mm, out of which more than 80 percent rainfall contributes during monsoon season (June–October). The direction of the prevailing wind is generally south- west during the period of April to July, while it is north - west during September to November. The general topography of command area is plain having gentle slopes. Soils of the Bina command area falls under the broad group of deep and medium black soils. The area having different sub command like as Bina main canal, Khurai branch canal, Dhikua-Hardua sub branch canal, Khurai and Kanjia sub branch canal. The data required for scheduling irrigation and their source have been mentioned in Table 1.

Bina command area

For proper management of irrigation in Bina command area, it is covered by various minor

Table 1. Data required for assessment of irrigation scheduling

S.No.	Parameter	Information required	Source
1.	Climate	Max and Min Temperature, Humidity, Wind Speed, Sunshine hours, Rainfall	IMD, Pune
3.	Soil	Max infiltration rate, Total available moisture content, Maximum rooting depth, initial soil moisture depletion	NBSS& LUP, Nagpur
4.	Crop	Crop coefficient, Crop stage, Yield response factor, Critical depletion, Rooting depth	Guideline for irrigation water requirements, Ministry of irrigation, Govt. of India and FAO 24 irrigation & drainage paper

and major canal systems but still, some part is not covered by this system. These systems are to be known as Bina main canal command area, Khurai branch canal command area, Dhikua-Hardua sub branch canal command area, Khurai sub branch canal command area and Kanjia sub branch canal command area. The culturable command area (Fig 1.) by various canal systems of Bina command area was prepared in GIS (Geographical Information System) environment with the support of water resource department, M.P.

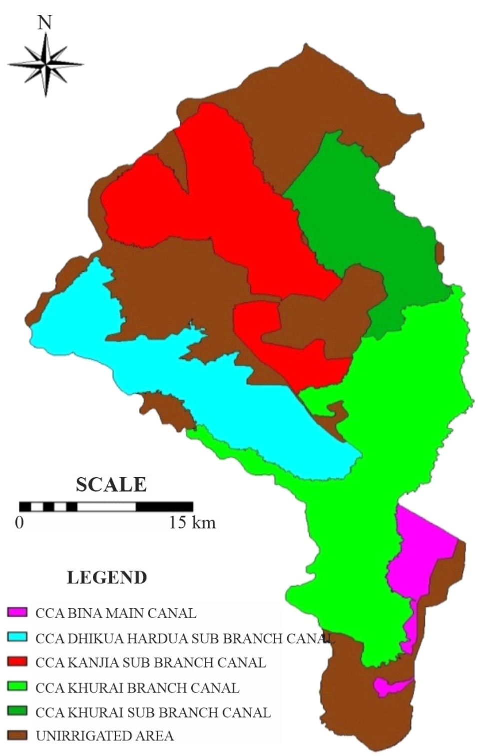

Fig. 1. CCA of different canal/branch in Bina command area

The distribution of gross command area (GCA), culturable command area (CCA) and culturable command area coverage are presented in Table 2.

Topography and soil

General topography of command area is plain having gentle slopes. Soils of the Bina Command area falls under the broad group of Deep and Medium Black soils. Distribution of soils in study area is presented in Table 3 and the soil map is shown in Fig 2. The major portion of the Bina command is covered by soil type 376 soil mapping unit, which is 63667.01 ha and second most dominant soil type is 398 soil mapping unit, which is 44581.81 ha. The soil mapping unit (SMU) 376 and 398 are covered 46.83% and 32.79% respectively of Bina command.

Crops and cropping pattern

In this study, primary crops of *Rabi* season have taken for the estimation of net irrigation water requirement, and irrigation scheduling. These crops are wheat, gram-pulses, and mustard while some other crops such as groundnut, pea, vegetables, and fruits are also grown in the small scale over the study area. The crop duration and existing cropping patterns over Bina command area are shown in Table 4.

Determination of irrigation scheduling

Irrigation scheduling is conventionally based on "soil water balance calculations", where the soil moisture status is estimated by water balance

Table 2. Distribution of CCA of different canals in the command area

Section	Canal command area	GCA (ha)	CCA (ha)	CCA coverage (ha)
I	Bina Main canal	3351.48	3016.34	2859
II	Khurai Branch canal	23270.54	20943.49	20544
III	Dhikua-Hardua Sub Branch canal	18368.19	16531.37	16548
IV	Khurai Sub Branch canal	12894.62	11605.16	11475
V	Kanjia Sub Branch canal	20649.72	18584.75	18616
	Total	78534.55	70681.11	70042

Table 3. The detail description of soils in study area

Soil Mapping units (SMUs)	Soil taxonomy	Area (ha)
305	Fine-loamy, Mixed, Hyperthermic, Typic Ustochrepts Clayey, Mixed, (Cal.), Hyperthermic, Lithic Ustochrepts	1388.60
317	Fine, Montmorillonitic, (Cal.), Hyperthermic, Typic Haplusterts Fine, Montmorillonitic, Hyperthermic, Vertic Ustochrepts	345.42
342	Loamy, Mixed, Hyperthermic, Lithic Ustochrepts Loamy, Mixed, Hyperthermic, Typic Ustochrepts	3218.04
352	Fine, Mixed, (Cal.), Hyperthermic, Typic Ustochrepts Loamy, Mixed, Hyperthermic, Lithic Ustorthents	2992.65
355	Loamy-Skeletal, Mixed, Hyperthermic, Lithic Ustorthents Loamy, Mixed, Hyperthermic, Lithic Ustorthents	1421.77
359	Fine, Montmorillonitic, Hyperthermic, Chromic Haplusterts Fine, Montmorillonitic, Hyperthermic, Typic Haplusterts	1363.67
362	Fine, Montmorillonitic, (Cal.), hyperthermic, typic haplusterts Clayey, Montmorillonitic, Hyperthermic, Typic Ustochrepts	1528.73
376	Fine, Montmorillonitic, Hyperthermic, Chromic Haplusterts Fine, Montmorillonitic, Hyperthermic, Vertic Ustochrepts	63667.01
377	Fine, Montmorillonitic, Hyperthermic, Typic Haplusterts Fine, Montmorillonitic,(Cal.), Hyperthermic, Chromic Haplusterts	6842.79
398	Fine, Montmorillonitic, Hyperthermic, Vertic Ustochrepts Fine, Montmorillonitic, Hyperthermic, Chromic Haplusterts	44581.81
410	Clayey, Montmorillonitic, Hyperthermic, Typic Ustochrepts Fine, Montmorillonitic, Hyperthermic, Vertic Ustochrepts	274.64
430	Loamy, Kaolinitic, Hyperthermic, Lithic Ustorthents Clayey, Kaolinitic, Hyperthermic, Typic Ustochrepts	894.43
433	Loamy, Kaolinitic, Hyperthermic, Lithic Ustorthents Loamy, Kaolinitic, Hyperthermic, Lithic Ustochrepts	341.71
443	Loamy, Kaolinitic, Hyperthermic, Lithic Ustochrepts Loamy, Kaolinitic, Hyperthermic, Typic Ustochrepts	3627.27
481	Loamy, Kaolinitic, Hyperthermic, Lithic Ustorthents Clayey, Kaolinitic, Hyperthermic, Lithic Ustorthents	3478.59

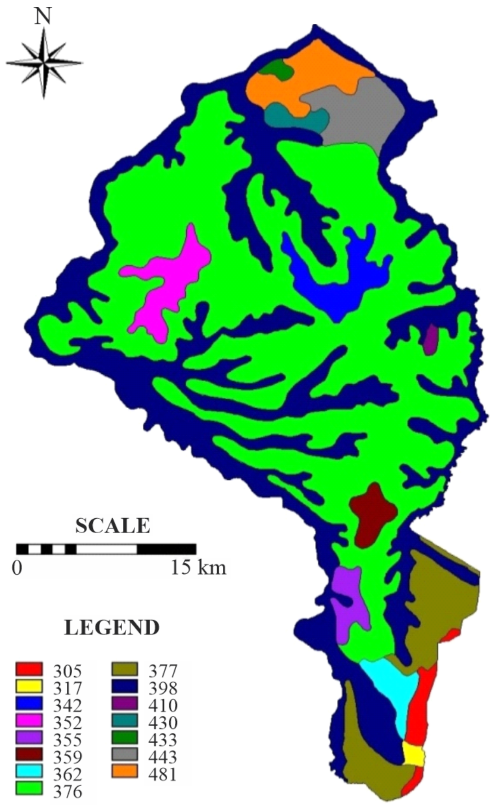

Fig. 2. Soil map of the study area

approach, in which the change in soil moisture storage over a period of time is given by the difference between the inputs (irrigation + precipitation) and the losses (runoff + drainage + ET). Irrigation scheduling involves the exact amount of water to apply to the field and the exact timing for application. This was done by selecting the options; irrigate at 100% critical depletion, from the irrigation-timing, refill soil to field capacity from irrigation application and irrigation efficiency 70% in scheduling criteria window of CROPWAT 8.0 model. In the present study, the average climatologically values, crops information and soil data have been used to estimate irrigation scheduling fordifferent soil mapping unit over different canal command area in the Bina command area.

The soil water balance aims to evaluate the soil moisture status accounting of all ingoing and outgoing water in the root zone over a defined time step. To express the water content as root zone depletion is useful as it makes the adding and subtracting of losses and gains straight forward as the various parameters of the soil water budget are usually expressed in terms of water depth. In the Schedule module of CROPWAT 8.0 model, the soil water balance is carried out on decade basis. As default, the page opens with Table format on "Irrigation schedule". To display day-by-day balance, change Table format from "Irrigation schedule" into "Daily soil moisture balance". The formula used for the calculation of irrigation scheduling was inside of the CROPWAT 8.0 model.

$$D_{r,i} = D_{r,i-1} + ET_{cadj,i} - P_i - I_i + (RO_i + DP_i) \ldots (1)$$

where, D_r is root zone depletion on days i, ET_{cadj} is crop evapotranspiration under non-standard conditions on day i, P is the total rainfall over day i, I is net irrigation on day i, RO is water loss by runoff from the soil surface on day i, DP is the water loss by deep percolation on day i, D_r is calculated prior to irrigation application, if any. It is assumed that RO occurs each time P exceeds the Maximum infiltration rate. DP is estimated to occur each time the available soil moisture content in the root zone exceeds field capacity (FC). Since precipitation losses are determined through RO and DP, total and not effective precipitation is used in the soil water balance.

Table 4. Existing cropping patterns of primary *Rabi* crops in Bina command area

Primary crops (*Rabi* Season)	Crop duration (days)	Sowing date	Area sown (ha)
Wheat	120	15-20 Nov	67285
Gram - Pulses	120	15-20 Nov	41105
Mustard	130	10-20 Oct	4440
Total			112830

Result and Discussion

Canal command wise crop distribution in different Soil mapping unit

Crop distribution over various soil mapping units was estimated in the GIS environment and it is represented in Table 5. Thematic layers of the canal command area, land use/land cover and soil map were prepared and multiplied the same in the ILWIS 3.0, which revealed the distribution of crops over the different soil mapping units in the various canal command areas. This information was further used for Irrigation Scheduling of Crops in different soil mapping units over the canal command area.

Net irrigation water requirement on the basis of climate, crops and soil information

The net irrigation water requirement has been calculated by using climate, crops and soil data (Fig. 3). The total net irrigation water requirement is computed as 154.21 Million Cubic meter (MCM) in Bina command area. This water requirement is comparatively lower than the net irrigation water requirement estimated on climate and crop data basis.

Irrigation scheduling for Bina command area

The irrigation scheduling was done for major crops of *Rabi* season spread over the Bina command area for proper operation of the proposed dam (Chakarpur Dam). For this purpose, irrigation scheduling was estimated by considering soil as a mapping unit (i.e. 305, 342, 352, 359, 362, 376, 377, 398, 410 and 443).

The proposed irrigation scheduling for major *Rabi* season crops such as wheat, gram-pulse and mustard over the Bina main canal command area was presented in Table 6. It was revealed from

Table 5. Canal command area wise crop distribution in different Soil mapping units (SMUs)

Canal Command area	Crop type / SMUs	Land use (ha)										
		305	342	352	355	359	362	376	377	398	410	443
Bina Main Canal Command area	Wheat	100.40	-	-	-	-	36.69	-	1188.49	547.66	-	-
	Gram-Pulses	86.22	-	-	-	-	33.51	-	802.20	365.29	-	-
	Mustard	9.27	-	-	-	-	3.60	-	80.94	37.84	-	-
Khurai Branch Canal Command area	Wheat	4.97	-	-	403.79	456.47	350.40	7473.19	285.04	4554.36	66.69	-
	Gram-Pulses	5.12	-	-	269.22	274.92	252.88	4369.74	203.56	2886.26	60.27	-
	Mustard	0.53	-	-	29.07	32.18	27.56	458.04	20.60	320.27	6.41	-
Dhikua-Hardua sub Branch canal Command area	Wheat	-	-	0.71	-	10.81	-	4442.36	-	3740.85	-	-
	Gram-Pulses	-	-	0.65	-	3.73	-	2981.08	-	2738.83	-	-
	Mustard	-	-	103.38	-	113.32	-	223.12	-	194.16	-	-
Khurai Sub Branch Canal Command area	Wheat	-	304.60	-	-	-	-	4814.21	-	1589.95	-	113.82
	Gram-Pulses	-	204.55	-	-	-	-	2598.34	-	1032.69	-	124.27
	Mustard	-	21.22	-	-	-	-	269.30	-	111.14	-	13.83
Kanjia sub Branch canal Command area	Wheat	-	392.88	54.70	-	-	-	7911.65	-	2955.06	-	-
	Gram-Pulses	-	833.02	359.92	-	-	-	3852.93	-	1162.68	-	-
	Mustard	-	121.64	55.24	-	-	-	375.45	-	111.70	-	-

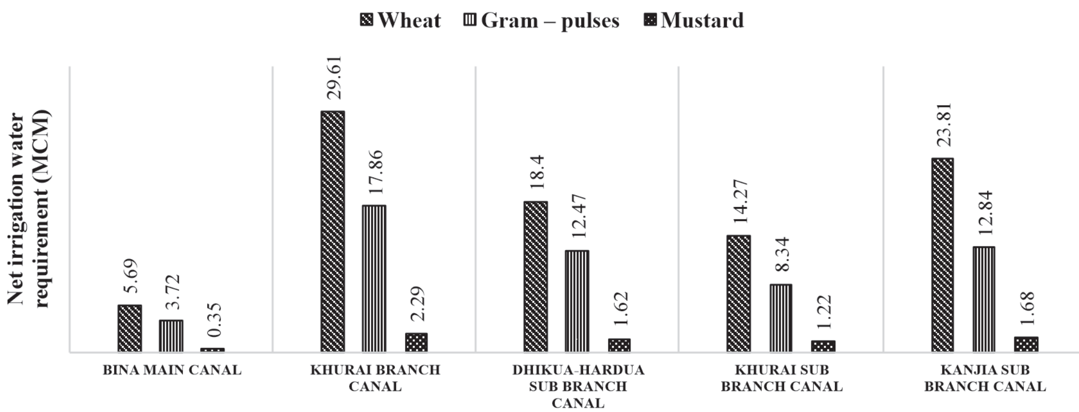

Fig. 3. Net irrigation water requirement on the basis of climate, crop and soil information for different canal command area

Table 6. Proposed irrigation scheduling for Bina main canal command area

Crops	Decades/ SMUs	Net Irrigation Water Requirements (MCM) 305	362	377	398	Total (MCM)
Wheat	DEC-III	0.055				0.055
	JAN-I	0.055	0.038	1.087		1.180
	JAN-II				0.698	0.698
	JAN-III	0.096		1.100		1.196
	FEB-I	0.098	0.054			0.152
	FEB-II				0.783	0.783
	FEB-III	0.115				0.115
	MAR-I			1.511		1.511
	Grand Total					5.689
Gram-Pulses	DEC-II	0.044				0.044
	DEC-III		0.023			0.023
	JAN-I	0.05		0.657	0.286	0.993
	JAN-III	0.051	0.026	1.153	0.3	1.53
	FEB-I	0.052	0.026			0.078
	FEB-II			0.728	0.327	1.055
	Grand Total					3.723
Mustard	NOV-II	0.003				0.003
	NOV-III		0.001	0.03	0.014	0.045
	DEC-I	0.004	0.001			0.005
	DEC-II			0.037	0.017	0.054
	DEC-III	0.004	0.001	0.037	0.017	0.059
	JAN-I	0.004	0.001			0.005
	JAN-II	0.004	0.001	0.037	0.017	0.059
	JAN-III	0.004	0.001	0.038	0.018	0.061
	FEB-I			0.037	0.017	0.054
	FEB-II	0.004	0.001			0.005
	Grand Total					0.350

the analysis that the net irrigation water demand for wheat, gram-pulses, and mustard crop was 5.689 MCM, 3.723 MCM, and 0.350 MCM, respectively. SMU 305 needed five times of irrigations to refill the soil for crop evapo-transpiration through the supply of estimated water demand for the successful growth of the Wheat crop and for same SMU the first irrigation (0.055 MCM) was required in third decade of December from the planting date and this decade include one critical stage i.e. crown root initiation of the crop occurs. While SMU 377 preferred three times of irrigation (JAN-I, JAN-III and MAR-I) followed by SMU 362 and SMU 398, which required two times of irrigations (i.e. JAN-I and FEB-I, JAN-II and FEB-II, respectively). For wheat crops, crown root initiation and milking are the critical stage, which requires adequate moisture into the soil. The result of the study indicated that there was adequate moisture present in SMU 362, 377 and 398 during critical growth stages. In the same way, irrigation scheduling was obtained for gram-pulses crop over the Bina canal command area and the result showed that the SMU 305 required four irrigation intervals (i.e. DEC-II, JAN-I, JAN-III and FEB-I) followed by SMU 362, which required three irrigation intervals (i.e. DEC-III, JAN-I, FEB-I), similar irrigation intervals were obtained for SMU 377 and SMU 398 (i.e. JAN-I, JAN-III, FEB-II) with different time periods. Seven irrigation intervals were required in SMU 305 and SMU 362 for the mustard crop, whereas SMU 377 and SMU 398 required Six irrigation intervals (i.e. NOV-III, DEC-II, DEC-III, JAN-II, JAN-III and FEB-I). It was seen that the irrigation intervals for mustard crop are maximum, but the net irrigation water requirement for all the irrigation intervals was very low as compared to other crops. This is due to the low crop water requirement of mustard crop. Irrigation intervals of any crop mainly depends on crop ET, effective rainfall, and available water holding capacity of the soil in the crop root zone and management allowable depletion.

In the case of Khurai branch canal command area, irrigation scheduling was proposed for major *Rabi* season crops (i.e. wheat, gram-pulse, and mustard) which is presented in Table 7. It is shown from the analysis that the net irrigation water demand for wheat, gram-pulses, and mustard crop was 29.608 MCM, 17.859 MCM and 2.285 MCM respectively. This canal command area covers maximum SMU among all the canal command area. From the planting date of wheat, total numbers of split irrigation applications were five in SMU 305 to refill the soil at the field capacity for evapotranspiration during all the critical stages. On the other hand, SMU 359, SMU 376 and SMU 410 needed only one irrigation application during the entire growth of this crop. This may be due to the good water holding capacity of soil as well as deep soil depth. In the same manner irrigation scheduling was determined for gram-pulses crop and obtained four irrigation applications for SMU 305 and SMU 355 followed by SMU 362, SMU 377, SMU 398 and SMU 410, which needed three irrigation applications for good growth of the crop.The irrigation interval was the same for SMU 377, SMU 398, and SMU 410 (i.e. JAN-I, JAN-III and FEB-II) and the first application of irrigation was required in the first decade of the month of January. For mustard crop, eight irrigation intervals were acquired for SMU 355 followed by SMU 305 and SMU 362, which needed to be applied in seven splits. Although six irrigations are applied to the remaining soil mapping unit i.e. SMU 359, SMU 376, SMU 377, SMU 398, and SMU 410 over this canal command area for the same crop, but the time for irrigation was different.

Irrigation scheduling was proposed for similar crops, over Dhikua-Hardua sub branch canal command area and presented in Table 8. The study revealed that the net irrigation water demand for wheat, gram-pulses, and mustard crop was 18.397 MCM, 12.471 MCM and 1.615 MCM respec-tively. In this order, the irrigation schedule was determined for wheat and gram-pulses and obtained that the SMU352 needed three application of irrigation with a different time period for these crops, while seven irrigation (i.e. NOV-I, DEC-I, DEC-II, JAN-I,JAN-II, JAN-III, and FEB-II) was applied to the mustard crop. The irrigation application timing was the same as

Table 7. Proposed irrigation scheduling for Khurai branch canal command area

Crops	Decades/	Net Irrigation Water Requirements (MCM)								Total
	SMUs	305	355	359	362	376	377	398	410	(MCM)
Wheat	DEC-III	0.003	0.329							0.332
	JAN-I	0.003			0.359		0.261			0.623
	JAN-II			0.65				5.802		6.452
	JAN-III	0.003	0.327			13.908	0.27		0.111	14.619
	FEB-I	0.003			0.366					0.369
	FEB-II		0.331					6.508		6.839
	FEB-III	0.003								0.003
	MAR-I						0.371			0.371
	Grand Total									29.608
Gram-Pulses	DEC-II	0.003								0.003
	DEC-III		0.158		0.175					0.333
	JAN-I	0.003		0.215		4.029	0.167	2.263	0.049	6.726
	JAN-II		0.18							0.180
	JAN-III	0.003		0.215	0.192		0.17	2.37	0.05	3.000
	FEB-I	0.003	0.178		0.193	4.199				4.573
	FEB-II						0.185	2.586	0.057	2.828
	FEB-III		0.216							0.216
	Grand Total									17.859
Mustard	NOV-II	0.0002	0.008							0.0082
	NOV-III			0.011	0.009	0.195	0.008	0.119	0.003	0.3450
	DEC-I	0.0002	0.01		0.011					0.0212
	DEC-II		0.01	0.014		0.232	0.009	0.144	0.003	0.4120
	DEC-III	0.0002	0.011	0.014	0.011		0.009	0.145	0.003	0.1932
	JAN-I	0.0002			0.011	0.233				0.2442
	JAN-II	0.0002	0.01	0.015	0.011	0.232	0.009	0.146	0.003	0.4262
	JAN-III	0.0002	0.011	0.015	0.011		0.01	0.149	0.003	0.1992
	FEB-I		0.011	0.014		0.232	0.009	0.145		0.4110
	FEB-II	0.0002	0.011		0.011				0.003	0.0252
	Grand Total									2.2854

Khurai branch canal command area for wheat, gram-pulses, and mustard crops spread over SMU 359, SMU 376 and SMU 398 in Dhikua-Hardua sub-branch canal command area. Due to the different size of canal command area, the water demand was different while the estimated net depth of water was the same at that time for the same crops over the same SMUs.

Similar crops have been taken and irrigation scheduling was proposed over Khurai sub branch canal command area and obtained that the net irrigation water demand for wheat, gram-pulses, and mustard crop were 14.270 MCM, 8.346 MCM and 1.212 MCM respectively. Perusal of the study reveals that the SMU 342 needed five and six irrigation applications for the wheat and gram-pulses crops, respectively while SMU 443 indented four and five irrigation during the entire growth of the same crops (Table 9). For mustard crop, SMU 342 and SMU 443 had eight and nine irrigation intervals from planting to harvesting, respectively. The irrigation scheduling for wheat, gram-pulses, and mustard crops spread over SMU 376 and SMU 398 in Khurai sub-branch canal command area was the same as Dhikua-Hardua sub-branch canal command area.

Table 8. Proposed irrigation scheduling for Dhikua-Hardua sub branch canal command area

Crops	Decades/ SMUs	Net Irrigation Water Requirements (MCM) 352	359	376	398	Total (MCM)
Wheat	JAN-I	0.001				0.001
	JAN-II		0.015		4.766	4.781
	JAN-III	0.001		8.267		8.268
	FEB-II				5.346	5.346
	MAR-I	0.001				0.001
	Grand Total					18.397
Gram-Pulses	DEC-III	0.0005				0.0005
	JAN-I		0.003	2.749	2.147	4.899
	JAN-II	0.0005	0.003		2.249	2.2525
	FEB-I	0.0005		2.865		2.8655
	FEB-II				2.454	2.454
	Grand Total					12.4715
Mustard	NOV-II	0.00002				0.00002
	NOV-III		0.0002	0.1391	0.1136	0.2529
	DEC-I	0.00003	0.0002	0.1652	0.1385	0.30393
	DEC-II	0.00003	0.0002		0.1391	0.13933
	JAN-I	0.00003		0.1662		0.16623
	JAN-II	0.00003	0.0002	0.1652	0.1403	0.30573
	JAN-III	0.00003	0.0002		0.1431	0.14333
	FEB-I		0.0002	0.1652	0.1388	0.3042
	FEB-II	0.00003				0.00003
	Grand Total					1.61570

Table 9. Proposed irrigation scheduling for Khurai sub branch canal command area

Crops	Decades/ SMUs	Net Irrigation Water Requirements (MCM) 342	376	398	443	Total (MCM)
Wheat	DEC-III				0.070	0.070
	JAN-I	0.139				0.139
	JAN-II	0.141		2.026	0.072	2.239
	JAN-III	0.142	8.959		0.074	9.175
	FEB-I	0.142				0.142
	FEB-II			2.272	0.076	2.348
	FEB-III	0.157				0.157
	Grand Total					14.270
Gram-Pulses	DEC-II	0.074			0.049	0.123
	JAN-I	0.087	2.396	0.81	0.067	3.360
	JAN-II	0.095			0.063	0.158
	JAN-III	0.096		0.848		0.944
	FEB-I	0.096	2.497		0.065	2.658
	FEB-II			0.925	0.07	0.995
	FEB-III	0.108				0.108
	Grand Total					8.346

Contd...

Crops	Decades/ SMUs	Net Irrigation Water Requirements (MCM)				Total (MCM)
		342	376	398	443	
Mustard	NOV-I				0.003	0.003
	NOV-II	0.005				0.005
	NOV-III		0.115	0.041	0.003	0.159
	DEC-I	0.006			0.022	0.028
	DEC-II	0.007	0.136	0.05	0.024	0.217
	DEC-III	0.007		0.05	0.025	0.082
	JAN-I	0.007	0.137		0.024	0.168
	JAN-II	0.007	0.136	0.051	0.023	0.217
	JAN-III	0.007		0.052	0.049	0.108
	FEB-I	0.007	0.136	0.05	0.025	0.218
	FEB-II	0.007				0.007
	Grand Total					1.212

Table 10. Proposed irrigation scheduling for Kanjia sub branch canal command area

Crops	Decades/ SMUs	Net Irrigation Water Requirements (MCM)				Total (MCM)
		342	352	376	398	
Wheat	JAN-I	0.179	0.051			0.230
	JAN-II	0.182			3.765	3.947
	JAN-III	0.183	0.051	14.724		14.958
	FEB-I	0.182				0.182
	FEB-II				4.223	4.223
	FEB-III	0.202				0.202
	MAR-I		0.066			0.066
	Grand Total					23.808
Gram-Pulses	DEC-II	0.093				0.093
	DEC-III		0.02			0.020
	JAN-I	0.109		4.084	1.171	5.364
	JAN-II	0.118	0.023			0.141
	JAN-III	0.120			1.226	1.346
	FEB-I	0.120	0.022	4.257		4.399
	FEB-II				1.338	1.338
	FEB-III	0.135				0.135
	Grand Total					12.836
Mustard	NOV-II	0.0072	0.0010			0.0082
	NOV-III			0.1987	0.0607	0.2594
	DEC-I	0.0090	0.0012			0.0102
	DEC-II	0.0104		0.2361	0.0739	0.3204
	DEC-II	0.0101	0.0012		0.0743	0.0856
	JAN-I	0.0106	0.0013	0.2375		0.2494
	JAN-II	0.0104	0.0012	0.2361	0.0749	0.3226
	JAN-III	0.0100	0.0013		0.0764	0.0877
	FEB-I	0.0104		0.2361	0.0741	0.3206
	FEB-II	0.0100	0.0013			0.0113
	Grand Total					1.6754

In the same manner, the irrigation scheduling was done for major *rabi* crops i.e. wheat, gram-pulses, and mustard spread over SMU 342, SMU 352, SMU 376, and SMU 398 in the Kanjia sub-branch canal command area and found net irrigation water demand were 23.808 MCM, 12.836 MCM, and 1.675 MCM, respectively for the same crops, and presented in table 10.

Conclusion

Irrigation scheduling is important to obtain maximum crop production and it is therefore is of prime importance to have an adequate knowledge of water resources availability in an area and based on that irrigation is to be provided at critical stages of crops. Bina command area situated in Madhya Pradesh region possesses many problems regarding water resources availability. Therefore, for effective crop production proper utilization of resources is essential with every bit of knowledge that effect crop in that region. The total net irrigation water requirement is computed as 154.21 Million Cubic Meter (MCM) in Bina command area. The command area is sub-divided into number of culturable command area and each has its unique characteristics as well i.e. different soil type and topography. Therefore, during irrigation scheduling it is important to sub divide basin into different sub culturable command area with adequate knowledge of soil type, net irrigation requirement and topography prevail in that region and based on that only irrigation be provided.

References

Chakraborty, D., Sehgal, V.K., Ray M., Dhakar, R., Sahoo, R.N., Das, D.K., Manjaiah, K.M., Lal, K. and Kumar, P. 2018. District-wise statistical yield modelling of wheat using weather and remote sensing inputs. *Journal of Agricultural Physics*. **18(1)**: 48-57.

Chowdary, V.M., Chandran, R.V., Neeti, N., Bothale, R.V., Srivastava, Y.K., Ingle, P., Ramakrishnan, D., Dutta, D., Jeyaram, A., Sharma, J.R. and Singh, R. 2008. Assessment of surface and sub-surface waterlogged areas in irrigation command areas of Bihar state using remote sensing and GIS. *Agricultural Water Management*, **95**(7): 754-766.

FAO. 1992. CROPWAT: a computer program for irrigation planning and management. Irrigation and drainage Paper. No. 46. FAO, Rome

Gangwar, A., Nayak, T.R., Singh, R.M., and Singh, A. 2017. Estimation of crop water requirement using CROPWAT 8.0 model for Bina command, Madhya Pradesh. *Indian Journal of Ecology*, **44 (sp. 3)**: 71-76.

Kang, S.Z., Zhang, L., Liang, Y.L., Hu, X.T., Cai, H.J. and Gu, B.J. 2002. Effects of limited irrigation on yield and water use efficiency of winter wheat in the Loess Plateau of China. *Agricultural Water Management*. **55**: 203-216.

Karim S.N.A.A., Ahmed, S.A., Nischitha, V. and Bhatt, S., Raj, S.K. and Chandrashekarappa, K.N. 2013. FAO 56 Model and Remote Sensing for the Estimation of Crop-Water Requirement in Main Branch Canal of the Bhadra Command area, Karnataka State. *Journal of Indian Society Remote Sensing*. **41**(4): 883-894.

MoWR. 2011. Model bill 2011: Model bill for the protection, conservation, management and regulation of groundwater. Accessed from http://www.planningcommission.gov.in/aboutus/committee/wrkgrp12/wr/mb_wtrgrndsor_181011.pdf

Setegn, A.S.G., Chowdary, V.M., Mal, B.C., Yohannes, F. and Kono, Y. 2011.Water balance study and irrigation strategies for sustainable management of a tropical Ethiopian lake: A case study of lake. *Water Resource Management* **25**: 2081-2107.

Singh, R., Singh, K. and Bhandarkar, D.M. 2014. Estimation of water requirement for soybean (*Glycine max*) and wheat (*Triticum aestivum*) under vertisols of Madhya Pradesh. *Indian Journal of Agricultural Science* **84**: 190-197.

Verma, R., Gangwar, A., Kumar, M. and Verma, R.K. 2019. Study on Water Requirement of Rice Using CROPWAT Model for Lucknow Division of Uttar Pradesh. *Journal of AgriSearch* **6**(1): 44-49.

Zegbe-Dominguez, J.A., Behboudian, M.H., Lang, A. and Clothier, B.E. 2003. Deficit irrigation and partial rootzone dyring maintain fruit dry mass and enhance fruit quality in 'Petopride' processing tomato (*Lycopersicon esculentum*, Mill.). *Scientia Horticulturae* **98**: 505-510.

Received: January 17, 2019; Accepted: May 15, 2019