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Calibration and validation of the canal simulation model: A case study on Nawagarh Distributary of Janjgir Branch Canal, District- Janjgir-Champa (Chhattisgarh, India)

Ravishankar, Devesh Pandey, Jitendra Sinha, Ganga Sharan Sahu and KK Singh

Abstract
Optimal irrigation scheduling and crop planning are the essential tasks for obtaining the maximum benefit from an irrigated command with the available water resources. This task can be achieved by assessing the irrigation system performance under existing scenarios. Keeping this in view, the present study was carried out to assess existing water supply-demand gap of the Nawagarh Distributary (Block-Nawagarh, District- Janjgir-Champa) of Hasdeo Bango Majo r Irrigation Project (District- Janjgir-Champa), Chhattisgarh, India. The required data on crop, weather; soil and canal flow pertaining to the study area were collected during the years 2012 and 2013 from various government departments, organizations and personal contact with the farmers of the command. To assess the existing supply-demand scenario of Nawagarh Distributary, CROPWAT 8.0 model was used. CROPWAT is a decision support system developed by the Land and Water Development Division of FAO in 1990 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. The selected model uses the FAO (1992) Penman-Montieth method for calculating the reference crop evapotranspiration. The model calibration was performed for the year 2012. The Root Mean Square Error (RMSE), Nash-Sutcliffe Coefficient (C_e), Correlation Coefficient (r^2), and Coefficient of Determination (R^2) were used as performance measures for calibration and validation. The model validation was carried out for the year 2013. The selected model was calibrated against the estimated (called as observed value) daily ET_o and decade ET_c. The model simulated daily ET_o and decade ET_c matched well with the estimated daily ET_o and decade ET_c for the study period considering served area and potential area.

Keywords: canal, calibration, command area, CROPWAT, irrigated agriculture, irrigation scheduling, modelling, simulation modelling, summer rice, supply and demand, validation

Introduction
Irrigation is the science of artificial application of water to land in accordance with the crop requirements throughout the crop period for full-fledged nourishment of crops. Land and water are most important natural resources. Effective use of these two are necessary for maximum benefit. The scarcity of water in the many parts of the world leads to the need of optimizing the benefits from the field of irrigation system by adopting effective & efficient water management. Our aim is to use water economically to get maximum crop output, for that simulation models are most widely accepted in the field of irrigation system planning and management. In India, the irrigated areas are likely to go down from the present 93% to 83% by 2025A.D. (Biswas, 1994) [5]. Thus, in future, irrigation needs to be more efficient and produce more crop yield per unit of water use (water use efficiency) which requires proper planning of irrigated commands based on simulation-optimization technique, considering the location specific conditions. Irrigation Scheduling involves deciding when and how much water to apply to a field. Good scheduling will apply water at the right time and in the right quantity in order to optimize production and minimize adverse environmental impacts. Bad scheduling will mean that either not enough water is applied or it is not applied at the right time, resulting in under-watering, or too much is applied or it is applied too soon resulting in over-watering. Under or overwatering can lead to reduced yields, lower quality and inefficient use of nutrients. "CROPWAT 8.0" is a decision support system developed by the Land and Water Development Division of Food and Agricultural Organization (FAO) for planning and management of irrigation system. It is a practical tool to carry out 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 through the planning of irrigation schedules under varying water supply conditions. For the study purpose Nawagarh Distributary (Block-Nawagarh, District- Janjgir-Champa) of Hasdeo Bango Major Irrigation Project (District- Janjgir-Champa) of Chhattisgarh is selected.

Materials and Methods

Study Area: The Hasdeo Bango Irrigation Project is one of the largest projects in the state of Chhattisgarh, India that provides irrigation facilities to about 2, 55,000 ha in 801 villages of 3 districts (Korba, Janjgir-Champa, and Raigarh) and also generates 120 MW hydel power. The *kharif* rice occupies 100% of the available cultural command area but in the *rabi* season, the occupied area varies according to the availability of water in the reservoir. Nawagarh Distributary (R.D. 22430 m of Janjgir Branch Canal) is selected for the present study, which lies in latitude of 22°19'35" N and longitude of 81°59'50" E. The distributary covers 32 villages of Nawagarh block of Janjgir-Champa district with the length 22.86 km consisting of 9 sub-distributaries and 39 minors. The design discharge of the distributary is 10.89 m^3/s. The Location map of the study area is shown in Figure 1.

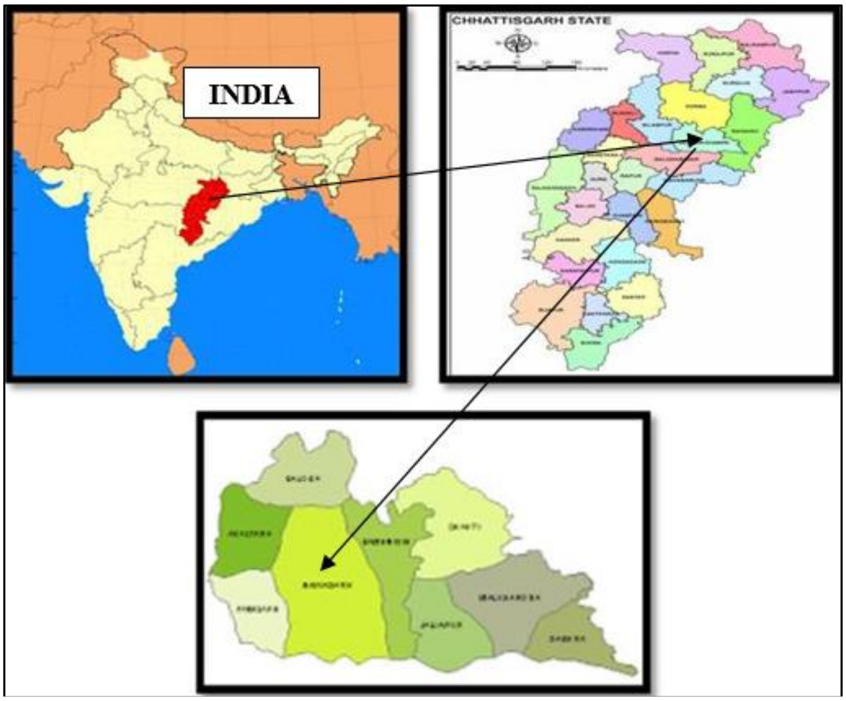


Fig 1: Location map of the study area

Collection of data: The data on weather, crop; soil and canal flow pertaining to the study area were collected from various state government departments/agencies like water resources, agriculture, agricultural research station and from personal contact with farmers of the command area for the study year 2012 and 2013.

Table 1: Operational status of Nawagarh distributary

Year	Canal				Water supply (Mm^3)	Area (ha)		Water supply Depth (cm)	Avg. rice Yield (kg/ha)
	Open	Close	Run (days)	Avg. disch- arge (m^3/s)		Targeted	Served		
2012	Jan, 2	May, 8	128	8.05	89.03	4444.91	4000.52	200	4044
2013	Jan, 9	May, 12	124	8.43	90.34	3978.13	3478.13	227	3622
Avg.			126	8.24	89.69	4211.52	3739.33	214	3833

Source: Department of Water Resources, Government of Chhattisgarh, India.

Table 2: Targeted and served area of Nawagarh distributary for *rabi* season year 2012 and 2013

S. No	Canal system	Command area (ha)	2012		2013	
			TA	SA	TA	SA
0	ND	11781.30	4444.91	4000.52	3978.13	3478.13
1	AmSD	950.73	581.86	551.86	560.00	510.00
2	BpSD	979.00	346.89	326.89	196.53	176.51
3	DhSD	1853.74	572.47	542.47	466.18	426.18
4	TM	74.75	50.00	50.00	50.00	50.00
5	NM-I	227.47	182.47	162.47	201.42	171.42
6	NM-II	113.77	90.00	90.00	100.00	90.00
7	NM-IV	123.38	100.47	90.00	100.47	90.47
8	PnSD	645.94	290.40	270.40	300.40	270.40
9	NM-III	255.74	182.47	162.47	201.42	171.42
10	BhSD	1383.71	560.05	490.05	467.26	367.26
11	KtM-II	32.46	20.00	20.00	20.00	20.00

12	KtM-I	190.65	181.20	161.30	180.00	160.00
13	KmSD	1438.90	488.39	424.39	477.33	371.03
14	KpM	265.91	101.21	91.21	110.53	100.53
15	KhM	265.73	170.45	150.45	172.87	152.87
16	GM-I	396.98	174.09	144.09	86.84	90.00
17	GM-II	155.52	120.52	100.52	86.84	90.00
18	TuM	166.04	110.04	90.01	100.04	90.04
19	KsSD	719.20	0	0	0	0
20	NdM	353.73	0	0	0	0
21	BrM	306.88	121.94	81.94	100.00	80.00
22	MhM	219.51	0	0	0	0
23	KrSD	203.57	0	0	0	0
24	MhSD	457.98	0	0	0	0

Source: Department of Agriculture, Government of Chhattisgarh, India.
(ND-Nawagarh Distributary, AmSD- Amoda Sub Distributary, BpSD- Barbaspur Sub Distributary, DhSD-Dahida Sub Distributary, TM-Turi Minor, NM-Nawagarh Minor, PnSD- Pendri Sub Distributary, BhSD-Bhatli Sub Distributary, KtM-Kirit Minor, KmSD-Karmandi Sub Distributary, KpM-Khaparidih Minor, KhM-Khairtal Minor, GM-Gangajal Minor, TuM-Tulsi Minor, KsSD-Kesla Sub Distributary, NdM-Nagaridih Minor, BrM-Barra Minor, MhM-Mohtara Minor, KrSD-Kera Sub Distributary, MhSD-Mohtara Sub Distributary, TA-Targeted area (ha), SA-Served area (ha).)

Model Overview - CROPWAT 8.0

CROPWAT model use the FAO (1992) [18] Penman-Montieth method for calculating the reference crop evapotranspiration. These estimates are used in crop water requirements and irrigation scheduling calculations. Model input is cover crop, meteorology, and soil data. The meteorology data includes: Maximum and minimum temperature; Wind speed; Sunshine hours; Relativity humidity; and Rainfall. There are four common empirical methods for calculating effective rainfalls (Smith 1992) [18] as follows: (1) fixed percentage of rainfall; (2) dependable rainfall; (3) empirical formula; and (4) USDA Soil Conservation Service Method.

1. Fixed Percentage of Rainfall

$PE_{Eff} = a * P_{tot}$ (1)

Where PE_{eff} is the effective rainfall; a is a fixed percentage coefficient (specified by the model user), with a typical range of values from 0.7 to 0.9; and P_{tot} is the measured (or generated) total daily rainfall.

2. Dependable Rainfall

This empirical formula was developed by the FAO to estimate dependable rainfall. This method may be used for design purposes where 80% probability of exceedance is required.

$$P_{tot} < 70\,mm;\ PE_{Eff} = 0.6\,P_{tot} - 10$$
$$P_{tot} > 70\,mm;\ PE_{Eff} = 0.8\,P_{tot} - 24 \qquad (2)$$

3. Empirical formula: This formula will determine the effective rainfalls based on analysis of local climatic records.

$$P_{tot} < Z\,mm;\ PE_{eff} = a\,P_{tot} + b$$
$$P_{tot} > Z\,mm;\ PE_{eff} = c\,P_{tot} + d \qquad (3)$$

Where a, b, c, d and z are empirically-derived correction coefficients.

4. USDA Soil Conservation Service method:

$$PE_{eff} = P_{tot} \times \frac{125 - 0.2P_{tot}}{125}\ for\ P_{tot} < 250\,mm$$
$$PE_{eff} = 125 + 0.1 \times P_{tot}\ for\ P_{tot} > 250\,mm \qquad (4)$$

Where, PE: effective rainfall (mm), P_{tot}: total rainfall (mm)

Given the input of the requirement data, the selected model can be used to calculate crop - related data in each decade of a month, such as: (1) crop coefficient, (2) crop leaf index, (3) crop evapotranspiration, (4) percolation, (5) effective rainfall, and (6) crop water requirements.

Also, the model can be applied to estimate the irrigation schedule for each crop with 5 different options:(1) each irrigation defined by irrigation manager, (2) irrigation at below or above critical soil depletion (% RAM), (3) irrigation at fixed interval per crop growing stage, (4) deficit irrigation, and (5) no irrigation. Afterwards, the selected model can simulate the on-farm crop water balance, including : (1) irrigation times, dates and depths, (2) soil moisture depletion, (3) amount of percolation, (4) actual crop evapotranspiration, and (5) crop yield.

The on-farm water balance was based on the theory of Eq. (5) below:

$SMD_t = SMD_{t-1} + ET_c$ – PE – IR + RO + DP (5)

Where:

t: time (decade of month)

SMD_t, SMD_{t-1}: soil moisture depletion at t and t-1 decade (mm)

ET_c: actual crop evapotranspiration (mm)

PE: effective rainfall (mm)

IR: irrigation depth (mm)

RO: runoff (mm)

DP: deep percolation (mm)

The crop yield reduction in each stage was evaluated based on the degree of soil moisture depletion due to supply of the crop evapotranspiration requirements. Eq. (6) calculates the crop yield reduction in each stage and the cumulative crop yield reduction represented by Eq. (7).

$$\left(1 - \frac{Y_a}{Y_{max}}\right) = K_y \left(1 - \frac{ET_a}{ET_{max}}\right) \qquad (6)$$
$$\left(1 - \frac{Y_a}{Y_{max}}\right)_i = 1 - \left(\frac{Y_a}{Y_m}\right)_1 \times \left(\frac{Y_a}{Y_m}\right)_2 \times \ldots\times \left(\frac{Y_a}{Y_m}\right)_i \qquad (7)$$

Where,

i: crop growth stage

K_y: crop yield reduction factor

Y_a, ET_a: crop actual yield and evapotranspiration, respectively

Y_{max}, ET_{max}: maximum crop yield and potential evapotranspiration, respectively.

After finishing the simulation of irrigation schedule for each crop, the selected model could furthermore be used to estimate the monthly agricultural water requirements of an irrigation scheme, based on different cropping patterns as expressed in the equation below:

$$Q_{gross} = \frac{1}{e_p \times t} \times [0.116 \times A_{scheme} \times \sum_{i=1}^{n} (ET_{crop} - P_{eff}) \times \frac{A_{crop}}{A_{scheme}}] \quad (8)$$

Where,
Q_{gross}: monthly agricultural water requirement of irrigation scheme (l/s)
e_p: irrigation efficiency (<=1, dimensionless)
t: time operational factor (<=1, dimensionless)
i : crop index of the cropping pattern for an irrigation scheme
A_{crop}: crop planted area (ha)
A_{scheme}: total area of irrigation scheme (ha)
ET_{crop}: crop evapotranspiration (mm/day)
P_{eff}: effective rainfall (mm/day).

The selected model is using the above procedure for estimated daily crop water requirement, irrigation schedule and irrigation scheme. The model consisted of 5 input windows and 3 output windows. The Data/Information on climate/weather, rain, crop, soil and cropping pattern are the input data and crop water requirements, irrigation schedule, and irrigation scheme are the output data for the model. After providing the required input data, clicked the output tool and to get the tabular output of the model. The output window consists of stagger wise estimation of ET_c, EFR and DP, CWR, Irrigation schedule and Irrigation scheme. The graphical output of the model is obtained by clicking the “Graph/Chart” button seen at the top. The rest of the calculation of assessment and estimation is done by the MS Excel.

Calibration and Validation

Calibration of a model is the process of adjusting model parameters to obtain a close agreement between the observed/estimated and simulated outputs. Validation of the calibrated model is essential to check the calibration precision. Several runs under the chosen operational and management conditions were performed to test the ability of model to produce meaningful results. First, the model was run for the year 2012 for calibration and run for the year 2013 for validation. The model simulated daily ET_o and decade ET_c was matched with the estimated (called as observed value) daily ET_o and decade ET_c and the chosen performance indices (root mean square error, Nash-Sutcliffe coefficient, correlation coefficient and coefficient of determination) were estimated. These performance indices are briefly described in the following section.

Performance Indices

The performance indices assess the level of confidence of the model predictions. These indices serve as a first step towards the usefulness of model as the term 'calibrated and validated model'. In this study, a comparison was made between the model simulated and estimated (called as observed value) daily ET_o and decade ET_c for both the two years (2012 and 2013) with different performance indices viz. root-mean-square error, Nash-Sutcliffe coefficient, correlation coefficient and coefficient of determination. The performance of the selected model was evaluated using the following performance indices.

(A) Root Mean Square Error (RMSE)

$$RMSE = \sqrt{\sum_{t=1}^{T} \frac{1}{T} (E - S)^2} \quad (3.1)$$

Where, E and S denote the estimated and simulated values of variables (ET_o and ET_c), T is the number of simulation days in the evaluation and t is the time index.

(B) Nash-Sutcliffe Coefficient (ASCE, 1993)

$$C_e = 1 - \frac{\sum_{t=1}^{T} (E - S)^2}{\sum_{t=1}^{T} \left(E - \bar{E} \right)^2} \quad (3.2)$$

Where, $\bar{E}$ denotes the mean estimated variable value

(C) Coefficient of determination

$$R^2 = \left[\frac{\sum_{t=1}^{T} \left(E - \bar{S} \right)\left(S - \bar{S} \right)}{\sqrt{\sum_{t=1}^{T} \left(E - \bar{E} \right)^2 . \sum_{t=1}^{T} \left(S - \bar{S} \right)^2}} \right]^2 \quad (3.3)$$

Where, $\bar{S}$ denotes the mean simulated variable value. The high value of R^2 indicating better agreement between the simulated and estimated values. The value of R^2 is 1 for the perfect model.

D. Correlation coefficient

Where, O_j = observed value, S_j = simulated value

$\bar{O}$ = mean of observed value, $\bar{S}$ = mean of simulated value

$$CC = \frac{\sum_{j=1}^{n} \left\{ \left(O_j - \bar{O} \right)\left(S_j - \bar{S} \right) \right\}}{\left\{ \sum_{j=1}^{n} \left(O_j - \bar{O} \right)^2 \sum_{j=1}^{n} \left(S_j - \bar{S} \right)^2 \right\}^{\frac{1}{2}}} x100 \quad (3.4)$$

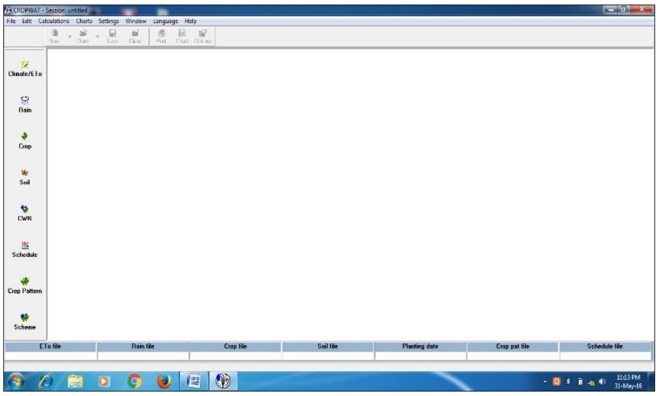


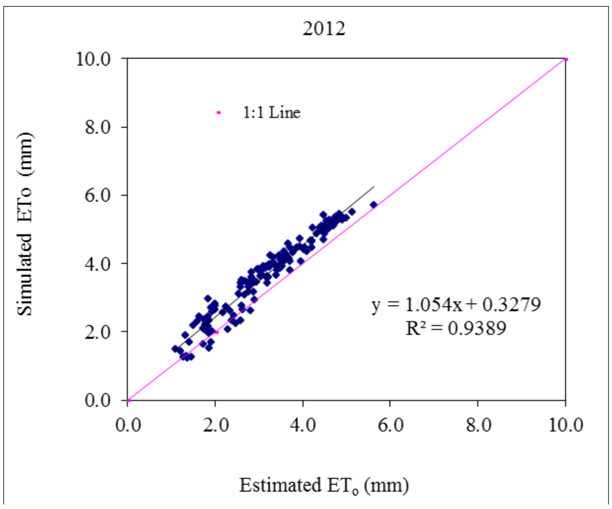
Fig 2: Screenshot of CROPWAT 8.0 irrigation management model window

Results and Discussion

Calibration and validation of the canal simulation model:

Model Calibration: The selected model was calibrated with estimated daily value (called as observed value) of ET_o and decade values of ET_c for summer rice seasons of 2012. For this purpose, several runs of the selected model were performed with input data set of summer rice for seasons 2012. The simulated and estimated daily ET_o and decade ET_c obtained were compared graphically, statistically and by the model performance indices. The scattergrams of the model simulated and estimated daily ET_o and decade ET_c for the calibration periods along with the 1:1 line are shown in Fig 3. The simulated ET_o and ET_c was distributed uniformly about the 1:1 line. For high values of ET_o and ET_c, the model simulated values were slightly above 1:1 line, indicating that the model slightly over predicted for high values of ET_o and ET_c. However, the high value of R^2 (0.94(for ET_o), 0.98(for ET_c)) for linear regression indicated a close relationship between the estimated and simulated ET_o and ET_c.

The time series of simulated and estimated daily ET_o and decade ET_c for the calibration period were compared graphically and presented in Fig 4. The model simulated daily ET_o and decade ET_c values matched well with the estimated values in the beginning of cropping season when ET_o and ET_c was low. However, there is slight difference between simulated and estimated values later in the cropping season. The statistical results showing comparison between the simulated and estimated daily ET_o and decade ET_c are given in Table 3. For the calibration period, the total simulated daily ET_o and total simulated decade ET_c was slightly higher than the total value of estimated because of the over prediction by the model.



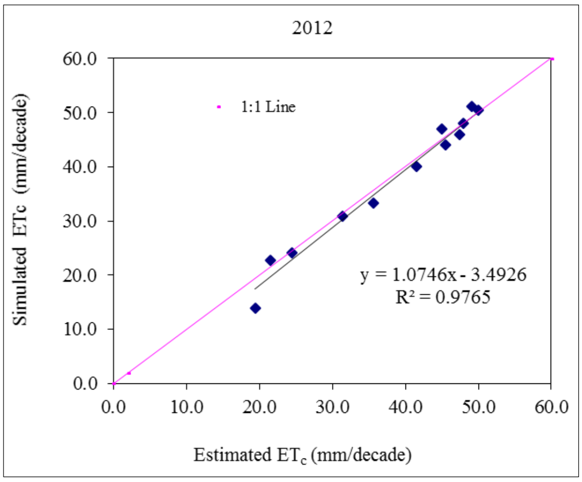


Fig 3: Scattergrams of ET_o and ET_c for the CROPWAT calibration period 2012

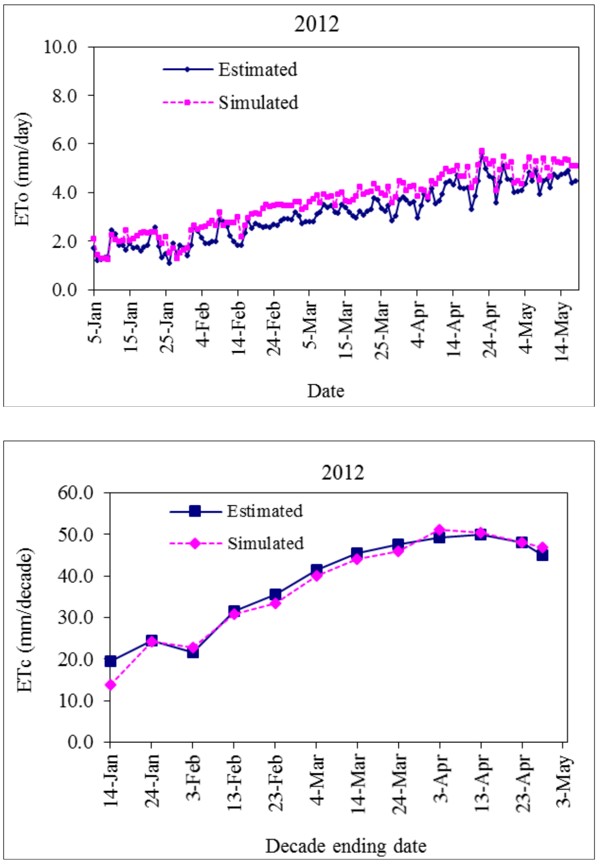


Fig 4: Time series of the simulated and estimated ET_o and ET_c for the CROPWAT calibration period 2012

Table 3: Statistical analysis and performance indices of daily ET_o and decade ET_c for CROPWAT calibration period, 2012

Parameters	ET_o		ET_c	
	Est.	Sim.	Est.	Sim.
Mean (mm)	3.13	3.63	38.26	37.62
SD (mm)	1.07	1.17	11.37	12.37
Max. (mm)	5.63	5.72	50.00	51.10
Min. (mm)	1.07	1.25	19.44	13.90
Sum (mm)	422.71	489.83	459.07	451.40
R^2	0.94		0.98	
C_e	0.71		0.96	
RMSE	0.58		0.68	
r^2	0.97		0.99	

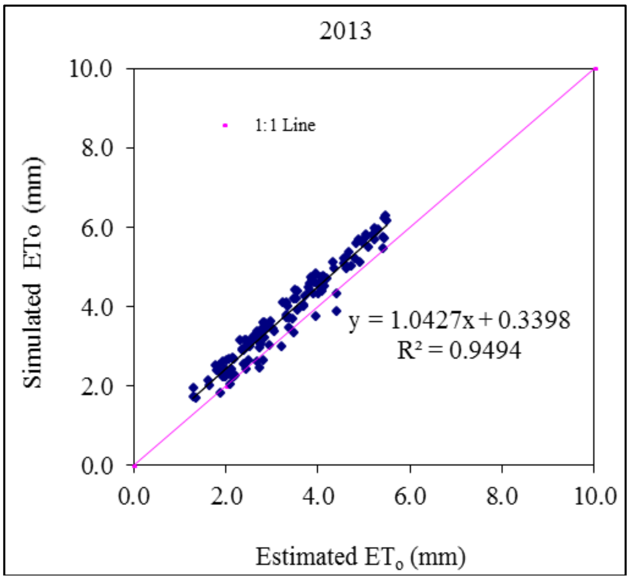
Note: C_e = Nash-Sutcliffe Coefficient, RMSE = Root mean square error,
R^2 = Coefficient of determination, r^2 = Correlation coefficient

Further, both the mean and standard deviation for simulated ET_o and ET_c were higher than that of the estimated ET_o and ET_c. However, SD indicated that the model simulated daily ET_o and decade ET_c during calibration period matched well with its estimated value. Further, high value of the C_e (0.71 (for ET_o) & 0.96 (for ET_c)) and low value of RMSE (0.58 mm/day (for ET_o) & 0.68 mm/day (for ET_c)) suggest close agreement between the simulated and estimated values of ET_o and ET_c. These results suggest that the model adequately predicts ET_o and ET_c. Thus, it can be said that the model is adequately calibrated.

Model Validation

The calibrated model was validated using estimated daily ET_o and decade ET_c for summer rice seasons of 2013. The graphical comparison of simulated and estimated ET_o and ET_c is shown in Fig 5. As in case of model calibration, the points are somewhat evenly distributed about the 1:1 line for 2013. Further, high values of R^2 for both ET_o and ET_c i.e., 0.95 and 0.96, respectively indicated a close relationship between the simulated and estimated ET_o and ET_c.

Similar to calibration, model simulated ET_o and ET_c was compared with the estimated ET_o and ET_c and the time series representation of validation results for the daily ET_o and decade ET_c are shown in Fig 6. It is observed that the simulated ET_o and ET_c matched closely with estimated values for 2013 data sets. The model was predicted slightly high seasonal ET_o and ET_c.



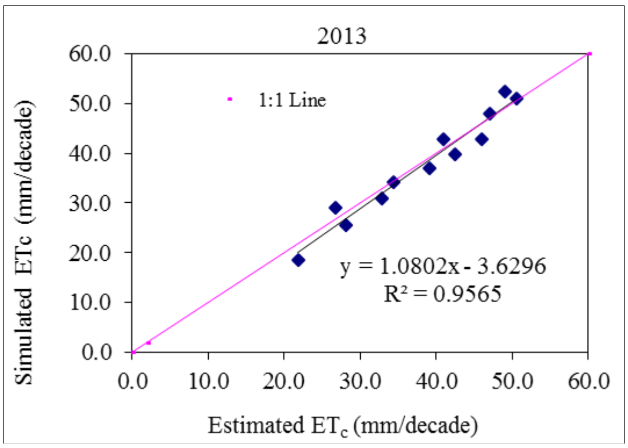
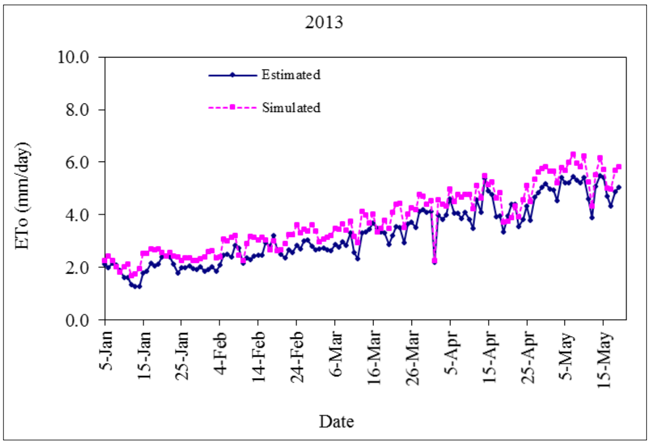


Fig 5: Scattergrams of ET_o and ET_c for the CROPWAT validation period 2013



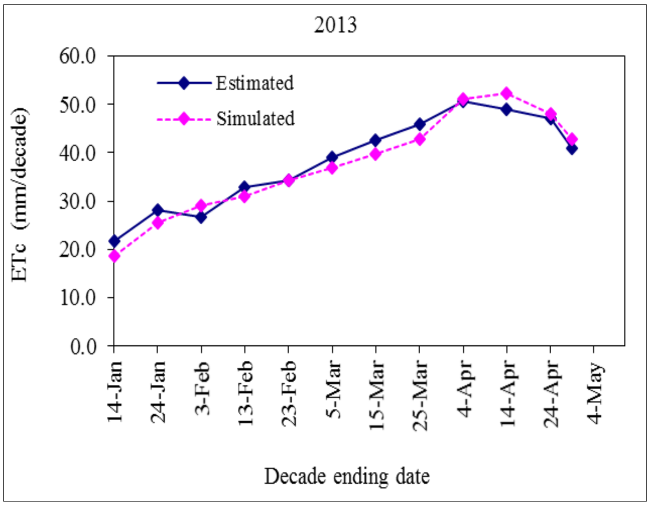


Fig 6: Time series of the simulated and estimated ET_o and ET_c for the CROPWAT validation period 2013

The descriptive statistics for both the simulated and estimated daily ET_o and decade ET_c for validation period 2013 are given in Table 4. Both mean and standard deviation of the simulated ET_o and ET_c were slightly higher than that of estimated ET_o and ET_c. High values of the C_e (0.76(for ET_o) and 0.94(for ET_c)), lower value of RMSE (0.55(for ET_o) and 0.74(for ET_c)) and high values of r^2 (0.97(for ET_o) and 0.98(for ET_c)) indicated that the model adequately predicts daily ET_o and decade ET_c and hence it can be considered as validated.

Table 4: Statistical analysis and performance indices of daily ET_o and decade ET_c for CROPWAT validation period 2013

Parameters	ET_o		ET_c	
	Est.	Sim.	Est.	Sim.
Mean (mm)	3.29	3.77	38.26	37.69
SD (mm)	1.14	1.22	9.44	10.43
Max. (mm)	5.50	6.30	50.52	52.30
Min. (mm)	1.28	1.69	21.83	18.60
Sum (mm)	444.40	509.25	459.06	452.30
R^2	0.95		0.96	
C_e	0.76		0.94	
RMSE	0.55		0.74	
r^2	0.97		0.98	

Note: C_e = Nash-Sutcliffe Coefficient, RMSE = Root mean square error,
R^2 = Coefficient of determination, r^2 = Correlation coefficient

Conclusions

The selected simulation model was calibrated with the estimated daily ET_o and decade ET_c for summer rice seasons of 2012. For this purpose, several runs of the model were performed with the data set of the year 2012. Then, the simulated and estimated daily ET_o and decade ET_c, were compared both graphically and statistically. Also the performance indices were determined. The scattergrams of the model simulated and estimated daily ET_o and decade ET_c for the calibration periods along with the 1:1 line are showed that the simulated ET_o and ET_c was distributed uniformly about the 1:1 line. For high values of ET_o and ET_c, the model simulated values were slightly above 1:1 line, indicating that the model slightly over predicted for high values of ET_o and ET_c. However, the high value of R^2 (0.94(for ET_o), 0.98(for ET_c)) for linear regression indicated a close relationship between the estimated and simulated ET_o and ET_c. The time series of the model simulated and estimated daily ET_o and decade ET_c for the calibration period were compared graphically. The model simulated daily ET_o and decade ET_c values matched well with estimated values in the beginning of cropping season when ET_o and ET_c was low. However, there is slight difference between model simulated and estimated values later in the cropping season. The statistical results showing comparison between the simulated and estimated daily ET_o and decade ET_c. For the calibration period, the total simulated daily ET_o and total simulated decade ET_c was slightly higher than the total value of estimated because of the over prediction by the model. Further, both the mean and standard deviation for simulated ET_o and ET_c were higher than that of the estimated ET_o and ET_c. However, SD indicated that the model simulated daily ET_o and decade ET_c during calibration period matched well with its estimated value. Further, high value of the C_e (0.71(for ET_o) & 0.96(for ET_c)) and low value of RMSE (0.58 mm/day (for ET_o) & 0.68 mm/day (for ET_c)) suggest close agreement between the simulated and estimated values of ET_o and ET_c. These results suggest that the model adequately predicts ET_o and ET_c. Thus, it can be said that the model is adequately calibrated.

The calibrated model was validated using the estimated daily ET_o and decade ET_c for summer rice seasons of 2013. As in case of model calibration, the points are somewhat evenly distributed about the 1:1 line for 2013. Further, high values of R^2 for both ET_o and ET_c i.e., 0.95 and 0.96, respectively indicated a close relationship between the simulated and estimated ET_o and ET_c. Similar to calibration, model simulated ET_o and ET_c was compared with the estimated ET_o and ET_c and the time series representation of validation results for the daily ET_o and decade ET_c. It is observed that the simulated ET_o and ET_c matched closely with estimated values for 2013 data sets. The model was predicted slightly high seasonal ET_o and ET_c. The descriptive statistics for both the simulated and estimated daily ET_o and decade ET_c for validation period 2013 are given. Both mean and standard deviation of the simulated ET_o and ET_c were slightly higher than that of estimated ET_o and ET_c. High values of the C_e (0.76(for ET_o) and 0.94(for ET_c)), lower value of RMSE (0.55(for ET_o) and 0.74(for ET_c)) and high values of r^2 (0.97(for ET_o) and 0.98(for ET_c)) indicated that the model adequately predicts daily ET_o and decade ET_c and hence it can be considered as validated.

Hence the specific conclusion of this study is the simulated and estimated daily ET_o and decade ET_c matched well for both the calibration and validation periods. Thus, it can be said that the selected model is adequately calibrated and validated for the study area.

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