Crop Water Requirement and Irrigation scheduling of Soybean and Tomato crop using CROPWAT 8.0

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Abstract: - *Water is becoming gradually scarce worldwide. Aridity and drought are considered natural causes of scarcity of water on earth. Man-made desertification and water shortages have further aggravated the natural scarcity of water worldwide. Water scarcity has a huge impact on food production. Without water, people do not have a means of watering their crops and therefore, to provide food for the fast growing population, farmers need to increase their output from existing cultivated areas to satisfy the food demand of an increasing population in the world especially in India. Irrigation systems will be essential to enhance crop productivity in order to meet future food demand and ensure food security. Dwindling water resources and increasing food requirements require greater efficiency in water use, both in rain fed and in irrigated agriculture. To conserve water, some form of irrigation scheduling should be used by the farming community.The objectives of present study is to determine Crop Water Requirement and irrigation scheduling of Soybean and Tomato crop using FAO- Cropwat 8.0 software. The study area considered here is Godhra Taluka of District-Panchmahals in Gujarat, India. Irrigation scheduling is carried out for various scenarios through which it was observed that the critical depletion scenario is the best one as the yield reduction is minimum. CWR for soybean is obtained 426.0 mm/dec and Irrigation requirement is 381.0 mm/dec with no yield reduction and CWR for tomato is 1180.7 mm/dec and Irrigation requirement is 1135.7 mm/dec with 0.1 % yield reduction.*

Key Words: Crop Water Requirement, irrigation scheduling, Penman monteith method, FAO-Cropwat, Soybean, Tomato crop.

1. INTRODUCTION

Due to the increase of population in the world, the demand of water is increasing and in many parts of the world there are major concerns regarding the sustainability of water resources for irrigated agriculture. Hence, the necessity for conservation of water resources increases, particularly in countries with limited water supply. Since the past decades, irrigation has traditionally been the major source of water usage for agriculture. To cope with shortage of water, it is necessary to adopt water saving agriculture counter measures. The main objective of irrigation is to apply water to soil to meet crop evapotranspiration requirement when rainfall is insufficient, to raise crop till harvesting. Irrigation includes application of the right quantity or amount of water at the right time to the soil for plant growth. Hence estimating irrigation water requirements is necessary for water project, planning and management. The term crop water requirement means the total amount of water required by the crop and the way in which it requires water from the time of being planted till the crop has been harvested. The objective of this study is to determine Crop Water Requirement and Irrigation scheduling for soybean crop and tomato crop. The CROPWAT software developed by the FAO Land and Water Development Division (FAO, 1992) includes a simple water balance model that allows the simulation of crop water stress conditions and estimations of yield reductions based on well-established methodologies for determination of crop evapotranspiration (FAO, 1998) and yield responses to water (FAO, 1979). [1]

2. STUDY AREA AND DATA COLLECTION

The study area considered here is Godhra Taluka of District- Panchmahals in Gujarat, India. Geographical location of Godhra is 22.77° North (Latitude) and 73.61° East (longitude) at an elevation of 73 meters. The area comes under Agro climatic Zone III. The climate here is semi-arid. The Monthly climatic data i: e maximum and minimum temperatures, Relative humidity, wind speed, sunshine hours, Rainfall and Soil type were collected.

3. METHODOLOGY

A) CROPWAT: Cropwat is a **decision support system** developed by FAO, having as main functions:

- **To calculate**: Reference evapotranspiration, crop water requirements, crop irrigation requirements;
- **To develop**: Irrigation schedules under various management conditions, scheme water supply.

It uses the Smith (1992) Penman-Monteith method for calculating reference crop evapotranspiration. These reference crop evapotranspiration estimate is used in crop water requirements and irrigation scheduling calculations. CROPWAT calculates the irrigation water requirements either per month or per week period or as requirement of a cropping pattern in an irrigated area, for various stages of crop development throughout the crops growing season. Major input parameters of the program are Meteorological data, crop growth data & soil data.

B) FAO Penman-Monteith Approach: The FAO Penman Monteith method to estimate ETo is expressed as:

$$ETo = 0.408\Delta(Rn - G) + \gamma\left[\frac{900}{T+273}\right]u_2\frac{(es - ea)}{\Delta} + \gamma(1 + 0.34u_2)$$

Where,
ETo= reference evapotranspiration [mm day^{-1}],
Rn =net radiation at the crop surface [MJ m^{-2} day^{-1}],
G= soil heat flux density [MJ m^{-2} day^{-1}],
T =mean daily air temperature at 2 m height [°C],
u_2= wind speed at 2 m height [m s^{-1}],
es= saturation vapour pressure [kPa],
ea= actual vapour pressure [kPa],
es – ea= saturation vapour pressure deficit [kPa],

C) CROP COEFFICIENT (Kc): The crop coefficient, Kc, is basically the ratio of the crop ETc to the reference ETo, and it represents an integration of the effects of four primary characteristics that distinguish the crop from reference grass i: e Crop height. Albedo of the crop-soil surface, Canopy resistance, Evaporation from soil, especially exposed soil [3]. In developing the crop coefficients for the growing season, different stages of crop development are considered:

1. Initial state: From planting through germination and plant emergence, and until about 10% ground cover is achieved.
2. Crop development stage: from 10% of ground cover to effective full ground cover. This occurs at about 70% or 80% ground cover.
3. Mid-season stage: from effective cover to the start of maturity. The crop is physiologically capable of the highest water use during this time. The crop coefficient is highest.
4. Late season stage: from the start of maturity until full maturity or harvest.

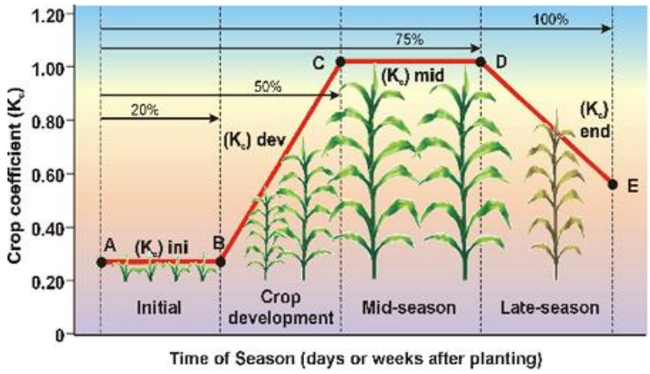


Fig -1: Crop coefficient (Kc)

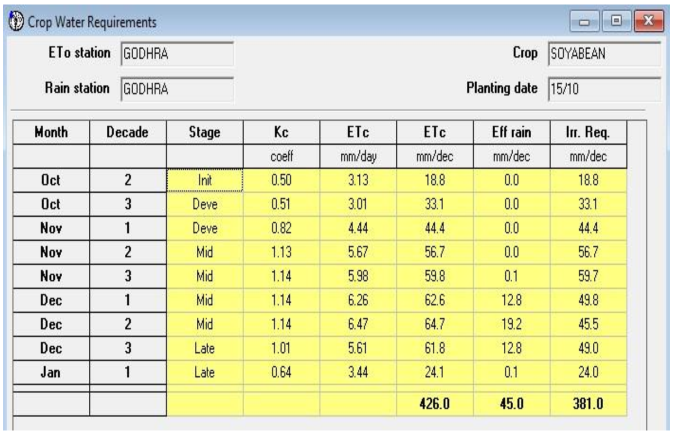
D) Crop Evapotranspiration (Etc): The amount of water required by the crop during whole season is defined as crop water requirement. ETc is determined by the crop coefficient approach whereby the effect of the various weather conditions are incorporated into ETo and the crop characteristics into the Crop coefficient:

$$ETc = Kc \times ETo$$

E) Irrigation Scheduling: Irrigation scheduling has been in practice primarily for regulating an optimum water supply for better productivity. The Food & Agricultural Organization (FAO) CROPWAT model for irrigation scheduling offers the possibility to design an indicative irrigation schedules, and its impact over yield, Evaluate field irrigation program in terms of efficiency of water use and yield reduction and Simulate field irrigation program under water deficiency conditions, rain-fed conditions, supplementary irrigation, etc.

4. RESULTS AND ANALYSIS

The crop water requirement of soybean obtained in Cropwat is shown below in Fig-2 and Irrigation Scheduling for soybean crop is show in Table-1.



Crop Water Requirements

ETo station GODHRA | Crop SOYABEAN
Rain station GODHRA | Planting date 15/10

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Oct	2	Init	0.50	3.13	18.8	0.0	18.8
Oct	3	Deve	0.51	3.01	33.1	0.0	33.1
Nov	1	Deve	0.82	4.44	44.4	0.0	44.4
Nov	2	Mid	1.13	5.67	56.7	0.0	56.7
Nov	3	Mid	1.14	5.98	59.8	0.1	59.7
Dec	1	Mid	1.14	6.26	62.6	12.8	49.8
Dec	2	Mid	1.14	6.47	64.7	19.2	45.5
Dec	3	Late	1.01	5.61	61.8	12.8	49.0
Jan	1	Late	0.64	3.44	24.1	0.1	24.0
					426.0	45.0	381.0

Fig -2: Crop Water Requirement of Soybean

Table -1: Irrigation scheduling of Soybean

Date	Day	Stage	Rain	Ks	Eta	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
15-Oct	1	Init	0	1	100	57	25.8	0	0	36.9	4.27
23-Oct	9	Init	0	1	100	54	38.2	0	0	54.6	0.79
04-Nov	21	Dev	0	1	100	56	62.1	0	0	88.7	0.86
18-Nov	35	Mid	0	1	100	61	85.6	0	0	122.2	1.01
04-Dec	51	Mid	0	1	100	64	89.2	0	0	127.4	0.92
22-Dec	69	Mid	0	1	100	61	85.7	0	0	122.4	0.79
07-Jan	End	End	0.1	1	100	46					

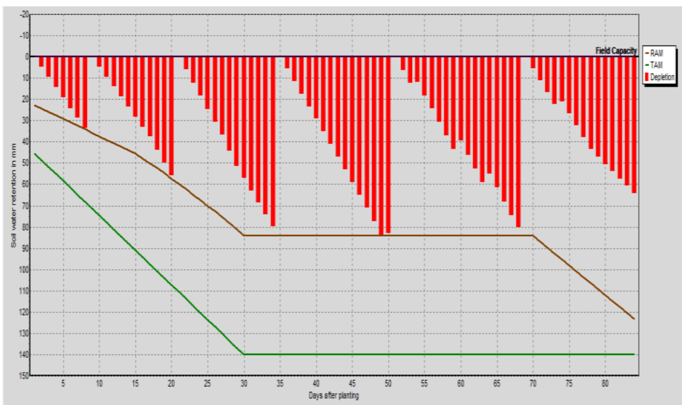
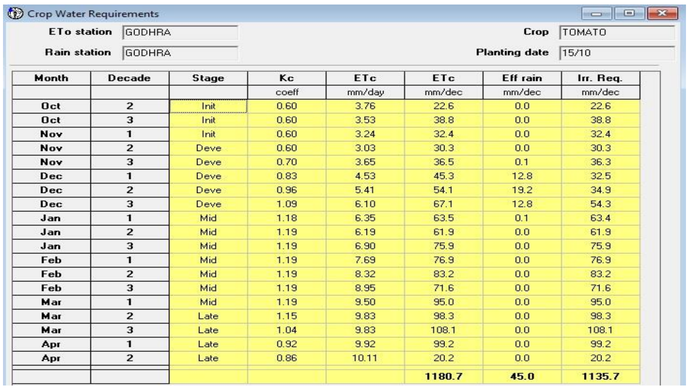


Chart -1: Irrigation Scheduling of Soybean

The crop water requirement for Tomato obtained from Cropwat is shown in Fig-3 and Irrigation Scheduling for Tomato crop is show in Table-2.



Crop Water Requirements

ETo station GODHRA | Crop TOMATO
Rain station GODHRA | Planting date 15/10

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Oct	2	Init	0.60	3.76	22.6	0.0	22.6
Oct	3	Init	0.60	3.53	38.8	0.0	38.8
Nov	1	Init	0.60	3.24	32.4	0.0	32.4
Nov	2	Deve	0.60	3.03	30.3	0.0	30.3
Nov	3	Deve	0.70	3.65	36.5	0.1	36.3
Dec	1	Deve	0.83	4.53	45.3	12.8	32.5
Dec	2	Deve	0.96	5.41	54.1	19.2	34.9
Dec	3	Deve	1.09	6.10	67.1	12.8	54.3
Jan	1	Mid	1.18	6.35	63.5	0.1	63.4
Jan	2	Mid	1.19	6.19	61.9	0.0	61.9
Jan	3	Mid	1.19	6.90	75.9	0.0	75.9
Feb	1	Mid	1.19	7.69	76.9	0.0	76.9
Feb	2	Mid	1.19	8.32	83.2	0.0	83.2
Feb	3	Mid	1.19	8.95	71.6	0.0	71.6
Mar	1	Mid	1.19	9.50	95.0	0.0	95.0
Mar	2	Late	1.15	9.83	98.3	0.0	98.3
Mar	3	Late	1.04	9.83	108.1	0.0	108.1
Apr	1	Late	0.92	9.92	99.2	0.0	99.2
Apr	2	Late	0.86	10.11	20.2	0.0	20.2
					1180.7	45.0	1135.7

Fig -3: Crop Water Requirement of Tomato

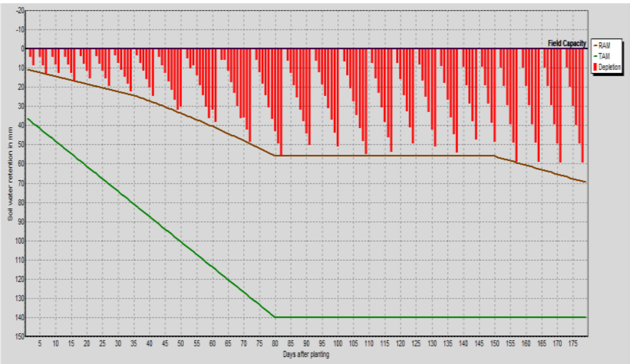


Chart -1: Irrigation Scheduling of Tomato

Table -2: Irrigation Scheduling of Tomato

Date	Day	Stage	Rain	Ks	Eta	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
15-Oct	1	Init	0	0.71	71	57	20.8	0	0	29.8	3.45
18-Oct	4	Init	0	1	100	33	13.3	0	0	19	0.73
22-Oct	8	Init	0	1	100	38	17.2	0	0	24.6	0.71
26-Oct	12	Init	0	1	100	33	16.8	0	0	24	0.69
31-Oct	17	Init	0	0.99	100	37	21	0	0	29.9	0.69
05-Nov	22	Init	0	1	100	31	19.5	0	0	27.9	0.65
11-Nov	28	Init	0	1	100	32	23.2	0	0	33.2	0.64
18-Nov	35	Init	0	1	100	32	25.9	0	0	36.9	0.61
25-Nov	42	Dev	0	1	100	32	28.9	0	0	41.3	0.68
04-Dec	51	Dev	0	1	100	35	35.3	0	0	50.5	0.65
15-Dec	62	Dev	0	1	100	38	44.2	0	0	63.2	0.66
26-Dec	73	Dev	0	1	100	42	55.3	0	0	78.9	0.83
05-Jan	83	Mid	0	1	100	44	62.2	0	0	88.8	1.03
14-Jan	92	Mid	0	1	100	40	56.4	0	0	80.6	1.04
23-Jan	101	Mid	0	1	100	41	57.8	0	0	82.6	1.06
01-Feb	110	Mid	0	1	100	45	62.9	0	0	89.8	1.15
09-Feb	118	Mid	0	1	100	44	61.5	0	0	87.8	1.27
16-Feb	125	Mid	0	1	100	41	57.6	0	0	82.3	1.36
23-Feb	132	Mid	0	1	100	43	60.1	0	0	85.9	1.42
02-Mar	139	Mid	0	1	100	46	63.8	0	0	91.1	1.51
08-Mar	145	Mid	0	1	100	41	57	0	0	81.5	1.57
14-Mar	151	End	0	1	100	42	58.3	0	0	83.3	1.61
21-Mar	158	End	0	1	100	49	68.8	0	0	98.3	1.63
28-Mar	165	End	0	1	100	49	68.8	0	0	98.3	1.62
04-Apr	172	End	0	1	100	49	69.2	0	0	98.8	1.63
11-Apr	179	End	0	1	100	50	69.6	0	0	99.5	1.64
12-Apr	End	End	0	1	0	0					

As irrigation scheduling carried using CROPWAT software, the gross water requirement for soybean and tomato is obtained 637.2 mm and 1458.5 mm respectively. The simulation results analysis suggest that crop water requirements of soybean crop is 426.0 mm/dec and irrigation requirement is 381.0 mm/dec. Also, Crop water requirement of tomato crop is 1180.7 mm/dec and irrigation requirement is 1135.7 mm/dec.

5. CONCLUSIONS

From the present study, it is concluded that Reference Crop Evapotranspiration, Effective Rainfall, Crop water requirement and Irrigation water requirement can be estimated using CROPWAT 8.0 Software with the input of climatic data like maximum and minimum temperature, relative humidity, wind speed and sunshine hours and rainfall.

The simulation results analysis suggest that crop water requirements of soybean crop is 426.0 mm/dec and irrigation requirement is 381.0 mm/dec. Crop water requirement of tomato crop is 1180.7 mm/dec and irrigation requirement is 1135.7 mm/dec.

The gross water requirement for soybean and tomato is obtained 637.2 mm and 1458.5 mm respectively.

The use of modern scientific tools like CROPWAT can assess the water requirement of crops with large accuracy and suggest the crop pattern and crop rotation which can be readily acceptable to farmers.

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