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## Calibration of FAO-aquacrop model for summer chilli (*Capsicum annum* L.) in Marathwada region

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### Abstract

Crop models are useful for different purposes; primarily, to interpret experimental results and as research tools for research knowledge synthesis. Lengthy and expensive field experiments, especially with a high number of treatments, can be pre-evaluated through a well-proven model. Optimum management practices, either strategic or tactic, such as planting date, cultivar selection, fertilization, or water and pesticides usage, can be assessed through proven simulation models for making seasonal or within-season decisions. The capability of AquaCrop model is tested and confirmed by various researches throughout the world. Findings of the field study were used to calibrate the AquaCrop Model for *summer* chilli in Marathwada region. Results from this study provided a set of first estimates for the calibration of the AquaCrop model on chilli for Marathwada conditions and for further testing and validation of the model at other agroclimatic conditions. AquaCrop model was calibrated by using field data of full irrigation treatment with harvesting index of 75% and water productivity 30 g/m<sup>2</sup> as there was close match between observed and simulated canopy cover with high value statistical parameter of R<sup>2</sup><sub>NS</sub> = 0.97 and CRM = -0.051. It was also cleared that the canopy cover was overestimated by model particularly during 36 to 84 DAT *i.e.* during development stage. But the scatter plot clears that as the canopy cover lie on both sides of 1:1 line, there was no consistent over or under estimation.

**Keywords:** Crop model, AquCrop, calibration

### Introduction

Simulation models are generally defined as simplification or abstraction of a real system (Loomis *et al.*, 1979) [9]. For biological systems like crops, models are composed of a number of components and processes interacting over a range of organizational levels (Sinclair and Seligman, 1996) [10]. These crop models are useful for different purposes; primarily, to interpret experimental results and as research tools for research knowledge synthesis. Lengthy and expensive field experiments, especially with a high number of treatments, can be pre-evaluated through a well-proven model (Whisler *et al.*, 1986) [10]. Optimum management practices, either strategic or tactic, such as planting date, cultivar selection, fertilization, or water and pesticides usage, can be assessed through proven simulation models for making seasonal or within-season decisions (Boote *et al.*, 1996) [4]. Other uses, such as planning and policy analysis, can benefit from modeling as well. Frequently applied crop yield models are: CropSyst, CERES, DSSAT, EPIC, CropWat, SWAP/WOFOST and AquaCrop.

Accurate crop development models are important tools in evaluating the effects of water deficits on crop yield or productivity. Food and Agricultural Organization (FAO) of United Nations addresses this need by providing a yield response to water simulation model (AquaCrop) with limited sophistication. It simulates crop yield response to water, and is particularly suited to address conditions where water is a key limiting factor in crop production. AquaCrop is developed from revision of 'FAO Irrigation and Drainage Paper No. 33 Yield Response to Water' (Doorenbos and Kassam, 1979) [5]. AquaCrop attempts to balance accuracy, simplicity, and robustness. AquaCrop is the successor of CropWat featuring new adjustment options to reproduce crop environment in more detail. The capacity of AquaCrop model in simulating the yield in response to water is proved by various researchers (Heng *et al.* 2009; Araya *et al.* 2010; Andarzian *et al.* 2011; Stricevic *et al.* 2011; Abedinpour *et al.* 2012 etc.) [6, 3, 2, 12, 1].

FAO AquaCrop is a canopy-level model which follows an engineering approach (Pasquale Steduto *et al.* 2009; Theodore C. Hsiao *et al.* 2009), simulates crop response in terms of biomass, canopy cover, and yield, to water availability in daily time steps. It considers water fluxes and generates crop responses taking into account daily transpiration. Total biomass and harvestable yield production depend on crop parameters such as water response, stomatal conductance, canopy senescence and harvest index (Pasquale Steduto *et al.* 2009).

Chilli (*Capsicum annum* L.) belongs to the *Solanaceae* family, has its unique place in the diet as a vegetable cum spice crop. Chilli is an indispensable spice due to its pungency, taste, appealing colour and flavor. It is the second largest commodity after black pepper (*Piper nigrum* L.) in the international spice trade. *Capsicum* spp. contain a range of essential nutrients and bioactive compounds which are known to exhibit antioxidant, antimicrobial, antiviral, anti-inflammatory and anticancer properties (Khan *et al.*, 2014)<sup>[8]</sup>. India is the largest producer, consumer and exporter of chilli, which contribute to 25 per cent of total world's production. In India, chilli is grown in almost all the states across the length and breadth of the country.

The capability of AquaCrop model is tested and confirmed by various researches throughout the world. There is a need to calibrate and validate the AquaCrop for local regions for optimizing water productivity of Chilli under different irrigation and fertigation level.

## Materials and Methods

### Brief description of model

AquaCrop model is based on crop growth engine which is basically water driven, in which, the crop growth and production are driven by the amount of water used through consumptive use. The complexity of crop responses to water deficits led to the use of empirical production functions as the most practical option to assess crop yield response to water.

AquaCrop has a structure that includes the soil, with its water balance; the plant, with its development, growth and yield processes; and the atmosphere, with its thermal regime, rainfall, evaporative demand and carbon dioxide concentration. Additionally, some management aspects are explicitly considered (*e.g.*, irrigation, fertilization, *etc.*), as they will affect the soil water balance, crop development and therefore final yield. Pests, diseases, and weeds are not considered. AquaCrop version 6.0 was used in the study.

### Data collection and input data preparation

AquaCrop model has a structure that overarches soil-plant-atmosphere continuum. For assessing crop water productivity of irrigated chilli, AquaCrop requires following data which were collected and processed as per requirement of model.

### Weather data

Weather data for the period 10<sup>th</sup> January 2018 to 10<sup>th</sup> May 2018, was obtained from Agro-meteorological Observatory, ARS, Badnapur and Phule Jal app. It comprised of maximum and minimum temperature (°C), mean daily relative humidity (%), daily sunshine hours (hr.), wind speed (ms<sup>-1</sup>), rainfall (mm) and evaporation (mmday<sup>-1</sup>).

### Crop data

Crop-specific parameters required by AquaCrop model are plant density, yield, biomass, harvest index (HI), effective rooting depth, crop growth stages and green canopy cover

(CC), while required user-specific parameters are crop cultivar, timing of crop cycle, water management and agronomic practices. The data was obtained from the field experiment "Impact of Irrigation and Fertigation Levels on Growth, Yield and Quality of *Summer Chilli (Capsicum annum* L.)" conducted during the period 10<sup>th</sup> January 2018 to 10<sup>th</sup> May 2018.

### Soil Data

The soil data obtained from the physic-chemical analysis of soil samples of experimental plots were used to characterize the soil.

### Model setup

The model was setup using create file menus. Using these menus input files for new climate, crop, irrigation management, soil profile, groundwater and field data were created.

### Climate file

Climate file consists of creating a temperature file, ETo file, rain file and CO<sub>2</sub> file. While creating ETo, rain or temperature file, frequency or interval of data (daily, 10-daily or monthly data) and time range was specified.

### Crop file

While creating a crop file, type of crop (fruit/grain producing crops, leafy vegetable crops, roots and tubers, or forage crops) and parameters such as planting method, cropping period and length of growing cycle were specified. With the help of this information AquaCrop generates a complete set of required crop parameters such as seedling emergence, duration of the various physiological periods from sowing date and harvesting date. Plant population was based on the recommended plant spacing for the site. The parameters were displayed and the values can be adjusted in the crop characteristics menu.

### Soil profile file

To create a soil profile file, soil characteristics *viz.* soil type, number of horizons and their thickness were specified. With the help of this information AquaCrop generates a complete set of soil profile parameters. The parameters were displayed and the values can be adjusted in the soil profile characteristics menu.

### Irrigation file

Type of irrigation file was specified first from the following list

- I. Net irrigation water requirement
- II. Irrigation schedule
- III. Generation of irrigation schedule

Subsequently in accordance to irrigation file specified, the following required information was also specified:

- a) The allowable depletion when determining the net irrigation requirement.
- b) The time, application depth and the irrigation water quality of the successive irrigation events.
- c) The irrigation water quality, time and depth criteria to generate irrigation events.

### Groundwater file

While creating groundwater file, type of file (from listed below) was specified first.

- I. Constant depth and water quality or
- II. Variable depth or water quality.

Subsequently, the depth and quality of the groundwater for various moments (if variable) in the season were specified in the groundwater characteristics menu.

#### Field data file

When creating a field data file, the observed green canopy cover (CC) on particular dates as obtained from field experiment data, was specified in the Field Data menu.

#### Calibration of AquaCrop model

The data of field experiment conducted during the period 10<sup>th</sup> January 2018 to 10<sup>th</sup> May 2018, was used for calibration of the model. The model was calibrated by varying following parameters manually:

- i. Harvest index
- ii. Water productivity (WP<sub>b</sub>)

#### Result and Discussion

##### Calibration of AquaCrop model

AquaCrop model was calibrated for the period 10<sup>th</sup> January 2018 to 10<sup>th</sup> May 2018 *i.e.* crop period, using field data for full irrigation treatment I<sub>4</sub>= Drip irrigation at 100 % of ETC. AquaCrop was calibrated manually by varying model parameters. The modeling parameters were derived from a default crop of tomato and modified for chilli. These parameters included canopy cover growth and canopy decline coefficient; crop coefficient for transpiration at full canopy; water productivity (WP); soil water depletion thresholds for inhibition of leaf growth, stomata conductance and acceleration of canopy senescence; and coefficients for adjusting the harvest index (HI) in relation to inhibition of leaf growth and stomata conductance. These parameters are presumed to be applicable to a wide range of conditions and not specific for a given crop cultivar. The crop characteristics required by the model were adjusted for the studied cultivar using measured data based mainly on green canopy cover. In crop simulation models, calibration was necessary to estimate the model parameter values for different crops, cultivars and ecosystems. Model calibration helps in reducing the parameter uncertainty. The performance of model was judged by comparing observed values of yield of chilli with simulated outputs. The performance of model was discussed in the following sections.

- AquaCrop model was set up as per procedure and by providing initial values for the following parameters

**Table 1:** Conservative and cultivar specific parameters

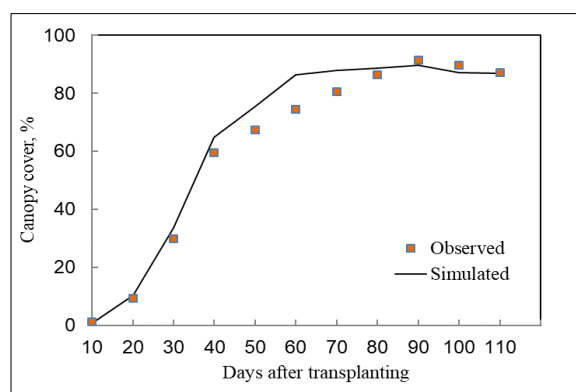
Description	Value
Base temperature, °C	4
Upper temperature, °C	43
Crop type	Fruit producing crop
Date of transplanting	10-01-2018
Date of harvesting	09-05-2018
Growing cycle, days	120

#### Canopy cover

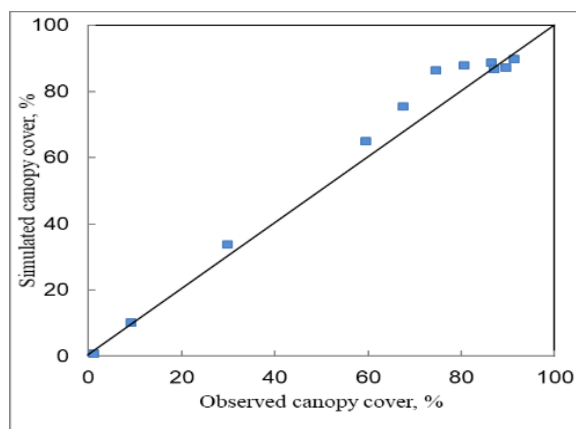
Canopy parameters *i.e.* initial canopy cover, canopy size of transplanted seedling, number of days to recover; maximum canopy cover and canopy cover decline etc. were adjusted manually during the calibration process. Table 2 presents the observed and simulated canopy cover.

**Table 2:** Observed and simulated canopy cover during calibration

Day after transplanting	Canopy cover	
	Observed	Simulated
10	1.09	0.8
20	9.2	10.2
30	29.8	33.6
40	59.6	64.9
50	67.5	75.4
60	74.5	86.4
70	80.6	87.8
80	86.4	88.7
90	91.4	89.8
100	89.6	87.2
110	87.1	86.8
R <sup>2</sup> <sub>NS</sub>	0.97	
CRM	-0.051	



**Fig 1:** Observed and simulated canopy cover for calibration period



**Fig 2:** Comparison between observed and simulated canopy cover for calibration period

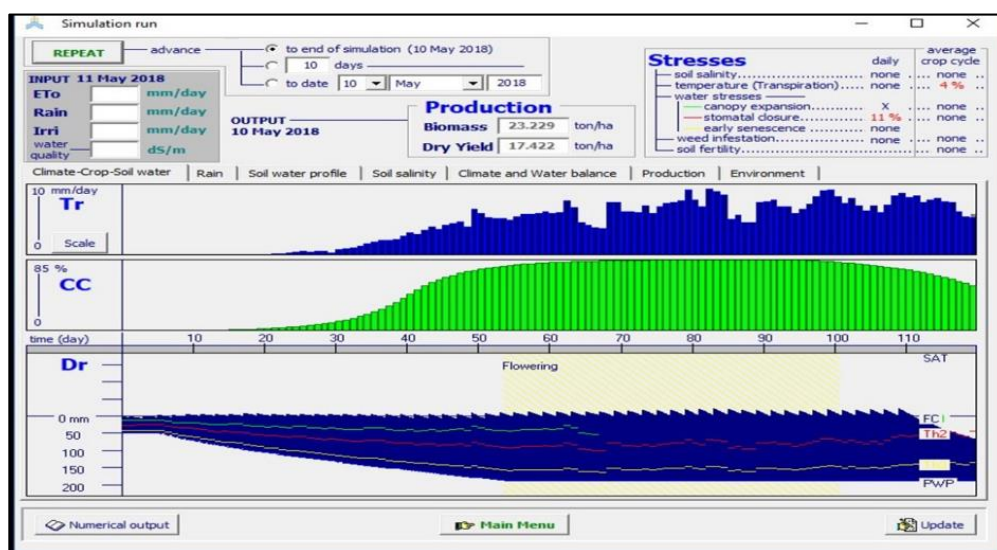
Temporal variation of observed and simulated canopy cover is presented in Fig. 1, while Fig. 2 shows comparison of observed and simulated canopy cover. Figure 1 indicates that there was close match between observed and simulated canopy cover. It was supported by high value of R<sup>2</sup><sub>NS</sub> (0.97). Another statistical parameter *i.e.* CRM having value as -0.051, indicates that the model overestimates the canopy cover. From Fig. 2 it was cleared that the canopy cover was overestimated by model particularly during 36 to 84 DAT *i.e.* during development stage. But the scatter plot clears that as the canopy cover lie on both sides of 1:1 line, there is no consistent over or under estimation.

#### Yield of chilli

After adjusting the canopy, for matching biomass, harvesting index and water productivity were varied manually.

**Table 3:** Cumulative observed and simulated yield

S. No.	Treatments	Observed Yield, $\text{tha}^{-1}$	Simulated Yield, $\text{tha}^{-1}$
1	I <sub>5</sub> = Drip irrigation at 100 % of ET <sub>c</sub>	17.02	17.42

**Fig 3:** Model generated transpiration, canopy cover and soil moisture in the root zone for drip irrigation at 1.0 ET<sub>c</sub> (I<sub>4</sub> for 2017-18): Calibration period

Model generated transpiration, canopy cover and soil moisture in the root zone for drip irrigation at 1.0 ET<sub>c</sub> (I<sub>4</sub> for 2017-18): for Calibration period was depicted in Fig. 3. It indicates that soil moisture in the rootzone was at field capacity throughout the crop growing period. Throughout the crop period soil moisture was within available water capacity. The transpiration need and canopy cover were found to be well matched. Chilli yield was observed as 17.02  $\text{tha}^{-1}$  for calibration period. For harvesting index of 75% and water productivity 30  $\text{g/m}^2$ , the model predicted yield was 17.42  $\text{tha}^{-1}$ .

Above results showed that the model calibration was satisfactory as the observed and simulated values of canopy cover and chilli yield matched well. Also  $R^2_{NS}$  and CRM statistics were acceptable. Hence, the AquaCrop model setup was considered as calibrated. Calibrated model parameters are presented in Table 4.

**Table 4:** Calibrated model parameters

Description	Measure
A) Canopy cover	
Initial canopy cover (CC <sub>0</sub> ), %	0.49
Mode of planting	Transplant
Canopy size of transplanted seedling, $\text{cm}^2\text{plant}^{-1}$	15.0
Maximum canopy cover, %	85
Plant density, $\text{plantha}^{-1}$	3.3
Canopy decline	Very slow
Day 1 to recovery, days	7
Day 1 to maximum canopy, days	65
Senescence, days	95
Root system	
Maximum effective depth, m	0.5
B) Harvesting index, %	
	75
C) Water productivity (WP <sub>b</sub> ), $\text{gm}^{-2}$	
	30

## Conclusion

Results from this study provided a set of first estimates for the calibration of the AquaCrop model on chilli for Marathwada conditions and for further testing and validation of the model at other agroclimatic conditions. AquaCrop model was

calibrated by using field data of full irrigation treatment with harvesting index of 75% and water productivity 30  $\text{g/m}^2$  as there was close match between observed and simulated canopy cover with high value statistical parameter of  $R^2_{NS} = 0.97$  and CRM = -0.051. It was also cleared that the canopy cover was overestimated by model particularly during 36 to 84 DAT *i.e.* during development stage. But the scatter plot clears that as the canopy cover lie on both sides of 1:1 line, there was no consistent over or under estimation.

## References

1. Abedinpour M, Sarangi A, Rajput TBS, Singh Man, 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 A, Bannayan M, Steduto P, Mazraeh H, Barati ME, 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, Habtu S, Hadgu KM, Kebede A, Dejene T. Test of AquaCrop model in simulating biomass and yield of water deficient and irrigated barley (*Hordeum vulgare*). *Agricultural Water Management*. 2010; 97:1838-1846.
4. Boote KJ, Jones JW, Pickering NB. Potential uses and limitations of crop models. *Agron. Journal*. 1996; 88:704-716.
5. Doorenbos J, Kassam AH, Bentvelsen CIM. Yield response to water, Rome. Food and Agriculture Organization of the United Nations, 1979.
6. Heng LK, Hsiao T, Evett S, Howell T, Steduto P. Validating the FAO AquaCrop Model for Irrigated and Water Deficient Field Maize. *Agron. Journal*. 2009; 101:488-498.
7. Hsiao TC, Heng L, 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. *Agron. Journal*. 2009; 101:448-459.

8. Khan MA, Asghar MA, Iqbal J, Ahmed A, Shamsuddin ZA. Aflatoxins contamination and prevention in red chillies (*Capsicum annuum* L.) in Pakistan. Food Additives & Contaminants., Part B. 2014; 7(1):1-6.
9. Loomis RS, Rabbinge R, Ng E. Explanatory models in crop physiology. Annu. Rev. Plant Physiol. 1979; 30:339-367.
10. Sinclair TR, Seligman NG. Crop modeling: from infancy to maturity. Agron. J. 1996; 88:698 -704.
11. 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. 2009; 101(3):426-437.
12. Stricevic R, Cosic M, Djurovic N, Pejic B, Maksimovic L. Assessment of the FAO AquaCrop model in the simulation of rainfed and supplementally irrigated maize, sugar beet and sunflower. Agricultural Water Management. 2011; 98:1615-162.
13. Whisler FD, Acock B, Bbaker DN, Fye RE, Hodges HF, Lambert JR *et al.* Crop simulation models in agronomic systems. Adv. Agron. Journal. 1986; 40:141-208.