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Water use Efficiency under Variable Irrigation Methods for Maize Crop using CROPWAT Model

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Research Article

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ABSTARCT

Water is the most significant requirement for crop cultivation. The need for water use management is growing owing to the limited availability of water resources and the dry and semi-arid climate of the region, the need for water use management is vital for the whole economy including the agricultural sector as this sector requires the largest water proportion. The current study was aimed at calculating the CWR (Crop Water Requirement), IWR (Irrigation Water Requirement) and developing irrigation scheduling using the Cropwat model to quantify the yield reduction for the maize crop during water shortage time. The gross irrigation requirement was calculated based on the different irrigation efficiencies with time in the study area. The study area was located at the Irrigation Research Station (IRS), Shuats, Allahabad, India. The maize crop was grown during the Kharif season (mid-June to October) and different treatments were applied based on the rainfall at different stages of crop growth. The fertilizers and chemicals were not used throughout the work but for specific periods only. Both the furrow and border irrigation were applied to different plots. The results from the study can be used for assisting the farmers and planners in making decisions about adjustments to their cropping systems as per the demand. Awareness about CWR, IWR, and the irrigation scheduling can help the farmers in making the appropriate decisions during the periods of water scarcity, thus preventing yield reduction or crop failures.

Keywords: Cropwat; Yield; Irrigation; Crop

INTRODUCTION

Irrigation is actually the main aspect of agriculture for above five thousand years and has been the cornerstone of the economic climate as well as the culture of several communities, changing through most of Asia to Arizona. Irrigation is the imitation application of water towards the land or soil. It is normally used to help in growing agricultural crops, preservation for landscaping as well as re-vegetation for disturbed soil in the dry areas particularly in substandard rainfall. Additionally, irrigation includes a couple of various uses in crop production, that consist of protection alongside frost, curbing weed growth in grain fields as well as avoiding soil consolidations. Agriculture utilizes about 70% of water extract worldwide.

The main purpose of an irrigation system is to maximize crop production to improve economic growth and alleviate hunger and poverty in the country. Therefore, water needs to be distributed efficiently, for the crops at the right time with an effective quantity. Efficient water allocation for crops can result in saving water, increasing the cultivated land area to some more extent, or else in using that amount of saved water for other economic and social purposes such as domestic and industrial use. In order to optimize water use and crop productivity, one has to improve the water resource allocation optimally in a water limiting condition region (arid and semi-arid), improve irrigation scheduling, and establish crop water needs, which are influenced by the rate of water used with the crops, Evapotranspiration (ET) and other losses such as soil retention characteristic.

Cropwat is a decision support system, originated by the "Land and Water Development Division" of FAO. In order to estimate "reference evapotranspiration", "Crop Water Requirement" (CWR) and to support the "Irrigation Water Requirement" (IWR). The algorithm for the estimation CWR and IWR in the model is based on the calculation of the reference Evapotranspiration (ETo) which is counting as per Penman-Monteith and other crops parameters. To develop irrigation scheduling under different management systems and scheme supply, to evaluate irrigation application efficiency, rain-fed production, and effect of drought, cropwat would be the appropriate tool for developing these all. Climatic and crop data are essential as inputs for cropwat. In addition, the climwat- database is obtained for 144 countries for climate data. The development of irrigation scheduling, rain-fed agriculture evaluation, and overall irrigation practices are grounded on a daily soil water balance approach using various alternatives in terms of supply and irrigation management systems.

Selecting a proper method for irrigation and the use of accurate crop water requirements is intrinsic for better crop production and water conservation, particularly in a country like India that is principally an agriculture-based nation. Certainly, there is a need for following appropriate irrigation scheduling which includes 'when to irrigate', 'how to irrigate' and 'how much irrigate'. Irrigation scheduling is essential toward capitalizing on the production and minimizing the various losses e.g., runoff as well as deep percolation ultimately increasing the overall irrigation efficiency. The present research focuses on assessing the crop water requirements, best irrigation method and level for maize that is certainly significant grain crop not only India but Worldwide. The crop is hypersensitive to water stress and needs better drainage facilities while in the beginning period of growth. Both the soil matric potential status may be used for monitoring the irrigation frequency. Indian farmers adopt various methods of irrigation like free flooding, check-basin, furrow, etc., for irrigating.

Maize (*Zea mays* L.) is one of the extremely significant cereal crops utilized on the human diet in huge components of the world and it is actually an essential feed ingredient for animals. In terms of overall globe production, maize on normal in excess of the previous five years out rated paddy rice (*Oryza sativa*) as well as wheat (*Triticum aestivum*)[1]. Worldwide production surpasses 600 metric tonnes with concerning 60% produced from the developed nations, specifically through the United States of America, China generates 27% from the world's maize along with the majority is certainly produced throughout nations of Africa, Latin America, and southern Asia with a huge percentage becoming generated from the tropics and subtropics. Maize provides a higher health benefit because it comprises 72% starch, 10% protein, 4.8% oil, 8.5% fiber, 3.0% sugar together with 1.7% ash [2]. In the land of India, maize could be the third among all significant food crop following rice and wheat. In accordance to enhance estimation, it is actually grown in 8.7 m ha (2010-2011) primarily while in Kharif season that masks 80% area. In India maize contributes nearly 9% in the nationwide food container and much more compared to to the agriculture GDP of 100 billion at present costs apart through the producing occupation. The downstream agricultural and industrial sectors are working intensely to provide food for human being and quality feed for animals whereas maize serves as a basic raw material to thousands of industrial product that produces starch, oil, protein, alcoholic beverages, food sweeteners, pharmaceutic, aesthetic, film, fabric, gum, plan as well as paper companies, etc.

Study area

The study experimental field is located at Irrigation Research Station (IRS), SHIATS, Allahabad, situated in the southern part of Uttar Pradesh, India, at 25.4137° N and 81.8491° E, at the bank of Yamuna River. The mean sea level is 98.00 meter. Allahabad has a monsoon semitropical weather. Often the annual mean maximum temperatures is 42.90°C, the mean lowest temperature, is 9.30°C. Allahabad experiences three seasons: Hot dried summer, cool dried cold weather as well as a comfortable moist monsoon. Summer endures through April to June; while in dried periods, the maximum temperature usually emulates 40°C in May as well as June. The highest recorded temperature is 48°C. Monsoon begins in earlier July and endures until September. The maximum monthly rainfall is entirely, 296 mm, occurs in August. The city receives 2961 hours of sunlight per year, with maximum sunlight exposure occurring in May. The average comparative humidity is 56% with July, August and September being the highest at 77%, 81%, and 78% respectively. The wind speed maximum is 5.16 km/hr. The experiment should be executed in 20 plots of 36 m^2 each. The total experimental area is about 720 m^2. Maize seed was sowing on 3rd August 2014, in the nursery at a depth of 0.05 m with a spacing of 25 cm between the rows. The crop was harvested from 18th November to 2014 based upon the maturity of maize the harvesting was done manually (Figures 1 and 2).

Figure 1. Field experiment location.

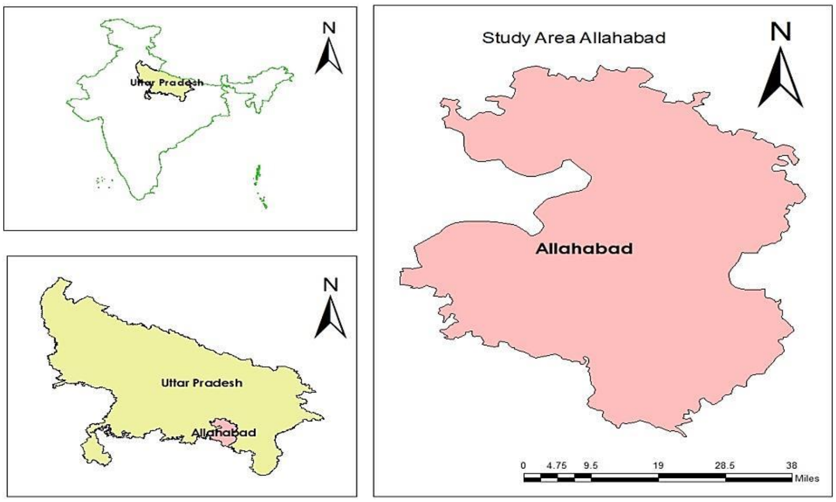
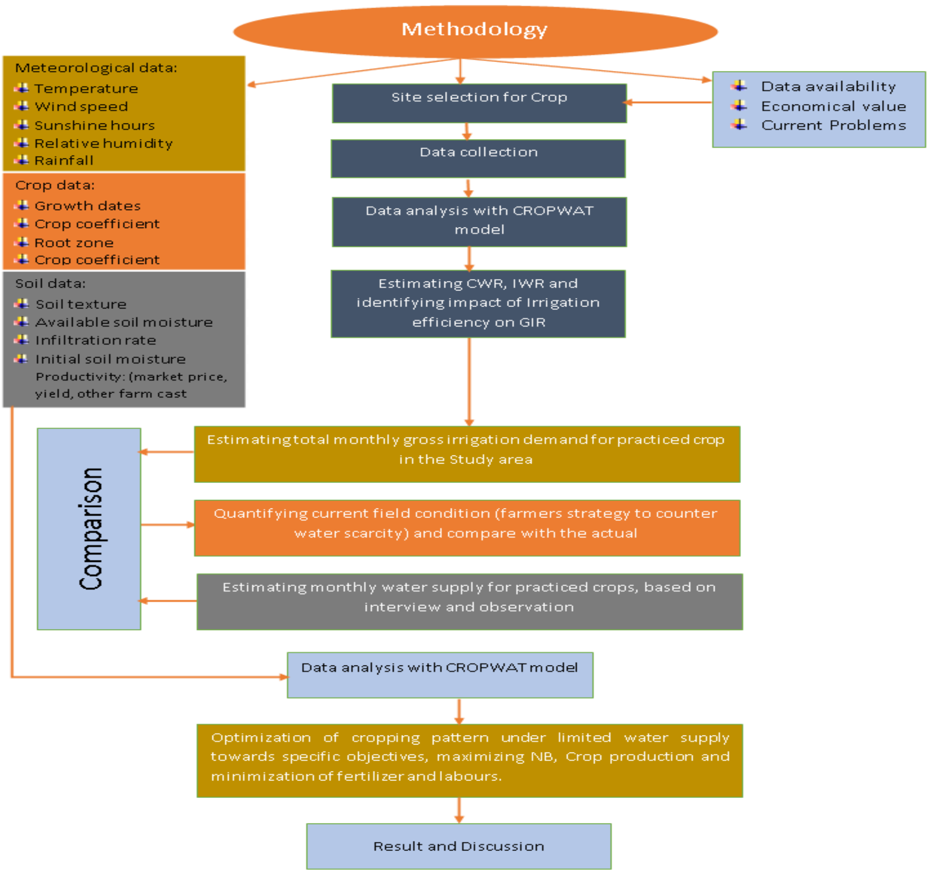


Figure 2. Methodology and comparison of CROPWAT model.



MATERIALS AND METHODS

Cropwat is a decision support system, originated by the “Land and Water Development Division” of FAO used to estimate “reference evapotranspiration”, “Crop Water Requirement” (CWR) and to support the “Irrigation Water Requirement” (IWR). The algorithm for the estimation CWR and IWR in the model is based on the calculation of the reference Evapotranspiration (ETo) which is counted as per Penman-Monteith and other crops parameters. Cropwat would be the appropriate tool for developing irrigation scheduling under different management systems and scheme supply, to evaluate irrigation application efficiency, rain-fed production, and effect of drought. Climatic and crop data are essential as inputs for cropwat. In addition, the climwat- database is obtained for 144 countries for climate data. The development of irrigation scheduling, rain-fed agriculture evaluation, and overall irrigation practices are grounded on a daily soil water balance approach using various alternatives in terms of supply and irrigation management system.

Crop water requirement

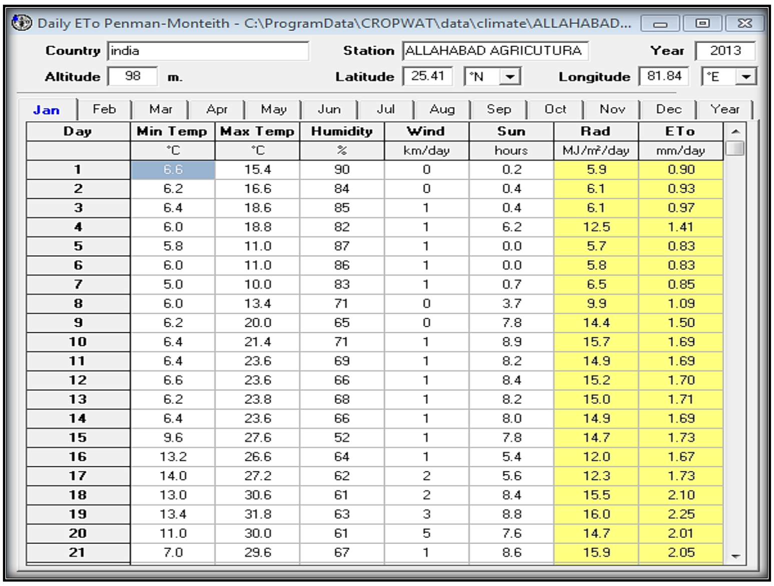
The crop needs a certain quantity of water to grow. The volume of water necessary for a crop to grow is labeled the Crop Water Requirement (CWR, mm). Each type of crop has a certain level of CWR varied spatially and temporally. Two factors influence the worth of the CWR of a certain crop, the crop coefficient (Kc) and the reference crop evapotranspiration (ET_0, mm). These factors are influenced by climate variations, such as temperature, sunshine, wind speed, and humidity. The CWR is calculated by ETo multiplied by the Kc. The CWR is equal to the actual crop evapotranspiration (ETc, mm), assuming there are no water limitations to crop growth so that the crop water requirements tend to be fully met (FAO, 2013).

$$ET_C = K_C \times ET_0 \left[mm\right]$$

$$CWR = ET_C$$

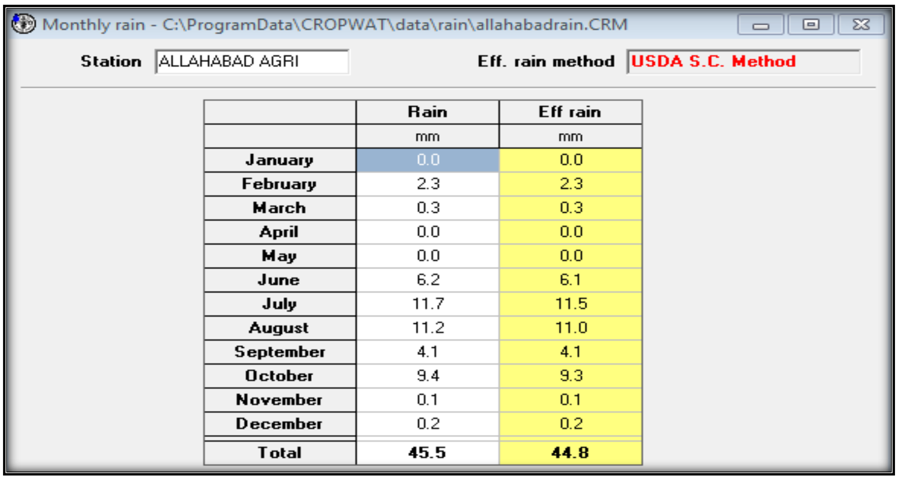
ETo is identified as the evapotranspiration rate from a reference surface, without shortage of water. The reference crop is a hypothetical grass reference crop with specific characteristics. This means that only climatic parameters will influence reference crop evapotranspiration and it does not consider a difference in crop characteristics and soil factors. Kc is a value that distinguishes field crops from the reference crop of grass used for ET0. Variations of the Kc occur because of the difference in crop characteristics over the length of a growing period. The variations of Kc are mainly determined by crop variety, climate, and crop growth stages. The growing period of a crop is split up into four growth stages: the initial stage, the development stage, the mid-season stage and the late-season stage [3]. Three values of the Kc are implemented: One at the initial stage (Kc, ini), one at the mid-season stage (Kc, mid), and one at the end of the late-season stage (Kc, end) (Figures 3-8).

Figure 3. Calculated ET_0 by CROPWAT.



Day	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	km/day	hours	MJ/m²/day	mm/day
1	6.6	15.4	90	0	0.2	5.9	0.90
2	6.2	16.6	84	0	0.4	6.1	0.93
3	6.4	18.6	85	1	0.4	6.1	0.97
4	6.0	18.8	82	1	6.2	12.5	1.41
5	5.8	11.0	87	1	0.0	5.7	0.83
6	6.0	11.0	86	1	0.0	5.8	0.83
7	5.0	10.0	83	1	0.7	6.5	0.85
8	6.0	13.4	71	0	3.7	9.9	1.09
9	6.2	20.0	65	0	7.8	14.4	1.50
10	6.4	21.4	71	1	8.9	15.7	1.69
11	6.4	23.6	69	1	8.2	14.9	1.69
12	6.6	23.6	66	1	8.4	15.2	1.70
13	6.2	23.8	68	1	8.2	15.0	1.71
14	6.4	23.6	66	1	8.0	14.9	1.69
15	9.6	27.6	52	1	7.8	14.7	1.73
16	13.2	26.6	64	1	5.4	12.0	1.67
17	14.0	27.2	62	2	5.6	12.3	1.73
18	13.0	30.6	61	2	8.4	15.5	2.10
19	13.4	31.8	63	3	8.8	16.0	2.25
20	11.0	30.0	61	5	7.6	14.7	2.01
21	7.0	29.6	67	1	8.6	15.9	2.05

Figure 4. Calculated effective rainfall by CROPWAT.


Monthly rain - C:\ProgramData\CROPWAT\data\rain\allahabadrain.CRM

Station ALLAHABAD AGRI Eff. rain method USDA S.C. Method

	Rain	Eff rain
	mm	mm
January	0.0	0.0
February	2.3	2.3
March	0.3	0.3
April	0.0	0.0
May	0.0	0.0
June	6.2	6.1
July	11.7	11.5
August	11.2	11.0
September	4.1	4.1
October	9.4	9.3
November	0.1	0.1
December	0.2	0.2
Total	45.5	44.8

Figure 5. Calculated crop by CROPWAT.

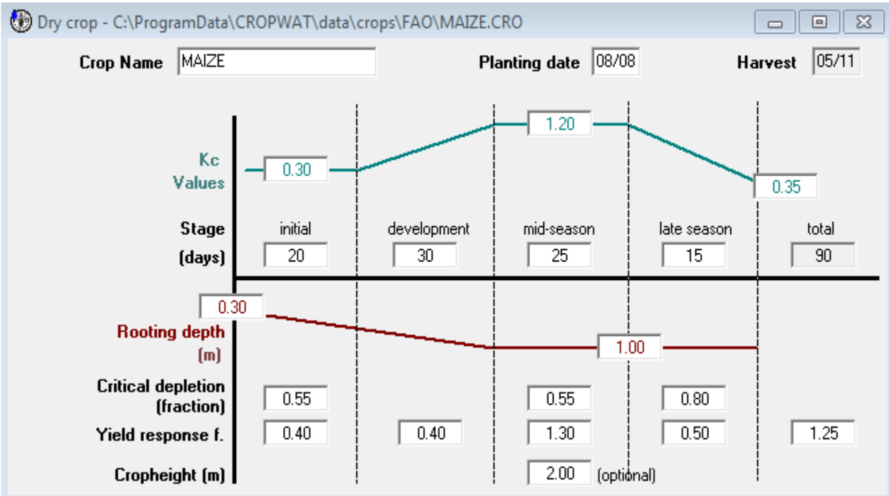


Figure 6. Calculated soil data by CROPWAT.

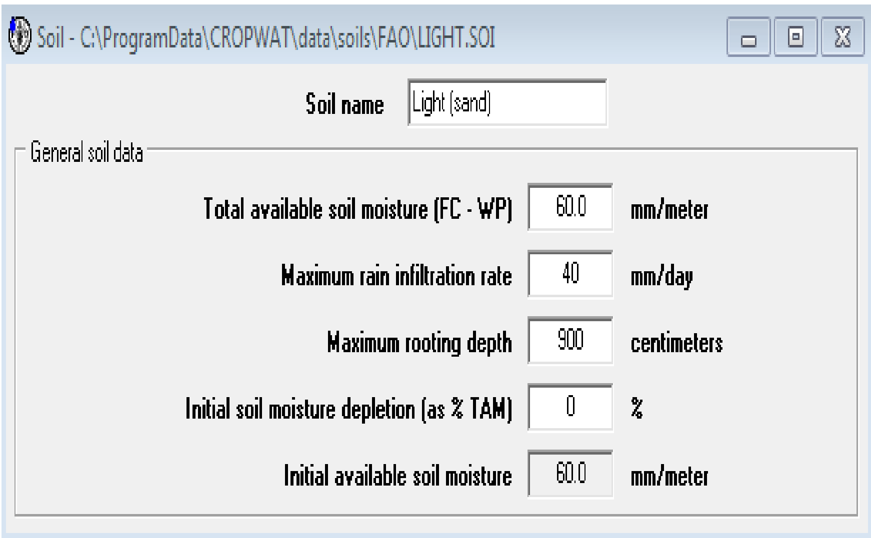


Figure 7. Calculated soil CWR by CROPWAT.

Crop Water Requirements

ETo station: ALLAHABAD AGRICUT | Crop: MAIZE
Rain station: ALLAHABAD AGRI | Planting date: 08/08

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Aug	1	Init	0.30	1.09	3.3	1.2	3.3
Aug	2	Init	0.30	1.28	12.8	3.9	8.9
Aug	3	Deve	0.32	1.13	12.4	3.1	9.3
Sep	1	Deve	0.53	1.94	19.4	1.8	17.6
Sep	2	Deve	0.78	2.93	29.3	0.8	28.5
Sep	3	Mid	0.99	3.74	37.4	1.6	35.9
Oct	1	Mid	1.03	2.46	24.6	2.9	21.7
Oct	2	Mid	1.03	2.54	25.4	3.7	21.6
Oct	3	Late	0.80	2.35	25.9	2.5	23.4
Nov	1	Late	0.44	1.25	6.2	0.1	6.1
					196.7	21.6	176.3

Figure 8. Calculated irrigation schedule by CROPWAT.

Crop irrigation schedule

ETo station: ALLAHABAD AGRICUT | Crop: MAIZE | Planting date: 08/08 | Yield red.: 0.0 %
Rain station: ALLAHABAD AGRI | Soil: Light (sand) | Harvest date: 05/11

Table format: Irrigation schedule / Daily soil moisture balance
Timing: Irrigate at 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
31 Aug	24	Dev	0.0	1.00	100	56	21.3	0.0	0.0	30.4	0.15
14 Sep	38	Dev	0.0	1.00	100	56	28.2	0.0	0.0	40.2	0.33
25 Sep	49	Dev	0.0	1.00	100	60	35.4	0.0	0.0	50.6	0.53
8 Oct	62	Mid	0.0	1.00	100	55	33.2	0.0	0.0	47.5	0.42
22 Oct	76	End	0.0	1.00	100	57	34.1	0.0	0.0	48.7	0.40
5 Nov	End	End	0.0	1.00	0	40					

Totals

Total gross irrigation	217.4	mm	Total rainfall	20.8	mm
Total net irrigation	152.2	mm	Effective rainfall	19.5	mm
Total irrigation losses	0.0	mm	Total rain loss	1.3	mm
Actual water use by crop	195.8	mm	Moist deficit at harvest	24.1	mm
Potential water use by crop	195.8	mm	Actual irrigation requirement	176.3	mm
Efficiency irrigation schedule	100.0	%	Efficiency rain	93.9	%
Deficiency irrigation schedule	0.0	%			

Treatment

The experiment consists of different irrigation. The details of the treatments are presented below.

Applied amount of water

T_1-50%

T_2-75%

T_3-100%

T_4-125%

T_5-150%

Economic analysis

In order to assess the economic viability of the surface irrigation system under variable irrigation, both fixed and operating cost is included. The total cost of production, gross return, the net return, and benefit-cost ratio under variable irrigation is estimated as per the following formulas.

The fixed cost including water development, irrigation equipment's, spraying and weeding types of equipment will be calculated as follows:

$$Capital\ Recovery\ Factor = i\ (1+i)^n\ /\ (1+i)^{n-1}$$

Where,

i=interest rate (fraction)

n=useful life of the components (years)

Annual fixed cost/ha=CRF× fixed cost/ha

Annual fixed cost/ha/season=(annual fixed cost/ha)/2

Total cost of production=fixed cost+operating cost

Gross return (Rs/ha)=Marketable yield (t/ha) X wholesale price of maize (Rs/t)

Net return (Rs/ha)=Gross return (Rs/ha)-Total cost of production (Rs/ha)

Benefit-cost ratio=Gross return (Rs/ha)/total cost of production (Rs/ha)

RESULTS AND DISCUSSION

The effect of irrigation application rate and irrigation levels on marketable yield of maize. The marketable yield of maize ranges from 4.07 to 9.84 t/ha. The marketable yield of maize increased significantly with irrigation application up to T_4 (125%) produced significant maximum marketable yield (9.84 and 8.86 t/ha) [4-7].

A further levels in irrigation application decreases T_1 (50%), T_2 (75%) and increase in irrigation application–level resulting from T_3 (100%), T_4 (125%) and T_5 (150%) of Furrow and Border irrigation application rate which further reduced the marketable yield (4.53 and 4.08 t/ha), (5.74 and 5.17 t/ha), (7.38 and 6.64 t/ha), (9.84 and 8.86 t/ha) and (8.16 and 7.34 t/ha) respectively and is significant due to reduction of fruits/plant and mean fruit weight induced by excessive soil moisture condition.

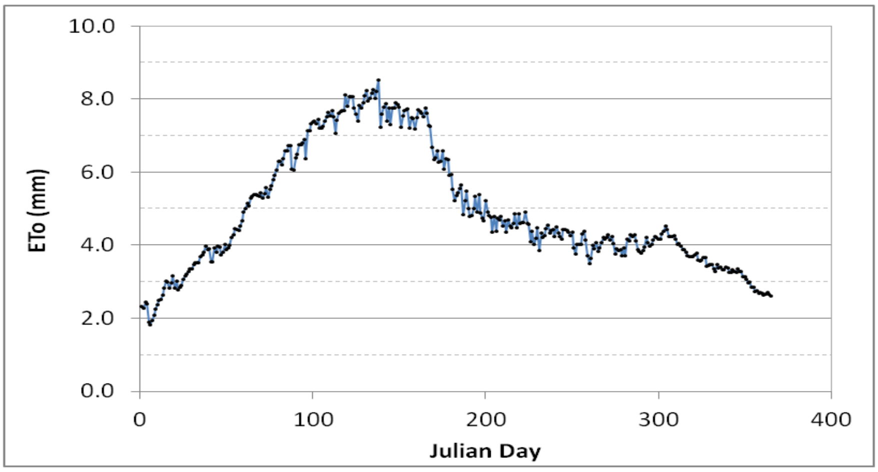
The total cost of production was considerably higher as compared with the irrigation application rate mainly due to variation in irrigation system cost. The gross return under different Furrow and Border irrigation application rates ranges from (90600 and 81540 to 196800.00 and 177120) Rs/ha respectively. The increase in gross return obtained when Furrow and Border irrigation was applied during crop growing season at treatment T_4 (8140 and m^3/ha) leading to considerably higher marketable yield. A further decrease T_1 (2956 m^3/ha), T_2 (4684 m^3/ha) and increase in Furrow and Border irrigation application-level resulting from T_3 (6412 m^3/ha), T_4 (8140 m^3/ha), T_5 (9868 m^3/ha) of Furrow and Border irrigation application rate decreased the gross return considerably due to reduction in marketable yield of Furrow and Border irrigation methods. The maximum net return for Furrow and Border irrigation application T_4 (8140 m^3/ha) methods were obtained during crop growing season was applied at T_3 (6412 m^3/ha) of Furrow and Border irrigation application. The increase in gross return obtained when Furrow and Border irrigation during crop growing season was applied at T_4 (8140 m^3/ha) leading to considerably higher marketable yield. A further decrease and increase in Furrow and Border irrigation applications resulting from 50%, 75% and 100%, 125%, 150% of irrigation application, decreased the gross return considerably due to a reduction in marketable yield. The Furrow and Border irrigation application resulted in almost the same gross return, but considerably low gross return due to lower marketable yield induced by poor water distribution. The net return increased considerably with a field capacity. The benefit-cost ratio for Furrow and Border irrigation applications ranges from (1.36 and 1.42 to 2.36 and 2.78) respectively. The benefit-cost ratio increased with T_4 (8140 m^3/ha) due to the significant increase in gross return [7]. A further decrease in T_1 (2956 m^3/ha), T_2 (4684 m^3/ha) and increase in Furrow and Border irrigation application-level resulting from T_3 (6412 m^3/ha), T_4 (8140 m^3/ha), T_5

(9868 m^3/ha) of reduced total cost of production. The overall result revealed that irrigation application at T_4 (8140 m^3/ha) resulted in higher gross return, net return and benefit-cost ratio. The results further revealed that Furrow and Border irrigation application rates resulted in a higher benefit-cost ratio [8-11].

Reference Evapotranspiration (ETo)

Reference ET in the present study was estimated using long term (2010-2014) weather data from SHIATS's agro meteorological station (Figure 9). The daily ETo during the growing season of Maize (Aug 1st to Nov 30th) varied between 3.3-4.9 mm with an average daily value of 4.1 mm and 0.3 mm of standard deviation [12].

Figure 9. Daily reference ET using long term (2010-2014) weather data.



The monthly total ETo during the growing period is provided in Table 1. ETo for the month of August was found to be highest (137.2 mm) as compared to the other months. This can be attributed to higher incoming solar radiation, hence higher air temperature than the rest of the months as the winter approached (Table 1).

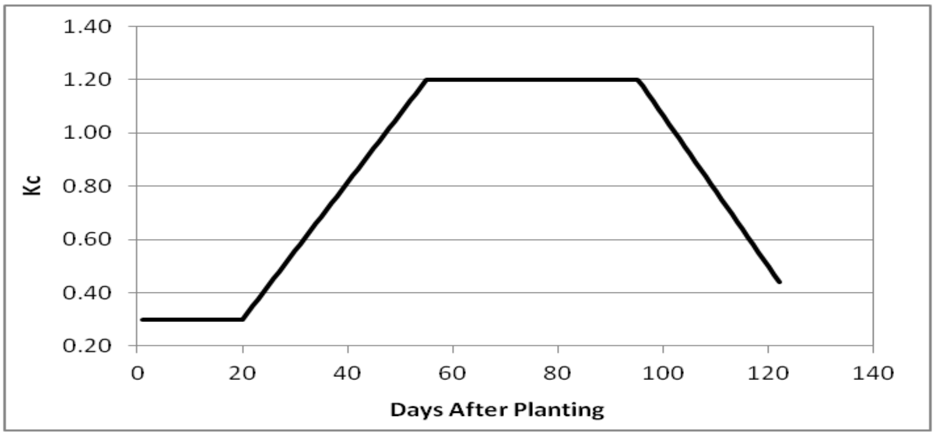
Table 1. Monthly ETo during the growing months of Maize.

Month	No. of days	ETo (mm)
August	31	137.2
September	30	122.8
October	31	126
November	30	112.4

Crop coefficient

The daily crop coefficients for maize were estimated using the FAO-56 guidelines and are presented in Figure 10. The daily crop coefficients for maize varied between 0.3-1.2 during the growing season (Aug 1st-Nov 30th) with an average of 0.8 and a standard deviation of 0.4.

Figure 10. Daily crop coefficients for Maize.



Monthly average of crop coefficients for maize during the growing period are provided in Table 2. The mean crop coefficient for maize was found to be maximum (1.1) in the month of February while minimum (0.5) being in November (Table 2).

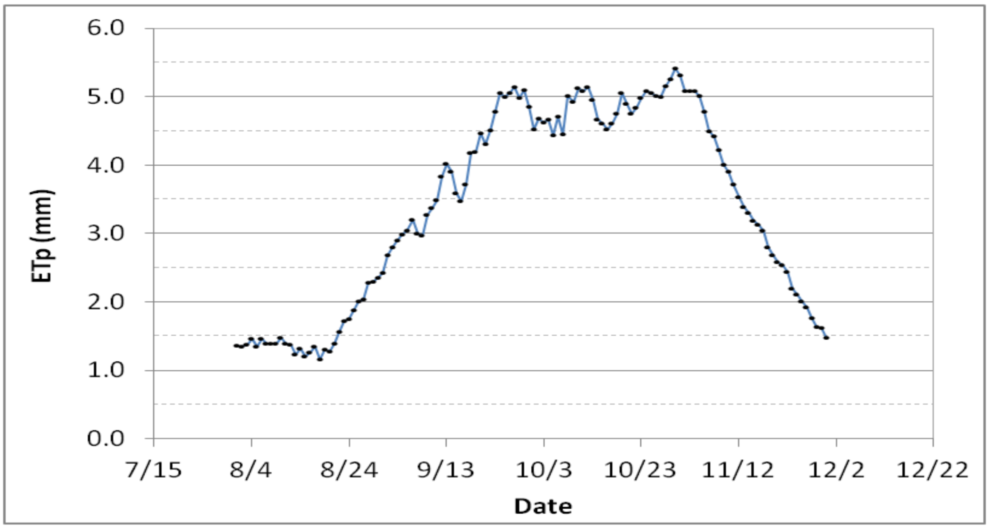
Table 2. Mean monthly crop coefficient for Maize.

Month	No. of days	Avg. Kc
August	31	0.35
September	30	0.96
October	31	1.2
November	30	0.85

Potential crop ET (ETp)

The daily potential ET of maize during the growing season (Aug 1st-Nov 30th) is presented in Figure 11. The potential ET for Maize varied from 1.2-5.4 mm with average being 3.4 mm and 1.4 mm of standard deviation [13].

Figure 11. Daily potential ET for Maize.



The monthly total potential ET of maize was found to be maximum (151.3) in the month of October which can be attributed to higher crop coefficients due to the maximum vegetative growth of the crop during that month (Table 3). The total potential ET for Maize for the entire growing season from Aug 1st-Nov 30th (122 days) was found to be 414.7 mm (Tables 3 and 4) (Figure 12).

Table 3. Monthly potential ET for Maize.

Month	No. of days	ETp (mm)
August	31	48.5
September	30	117.8
October	31	151.3
November	30	97.1

Figure 12. Maize yields under varying irrigation methods and levels. **Note:** ( ) Furrow; ( ) Border.

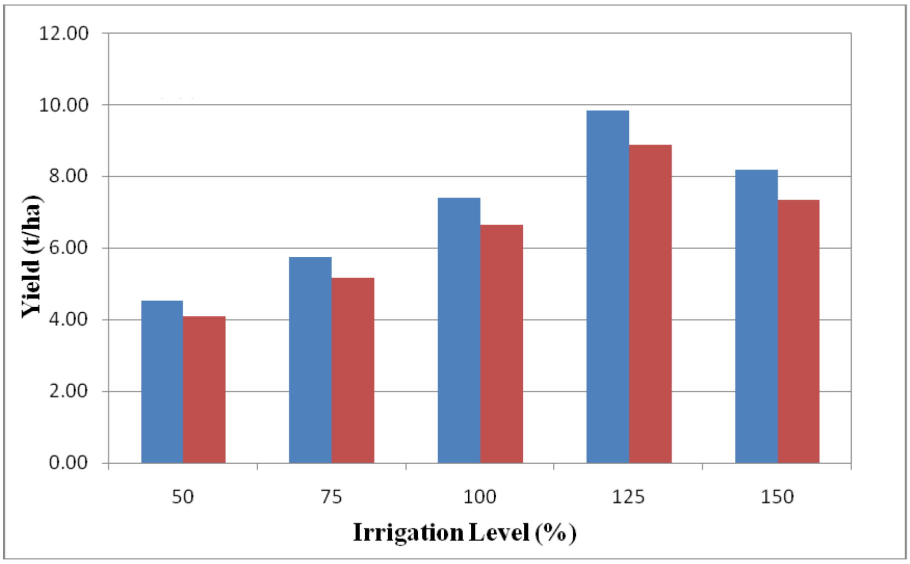


Table 4. Total yields of maize varying under irrigation levels.

Treatment (%)	Yield of (t/ha)	Treatment (%)	Yield of (t/ha)
T_1 50 F	4.53	T_1 50 B	4.08
T_2 75 F	5.74	T_2 75 B	5.17
T_3 100 F	7.38	T_3 100 B	6.64
T_4 125 F	9.84	T_4 125 B	8.86
T_5 150 F	8.16	T_5 150 B	7.34
Note: F-furrow and B-border.			

CONCLUSION

Maize crop was grown at the Irrigation Research Centre of SHIATS using border and furrow irrigation methods with five irrigation levels (50%, 75%, 100%, 125%, and 150%). Seasonal crop water requirement and irrigation requirements were computed using the cropwat model following the FAO guidelines. The best irrigation method from border and furrow, as well as irrigation level, was assessed for maize based on its yield and water use efficiencies. The conclusion was drawn from this study is reference ET (ETo) was found to be between 3.3 and 4.9 mm/day with an average of 4.1 mm during the growing season (August-November) showing the decrease in atmospheric demand due to approaching winter. Potential ET for Maize was highest in (151.3) during the mid-season showing the high crop water demand during this period. The overall maximum yield (9.84 t/ha) was obtained when the plots were irrigated using furrow irrigation with an irrigation level of 125%. The overall maximum water use efficiency (1.5 kg/m^3) was obtained at an irrigation level of 50% using the furrow irrigation method. In context to the present study, furrow irrigation was found to be a better option for irrigating maize than border irrigation method as both yield and water use efficiency was higher for the furrow irrigation with respect to irrigation level, when water is not a limiting factor (both cost and quantity-wise). Maize can be irrigated at 125% of the total crop water requirement for better yield. However, if water indeed is a limiting factor than maize can be provided only 50% of the total crop water requirement to achieve a better crop productivity per unit volume of water used.

REFERENCES

1. McDonald AH, et al. Nematode parasites of cereals. In Plant Parasitic Nematodes in Subtropical and Tropical Agriculture. (2nd edn). 2005.
2. Chaudhary SK. Environmental factors: Extensive use of copper utensils and vegetarian diet in the causation of Indian childhood cirrhosis. Indian Pediatr. 1983;20:-529-531.
3. Allen RG, et al. Crop evapotranspiration–Guidelines for computing crop water requirements. FAO Irrigation and drainage paper 56, Rome. 1998.
4. Beutler AM, et al. Implementation of FAO-56 penman-monteith evapotranspiration in a large scale irrigation scheduling program. ASCE Library. 2005;22:9-12.
5. Deng XP, et al. Improving agricultural water use efficiency in arid and semiarid areas of China. Agric Water Manag. 2006;80:23-40.
6. Dong B, et al. Growth, grain yield, and water use efficiency of rain-fed spring hybrid millet (*Setaria italica*) in plastic-mulched and unmulched fields. Agric Water Manag. 2014;143:93-101.
7. Doorenbos J, et al. Yield response to water. In: Land and Water Development Division, FAO, Rome. 1986.
8. Doorenbos J, et al. Guidelines for predicting crop water requirements. In: FAO Irrigation and Drainage Paper. 1977.
9. Hu H, et al. Coupling effects of urea types and subsoiling on nitrogen-water use and yield of different varieties of maize in northern China. Field Crops Res. 2013;142:85-94.
10. Hvistendahl M. China’s push to add by subtracting fertilizer. Science. 2010;327:801.
11. Jia Y, et al. Soil water and alfalfa yields as affected by alternating ridges and furrows in rainfall harvest in a semiarid environment. Field Crops Res. 2006;97:167-175.
12. Li R, et al. Effects on soil temperature, moisture, and maize yield of cultivation with ridge and furrow mulching in the rainfed area of the Loess Plateau, China. Agric Water Manag. 2013;116:101-109.
13. Li YS, et al. Influence of continuous plastic film mulching on yield, water use efficiency and soil properties of rice fields under non-flooding condition. Soil Tillage Res. 2007;93:370-378.