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Pakistan's Northern Dry Mountain Agricultural Ecological Zone Autumn Maize Crop Water Requirement, and Irrigation Scheduling Using FAO Computer Programming Cropwat 8.0

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Abstract

Water is one of the most important elements in this universe. No life will exist without water. The main consumer of water is agriculture. But due to mismanagement, overpopulation, and climatic changes this valuable natural resource is getting scare position throughout the world. It has become very important to define appropriate strategies for planning, development, and management of water resources. The main objective of this paper is to develop an optimal irrigation scheduling for maize crops, to increase crop yield under water scarcity conditions of Pakistan's northern dry mountain ecological zone, which includes Chitral, Dir, Swat, Malakand, Khyber, and triable areas of Peshawar. On the basis of last 36 years climatic data, the crop water requirement at 80% field efficiency was found to be 504.7mm, irrigation water requirement was 460.9 mm, total net irrigation was 327.4mm and grass irrigation was 409.2mm. On refilling soil to field capacity with irrigation at 80mm critical depletion. The research shows that the irrigation management model can effectively and efficiently estimate 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. Keywords: Maize, irrigation Scheduling, Crop water requirement, Cropwat 8.0.

Introduction :

As population increased, demand of water and foods also increased through the growth of irrigation and industrial production to congregate essential human needs, the major aim of irrigation is to apply water to maintain crop Evapotranspiration (ET) when precipitation is not enough. Hess (2005) defined crop water requirements as the whole water needed for evapotranspiration, from planting to harvest for a given crop in a specific climate system, when sufficient soil water is maintained by rainfall and/or irrigation so that it does not oppose plant growth and yield. Irrigation technologies and irrigation scheduling may be adapted for more effective and rational uses of limited water supplies. Crops water depend on different factors like soil type, environmental conditions, crops type and areas, session from crops growing and frequency for crop production (FAO, 2009; George *et al.,* 2000). In the year 1991 smith design a computer programming for FAO, named as CROPWAT, which is use in water management throughout the world for estimating crop water requirement and irrigation scheduling 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. This programming lets the development of recommendations for improved irrigation performs, the planning of irrigation schedules under diverse water supply circumstances, and the valuation of production under rain fed circumstances or deficit irrigation (FAO 1992). Water use requisite for same crop differs under different weather circumstances. To attain real planning on water resources, precise information is required for crop water requirements, irrigation extraction as a function of crop, soil type and weather conditions. CROPWAT is a FAO model for irrigation supervision designed by Smith [17] which assimilates data on climate, crop and soil to measure reference evapotranspiration (ETo), crop evapotranspiration (ETc) and irrigation water needs.

Materials and Methods:

Study Location: The study area was Batkhela District Malakand of Khyber Pakhtunkhwa Pakistan This study area lies in the altitude 648m, Latitude 34.61^0 N and longitude of 71.92 ^{0} E .

Crop water requirement:

CROPWAT for Windows is a decision support system established by the Land and Water Development Division of FAO, Italy with the help 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. CROPWAT8.0 lets the development of references for improved irrigation performs, the planning of irrigation schedules, and the assessment of production under rain-fed or stress irrigation circumstances. (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 office of Agriculture Extension Malakand at Batkhela. These data include the maximum and minimum temperature, and monthly rainfall data of the growing session and long term climatic data from 1980 to 2016 were took from online source of weather spark. A sample of computation of reference crop evapotranspiration, ETo by penman Monteith method, and effective rain is shown in Table.1

Crop data:

The software needs some information about the maize crops. This information has been obtained from Pirsabaq research center Nowshera kpk Pakistan and from FAO manual 56 [1], for maize crop including crop name (Jalal); planting date (20/6/2020 and 2021); harvest, crop coefficient, Kc; rooting depth length of plant growth stages; critical depletion and yield response factor. Values of Kc, rooting depth also are taken from the FAO manual [1], Table. (2) Shows crop data applied in this software.

Soil data:

Soil type in this area is a silty loam. 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] and some were found from soil sample testing in the soil testing laboratory of UET Peshawar kpk Pakistan. Table. (3) Shows the application of these information in the software.

Irrigation Schedule:

Irrigation scheduling characterizes the genuine measure of water and specific chance to flood the command area. The CROPWAT model figures the ET0, crop water prerequisite and irrigation necessities to foster the irrigation plans under different administration conditions and water supply plans.

Results and Discussion :

FAO computer programming CROPWAT 8.0 was used to make the irrigation schedule for autumn maize crop in northern dry mountain agriculture ecological zone Malakand at Batkhela of KPK Pakistan. The model predicted the daily, decadal as well as monthly crop water requisite at diverse growing stages of autumn maize crop. The crop water requirement and irrigation requirement for the maize crop was found to be 504.7mm and irrigation water requirement was 460.9mm at 80% field efficiency. Table.1 shows the Crop water Requirement and Irrigation requirement of maize crop for both growing sessions. For the application of irrigation, the critical soil moisture depletion was considered 80mm. From the results, it was found that 2.3% yield reduction will occur. The detailed results of irrigation scheduling, total gross irrigation, total net irrigation, actual water use by crop, and potential water use by the crop are given in (Table 4). The rain efficiency of 90.4% was found and by this efficiency, effective rainfall was found to be 117.6mm. The total net irrigation varied from the irrigation requirement due to changes in effective rainfall efficiency. Fig.1 show the irrigation schedule pattern at 100% FC and 80mm critical depletion for maize during growing session 2020, 2021. Fig.2, indicate maximum and minimum temperature, evapotranspiration, and rain data during the growth period based on last 36 years climatic data. While Fig 3, shows the crop water requirement and irrigation water demand for maize crops during the growing session.

Table. 1. Crop water requirement and Irrigation water requirement

Crop Water Requirements

ETo station: Batkhela | Crop: MAIZE (Grain)

Rain station: Batkhela | Planting date: 20/06

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Jun	2	Init	0.40	2.96	3.0	0.0	3.0
Jun	3	Init	0.40	2.85	28.5	0.8	27.6
Jul	1	Deve	0.40	2.73	27.3	4.8	22.5
Jul	2	Deve	0.56	3.68	36.8	7.0	29.8
Jul	3	Deve	0.82	5.16	56.8	6.9	49.8
Aug	1	Mid	1.07	6.45	64.5	7.1	57.4
Aug	2	Mid	1.14	6.56	65.6	7.5	58.1
Aug	3	Mid	1.14	6.32	69.5	5.5	64.0
Sep	1	Mid	1.14	6.08	60.8	2.7	58.0
Sep	2	Late	1.13	5.80	58.0	0.7	57.2
Sep	3	Late	1.04	4.88	34.2	0.5	33.4
					504.7	**43.6**	**460.9**

Table.(2) shows a crop data applied in software

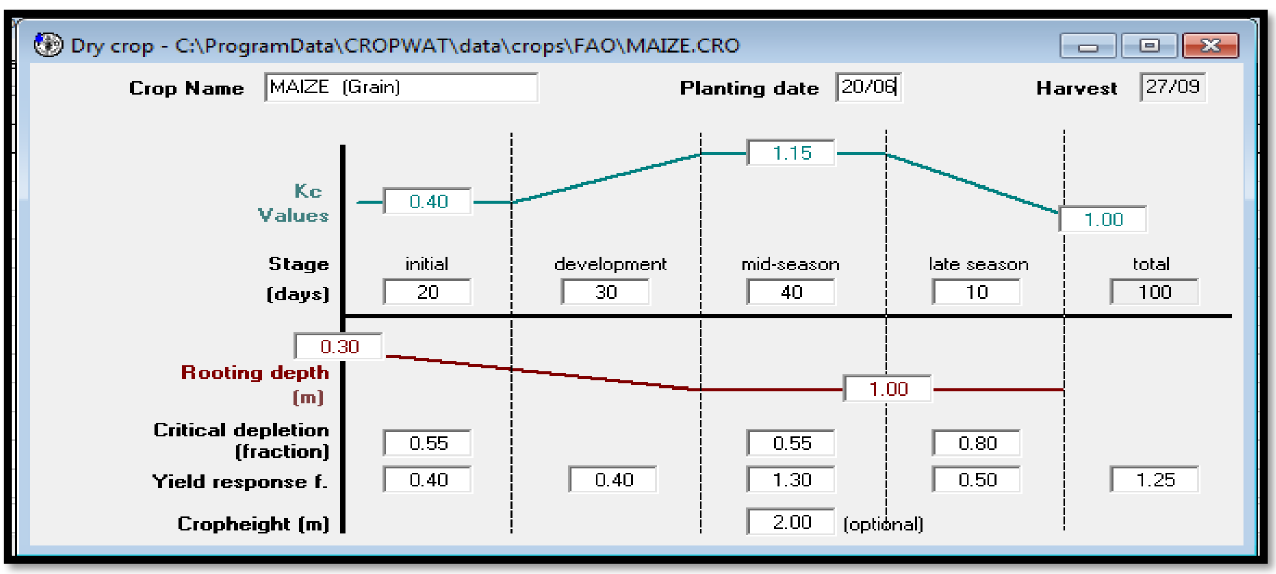

Table.(3) shows a soil data applied in software

Soil - C:\ProgramData\CROPWAT\data\soils\Batkhela36.SOI

Soil name: silt loam

General soil data

Total available soil moisture (FC - WP)	144.0	mm/meter
Maximum rain infiltration rate	40	mm/day
Maximum rooting depth	91	centimeters
Initial soil moisture depletion (as % TAM)	0	%
Initial available soil moisture	144.0	mm/meter

Soil - C:\ProgramData\CROPWAT\data\soils\Batkhela36.SOI

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General soil data

Total available soil moisture (FC - WP)	144.0	**mm/meter**
Maximum rain infiltration rate	40	**mm/day**
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Initial soil moisture depletion (as % TAM)	0	**%**
Initial available soil moisture	144.0	**mm/meter**

Table.4. irrigation Scheduling, net and grass irrigation, and yield reduction

CROP IRRIGATION SCHEDULE

ETo station: Batkhela Crop: MAIZE (Grain) Planting date: 20/06
Rain station: Batkhela Soil: silt Loam Harvest date: 27/09

Yield red.: 2.3 %

Crop scheduling options
Timing: Irrigate at 80 mm depletion
Application: Refill to 100 % of field capacity
Field eff. 80 %

Table format: Irrigation schedule

Date	Day	Stage	Rain mm	Ks fract.	Eta %	Depl %	Net Irr mm	Deficit mm	Loss mm	Gr. Irr mm	Flow l/s/ha
30 Jul	41	Dev	0.0	0.70	95	72	82.7	0.0	0.0	103.4	0.29
16 Aug	58	Mid	0.0	0.93	100	63	82.2	0.0	0.0	102.8	0.70
31 Aug	73	Mid	0.0	0.95	100	62	80.8	0.0	0.0	101.0	0.78
16 Sep	89	Mid	0.0	0.93	100	62	81.7	0.0	0.0	102.1	0.74
27 Sep	End	End	0.0	1.00	0	35					

Totals:

Total gross irrigation	409.2	mm	Total rainfall	129.9	mm
Total net irrigation	327.4	mm	Effective rainfall	117.6	mm
Total irrigation losses	0.0	mm	Total rain loss	12.4	mm
Actual water use by crop	490.6	mm	Moist deficit at harvest	45.7	mm
Potential water use by crop	499.8	mm	Actual irrigation requirement	382.3	mm
Efficiency irrigation schedule	100.0	%	Efficiency rain	90.5	%
Deficiency irrigation schedule	1.8	%			

Yield reductions:

Stagelabel	A	B	C	D	Season	
Reductions in ETc	0.0	5.5	0.5	0.0	1.8	%
Yield response factor	0.40	0.40	1.30	0.50	1.25	
Yield reduction	0.0	2.2	0.6	0.0	2.3	%
Cumulative yield reduction	0.0	2.2	2.8	2.8		%

Fig.1. irrigation scheduling during growth period

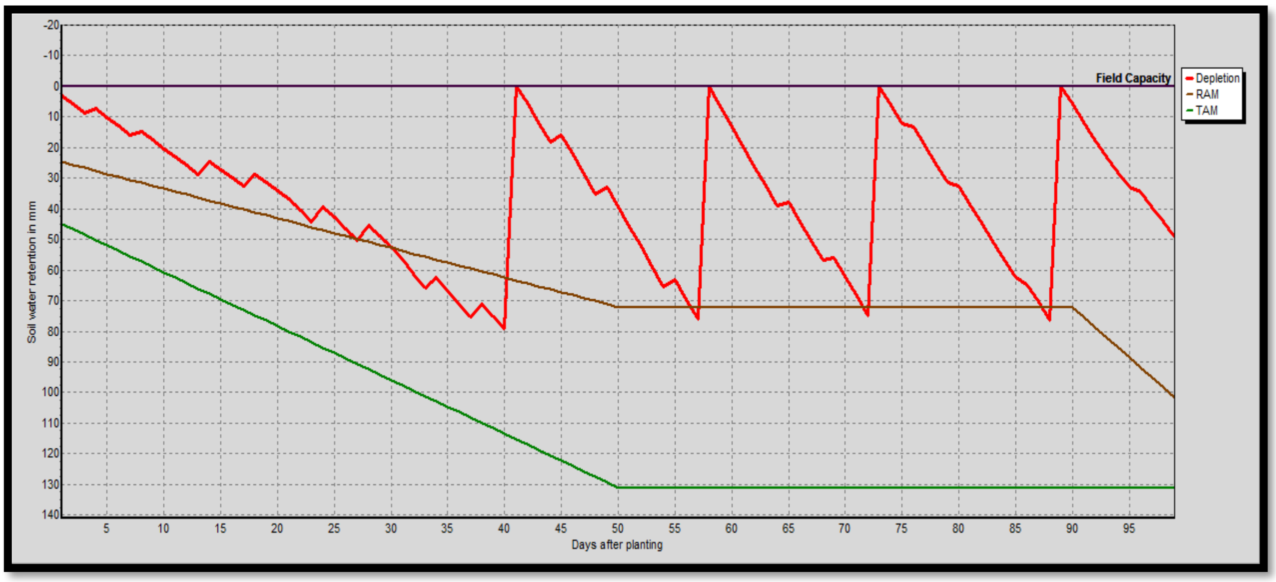


Fig.2 Max and Min Temperature, Evapotranspiration and rain throughout the year.

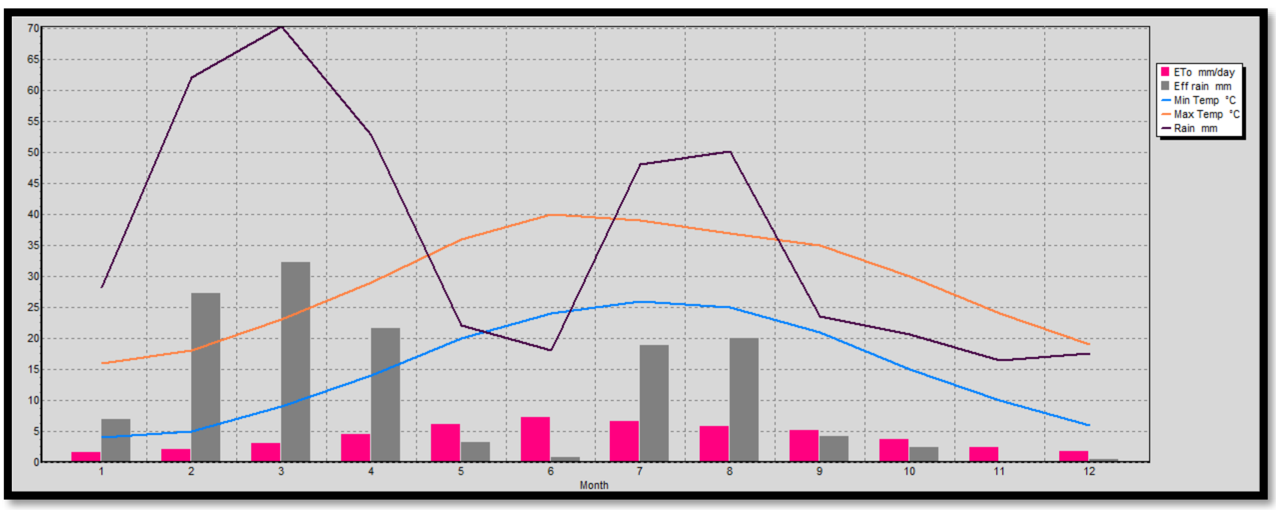
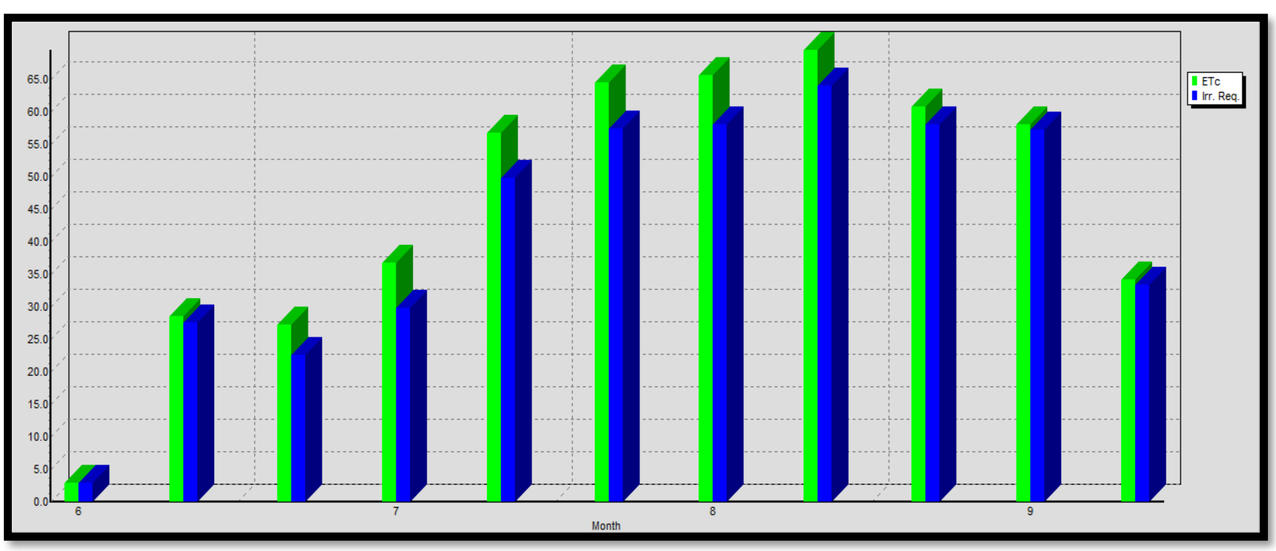


Fig. 3 irrigation requirement during growth period.



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