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# Estimation of water requirement in maize using CROPWAT model

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**Abstract**
CROPWAT V 4.2 (Crop requirement model) developed by Derek Clarke *et al*. (1998) was used to estimate water requirement and yield reduction due to water stress in maize, as it is one of the simple scientific knowledge based tool. A field experiment was laid out in a randomized block design with 7 treatments *viz*., drip irrigation at 50, 75 and 100 per cent of pan evaporation throughout the crop period and with permutation and combinations of the above up to tasseling and during subsequent crop period, *rabi* 2006-07, at Student Farm, College of Agriculture, Rajendranagar, Hyderabad.
Crop coefficient curve was constructed and Irrigation Water Requirement (IWR) was estimated. Close scatter of simulated yields, irrigation water requirement and respective measured values around the regression line and 1:1 line explained 95 per cent variation in yield and 98 per cent variation in irrigation water requirement (IWR) by CROPWAT. The estimated RMSE (Root Mean Square Error) for yield was 400 kg ha $^{-1}$.

**Keywords:** CROPWAT, irrigation water requirement, maize

## Introduction

Models that simulate the effect of water stress on yield can be valuable tools in irrigation management. However, testing of a model is necessary for its use in a new area while planning water requirement of a crop.

Farmers commonly raise irrigated maize under surface method of irrigation (furrow) wherein conveyance, distribution, application, evaporation and percolation losses are common besides adverse effects of cyclic over irrigation (or) under irrigation on yield (Rao and Savani., 1999) [10]. Drip irrigation is the most effective way to supply water to the plant, avoiding above losses and improving the yield in consequence to continuous maintenance of soil moisture near field capacity, various models have been developed to estimate the water requirements under different irrigation schedules to identify a better irrigation schedule with optimum yield and high water use efficiency.

## Material and Methods

In the present study, CROPWAT (Crop Water Requirement Model) developed by Derek Clarke *et al*. (1998) [6] for Windows version 4.2 was used to estimate water requirement and yield reduction due to stress. It is one of the simple, quantitative and scientific knowledge based tool, which requires less data set unlike the other mechanistic CropSyst, GOSSYM (Baker *et al*., 1983) [5] etc. models.

The Cropwat model indicates the percent of yield reduction due to water stress and thus comes handy in calculating the required agronomic inputs more so irrigation water requirement in achieving target yields. The other advantage of using a calibrated model is, it cuts down requirement of huge contingent of manpower required to carry out field experiments to draw logical conclusions. Moreover, the model has not been evaluated under Hyderabad conditions of Andhra Pradesh.

A field experiment was laid out with 7 treatments *viz*., drip irrigation at 50, 75 and 100 per cent of pan evaporation throughout the crop period and with permutation and combinations of the above up to tasseling and during subsequent crop period also at Students farm, College of Agriculture, Rajendranagar, Hyderabad during *rabi*, 2006-07.

The treatment variables are: Drip irrigation at 50 per cent of pan evaporation ($I_1$), 75 per cent of pan evaporation ($I_2$), 100 per cent of pan evaporation ($I_3$), 50 per cent of pan evaporation up to tasseling thereafter 75 per cent of pan evaporation ($I_4$), 50 per cent of pan evaporation up to tasseling thereafter 100 per cent of pan evaporation ($I_5$), 75 per cent of pan evaporation up to tasseling thereafter 100 per cent of pan evaporation ($I_6$), 50 per cent of pan evaporation up to tasseling followed by 75 per cent of pan evaporation thereafter 100 per cent of pan evaporation ($I_7$).

Moisture content in the soil was measured using TDR apparatus, (Model TRIME – FM with a tube probe IMKO). Actual evapotranspiration or (crop Eta) was also computed. Reference Evapotranspiration ($ET_0$) was estimated by following pan evaporation method (Doorenbos and Kassam, 1979). Crop coefficients for different crop growth sub-periods were estimated and crop curve was constructed (Fig. 1) for calculation of irrigation requirement.

The crop coefficient values were lower during initial stage, gradually increased with the advancement of crop age, attained maximum value at mid season stage and subsequently declined towards the late season stage.

## Statistical Analysis

The data generated through the field experimentation in the *rabi*, 2006 was subjected to statistical analysis of ANOVA. Comparisons were made between the model simulated (Y) data of yield and WR and their corresponding observed (X) data, with regression analysis of the form Y= a + bX. Measures of accuracy were made with the adjusted coefficient of determination ($R^2$).

## Evaluation of model

Different test criteria suggested by Willmott (1982) *viz*., summary measures, different measures and descriptive measures were followed, while evaluating the performance of models

## Results and Discussion

Grain yield registered in drip irrigation scheduled at 100 per cent of pan evaporation ($I_3$) was the highest, where irrigation water applied was equivalent to that lost in evapotranspiration (ETa = ET' m) throughout the crop growing season. The higher yield obtained in this treatment can be attributed to better growth and higher values of yield attributes due to no deficit of soil moisture.

Grain yield in drip irrigation at 75 per cent of pan evaporation up to tasseling thereafter 100 per cent of pan evaporation ($I_6$), was statistically on par with drip irrigation at 100 per cent of pan evaporation ($I_3$ Table 1) indicting that scheduling irrigation at 85 per cent of pan evaporation up to tasseling stage had little adverse effect on subsequent growth and yield as there was no further water stress till the harvest of the crop. This was because of the ability of the crop to recover fully once the water deficit was relieved which was created at the start of tasseling stage only. Thus, the magnitude adverse effect of plant water deficit on final yield depends on stage of the growth at, which the moisture stress occurs (Jama and Ottman, 1993) [7].

Drip irrigation at 50 per cent of pan evaporation ($I_1$) caused a significant reduction in grain yield. This was due to concurrent reduction in growth and yield trials in this treatment.

## Simulation Discussion

### Grain yield

Simulated grain yields were calculated based on the percentage of yield reduction in simulated by CROPWAT. Minimum simulated yield reduction was noticed in the treatment of $I_3$ and hence, its corresponding observed grain yield was considered as base yield, while estimating the simulated grain yield for the rest of the treatments. Simulated grain yield reduction was less in $I_6$ as compared to $I_3$. It was maximum (42.6%) in $I_1$. CROPWAT calculates yield reduction in each crop growth stage according to the crop response factor (Doorenbos and Kassam, 1979), which indicates the percent of yield reduction per percent of ET reduction. Thus, yield reduction was more in $I_1$ as ET was also less due to more water deficit.

Significant correlation (r = 0.97) between measured and simulated yield by CROPWAT was observed (Table 3). Further, the simulated yield by CROPWAT explained 95 per cent of variation in the yield (Fig.2) and 8.7 per cent of observed value RMSE (Root Mean Square Error). The close scatter of simulated and measured values around the regression line indicated good performance of the model in estimating maize. Panda *et al.* (2004) [9] from West Bengal reported goodness fit value of 0.95 between simulated and observed yield of Maize grown in Karagpur using CERES-Maize model. Validation of CERES Maize model was done by Ritchie and Gopal Alagarswamy (2003) [13]. They stated that the revised model simulated the yield reasonably well, with RMSE 0.63 Mg $ha^{-1}$ as compared with the original model estimated of RMSE 1.25 Mg $ha^{-1}$ across a wide range of plant densities.

The error percent in CROPWAT simulated grain yield varied from -13.56 ($I_4$) to -5.76 ($I_6$, Table 2). In all the treatments, under estimation was noticed. The treatment of drip irrigation at 50 percent of pan evaporation up to tasseling followed by 75 percent of pan evaporation thereafter 100 per cent of pan evaporation ($I_7$) followed $I_4$ in expressing an error of -13.0 percent. This shows the poor response of model under sub-optimal conditions in estimating grain yields of maize. CROPWAT does not consider some process, such as the direct effect of water stress on root growth and the changes in biomass portioning between shoots and roots as a consequence of water stress. Besides, if water stress is severe enough, photosynthetic capacity of leaves get effected irreversibly (Boyer and Mc Pherson 1975) [4], leading to lower biomass production than expected. Similar findings were reported by Wilson *et al*, *(*1995) [16]. He stated that modified model (radiation and temperature driven maize simulation model) gave good agreement between observed independent data sets and simulated value of grain yield in maize under tropical, sub-tropical and cool temperate locations. Root mean square deviations of the comparisons averaged across all locations were about 12 percent of the mean value. Similar opinion was expressed by Karthikeyan and Bala Subramanian (2005) [8] after working with CERES-maize simulation model under Tamil Nadu conditions. They stated that CERES-maize model showed good agreement with the observed values.

Similar findings were reported by Baby Akula and Shekh (2005) [2, 3] in case of wheat yields estimation by InfoCrop under Anand conditions of Gujarat during 2000 and 2001. Response of the model was relatively poor when number of irrigations in wheat reduced from six to four. Similar opinion was elicited by Seligal (2000) [14] and Robertson *et al.* (2001) [12], while estimating, respectively wheat and pigeon pea yields.

## Irrigation Water Requirement (IWR)

Mean measured and CROPWAT simulated irrigation water requirement along with standard deviation are 228 ± 40 mm and 216 ± 30 mm (Table 3), respectively.

Significant correlation (r=0.99, Table 3) between measured and simulated irrigation water requirement by CROPWAT was observed. Rathore *et al.* (1998) [11] reported from the result of six year data that the SPAW model could be successfully used for irrigation scheduling in maize by simulating the moisture content of soil profile with a high correlation coefficient of 0.89. Similar is the case with regression coefficient. The regression coefficient explained 98 percent of variation in irrigation water requirement (Fig.3). The RMSE constituted 7.06 percent of observed value.

Despite drip irrigation at 100 percent of pan evaporation ($I_3$), the under estimation of IWR by model was relatively more unlike in case of yield, which can be substantiated in the light of fact that, CROPWAT calculates IWR in two steps, first it calculates reference evapotranspiration ($ET_0$) by using Penman-Monteith methodology. Second, the resulting values are subsequently used in crop water requirement calculations. Although it calculates $ET_0$, derived $Et_0$ values calculated by pan evaporation method were given as input to the model. The model is basically designed to compare surface irrigation water requirement. Hence care was taken by adding wetting factor while calculating irrigation water requirement. These $ET_0$ values were lower than actual evapotranspiration, which in turn resulted in under estimation of IWR. Thus, to state that model did not work out is unjust and needs further study.

The error percent in CROPWAT simulated irrigation water requirement varied (Table 2) from -10.3 ($I_3$) to 0.90($I_1$). In most of the treatments under estimation was noticed similar to yield except in $I_1$, were in error of over estimation was negligible. Leaving this small deviation aside under estimation values ranged from -10.30($I_3$) to -2.42($I_2$). Similar findings were reported by Anadranistakis *et al.* (2000) [1] who stated that error between observed and estimated evapotranspiration was within the 8 percent, from the trials carried out in maize at Agricultural University of Athens using SW model. Baby Akula *et al*. (2005) [2, 3] estimated volumetric ET values by gravimetric methods before and after each irrigation in wheat at Gujarat Agricultural University, Anand and were compared with simulated values by WTGROWS. The pooled RMSC was 2.9 percent of the observed mean ET. The index of agreement was 0.96 during both the years (2000 and 2001) of study.

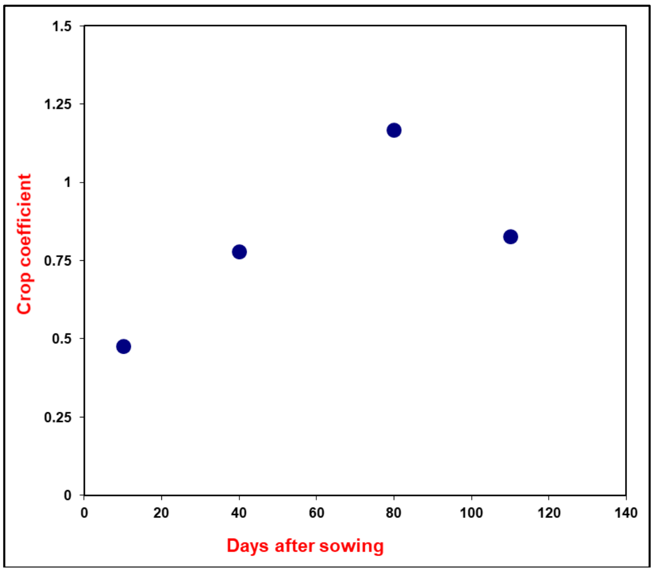


**Fig 1:** Crop coefficients of Maize based on reference evapotranspiration (ETo) estimated by Pan Evaporation Method

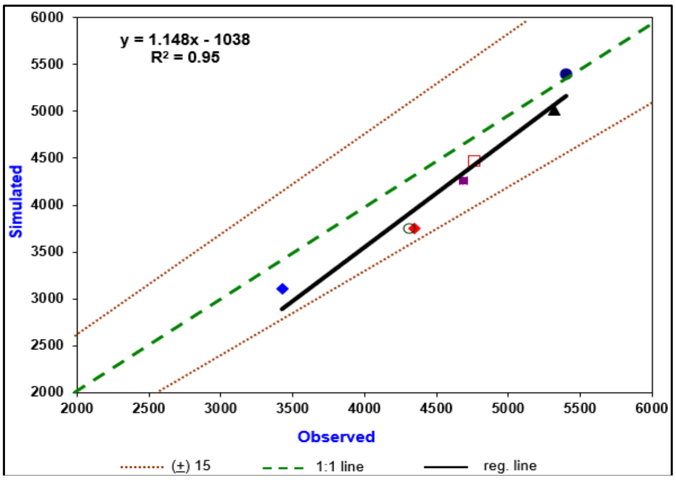


**Fig 2:** Comparison of CROPWAT simulated yield with that observed in Maize, *Rabi* 2006-07

- $I_1$: Irrigation at 50% of pan evaporation
- $I_2$: Irrigation at 75% of pan evaporation
- $I_3$: Irrigation at 100% of pan evaporation
- $I_4$: Irrigation at 50% of pan evaporation Up to tasseling and thereafter 75% of pan evaporation
- $I_5$: Irrigation at 50% of pan evaporation up to tasseling and thereafter 100% of pan evaporation
- $I_6$: Irrigation at 75% of pan evaporation up to tasseling and thereafter 100% of pan evaporation
- $I_7$: Irrigation at 50% of pan evaporation up to tasseling followed by 75% of pan evaporation up to 45 days and thereafter 100% of pan evaporation.

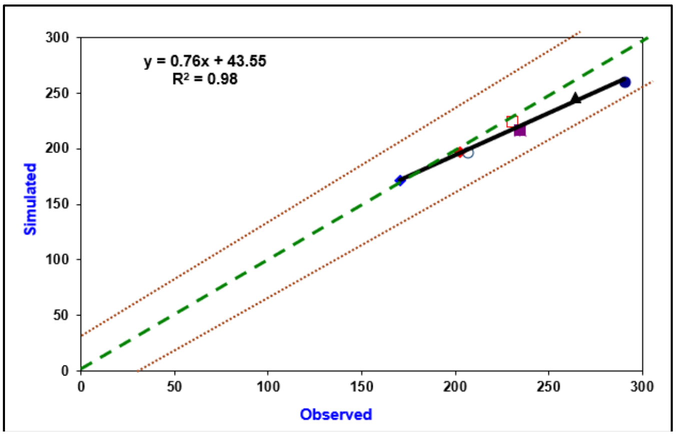


**Fig 3:** Comparison of CROPWAT simulated irrigation water requirement with that measured in Maize *Rabi* 2006-07

- $I_1$: Irrigation at 50% of pan evaporation
- $I_2$: Irrigation at 75% of pan evaporation
- $I_3$: Irrigation at 100% of pan evaporation
- $I_4$: Irrigation at 50% of pan evaporation upto tasseling and thereafter 75% of pan evaporation
- $I_5$: Irrigation at 50% of pan evaporation upto tasseling and thereafter 100% of pan evaporation
- $I_6$: Irrigation at 75% of pan evaporation upto tasseling and thereafter 100% of pan evaporation
- $I_7$: Irrigation at 50% of pan evaporation upto tasseling followed by 75% of pan evaporation upto 45 days and thereafter 100% of pan evaporation.

**Table 1:** Observed and Simulated grain yield of Maize as influenced by drip irrigation treatments

| Treatments | Observed grain yield (kg ha$^{-1}$) | Simulated grain yield (kg ha$^{-1}$) | Measured Irrigation water requirement (mm) | Simulated Irrigation water requirement (mm) |
|---|---|---|---|---|
| $I_1$: Irrigation at 50% of PE* | 3423 (36.6) | 3101 (42.6) | 170.26 | 171.8 |
| $I_2$: Irrigation at 75% of PE | 4760 (11.9) | 4473 (17.2) | 230.39 | 224.8 |
| $I_3$: Irrigation at 100% of PE | 5402* | - | 290.53 | 260.6 |
| $I_4$: Irrigation at 50% of PE of up to tasseling thereafter 75% of PE | 4343 (19.6) | 3754 (30.5) | 202.51 | 197.0 |
| $I_5$: Irrigation at 50% of PE up to tasseling thereafter 100% of PE | 4685 (13.3) | 4262 (21.1) | 234.76 | 216.6 |
| $I_6$ : Irrigation at 75% of PE up to tasseling thereafter 100% of PE | 5325 (1.4) | 5018 (7.1) | 264.12 | 245.7 |
| $I_7$: Irrigation at 50% of PE up to tasseling followed by 75% of PE up to 45 days and thereafter 100% of PE | 4315 (20.1) | 3754 (30.5) | 206.80 | 197.0 |
| S.Em± | 52.6 | | | |
| C.D 5% | 164.0 | | | |

PE -Pan Evaporation, *Base yield

Note: The values in the parenthesis indicate respective yield reduction in percentage

**Table 2:** Error per cent by CROPWAT simulated grain yield and Irrigation Wate Requirement (IWR) from observed in Maize *rabi* 2006-07

| Treatment | Error per cent* of yield | Error per cent of IWR |
|---|---|---|
| $I_1$ | -9.40 | 0.90 |
| $I_2$ | -6.02 | -2.42 |
| $I_3$ | - | -10.30 |
| $I_4$ | -13.56 | -2.72 |
| $I_5$ | -9.02 | -7.73 |
| $I_6$ | -5.76 | -6.97 |
| $I_7$ | -13.00 | -4.73 |

*Error per cent [(Simulated –Observed)/ Observed)] × 100

**Table 3:** Test criteria in evaluation of CROPWAT with respect to yield (kg ha$^{-1}$) and Irrigation Water Requirement (IWR, mm)

| Parameter | Grain yield (kg ha$^{-1}$) | Irrigation Water Requirement (mm) |
|---|---|---|
| OIWR | 4608 | 228 |
| SDo | 675 | 40 |
| SIWR | 4252 | 216 |
| SDs | 794 | 31 |
| R | 0.97** | 0.99** |
| $R^2$ | 95 | 98 |
| MAE | 356 | 12.7 |
| MBE | -356 | -12.2 |
| RMSE | 400 | 15.6 |
| % OF observed RMSE | 8.7 | 7.06 |
| Index of Agreement (D) | 0.91 | 0.94 |

MAE –Mean Absolute Error, MBE – Mean Bias Error, SD –Standard deviation

OIWR* -Observed irrigation water requirement (mm)

SIWR* -Simulated irrigation water requirement (mm)

## References


1. Anadranistakis M, Liakatas A, Kerkides P, Rizos S, Gavanosis J, Poulovassilis A. Crop water requirements model tested for crops grown in Greece. Agricultural Water Management. 2000; 45:297-396.
2. Baby Akula, Shekh AM. Field calibration and evaluation of crop simulation model Infocrop to estimate Wheat yields. Journal of Agrometerology. 2005; 7(2):199-207.
3. Baby Akula, Shekh AM, Parmar RS. Estimation of Evapotranspiration by WTGROWS Model. Journal of Agrometeorology. 2005; 7(1):64-68.
4. Boyer JS, McPherson HG. Physiology of water deficits in cereal crops. Adv. Agron. 1975; 27:1-23.
5. Baker DM, Lambert JR, McKinion JM. GOSSYM: A simulation of cotton crop growth and yield. South Carolina Agricutlural Experimental Station, Technical Bulletin, 1089, Clemson, USA, 1983.
6. Derek Clarke, Martin Smith, Khale-n Askari. University of Southampton UK, DC @ SOTON, AC, UK Cropwat for windows: User guide, 1998.
7. Jama CA, Ottman MJ. Timing of the irrigation in corn and water stress conditioning, Agron. J. 1993; 85:1159-1164.
8. Karthikeyan R, Balasubramanian TN. Evaluation of DSSAT V 3.5 CERES-Maize model for western zone of Tamil Nadu. J Agrometeol. 2005; 7(2):190-198
9. Panda RK, Behera SK, Kashyap PS. Effective management of irrigation water for maize under stress conditions. Agric. Watermanag. 2004; 66:181-203.
10. Rao BB, Savani MB. Application of PLANTGRO, a water use model for differentially irrigated pearl millet. J Agrometeol. 1999; 1:65-72.
11. Rathore LS, Nisha Mendiratta, Singh KK. Soil moisture prediction under maize in sandy loam. Annals of Arid Zone. 1998; 37(1):47-52.
12. Robertson MJ, Carberry P, Chuhan YS, Ranganathan R. Leary O, GJ. Predicting growth and development of pigeoeonpea: a simulation model. Field Crops Res. 2001; 71:195-210.
13. Ritchie Joe T, Gopal Alagarswamy. Model concepts to express genetic difference in maize yield components. Agron. J. 2003; 95:4-9.
14. Sehgal VK. Regional wheat yield estimation by crops simulation model using remote sensing inputs and geographic information system. Ph.D. thesis (Agri.) submitted to IARI, New Delhi, 2000.

15. Willmott. Validation of the model. Chapter No.8 in CERES- Wheat Book draft, 1982, 1.
16. Wilson D, Muchow RC, Murgatroyd CJ. Model analysis of temperature and solar radiation limitations to maize potential productivity in cool climate. Field Crops Res. 1995; 43:1-18.