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Performance Evaluation of AquaCrop Model for *Rabi* Maize Crop in the North Bihar Condition

Vicky Kumar, Ravish Chandra and SK Jain

Abstract

A field experiment was conducted in *Rabi* season of 2016-17 at experimental field of AICRP on Irrigation Water Management, Dr. Rajendra Prasad Central Agricultural University, Pusa (Bihar), India. This experiment was undertaken to study the response to evaluate the FAO-AquaCrop model for *Rabi* maize at different levels of irrigation. Crop growth simulation models of varying complexity have been developed for predicting the effects of soil, water and nutrients on grain and biomass yields and water productivity of different crops. The experiment was laid out in randomized block design with four treatment, five replication and five irrigations were applied in the main plot. The irrigation treatments consisted of all possible combinations of full irrigation or limited irrigation in such that T_1 (full/control irrigation), T_2 (75% of CI), T_3 (50% of CI) and T_4 (Rainfed / No Irrigation). The AquaCrop model evaluated for grain yield and biomass under different irrigation levels resulted in prediction error ranging from 2.25% to 9.59% and 2.44% to 11.84% respectively. The AquaCrop model was evaluated for simulation of grain yield and biomass of *Rabi* maize for all treatment with the prediction statistics $0.971 < E < 0.988$, $0.221 < RMSE < 0.731$, $0.987 < R^2 < 0.997$ and $0.421 < MAE < 0.806$ t ha^{-1}. The AquaCrop model predictions for grain yield and biomass of *Rabi* maize were in line with the observed data corroborated with E and R^2 values approaching one. The AquaCrop model was more accurate in predicting the *Rabi* maize yield under full and 75% of CI as compared to the Rainfed and 50% CI.

Keywords: *Rabi* maize, AquaCrop model, simulation, grain yield and biomass

Introduction

Fresh water is an indispensable natural resource, which plays a vital role in the development of any country. Presently, many countries and regions of the world are experiencing scarcity of fresh water. Water demand for drinking and hygiene by the ever-growing population, agricultural water demand to feed the population, demand from industry and to sustain ecology, are all competing with one another, aggravating the scarcity situation (FAO, 2008).

Maize (*Zea mays* L.) is an important cereal crop in the world after wheat and rice, occupying an area of 146 million hectares with a production of 685 million tons and average productivity of 4.7 t ha^{-1} (FAOSTAT, 2015). Maize ranks third among cereal crops in India after rice and wheat, with an area of 9.3 million hectares, with a production of 23.67 million tons (Directorate of Economics Statistics, 2014-15). Bihar is one of the major maize growing states contributing nearly 8.9% of the total maize production of the country with nearly 0.28 million hectares being cultivated under maize per year (Directorate of Economics Statistics, 2014-15). *Rabi* maize is grown on an area of 1.2 million hectares with the grain production of 5.08 million tons, with an average productivity of 4.0 t/ha (Directorate of Economics Statistics, 2014-15). Crop growth simulation models of varying complexity have been developed for predicting the effects of soil, water and nutrients on grain and biomass yields and water productivity of different crops (Abedinpour *et al.* 2012). Simulation models are designed to imitate the behavior of a system. The water driven crop growth models assume a linear relationship between biomass, growth rate, and transpiration through a water productivity (WP) parameter (Tanner and Sinclair 1983, Steuduto and Albrizio 2005). The water driven growth concept is used in Crop syst and AquaCrop model (Steduto *et al.* 2009, Raes *et al.* 2009). One of the major advantages of the water driven model over driven is the opportunity to normalize the WP parameter for climate (both evaporative demand and atmospheric CO_2 concentration) in the former which, therefore, has a greater applicability in different locations under varying spatiotemporal settings. Much progress has been made in quantifying and understanding crop growth about water in the last 30 years. This led to the development of AquaCrop, the FAO's crop water productivity simulation model. For this development, FAO organized consultations with recognized authorities and experts from major scientific and academic institutions, national and international research centers and governmental organizations worldwide. The outcome is a revised framework that treats herbaceous

Crops and tree crops separately. FAO-AquaCrop model version 3.1 plus was developed in the January 2011 by a group of researchers (Raes *et al*., 2009). The herbaceous crops are to be simulated by the model AquaCrop parameterized for each crop species. The model is to strike a balance between accuracy, simplicity, and robustness. It is to be used for irrigation management, project planning, and scenario simulations at different scales. These model usually offer the possibility of specifying management options, and they can be used to investigate a wide range of management strategies at low costs (Kumar and Ahlawat 2004). Keeping the importance of simulation crop growth models, the present study was undertaken to evaluate the FAO-AquaCrop model for *Rabi* maize at different levels of irrigation in North Bihar condition.

Materials and Methods

The experimental site is located at the farm of Irrigation Water Management, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar, India on the southern and western bank of the river Burhi Gandak at 25°59'N latitude and 85°48'E longitude. Altitude of the site is 52.92 m above mean sea level. The plot had a fairly uniform topography and the soil was deep and well drained. The soil was calcareous which was characterized by the presence of 26.6% calcium carbonate. It consists of sandy loam with sand (57%), silt (31%) and clay (12%). The average bulk density, field capacity, and permanent wilting point were 1.63 g/cm^3, 16.92%, and 7.22% respectively. The seeds of *Rabi* maize (variety - DKC 9120) were sown with a spacing of 60 cm × 100 cm on Nov. 4, 2016, on the raised beds of sterilized soil. The experiment was laid out in a randomized block design with four treatment, five replication, with a plot size of 7 m × 6 m and five irrigations were applied in the main plot in *Rabi* season of 2016-17. The treatment details of experiments are presented in Table 1. The data on the weather condition during the crop growing season of present investigation concerning maximum and minimum temperature, rainfall, wind speed, relative humidity, evaporation and bright sunshine were obtained from Agro-meteorology observatory, Dr. RPCAU, Pusa. It has been presented in Table 2.

Table 1: Irrigations treatments details of experiments

Treatments	Details of irrigation treatments
T_1	100% level of estimated crop water requirement base on cumulative pan evaporation (Control/Full irrigation)
T_2	75% of CI (Treatment T_1)
T_3	50% of CI
T_4	Rainfed /No Irrigation

FAO-AquaCrop Model: The AquaCrop model (Steduto *et al.,* 2009; Raes *et al.*, 2011) is a crop growth model which combines four sub-models: (1) the soil water balance; (2) the crop development, growth and yield; (3) the atmosphere sub-model, handling rainfall, evaporative demand (reference evapotranspiration, ET_O) and CO_2 concentration; (4) and the management sub-model, which includes irrigation and fertilization (Raes *et al*., 2011).

Soil water balance: The amount of water stored in the root zone is simulated by accounting for the incoming and outgoing water fluxes at its boundaries. The root zone depletion determines the magnitude of a set of water stress coefficients (Ks) affecting: (a) green canopy (CC) expansion, (b) stomatal conductance and hence transpiration (Tr) per unit CC, (c) canopy senescence and decline, (d) the harvest index (HI) and (e) the root system deepening rate.

Crop development: In the simulation of crop development, the canopy expansion is separated from the expansion of the root zone. The interdependence between shoot and root is indirect via water stress. AquaCrop uses canopy cover to describe crop development. The canopy is a crucial feature of AquaCrop. Through its expansion, aging, conductance, and senescence, it determines the amount of water transpired (Tr), which in turns determines the amount of biomass produced (B) and the final yield (Y). If water stress occurs, the simulated CC will be less than the potential canopy cover (CCpot) for no stress conditions and the maximum rooting depth might not be reached.

Crop transpiration (Tr): Crop transpiration is obtained by multiplying the evaporating power of the atmosphere (ETo) with a crop coefficient. The crop coefficient (Kcb) is proportional to CC and hence continuously adjusted. The evaporating power is expressed by the reference grass evapotranspiration (ETo) as determined by the FAO Penman-Monteith equation. If water stress induces stomatal closure, the water stress coefficient for stomatal conductance (Ks) reduces transpiration accordingly. Green canopy cover and duration represent the source for transpiration; stomatal conductance represents transpiration intensity.

Table 2: Monthly Weather Data Recorded at Agro-Meteorological Observatory, Dr. RPCAU, Pusa During Crop Season 2016-2017.

Month	Temperature (^{0}C)		Relative humidity (%)		Wind Speed (km/h)	Rainfall (mm)	Evaporation (mm)	Bright Sunshine (h)
	Maximum	Minimum	Morning	Evening				
November	28.68	15.52	86.78	44.37	1.60	0.0	1.97	5.65
December	22.3	11.3	90	65	2.7	0.0	0.8	1.9
January	22.4	8.7	93	62	2.9	0.0	1.3	5.1
February	26.0	10.9	90	58	2.9	0.0	2.2	7.0
March	29.7	15.5	86	54	4.9	10.6	3.4	7.3
April	34.59	20.35	75.62	53.54	7.00	0	5.55	6.86

AquaCrop (Steduto *et al*., 2007; Raes *et al.*, 2009; Hsiao *et al*., 2009) evolves from the Ky approach by separating**:** (i) The actual evapotranspiration (ET) into soil evaporation (E) and crop transpiration (Tr): $ET = E + Tr$ ... (1)

The separation of ET into soil evaporation and crop transpiration avoids the confounding effect of the non-productive consumptive use of water (soil evaporation). This is important especially when ground cover is incomplete early in the season or as the result of sparse planting. (ii) The final yield (Y) into biomass (B) and harvest index (HI): Y = HI. B … (2)

The separation of yield into biomass and harvest index allows the partitioning of the corresponding functional relations as a response to environmental conditions. These responses are in fact fundamentally different, and their separation avoids the confounding effects of water stress on B and HI.

The changes described leads to the following equation at the core of the AquaCrop growth engine: $B = WP \cdot \Sigma Tr$ … (3)

Where Tr is the crop transpiration (in mm), and WP is the water productivity parameter. This step-up from Eq.1 to Eq.3 has a fundamental implication for the robustness of the model due to the conservative behavior of WP (Steduto *et al.*, 2007). It is worth noticing, though, that both equations have water as driving force for growth.

Aboveground biomass (B): The cumulative amount of water transpired (Tr) translates into a proportional amount of biomass produced through the biomass water productivity (Eq.2). In AquaCrop the water productivity normalized for atmospheric demand and air CO2 concentrations (WP*) is used. It expresses the healthy relationship between photosynthetic CO2 assimilation or biomass production and transpiration independently of the climatic conditions. Beyond the partitioning of biomass into yield (Step 5), there is no partitioning of above-ground biomass among various organs. This choice avoids dealing with the complexity and uncertainties associated with the partitioning processes, which remain among the least understood and most difficult to model.

Partitioning of biomass into yield (Y): given the simulated aboveground biomass (B), crop yield is obtained with the help of the Harvest Index (Eq.2). In response to water and temperature stresses, HI is continuously adjusted during yield formation.

Input data requirement of AquaCrop model: AquaCrop uses a relatively small number of explicit parameters and mostly intuitive input variables, either widely used or requiring simple methods for their determination. Input consists of weather data, crop and soil characteristics, and management practices that define the environment in which the crop will develop. The inputs are stored in climate, crop, soil and management files and can be easily adjusted through the user interface.

Climatic data: the weather data required by AquaCrop model are daily values of minimum and maximum air temperature, reference crop evapotranspiration (ET_o), rainfall and mean annual carbon dioxide concentration (CO_2). ETo was estimated using ET_o calculator using the daily maximum and minimum temperature, wind speed at 2 m above the ground surface, solar radiation and mean relative humidity (RH).

Crop data: AquaCrop uses a relatively small number of crop parameters describing the crop characteristics. FAO has calibrated crop parameters for major crops and provides them as default values in the model. When selecting a crop, its crop parameters are downloaded.

Soil data: Data about the soil of experiment site required as input parameters for AquaCrop are viz number of soil horizons, soil texture, field capacity (θ_{FC}), permanent wilting point (θ_{PWP}), saturated hydraulic conductivity (K_{sat}), and volumetric water content at saturation (θ_{sat}). The user can make use of the indicative values provided by AquaCrop for various soil texture classes, or import locally determined or derived data from soil texture with the help of pedo-transfer functions. If a layer blocks the root zone expansion, its depth in the soil profile has to be specified as well.

The saturation soil moisture content and field capacity of the soil was determined from the field technique. The test plot was irrigated until the soil profile is saturated to a depth of about one meter. Then the plot was covered to prevent evaporation. The soil moisture was measured after every 24 hours until the changes are tiny, at which point the soil moisture content was an estimate of field capacity. The permanent wilting point was derived from pedo transfer function software. The field capacity was found to be 16.92 percent, and the permanent wilting point was estimated as 7.22 percent by weight basis. The experiment site did not contain any impervious or restrictive soil layer to obstruct the expansion of root growth. The curve number of the site was used to estimate surface runoff from rainfall that occurred during the experiment.

Management practice: Management practices are divided into two categories: field management and irrigation management practices: Under field management practices are choices of soil fertility levels, and practices that affect the soil water balance such as mulching to reduce soil evaporation, soil bunds to store water on the field, and tillage practices such as soil ridging or contours reducing run-off of rainwater. The fertility levels range from non-limiting to poor, with effects on WP, on the rate of canopy growth, on the maximum canopy cover, and on senescence; - Under irrigation management, the user chooses whether the crop is rainfed or irrigated. If irrigated, the user can select the application method (sprinkler, drip, or surface), the fraction of surface wetting, and specify for each irrigation event, the irrigation water quality, the timing and the applied irrigation amount. There are also options to assess the net irrigation requirement and to generate irrigation schedules based on specified time and depth criteria. Since the criteria might change during the season, the program provides the means to test deficit irrigation strategies by applying chosen amounts of water at various stages of crop development. Irrigation management comprised data about both the situations of full irrigation and deficit irrigation. In full irrigation treatment (i.e., Irrigation water application according to 100% of cumulative pan evaporation through furrow irrigation system) water was applied according to the evaporative demand. In the deficit irrigation treatments (i.e., 75 and 50% of the full irrigation), water was applied on the same day as the fully irrigated plot, but the irrigation depths were reduced to 75 and 50% of the full irrigation. The plant under furrow method was irrigated by impounding water in furrows. The same fertility level was maintained in all the treatments.

Testing of AquaCrop model: The FAO-AquaCrop model was tested for *Rabi* maize under a different levels of irrigation. It has been widely studied because of its mathematical simplicity. Evaluation of the AquaCrop model was accomplished by using the observed values from the field experiment during 4th November 2016 to 13th April 2017 for *Rabi* maize as model input and then simulating the model to predict the output viz the yield and biomass. Subsequently, the predicted output values were compared with the observed yield and biomass of the experimental plot. The difference between the model predicted and experimental data was minimized by using a trial and error approach in which one specific input variable was chosen as the reference variable at a time and adjusting only those parameters that were known to influence the reference variable the most. The procedure was repeated to arrive at the closest match between the model simulated and the observed value of the experiment for each treatment combination. The standard crop parameters were adopted for crop growth simulation. The AquaCrop parameters which were calibrated, measured and adopted are as follows:

- Cut-off temperature
- Adapted Canopy cover per seedling at 90% emergence (CC0)
- Canopy growth coefficient (CGC)
- Calibrated Maximum canopy cover (CCx)
- Canopy decline coefficient (CDC)
- Water productivity (WP*)
- Dry above-ground biomass per m^2
- Reference harvest index (HIo)
- Upper threshold for canopy expansion
- Lower threshold for canopy expansion
- Leaf expansion stress coefficient curve shape
- Upper threshold for stomatal closure
- Stomata stress coefficient curve shape
- Time from transplanting to recovered transplant
- Time from transplanting to a maximum rooting depth
- Time from transplanting to start senescence
- Time from transplanting to maturity
- Maximum effective rooting depth

3.5 Model evaluation criterion

Aqua Crop simulation results of *Rabi* maize yield and biomass were compared with the observed values from the experiment during 2016-17. The goodness of fit between the simulated and observed values was corroborated by using the prediction error statistics. The prediction error (P_e), the coefficient of determination (R^2), mean absolute error (MAE), root mean square error (RMSE) and model efficiency were used as the error statistics to evaluate results of the model. The R^2 and E were used to access the predictive power of the model while the Pe, MAE, and RMSE indicated the error in model prediction.

In this study, the model output regarding prediction for grain yield and aboveground biomass during harvest was considered for evaluation of the model. The following statistical indicators were used to compare the measured and simulated values. Model performance was evaluated using the following statistical parameters such as prediction error (Pe) and model efficiency (E) (Nash and Sutcliffe, 1970), given by:

$$\mathrm{Pe} = \frac{(\mathrm{Si}-\mathrm{Oi})}{\mathrm{Oi}} \times 100 \qquad \text{... (4)}$$

$$\mathrm{E} = 1 - \frac{\sum_{i=1}^{N}(\mathrm{Oi}-\mathrm{Si})^2}{\sum_{i=1}^{N}(\mathrm{Oi}-\overline{\mathrm{Oi}})^2} \qquad \text{... (5)}$$

Where S_i and O_i are predicted and actual (observed) data, O_i is mean value of O_i and N is the number of observations.

$$\mathrm{RMSE} = \sqrt{\frac{1}{(\mathrm{N})\sum_{i=1}^{N}(\mathrm{Oi}-\mathrm{Si})^2}} \qquad \text{... (6)}$$

$$\mathrm{MAE} = \sqrt{\sum_{i=1}^{N}\frac{(\mathrm{Si}-\mathrm{Oi})}{\mathrm{n}}} \qquad \text{... (7)}$$

Model efficiency (E) and R^2 approaching one and P_e, MAE and RMSE close to zero were indicators for better model performance.

Results and discussion

FAO-AquaCrop Model Evaluation for *Rabi* Maize

AquaCrop model was evaluated using the experimental data of 2016-17 to predict crop yield and biomass under different levels of irrigation. Grain yield and biomass were considered for model evaluation. Observed and simulated crop yield and biomass values were compared. The model evaluation was done for three level of irrigation and rainfed condition. The goodness of fit between the simulated and observed values was corroborated by using the prediction error statistics. The prediction error, coefficient of determination, mean absolute error, root mean square error and model efficiency was used as error statistics to evaluate results of model. The adopted crop parameters used in FAO-AquaCrop model to simulate maize productivity are presented in Table 3. The adopted values of canopy growth and decline coefficient were 15.4% $day^{-1}$and 9.5% day^{-1} respectively. The time from emergence sowing to flowering, senescence and maturity were 60, 142 and 161 days respectively. The maximum rooting depth was adopted as 1.8 m. The base and cutoff temperature was set to 8^0C and 30^0Crespectively. The adopted WP water productivity was obtained as 30.7 gm^{-2} which was in the range suggested for AquaCrop for C4 crops (i.e., crops produced four carbon compound oxalocethanic acid as the first stage of photosynthesis.) The harvestable yield produced by the crop was the product of biomass and harvest index. The harvesting index was obtained as 48%.

Table 3: Input data of adapted crop parameters (*Rabi* maize) used in AquaCrop

S. N.	Crop Parameters	Value	Unit
1.	Base temperature	8.0	^{0}C
2.	Cutoff temperature	30.0	^{0}C
3.	Canopy cover per seedling at 90 % emergence (CC_0)	6.5	cm^2
4.	Canopy growth coefficient (CGC)	15.4	% day^{-1}
5.	Canopy decline Coefficient at Senescence (CDC)	9.5	% day^{-1}
6.	Water productivity (WP)	30.7	gm^{-2}
7.	Reference Harvesting Index (HI_0)	48.0	%
8.	Upper threshold for canopy expansion	0.14	-
9.	Lower threshold for canopy expansion	0.72	-
10.	Leaf expansion stress coefficient curve shape	2.9	-
11.	Upper threshold for stomata closure	0.69	-
12.	Stomata stress coefficient curve shape	6.0	-
13.	Time from sowing to emergence	6	days
14.	Time from sowing to start flowering	60	days
15.	Time from sowing to start senescence	142	days
16.	Time from sowing to maturity	161	days
17.	Duration of flowering	15	days
18.	Maximum effective rooting depth	1.8	m

AquaCrop model evaluation results

The model performance about grain yield is shown in fig 1. which shows a good correlation between observed and simulated yield. It was observed from the table 4. That the highest grain yield and biomass was 11.122 t/ha and 24.92 t/ha respectively for treatment T_1 (CI). The minimum value of grain yield and biomass was 3.35 t/ha and 7.93 t/ha for treatment T_4 (Rainfed). The model simulation results grain yield and biomass was observed to be 11.37 t/ha and 25.53 t/ha respectively and the lowest grain yield and biomass was 3.03 t/ha and 7.10 t/ha respectively. The model performance of biomass is also shown in Fig 2. Which reveals a good correlation between observed and simulated yield. It was observed that the maximum and minimum error of grain yield prediction during model evaluation with the data of 2016-17 was for T_4 and T_1 treatments amounting to 9.59% and 2.2%, respectively (Table 4). Moreover, the maximum and minimum error for biomass were observed to be in T_3 and T_1 treatments with 11.84% and 2.44%, respectively. The prediction error statistics of model evaluation is shown in Table 4. It was observed from Table 5. That the model was evaluated for yield and biomass with all treatment combinations with prediction error statistics values $0.971 < E < 0.988$, $0.221 < RMSE < 0.731$, $0.987 < R^2 < 0.997$ and $0.421 < MAE < 0.806$ t ha^{-1}. The model evaluation results and the observed values of grain yield and biomass for all treatment combinations were plotted in Figs. 1. And 2., respectively. The table 4 and 5 clearly shows that FAO-AquaCrop model was more accurate in predicting grain yield under treatment T_1 (CI) compared to T_4 (Rainfed). The similar trend was observed for biomass. It was observed from the E and R^2 values that the grain yield and biomass prediction by AquaCrop model under different irrigation levels were in line with the observed values. Overall, the simulation results of AquaCrop model for grain yield and biomass of *Rabi* Maize showed a close match with the observed values under varying irrigation levels. There are several modeling evidence that AquaCrop had acceptable performance in simulating grain yield and biomass of different crops. The model has been successfully tested for grain yield and biomass of maize (Mebane *et al*. 2013; Katerji *et al*. 2013;Vila and Fereres 2012; Abedinpour *et al*. 2012; Hsiao *et al*. 2009; Heng *et al*. 2009), wheat (Andarzian *et al.* 2011), cotton (Farahani *et al*. 2009; Garcia-Vila *et al.* 2009), canola (Zeleke *et al*. 2011), sunflower(Todorovic *et al*. 2009), barley (Araya *et al*. 2010), wheat (Singh *et al*. 2013; Zhang *et al*.2013; Mkhabela and Bullock 2012), cabbage (Wellens *et al*. 2013), and tomato (Katerji *et al*. 2013). The RMSEs in this study for the grain yield and biomass are comparable with previous studies onmaize. FAO-AquaCrop studies on maize (Katerji*et al*. 2013; Heng *et al*. 2009), canola (Zeleke *et al*. 2011), and wheat (Iqbal *et al*. 2014) reported that accurate biomass and grain yield simulations have been achieved under full irrigation and mild water stress conditions, but less satisfactory simulations were observed in rainfed condition.

Table 4. Evaluated results of grain yield and biomass of *Rabi* maize under different level of irrigation

Grain yield (t/ha)				Biomass (t/ha)		
Treatments	**Observed (O_i)**	**Simulated (S_i)**	**Prediction Error (±%)P_e**	**Observed (O_i)**	**Simulated (S_i)**	**Prediction Erro (±%) P_e**
T_1 (CI)	11.12	11.37	2.25	24.92	25.53	2.44
T_2 (75% of CI)	10.98	11.37	3.54	24.65	25.52	3.52
T_3 (50% of CI)	7.61	7.99	5.13	16.49	18.44	11.84
T_4 (Rainfed)	3.35	3.03	9.59	7.93	7.10	10.44

Table 5. Prediction error statistics of the evaluation of AquaCrop model

Model output parameters	**Mean**		**Model efficiency (E)**	**RMSE**	**MAE**	**R^2**
	Observed (O_i)	**Simulated (S_i)**				
Grain yield (t/ha)	8.26	8.44	0.988	0.73	0.42	0.997
Biomass (t/ha)	18.50	19.15	0.971	0.22	0.81	0.987

Conclusion

The water driven FAO-AquaCrop model could be used to predict *Rabi* maize with acceptable accuracy under variable irrigation management situation in alluvial plains of North Bihar.

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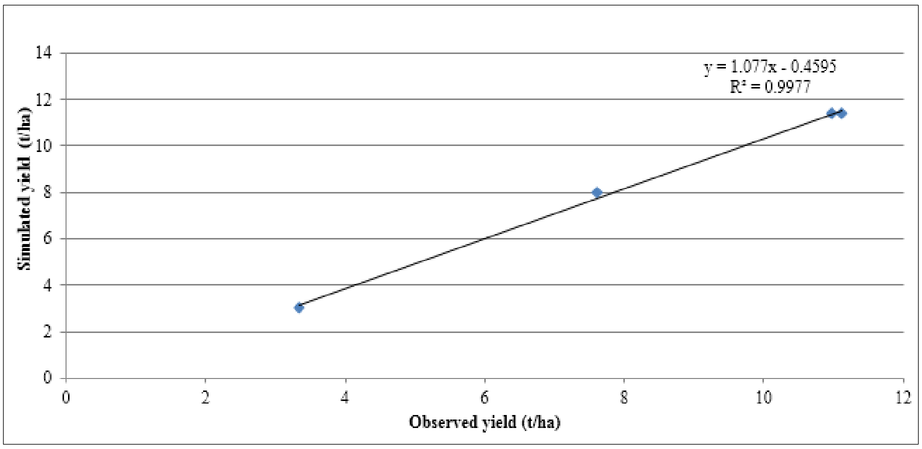

Fig 1: Model tested results for grain yield under all irrigation

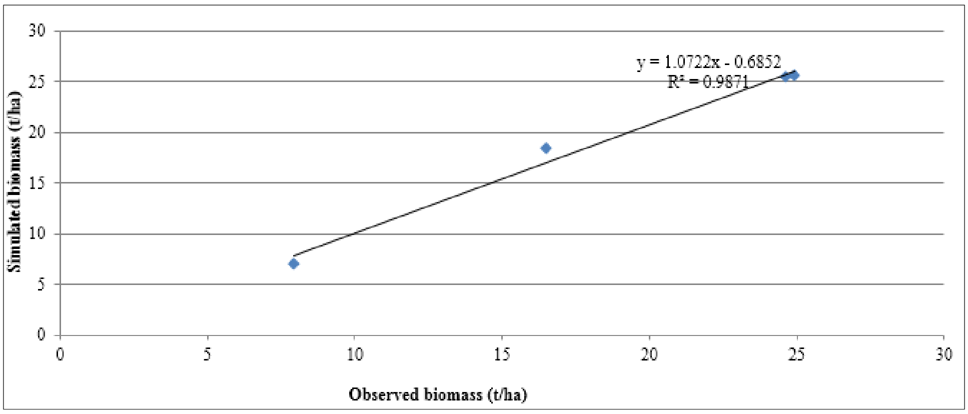

Fig 2: Model tested results for biomass under all irrigation level

References

1. Abedinpour M, Sarangi A, Rajput TBS, Singh M, Pathak H, Ahmad T. Performance evaluation of AquaCrop model for maize crop in a semi-arid. Environment, Agricultural Water Management. 2012; 110: 55-66.
2. Andarzian B, Bannayan M, Steduto P, Mazraeh H, Barati M, Barati MA *et al.* Validation and testing of the AquaCrop model under full and deficit irrigated wheat production in Iran. Agricultural Water Management. 2011; 100: 1-8.
3. Araya A, Keesstra SD, Stroosnijder L. Simulating yield response to water of Teff (*Eragrostis tef*) with FAO-AquaCrop model. Field Crops Research. 2010; 116:196-204.
4. Directorate of Economics and Statistics, Ministry of Agriculture and Farmers Welfare. 2014-15. (online) http://eands.dacnet.nic.in/
5. FAO, Hot Issues: Water Scarcity, FAO web link: http://www.fao.org/nr/water/issues/scarcity.html, 2008.
6. FAOSTAT (online) http://faostat.fao.org, 2015.
7. Farahani JH, Izzi G, Oweis YT. Parameterization and evaluation of the AquaCrop model for full and deficit irrigated cotton. Agronomy Journal (American Society of Agronomy). 2009; 101(3):469-476.
8. Hang KL, Hsiao T Evett, S Howell, T Steduto P. Validating the FAO-AquaCrop model for irrigated and water deficient field maize. Agronomy Journal (American Society of Agronomy), 2009; 101(3):488-498.
9. Hsiao TC, Heng LK, Steduto P, Rojas-Lara B, Raes D, Fereres E. AquaCrop the FAO crop model to simulate yield response to water III. Parameterization and testing for maize. Agronomy Journal (American Society of Agronomy). 2009; 101:448-459.
10. Huang Y, Chen L, Fu B, Huang Z, Gong J. The wheat yields and water-use efficiency in the Loess Plateau: straw mulch and irrigation effects. Agricultural Water Management. 2005; 72:209-222.
11. Iqbal AM, Shen Y, Stricevi R, Pei H, Sun H, Amiri E. Evaluation of the FAO-AquaCrop model for winter wheat on the North China Plain under deficit irrigation from field experiment to regional yield simulation. Agricultural Water Management. Penas, A. and Rio, S.D. 2014; 135:61-72.
12. Katerji N, Campib P, Mastrorilli M. Productivity, evapotranspiration, and water use efficiency of corn and tomato crops simulated by AquaCrop under contrasting water stress conditions in the Mediterranean region. Agricultural Water Management. 2013; 130:14-26.
13. Kumar V, hlawat IPS. Carry-over of biofertilizers and nitrogen applied to wheat (*Triticum aestivum* L.) and direct applied N in maize (*Zea mays* L.) in wheat maize crooping system. India Journal of Agronomy. 2004; 49 (4):233-236.
14. Mebane V, Day RL, Hamlett JM, Watson JE, Roth GW. Validating the FAO-AquaCrop model for rainfed maize in Pennsylvania. Agronomy Journal (American Society of Agronomy). 2013; 105(2):419-427.
15. Mkhabela MS, Bullock PR. Performance of the FAO-AquaCrop model for wheat grain yield and soil moisture simulation in Western Canada. Agricultural Water Management. 2012; 110:16-24.
16. Nash JE, Sutclifee JV. River flow forecasting through conceptual models I.A. discussion of principal. Journal of Hydrology. 1970; 10:282-290.
17. Raes D, Steduto P, Hsiao CT, Fereres E. FAO crop water productivity model to simulate yield response to water. Reference Manual, AquaCrop Version 3.1 plus, 2011, 01-21.
18. Raes D, Steduto P, Hsiao TC, Fereres E. AquaCrop - the FAO crop model to simulate yield response to water II. Main algorithms and soft ware description. Agronomy Journal (American Society of Agronomy). 2009; 10: 438-447.
19. Singh A, Saha S, Mondal S. Modelling irrigated wheat production using the FAO-AquaCrop model in West Bengal, India, for Sustainable Agriculture. Journal of Irrigation and Drainage. 2013; 62:50-56.
20. Steduto P, Albrizio R. Resource-use efficiency of field-grown sunflower, sorghum, wheat and chickpea. II. Water use efficiency and comparison with radiation use efficiency. Agricultural Meteorology. 2005; 130:269-281.
21. Steduto P, Hsiao TC, Fereres E. On the conservative behavior of biomass water productivity. Irrigation Science. 2007; 25:189-207.
22. Steduto P, Hsiao TC, Raes D, Fereres E. AquaCrop the FAO Crop model to simulate yield response to water I. concepts and underlying principles. Agronomy Journal (American Society of Agronomy). 2009; 101:426-437.
23. Tanner CB, Sinclair TR. Efficient water use in crop production: research or re-search? In: Taylor, H.M., Jordan, W.A., Sinclair, T.R. (Eds.), limitations to efficient water use in crop production, Agronomy Journal (American Society of Agronomy) Madison, 1983.
24. Todorovic M, Albrizio R, Zivotic L, Abi saab, M Stwckle C. Assessment of AquaCrop, Crop Syst and WOFOST models in the simulation of sunflower growth under

different water regimes. Agronomy Journal (American Society of Agronomy). 2009; 101:509-521.

25. Vila MG, Fereres E. Combining the simulation crop model AquaCrop with an economic model for the optimization of irrigation management at farm level. European Journal of Agronomy. 2012; 36(1):21-31.
26. Zeleke KT, Luckett D, Cowley R. Calibration and testing of the FAO-AquaCrop model for canola. Agronomy Journal (American Society of Agronomy). 2011; 103(6):1610-1618.
27. Zhang W, Liu W, Xue Q, Chen J, Han X. Evaluation of the AquaCrop model for simulating yield response of winter wheat to water on the southern Loess Plateau of China. Water Science and Technology. 2013; 68(4):821.