

Original Research Article

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Water Requirements and Irrigation Scheduling of Maize Crop using CROPWAT Model

Shakeel Ahmad Bhat^{1*}, B.A. Pandit¹, J.N. Khan¹, R. Kumar¹ and Rehana Jan²

¹Division of Agricultural Engineering, SKUAST Kashmir, India

²Division of Soil Science SKUAST-K, India

*Corresponding author

ABSTRACT

Keywords

Irrigation Management, Crop Water Requirement, CROPWAT, Optimal Irrigation Scheduling.

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Due to overexploitation of available water resources, it has become very important to define appropriate strategies for planning, development and management of water resources of the country. The study aims to develop an optimal irrigation scheduling, to increase crop yield under water scarcity conditions. The crop water requirement was found to be 304 mm and irrigation requirement 288.2 mm. On refilling soil to field capacity with irrigation at critical depletion, irrigate at a given ET crop reduction per stage and irrigate at fixed interval per stage at 70% field efficiency gave a yield reduction of about 0%, 14.9%, 25.1% respectively. Irrigation should be done at the critical depletion to achieve 0% yield reduction of maize and maximum rainfall efficiency. The research shows that the irrigation management model can effectively and efficiently estimate the crop water requirements. The model, that calculates evapotranspiration and crop water requirements, allows the development of recommendations for improved irrigation practices, the planning of irrigation schedules under varying water supply conditions and yields reduction under various conditions.

Introduction

Increased water demand brought about by rapid population growth has created the necessity to increase food production through the expansion of irrigation and industrial production to meet basic human needs. The primary objective of irrigation is to apply water to maintain crop Evapotranspiration (ET) when precipitation is insufficient. Hess (2005) defined crop water requirements as the total water needed for evapotranspiration, from planting to harvest for a given crop in a specific climate regime, when adequate soil water is maintained by rainfall and/or irrigation so that it does not limit plant growth and crop yield. Irrigation technologies and

irrigation scheduling may be adapted for more effective and rational uses of limited water supplies. CWR depend on climatic conditions, crop area and type, soil type, growing seasons and crop production frequencies (FAO, 2009; George *et al.*, 2000). CROPWAT is one of the models that are being extensively used in the field of water management throughout the world which is designed by Smith (1991) of the Food Agricultural Organization (FAO). CROPWAT facilitates the estimation of the crop evapotranspiration, crop water requirements and irrigation schedule with different cropping patterns for irrigation planning (Kuo *et al.*, 2006; Gowda *et al.*,

2013; George *et al.*, 2000; Gouranga and Verma, 2005; Martyniak *et al.*, 2006; Dechmi *et al.*, 2003; Zhiming *et al.*, 2007).

CROPWAT is a decision support system developed by the Land and Water Development Division of FAO for planning and management of irrigation. CROPWAT is meant as a practical tool to carry out standard calculations for reference evapotranspiration, crop water requirements and crop irrigation requirements, and more specifically the design and management of irrigation schemes. It allows the development of recommendations for improved irrigation practices, the planning of irrigation schedules under varying water supply conditions, and the assessment of production under rain fed conditions or deficit irrigation (FAO 1992). Water use requirement for same crop varies under different weather conditions. To achieve effective planning on water resources, accurate information is needed for crop water requirements, irrigation withdrawal as a function of crop, soil type and weather conditions. CROPWAT is a FAO model for irrigation management designed by Smith [17] which integrates data on climate, crop and soil to assess reference evapotranspiration (ET_o), crop evapotranspiration (ET_c) and irrigation water requirements.

Materials and Methods

Model description and input data

CROPWAT for Windows is a decision support system developed by the Land and Water Development Division of FAO, Italy with the assistance of the Institute of Irrigation and Development Studies of Southampton, UK and National Water Research Center, Egypt. The model carries out calculations for reference evapotranspiration, crop water requirements and irrigation requirements in order to

develop irrigation schedules under various management conditions and scheme water supply. It allows the development of recommendations for improved irrigation practices, the planning of irrigation schedules and the assessment of production under rainfed conditions or deficit irrigation (Adriana *et al.*, 1999). CROPWAT for Windows uses the FAO (1992) Penman-Monteith method for calculation reference crop evapotranspiration.

Climate data: Which was collected from the Agro- meteorological station SKUAST-K. These data include maximum and minimum temperature, humidity, wind speed and sun hours. These data are essential to calculate ET_o. CROPWAT calculate radiation and ET_o depending on climate data. A sample of computation of reference crop evapotranspiration, ET_o by penman Monteith method shown in Figure 1.

Rain data: Rain data was also collected from the Agrometeorological station and applied in CROPWAT software to obtain effective rainfall. Figure 2 shows a sample of rain data with effective rainfall obtained.

Crop data: The software needs some information about maize crop. These information have been obtained from FAO manual 56 [1] for maize crop including crop name; planting date; harvest, crop coefficient, K_c; rooting depth length of plant growth stages; critical depletion and yield response factor. Values of K_c, rooting depth also are taken from FAO manual [1], Figure 3 shows a crop data applied in this software.

Soil data: Soil type in this area is a silty clay loam according to [3]. The software needs some general soil data like total available soil moisture; maximum rain infiltration rate; maximum rooting depth; initial soil moisture depletion and initial available soil moisture.

These information obtained from FAO manual 56[1]. Figure 4 shows the application of these information in the software.

Results and Discussion

The CROPWAT 8.0 was used to prepare the irrigation schedule for maize crop. The model predicted the daily, decadal as well as monthly crop water requirement at different growing stages of maize crop. The crop water requirement and irrigation requirement for the maize crop was found to be 304mm and 288.2mm respectively. Figure 5 shows the graph of CROP water Requirement and Irrigation requirement of maize crop. For the application of irrigation, the critical soil

moisture depletion was considered at 100%. From the results, it was found that the yield reduction will not occur at any growing stage with maximum rainfall efficiency as predicted with irrigation at 100 % critical depletion and by refilling the soil to the field capacity (Table 3). The detailed results of total gross irrigation, total net irrigation, actual water use by crop and potential water use by crop is given in the Table 2. The rain efficiency of 66 % was found and by this efficiency, effective rainfall was found to be 10.5 mm. The total net irrigation varied from the irrigation requirement due to change in effective rainfall efficiency. The Figure 6 showed the irrigation schedule pattern at 100% critical depletion.

Table.1 Daily and decadal ETc and irrigation requirement

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Jul	2	Init	0.3	1.32	13.2	2.2	11
Jul	3	Deve	0.3	1.25	13.8	2.1	11.6
Aug	1	Deve	0.49	1.88	18.8	2	16.8
Aug	2	Deve	0.77	2.78	27.8	1.9	25.9
Aug	3	Deve	1.07	3.61	39.7	1.5	38.1
Sep	1	Mid	1.29	4.05	40.5	1.1	39.4
Sep	2	Mid	1.3	3.77	37.7	0.7	37
Sep	3	Mid	1.3	3.38	33.8	0.8	33
Oct	1	Mid	1.3	2.99	29.9	1	28.9
Oct	2	Late	1.23	2.47	24.7	1	23.6
Oct	3	Late	1	1.69	18.6	0.8	17.8
Nov	1	Late	0.75	0.55	5.5	0.6	4.9
Nov	2	Late	0.61	0.06	0.1	0.1	0.1
					304	15.9	288.2

Table.2 Total gross irrigation, total net irrigation and efficiency of rain

Totals			
Total gross irrigation	395.8mm	Total rainfall	15.9mm
Total net irrigation	277.1mm	Effective rainfall	10.5mm
Total irrigation losses	0mm	Total rain loss	5.4mm
Actual water use by crop	304mm	Moist deficit at harvest	16.4mm
Potential water use by crop	304mm	Actual irrigation requirement	293.5mm
Efficiency irrigation schedule	100%	Efficiency rain	66%
Deficiency irrigation schedule	0%		

Table.3 Yield reduction at 100 % of critical depletion

Yield reductions	A	B	C	D	Season
Stage label	A	B	C	D	Season
Reduction in ETc	0	0	0	0	0%
Yield response factor	0.4	1	1.3	0.5	1.25
Yield reduction	0	0	0	0	0 %
Cumulative yield reduction	0	0	0	0	0%

Table.4 Comparison of Irrigation water requirements, yield reduction and cropping intensity for maize

Parameter of comparison	No water stress	with water stress
Total gross irrigation	395.8mm	321.9mm
Total net irrigation	277.1mm	225.3mm
Actual water use by crop	304mm	242.9
Potential water use by crop	304mm	304
Yield Reduction %	0%	25.10%
Timing	Irr. At 100% deplet.	Irrig. At fixed interval per stage (Interval in days: initial 7, development 7, mid 20, late 7)
Application	Refill to 100 % of field capacity	Refill to 100 % of field
Field efficiency: (%)	70	70
CROPWATT 8.0		

Fig.1 Climate file

Country	INDIA	Station	SKUAST-K	Year	2011		
Altitude	1583 m.	Latitude	74.80 N	Longitude	34.50 E		
Day	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	m/s	hours	MJ/m ² /day	mm/day
13	7.5	30.5	58	2.0	12.0	20.5	5.12
14	8.5	33.5	66	1.3	12.0	20.3	4.83
15	10.5	33.5	75	2.3	12.0	20.2	5.10
16	13.5	32.6	69	0.7	6.2	15.2	3.59
17	12.2	27.0	84	1.3	4.5	13.7	3.02
18	15.5	24.0	87	1.5	1.9	11.4	2.49
19	13.0	26.0	85	2.6	6.0	14.7	3.21
20	13.5	30.0	74	1.0	9.8	17.6	3.86
21	13.0	32.2	65	2.2	7.9	15.9	4.53
22	12.0	27.5	74	1.9	7.4	15.4	3.63
23	9.1	29.6	80	2.5	5.8	14.0	3.67
24	13.0	28.5	69	2.2	10.8	17.7	4.24
25	12.0	29.0	73	1.6	9.2	16.3	3.77
26	12.0	29.5	75	2.2	7.4	14.8	3.75
27	13.0	30.0	78	2.6	12.0	18.1	4.23
28	14.6	32.5	83	2.8	10.7	16.9	4.18
29	12.5	31.0	85	2.6	9.8	16.0	3.80
30	15.5	33.4	68	0.3	8.6	15.0	3.21
31	11.0	32.3	82	2.6	10.3	16.0	4.06
Average	11.3	29.6	73	2.0	9.4	17.7	4.20

Fig.2 Rain file

Station Eff. rain method **Fixed percentage**

	Rain	Eff rain
	mm	mm
January	0.5	0.4
February	8.9	7.1
March	14.2	11.4
April	6.2	5.0
May	21	1.7
June	4.2	3.3
July	6.5	5.2
August	5.6	4.5
September	25	2.0
October	3.0	2.4
November	1.3	1.0
December	0.7	0.6
Total	55.7	44.5

Fig.3 Crop file

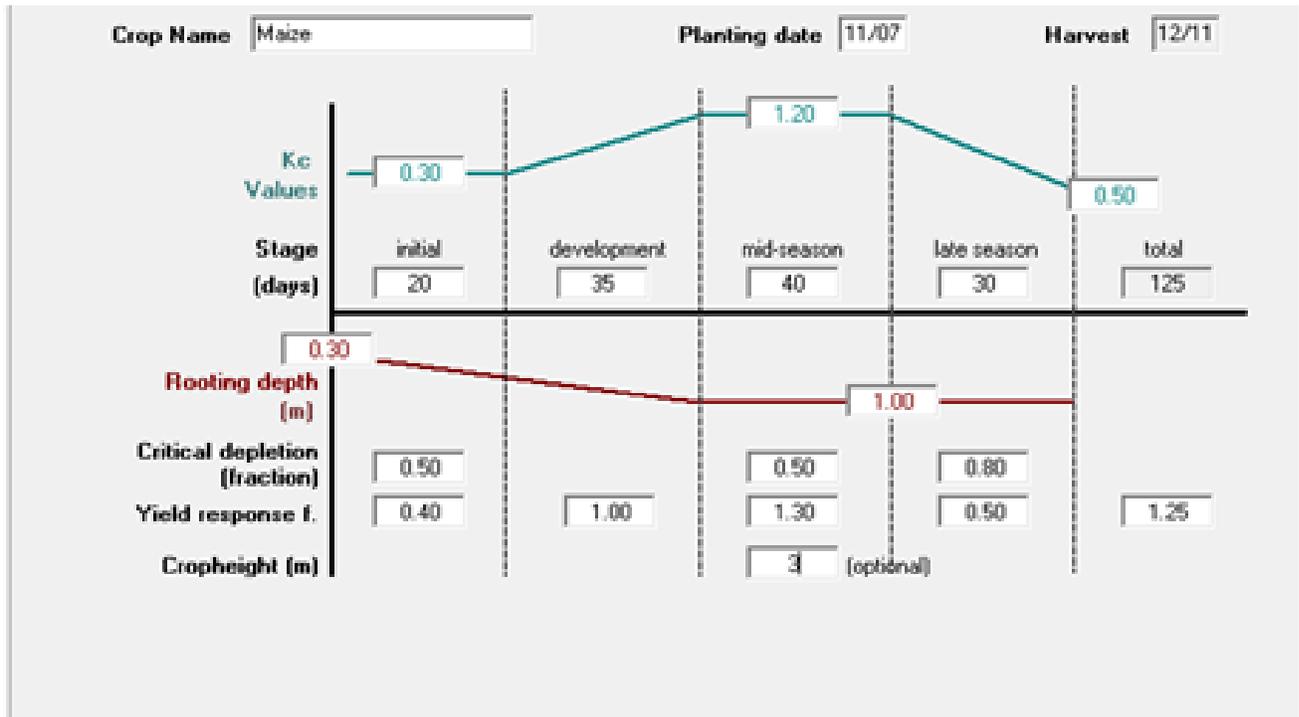


Fig.4 Soil file

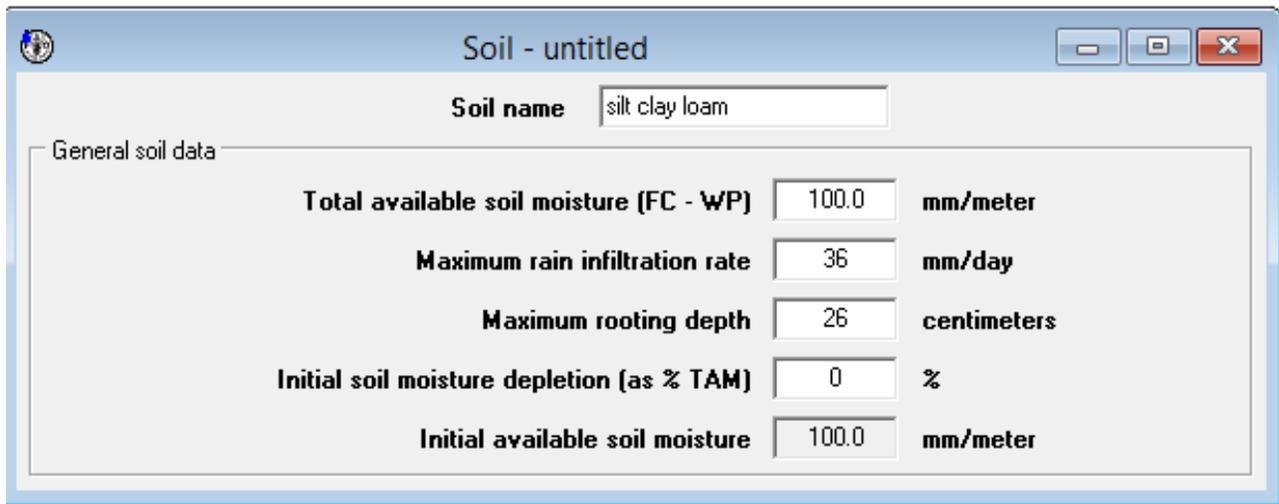


Fig.5 CROP water requirement and irrigation requirement of maize crop

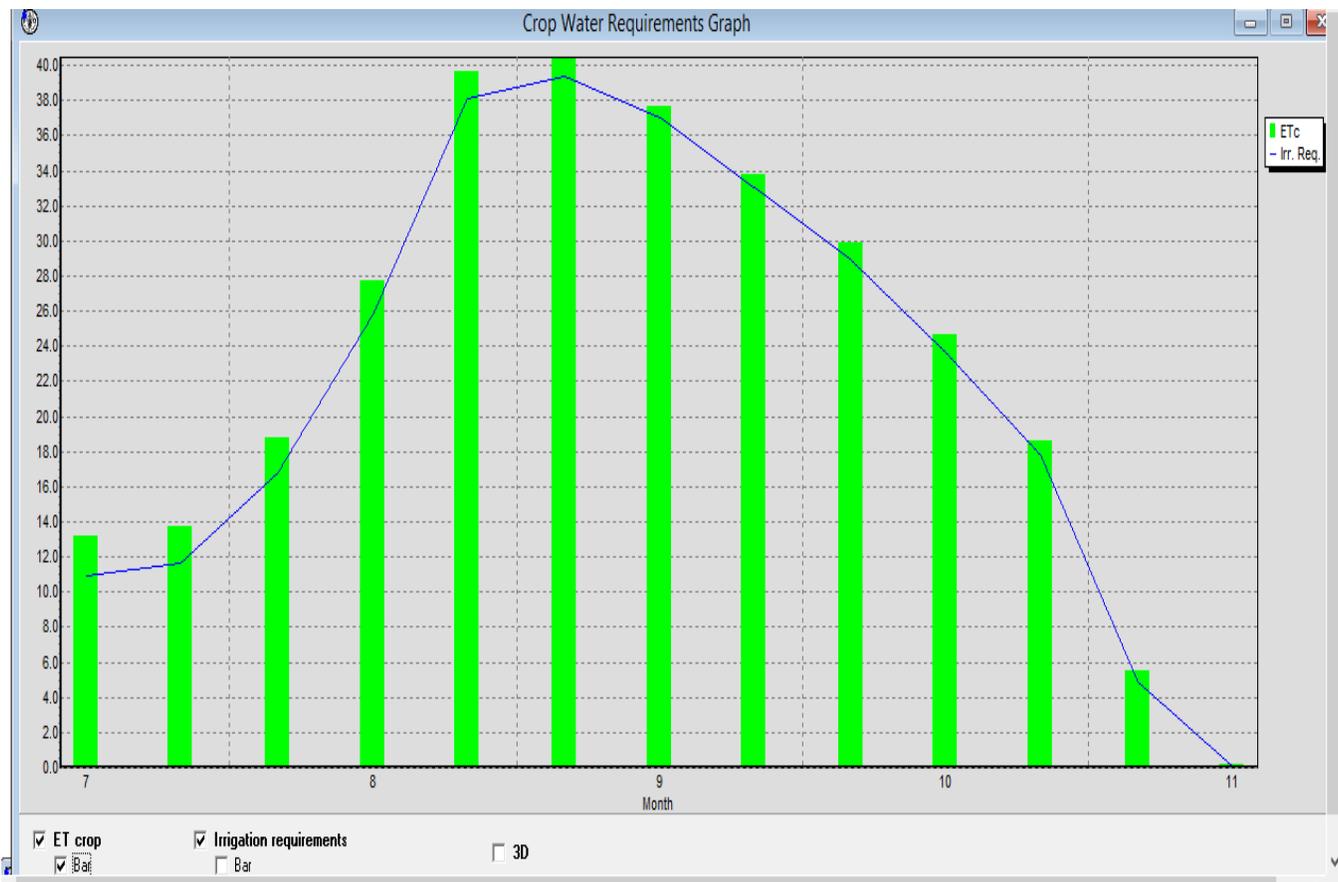


Fig.6 Irrigation scheduling without water stress

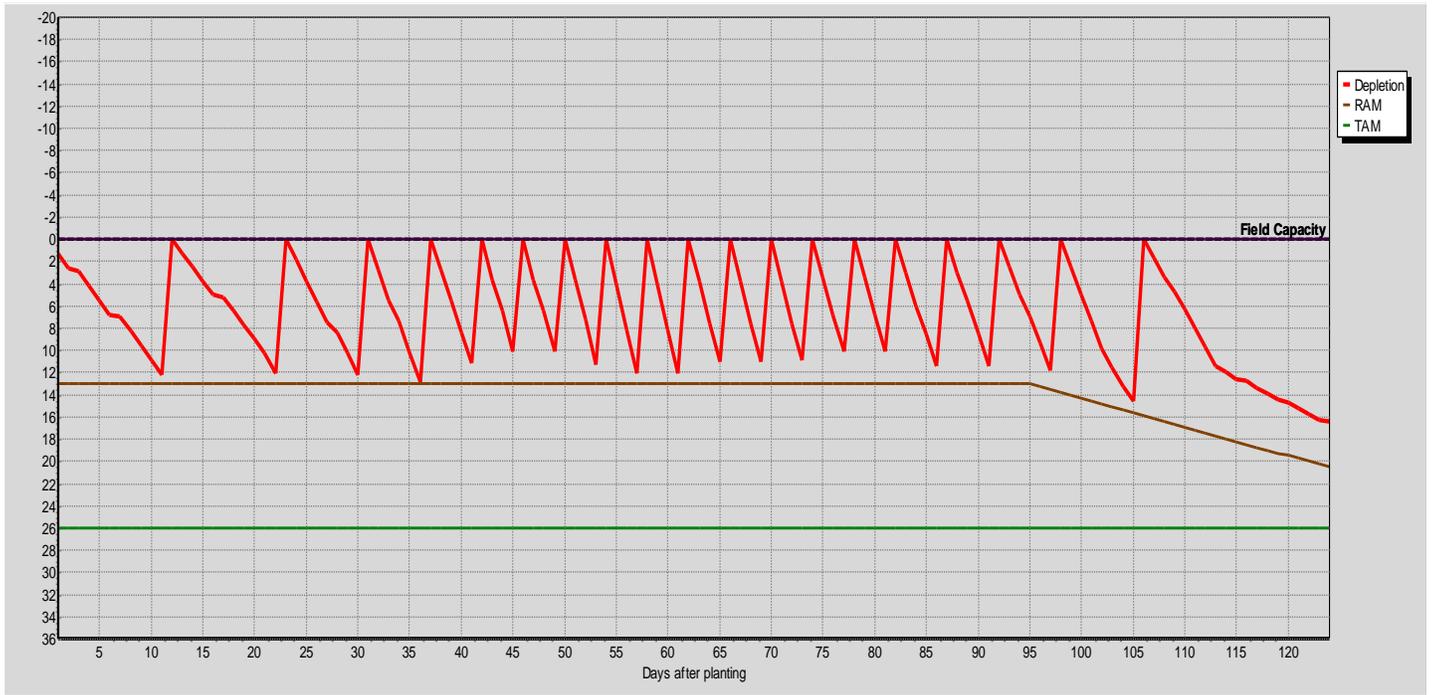


Fig.7 Irrigation scheduling with water stress

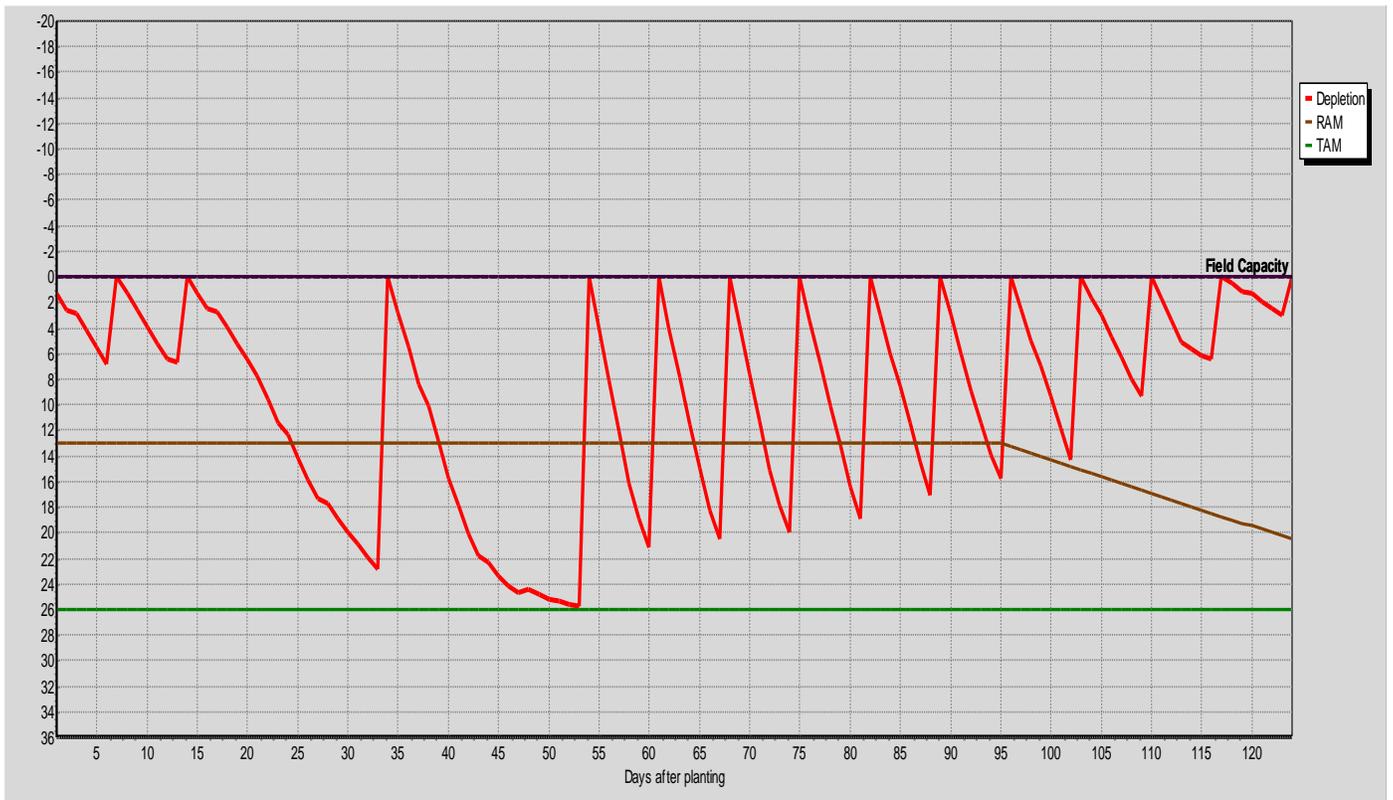


Table 4 shows application to 100 % of field capacity with irrigation at 100 % depletion achieved 70 % of *field efficiency* where yield reduction was “zero”. These met conditions and data for the optimal irrigation treatment (with no stress water applied) (Fig 6). Second step with water stress consisted of application to 100 % of field capacity with Irrigation at fixed interval per stage), where the yield reduction was 25.10 %. This was achieved by adapting fixed interval per stage (Interval in days: initial 7, development 7, mid 20, late 7) (Fig. 7).

The adequacy of water resources has been studied in detail to enable development of net irrigation requirements for maize crop. Proper and optimal scheduling of irrigation using CROPWAT 8.0 enabled the efficient water use to 70%.The crop water requirement for maize crop was found to be 304 mm and irrigation requirement 288.2 mm. Yield reduction at critical depletion, irrigate at a given ET crop reduction per stage and irrigate at fixed interval per stage at 70% field efficiency was found to be 0 %, 14.9% and 25.1% respectively. Also yield reduction at no water stress and at water stress was found to be 0% and 26.80% respectively.

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