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A Study on Determination of Crop Water requirement and Irrigation scheduling using CROPWAT 8.0

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Abstract: ***water, the important resource to prolong the lives on the earth. With the advances in agricultural sector, precise knowledge of all the input parameters has gained importance. Water is one of the major inputs and crops the other. The knowledge of crop water requirement and irrigation scheduling is therefore imperative both for optimization of crop yields and economic use of water and optimization of crop which may lead to attain more crop per drop. In this project, A study is carried out to determine crop water requirement and irrigation scheduling of crops in Aurangabad region, Aurangabad district, Maharashtra. Crop water requirement and irrigation scheduling in this region is determined using Cropwat 8.0. The major crops are Wheat, Sorghum, Cotton, Onion and Maize. The Penman Monteith method is used to determine reference evapotranspiration. For the purpose of effective scheduling, cropping pattern and soil characteristics were obtained. From the final output it has been observed that crop water requirement for Sorghum is less and Wheat is high as compared to other crops whereas the number of irrigation events required for Sorghum is less and Onion is high as compared to other crops.***

1.Introduction

A sustainable development and effective water management are the two major challenges faced by many nations particularly India. India being an agriculture based country where more than 70% population depends on agriculture is highly susceptible to the problem of serious water shortage and high climatic variability. About one third of the geographical area of the country is drought prone. An array of factors leading to the evidence of crises are non-continuous drinking water supply, low water quality been observed in many rural habitations, major and medium irrigation projects remain under execution, over exploitation of ground water, degradation of the catchment area, lower water quality of rivers and lakes, difference between irrigation potential created and area actually irrigated is large. Some of the reasons to such crises are increasing population, growing urbanization and rapid industrialization combined with the need for higher agricultural production (Planning Commission, GOI, 2012). An adequate knowledge of crop water demand and irrigation planning and management would prove to be useful in increasing agricultural productivity.

Crop water requirement is the total water required for the crops for a particular period i.e. from sowing to harvesting. Climatic condition of a particular place plays a major role in the determination of water requirement of crops. Different crops require different water requirement under the same climatic conditions. Thus, it is of paramount importance to have knowledge about the water requirement of crops intended to be grown in the area.

Irrigation is the application of supplementary water where rainfall is insufficient to meet the crop water requirement. This irrigation requirement should be appropriately estimated and accurately supplied. As under irrigation may lead to yield reduction and over irrigation may lead to water logging, salinity either in any of the case crop growth is seriously affected. Irrigation scheduling provides answer to the two questions — when to irrigate? How much to irrigate? Here time and depth criteria is taken into consideration. Irrigation scheduling forms the sole means for increasing yield which also result in water saving. Thus for proper water management irrigation scheduling must be done.

2. Objective of Study

To calculate reference evapotranspiration using Cropwat. To determine crop water requirement using Cropwat. To determine irrigation scheduling using Cropwat

3.Study Area

The present study area is located on the tributary of Sukhna River at Kaudgaon, Paithan taluka, Aurangabad district, Maharashtra. It is a minor irrigation project .Catchment area is 17.25 sq.km. It comes under the co-ordinates of 20˚37’ East and 19˚48’ north. The climate characterized as semiarid climate. The average annual precipitation is 644 mm and the average temperature is 829.14mm. The soil is mainly suitable for kharif crops. Wheat is the main crop sown in this area.

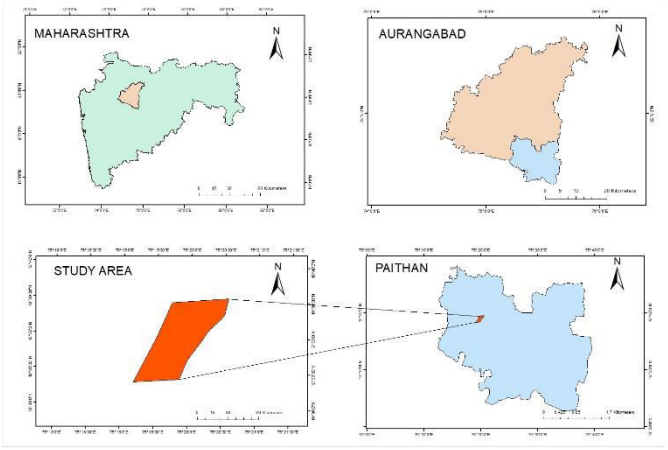


Figure 3.1: Study area map

4. Data Collection

The required climatic data was taken from globalweather.tamu and the data related to crops and cropping pattern was taken from Irrigation Department of Aurangabad District. The soil data and other management data was taken from Agricultural department of Aurangabad District.

4.1. Reference Evapotranspiration

The result of average monthly reference evapotranspiration is as follows:

Monthly ETo Penman-Monteith - C:\ProgramData\CROPWAT\data\climate\Aurangabad ETo.P...

Country India Station Aurangabad

Altitude 560 m. Latitude 19.48 °N Longitude 75.37 °E

Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	km/day	hours	MJ/m²/day	mm/day
January	13.3	28.9	36	229	8.5	17.4	5.03
February	15.8	32.3	28	237	9.4	20.4	6.24
March	19.4	36.7	20	234	9.4	22.5	7.54
April	23.2	40.3	19	261	9.8	24.4	9.05
May	25.5	40.4	29	365	9.8	24.7	10.49
June	24.5	34.3	59	347	7.1	20.5	6.90
July	22.5	28.5	79	339	4.0	15.8	4.12
August	21.7	27.3	84	305	4.4	16.2	3.60
September	21.3	28.5	84	226	6.4	18.4	3.85
October	18.8	30.0	63	177	8.4	19.5	4.57
November	15.9	29.2	54	196	8.7	17.9	4.45
December	13.5	28.5	43	212	8.7	17.0	4.56
Average	19.6	32.1	50	261	7.9	19.6	5.87

Figure 4.1: Average monthly reference evapotranspiration.

Figure 4.1 shows an average climatic data which is given as input for the determination of reference evapotranspiration. Solar radiation is also one of the climatic parameter calculated by the model with the given input parameters as it is required for the calculation of reference evapotranspiration. The average monthly minimum, maximum temperature showed an increasing trend from January till May which was highest in May and then a decreasing trend was found. Humidity showed an increasing trend from June to September which was highest in September and then a decreasing trend was found. For wind speed higher values were observed from May to August. Sunshine hours and solar radiation had higher values from February to May. The monthly average minimum and maximum temperature was 19.60˚C and 32.10˚C respectively. Humidity was 50%, wind speed was 261km/day, sunshine was 7.9hours, radiation was 19.6 MJ/m2/day and reference evapotranspiration was 5.87mm/day.

.4.2 Crop Water Requirement using Cropwat

The results of crop water requirement of different crops during its total growing period are as follows:

1) Wheat:

Crop Water Requirements

ETo station Aurangabad Crop Wheat

Rain station Aurangabad Planting date 15/11

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Nov	2	Init	0.18	0.80	4.8	6.8	0.0
Nov	3	Deve	0.18	0.83	8.3	7.8	0.5
Dec	1	Deve	0.44	2.00	20.0	2.0	18.0
Dec	2	Deve	0.85	3.85	38.5	0.0	38.5
Dec	3	Mid	1.17	5.50	60.5	0.2	60.3
Jan	1	Mid	1.19	5.79	57.9	0.9	57.0
Jan	2	Mid	1.19	5.97	59.7	0.9	58.8
Jan	3	Mid	1.19	6.45	71.0	1.0	70.0
Feb	1	Mid	1.19	6.94	69.4	1.1	68.2
Feb	2	Late	1.07	6.70	67.0	1.3	65.7
Feb	3	Late	0.79	5.27	42.1	1.4	40.8
Mar	1	Late	0.50	3.57	35.7	1.4	34.3
Mar	2	Late	0.28	2.10	8.4	0.6	7.7
					543.3	25.3	519.8

Figure 4.2: Crop water requirement of Wheat using Cropwat

Figure 4.2 shows, depending upon the climatic parameters and crop characteristics the crop water requirement for Wheat for total growing period was found to be 519.8mm/dec. The crop evapotranspiration was found to be 543.3mm/dec which was at some extent satisfied by effective rainfall of 25.3mm/dec and the remaining was satisfied by irrigation requirement of 519.8mm/dec.

2) Sorghum :

Crop Water Requirements

ETo station Aurangabad Crop Sorghum

Rain station Aurangabad Planting date 07/07

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Jul	1	Init	0.40	1.96	7.9	17.5	0.0
Jul	2	Init	0.40	1.57	15.7	47.4	0.0
Jul	3	Deve	0.53	2.03	22.3	48.3	0.0
Aug	1	Deve	0.81	3.05	30.5	50.5	0.0
Aug	2	Mid	1.03	3.72	37.2	52.5	0.0
Aug	3	Mid	1.06	3.90	42.9	46.9	0.0
Sep	1	Mid	1.06	3.99	39.9	41.0	0.0
Sep	2	Mid	1.06	4.07	40.7	36.5	4.3
Sep	3	Late	1.05	4.30	43.0	29.4	13.6
Oct	1	Late	1.02	4.42	44.2	20.5	23.6
Oct	2	Late	0.99	4.52	40.7	11.7	27.7
					364.9	402.1	69.2

Figure 4.3: Crop water requirement of Sorghum using Cropwat

Figure 4.3 shows, depending upon the climatic parameters and crop characteristics the crop water requirement for Sorghum for total growing period was found to be 69.2 mm/dec. The crop evapotranspiration was found to be 364.9 mm/dec which was partially satisfied by effective rainfall of 402.1mm/dec and the remaining was satisfied by irrigation requirement of 69.2 mm/dec.

3) **Cotton:**

Crop Water Requirements

ETo station: Aurangabad | Crop: Cotton
Rain station: Aurangabad | Planting date: 01/07

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Jul	1	Init	0.18	0.88	8.8	43.8	0.0
Jul	2	Init	0.18	0.71	7.1	47.4	0.0
Jul	3	Deve	0.18	0.69	7.6	48.3	0.0
Aug	1	Deve	0.31	1.17	11.7	50.5	0.0
Aug	2	Deve	0.51	1.84	18.4	52.5	0.0
Aug	3	Deve	0.72	2.66	29.3	46.9	0.0
Sep	1	Deve	0.93	3.52	35.2	41.0	0.0
Sep	2	Mid	1.13	4.35	43.5	36.5	7.0
Sep	3	Mid	1.18	4.85	48.5	29.4	19.1
Oct	1	Mid	1.18	5.13	51.3	20.5	30.8
Oct	2	Mid	1.18	5.42	54.2	13.0	41.2
Oct	3	Mid	1.18	5.37	59.1	12.2	46.9
Nov	1	Mid	1.18	5.32	53.2	12.6	40.6
Nov	2	Late	1.18	5.25	52.5	11.3	41.2
Nov	3	Late	1.11	4.97	49.7	7.8	41.9
Dec	1	Late	1.01	4.59	45.9	2.0	43.9
Dec	2	Late	0.92	4.21	42.1	0.0	42.1
Dec	3	Late	0.83	3.89	42.8	0.2	42.6
Jan	1	Late	0.73	3.55	35.5	0.9	34.6
Jan	2	Late	0.68	3.41	3.4	0.1	3.4
					699.7	**476.7**	**435.1**

Figure 4.4: Crop water requirement of Cotton using Cropwat

Figure 4.4 shows, depending upon the climatic parameters and crop characteristics the crop water requirement for cotton for total growing period was found to be 435.1 mm/dec. The crop evapotranspiration was found to be 699.7 mm/dec which was partially satisfied by effective rainfall of 476.7 mm/dec and the remaining was satisfied by irrigation requirement of 435.1 mm/dec

4) Onion:

Crop Water Requirements

ETo station: Aurangabad | Crop: Onion
Rain station: Aurangabad | Planting date: 07/11

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Nov	1	Init	0.50	2.25	9.0	5.0	2.7
Nov	2	Init	0.50	2.23	22.3	11.3	10.9
Nov	3	Deve	0.61	2.73	27.3	7.8	19.5
Dec	1	Deve	0.85	3.84	38.4	2.0	36.4
Dec	2	Mid	1.06	4.85	48.5	0.0	48.5
Dec	3	Mid	1.10	5.19	57.1	0.2	56.9
Jan	1	Mid	1.10	5.36	53.6	0.9	52.7
Jan	2	Mid	1.10	5.53	55.3	0.9	54.4
Jan	3	Late	1.08	5.85	64.4	1.0	63.3
Feb	1	Late	0.96	5.62	56.2	1.1	55.0
Feb	2	Late	0.85	5.29	47.6	1.1	46.4
					479.6	**31.4**	**446.8**

Figure 4.5: Crop water requirement of Onion using Cropwat

Graph 4.5 shows, depending upon the climatic parameters and crop characteristics the crop water requirement for cotton for total growing period was found to be 446.8 mm/dec. The crop evapotranspiration was found to be 479.6 mm/dec which was partially satisfied by effective rainfall of 31.4 mm/dec and the remaining was satisfied by irrigation requirement 446.8 mm/dec.

5) Maize :

Crop Water Requirements

ETo station: Aurangabad | Crop: Maize
Rain station: Aurangabad | Planting date: 07/10

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Oct	1	Init	0.40	1.73	6.9	8.2	0.0
Oct	2	Init	0.40	1.83	18.3	13.0	5.3
Oct	3	Deve	0.44	1.97	21.7	12.2	9.5
Nov	1	Deve	0.67	3.03	30.3	12.6	17.7
Nov	2	Deve	0.93	4.16	41.6	11.3	30.3
Nov	3	Mid	1.16	5.19	51.9	7.8	44.1
Dec	1	Mid	1.18	5.35	53.5	2.0	51.5
Dec	2	Mid	1.18	5.39	53.9	0.0	53.9
Dec	3	Mid	1.18	5.58	61.4	0.2	61.2
Jan	1	Late	1.14	5.57	55.7	0.9	54.9
Jan	2	Late	0.97	4.88	48.8	0.9	47.8
Jan	3	Late	0.78	4.21	46.4	1.0	45.3
Feb	1	Late	0.65	3.77	11.3	0.3	10.7
					501.7	**70.5**	**432.3**

Figure 4.6: Crop water requirement of Maize using Cropwat

Figure 4.6 shows, depending upon the climatic parameters and crop characteristics the crop water requirement for cotton for total growing period was found to be 432.3 mm/dec. The crop evapotranspiration was found to be 501.7 mm/dec which was partially satisfied by effective rainfall of 70.5 mm/dec. and the remaining was satisfied by irrigation requirement of 432.3 mm/dec.

Crops	Crop Evapotranspiration (mm/dec)	Irrigation Requirement (mm/dec)
Wheat	543.3	519.8
Sorghum	364.9	69.20
Cotton	699.7	435.1
Onion	479.6	446.8
Maize	501.7	432.3

Table 4.1: Crop water requirement of different crops using Cropwat

From table 4.1, Crop water requirement varies depending upon the crops. Sorghum has the lowest requirement i.e. 364.9 mm whereas Cotton has the highest requirement i.e. 699.7mm

4.3 Irrigation Scheduling using Cropwat

While performing irrigation scheduling in Cropwat a range of options are available, depending upon the objective of the user a suitable one is to be selected. The scheduling option refers to two different categories:

1) Time option — when the irrigation is to be applied.

2) Application option — how much water is to be given per irrigation interval. Suitable option is to be selected from the drop down menu of the setting.

In the present study irrigation scheduling was carried out by three different options:

Option 1 — Irrigate at critical depth and refill the soil back to field capacity (50% critical depletion)

1) Wheat:

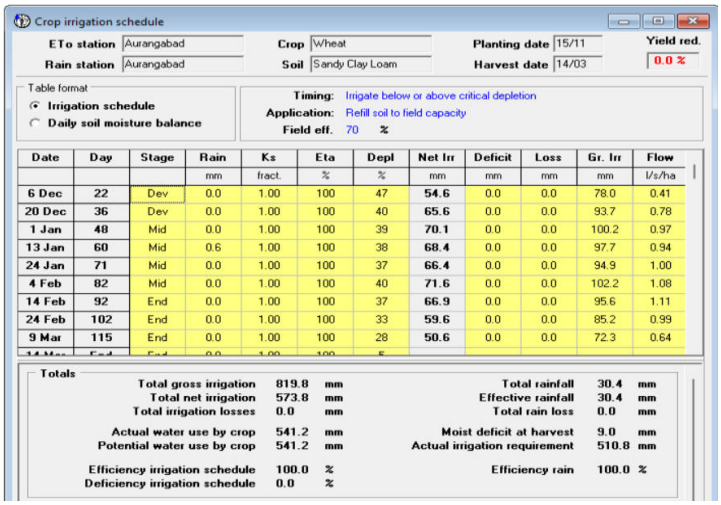


Figure 4.7: Irrigation Scheduling of Wheat using Cropwat

From the Figure 4.7, it was observed that yield reduction will not occur from the present irrigation scheduling. Actual irrigation requirement was 510.8mm. It is the difference of actual water use by the crop and effective rainfall. The net irrigation requirement was 573.8 mm considering 70% irrigation efficiency the gross irrigation requirement was 819.8 mm. Irrigation scheduling efficiency was 100%. Rainfall efficiency was 100.0%. It is the ratio of effective and total rainfall. Lower the losses higher the efficiency. Nine irrigation events of 51mm to 72mm depth is required.

2) Sorghum:

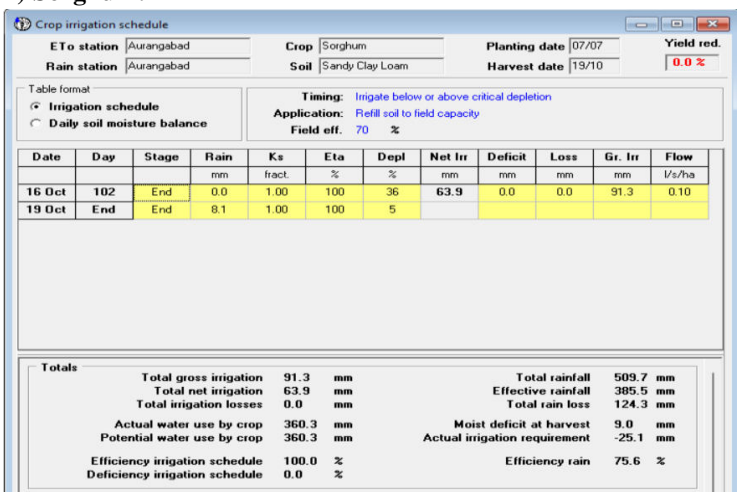


Figure 4.8: Irrigation Scheduling of Sorghum using Cropwat

From the Figure 4.8, it was observed that yield reduction will not occur from the present irrigation scheduling. Actual irrigation requirement was -25.1mm. It is the difference of actual water use by the crop and effective rainfall. The net irrigation requirement was 63.9mm considering 70% irrigation efficiency the gross irrigation requirement was 91.3 mm. Irrigation scheduling efficiency was 100%. Rainfall efficiency was 75.6%. It is the ratio of effective and total rainfall. Lower the losses higher the efficiency. Only one irrigation event with 63.9mm depth is required.

3) Cotton:

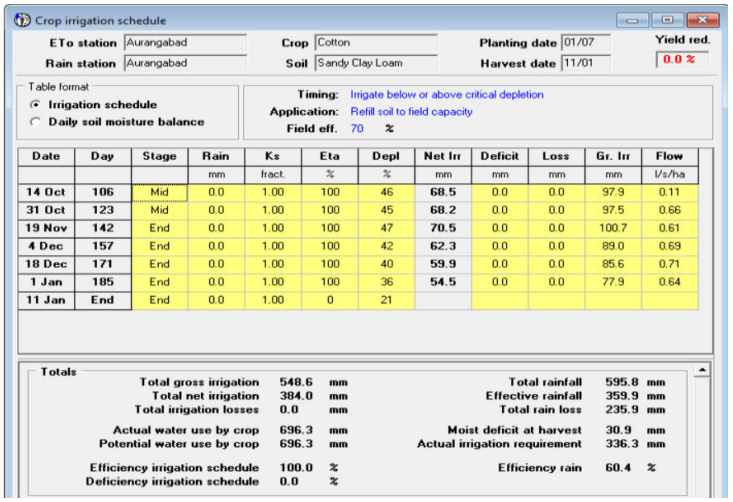
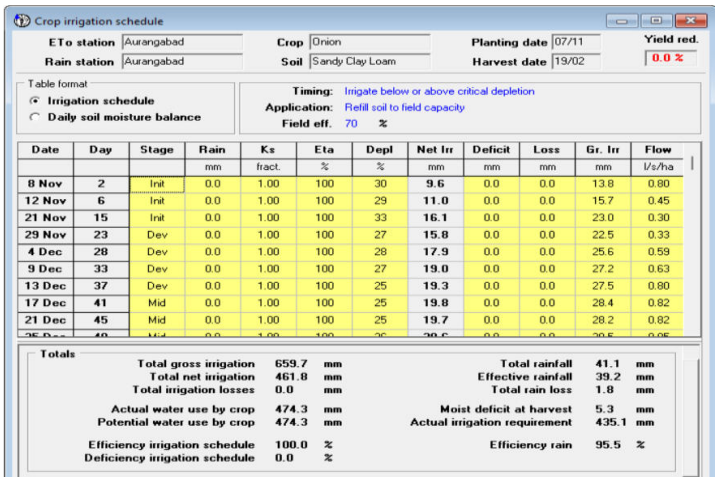


Figure 4.9: Irrigation Scheduling of Cotton using Cropwat

From the Figure 4.9, it was observed that yield reduction will not occur from the present irrigation scheduling. Actual irrigation requirement was 336.3mm. It is the difference of actual water use by the crop and effective rainfall. The net irrigation requirement was 384.0mm considering 70% irrigation efficiency the gross irrigation requirement was 548.6mm.

Irrigation scheduling efficiency was 100%. Rainfall efficiency was 60.4%. It is the ratio of effective and total rainfall. Lower the losses higher the efficiency. Six irrigation event of one irrigation event with 55mm depth to 71mm is required.

4) Onion:


Crop irrigation schedule

ETo station Aurangabad | Crop Onion | Planting date 07/11 | Yield red. 0.0 %
Rain station Aurangabad | Soil Sandy Clay Loam | Harvest date 19/02

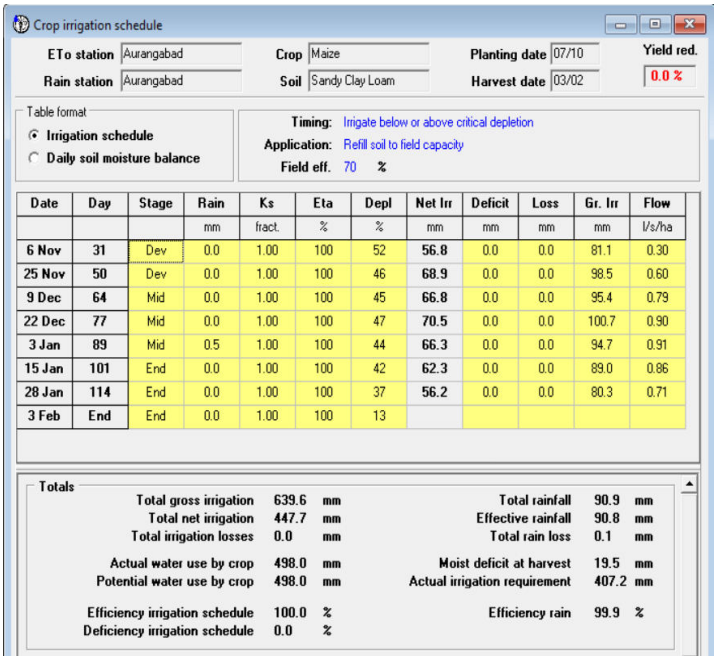
Table format: Irrigation schedule / Daily soil moisture balance
Timing: Irrigate below or above critical depletion
Application: Refill soil to field capacity
Field eff. 70 %

Date	Day	Stage	Rain	Ks	Eta	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
8 Nov	2	Init	0.0	1.00	100	30	9.6	0.0	0.0	13.8	0.80
12 Nov	6	Init	0.0	1.00	100	29	11.0	0.0	0.0	15.7	0.45
21 Nov	15	Init	0.0	1.00	100	33	16.1	0.0	0.0	23.0	0.30
29 Nov	23	Dev	0.0	1.00	100	27	15.8	0.0	0.0	22.5	0.33
4 Dec	28	Dev	0.0	1.00	100	28	17.9	0.0	0.0	25.6	0.59
9 Dec	33	Dev	0.0	1.00	100	27	19.0	0.0	0.0	27.2	0.63
13 Dec	37	Dev	0.0	1.00	100	25	19.3	0.0	0.0	27.5	0.80
17 Dec	41	Mid	0.0	1.00	100	25	19.8	0.0	0.0	28.4	0.82
21 Dec	45	Mid	0.0	1.00	100	25	19.7	0.0	0.0	28.2	0.82

Totals

Total gross irrigation	659.7	mm	Total rainfall	41.1	mm
Total net irrigation	461.8	mm	Effective rainfall	39.2	mm
Total irrigation losses	0.0	mm	Total rain loss	1.8	mm
Actual water use by crop	474.3	mm	Moist deficit at harvest	5.3	mm
Potential water use by crop	474.3	mm	Actual irrigation requirement	435.1	mm
Efficiency irrigation schedule	100.0	%	Efficiency rain	95.5	%
Deficiency irrigation schedule	0.0	%			

Figure 4.10: Irrigation Scheduling of Onion using Cropwat


Crop irrigation schedule

ETo station Aurangabad | Crop Maize | Planting date 07/10 | Yield red. 0.0 %
Rain station Aurangabad | Soil Sandy Clay Loam | Harvest date 03/02

Table format: Irrigation schedule / Daily soil moisture balance
Timing: Irrigate below or above critical depletion
Application: Refill soil to field capacity
Field eff. 70 %

Date	Day	Stage	Rain	Ks	Eta	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
6 Nov	31	Dev	0.0	1.00	100	52	56.8	0.0	0.0	81.1	0.30
25 Nov	50	Dev	0.0	1.00	100	46	68.9	0.0	0.0	98.5	0.60
9 Dec	64	Mid	0.0	1.00	100	45	66.8	0.0	0.0	95.4	0.79
22 Dec	77	Mid	0.0	1.00	100	47	70.5	0.0	0.0	100.7	0.90
3 Jan	89	Mid	0.5	1.00	100	44	66.3	0.0	0.0	94.7	0.91
15 Jan	101	End	0.0	1.00	100	42	62.3	0.0	0.0	89.0	0.86
28 Jan	114	End	0.0	1.00	100	37	56.2	0.0	0.0	80.3	0.71
3 Feb	End	End	0.0	1.00	100	13					

Totals

Total gross irrigation	639.6	mm	Total rainfall	90.9	mm
Total net irrigation	447.7	mm	Effective rainfall	90.8	mm
Total irrigation losses	0.0	mm	Total rain loss	0.1	mm
Actual water use by crop	498.0	mm	Moist deficit at harvest	19.5	mm
Potential water use by crop	498.0	mm	Actual irrigation requirement	407.2	mm
Efficiency irrigation schedule	100.0	%	Efficiency rain	99.9	%
Deficiency irrigation schedule	0.0	%			

Figure 4.11: Irrigation Scheduling of Maize using Cropwat

From the Figure 4.10, it was observed that yield reduction will not occur from the present irrigation scheduling. Actual irrigation requirement was 435.1mm. It is the difference of actual water use by the crop and effective rainfall. The net irrigation requirement was 461.8mm considering 70% irrigation efficiency the gross irrigation requirement was 659.7mm. Irrigation scheduling efficiency was 100%. Rainfall efficiency was 95.5%. It is the ratio of effective and total rainfall. Lower the losses higher the efficiency. Twenty seven events from 10mm to 22mm depth is required.

From the Figure 4.11, it was observed that yield reduction will not occur from the present irrigation scheduling. Actual irrigation requirement was 407.2mm. It is the difference of actual water use by the crop and effective rainfall. The net irrigation requirement was 447.7mm considering 70% irrigation efficiency the gross irrigation requirement was 639.6mm. Irrigation scheduling efficiency was 100%. Rainfall efficiency was 99.9%. It is the ratio of effective and total rainfall. Lower the losses higher the efficiency. Seven irrigation events of 57mm to 69mm depth is required.

5) Maize:

Crops	Net Irrigation Req.(mm)	Irrigation Events (In No.)	Application Depth (mm)
Wheat	573.8	9	51-72
Sorghum	63.9	1	63.9
Cotton	384	6	55-71
Onion	461.8	27	10-22
Maize	447.7	7	57- 69

5.Conclusion

In the present study, crop water requirement and irrigation scheduling of Wheat, Sorghum, Cotton, Onion and Maize in the study area is successfully determined by using Cropwat. It has been observed that reference evapotranspiration is estimated by Cropwat was highest in the month of May and lowest in the month of April the average reference evapotranspiration in the study area was found to be 5.87 mm/day.

The crop evapotranspiration of different crops namely Wheat, Sorghum, Cotton, Onion and Maize is 543.3mm, 364.9mm, 699.7mm, 479.6mm and 501.7mm respectively. And the irrigation requirement of the crops Wheat, Sorghum, Cotton, Onion and Maize is 519.8mm, 69.20mm, 435.1mm, 446.8mm,

and 432.3mm respectively.

From the final output it has been observed that crop water requirement for Sorghum is less and Wheat is high. Whereas the number of irrigation events required for Sorghum is less and Onion is high.

The irrigation scheduling was initially done by Cropwat using time and depth criteria to study its effects on yield reduction, rainfall and irrigation scheduling efficiency The results of irrigation scheduling indicated that irrigation at critical depletion and refill the soil back to field capacity would result in minimum yield reduction, net irrigation requirement, maximum rainfall and scheduling efficiency could be achieved.

6. Reference

1) Sebastian Kloss & Raji Pushpalatha & Kefasi J. Kamoyo & Niels Schütze (2012), Evaluation of Crop Models for Simulating and Optimizing Deficit Irrigation Systems in Arid and Semi-arid Countries Under Climate Variability, Water Resources Management,Springer, DOI 10.1007/s11269-011-9906-y
2) Ashutosh Rath & Prakash Chandra Swain (2018), Evaluation of performance of irrigation canals using benchmarking techniques—a case study of Hirakud dam canal system, Odisha, India ISH Journal of Hydraulic Engineering, Taylor and Francis, DOI: 10.1080/09715010.2018.1439777
3) S. K. Raull; Sudhindra N. Panda, M.Sectoral, Conjunctive Use Planning for Optimal Cropping under Hydrological Uncertainty (2012), Journal of irrigation and drainage engineering, ASCE, DOI:101061/(ASCE)IR.1943-47740000393.
4) U.Surendran*, C.M.Sushanth, George Mammen, and E.J.Joseph, Modelling the crop water requirement using FAO-CROPWAT and assessment of water resources for sustainable water resource management: A case study in Palakkad district of humid tropical Kerala, India(2015), Science Direct, Elsevier, DOI: 10.1016/j.aqpro.2015.02.154
5) Ioannis D. Tsakmakisl & Maria Zoidoul & Georgios D. Gikasl & Georgios K. Sylaiosl Impact of Irrigation Technologies and Strategies on Cotton Water Footprint Using AquaCrop and CROP WAT Models (2018), Nature Environment Processor, Springer, DOI: 10.1007/s40710-018-0289-4
6) 10. Seung Hwan Y 00, Jin Yang Chai, Min Wan Jang ,Estimation of design water requirement using FAO Penman Monteith and optimal probability distribution function in South Korea(2008), Science Direct, Elsevier, DOI: 10.1016/j.agwat.2008.02.010

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