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Original article

Evaluation of AquaCrop model for estimating of changes process of soil moisture, evapotranspiration and yield of maize under salinity and fertility stresses

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Extended abstract

Introduction

In the presence of environmental stresses such as salinity and fertility stresses, water and nutrients less absorbed by the plant. Despite the stresses of salinity and nitrogen deficiency (fertility stress), the determination of the actual water requirement of plants with the AquaCrop model, will be important. Therefore, the aim of this research was to evaluate the AquaCrop model for estimating the soil moisture, evapotranspiration and yield of maize, under the salinity and fertility stresses.

Materials and methods

In this research, two treatments of water salinity and nitrogen deficiency in four levels and three replications, with a control plot, were implemented as a factorial experiment in a randomized complete of block design. The studied plant was maize with cultivar of 704 Sc and was planted in plots with dimensions of 3 × 3 meters and 1.5 meters apart. In this plan, fertility stress was in the form of nitrogen fertilizer consumption and at four levels. Treatments of N0, N1, N2 and N3 consisted of consumption of 100, 75, 50 and 25% of nitrogen fertilizer based on fertilizer recommendation, respectively. Salinity stress has been applied by irrigation of the plant with saline water. Water salinity treatments were selected based on yield potential of maize at four levels of 100, 90, 75 and 50% (3). According to the above four performance levels, treatments of S0, S1, S2 and S3 were included; irrigation water with electric conductivity of 0.5, 1.2, 3.5 and 7.5 ($ds.m^{-1}$) respectively. Determining the irrigation time, was the same as the moisture content reached the RAW (Readily Available Water) level. Between the two irrigation intervals, the stomatal resistance of maize leaf, was measured by the AP4 prometer device. At the same time as increasing stomatal resistance, RAW was calculated and plots were irrigated. In the days of between two irrigation, was measured the soil moisture content of the plots at the depth of root development. The daily evapotranspiration of the plant, was calculated based on the amount of daily water depletion. For optimal calibration of parameters in the AquaCrop model, was used the method of Generalized Likelihood Uncertainty Estimation (GLUE). Among 16 treatments, 8 treatments were randomly selected for calibration and the rest were selected for validation.

Results and discussion

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Results were obtained for evaluating the AquaCrop model at the validation stage. The root mean square error (RMSE) of soil moisture simulation, varied from 1.43 to 2.6%. The normalized error value (NRMSE) ranged from 4 to 6 percent. The AquaCrop model showed a similar trend in the evapotranspiration simulation. The root mean square error (RMSE) of evapotranspiration simulation, varied from 1.85 to 2.35 mm. The normalized error value (NRMSE) ranged from 3.5 to 4.5 percent. For yield simulation, RMSE was 0.34 t ha^{-1} and NRMSE was 0.65%. The value of the R^2, EF, and d statistics showed a good correlation between the data and the optimal efficiency of the modeling. Therefore, the results showed that the performance of the model was good in estimating the parameters.

Conclusions

Evaluating the capability of the models is a great help to the agricultural sector planners, in estimation the parameters. In this research, evaluated the estimation of soil moisture content, evapotranspiration and yield of maize, under salinity and fertility stresses with AquaCrop model. The purpose of the model calibration was to nearing the simulated data to the real data (measured in the region). The obtained amounts for NRMSE and R^2 were less than 10% and greater than 0.9, respectively, which indicated the optimal performance of the model in this regard.

Keywords: Calibration and validation of crop model; Soil nitrogen; Water requirement; Water salinity

Table 1. Results of soil chemical analysis, before planting

Soil depth (cm)	Organic carbon (%)	Total nitrogen (%)	Absorbable phosphorus (ppm)	Absorbable potassium (ppm)	Electrical conductivity of soil (dS/m)	Soil acidity (PH)
0-30	0.06	0.06	4	288	0.33	7.4
30-60	0.09	0.1	1	60	0.35	7.46

Table 2. Results of soil Physical analysis, before planting

Soil depth (cm)	Soil texture	Clay (%)	Silt (%)	Sand (%)	Bulk density (gr/cm^3)	Moisture content at FC (%)	Moisture content at PWP (%)	Hydraulic conductivity (m/day)
0-30	Sandy Loam	10	33	57	1.33	23	14	0.6
30-60	Sandy Loam	8	24.5	67.5	1.41	22	13.5	0.6

Table 3. Calibration of maize parameters in the AquaCrop model

Parameter	Unit	Parameter value	Calibration method
Base growth temperature	℃	10	Default
Upper temperature	℃	30	Default
Seed density	plant/ha	80000	Was measured
Seed germination time	day	6	Was measured
Initial canopy cover	%	1	Was calibrated
Ratio of crown surface to plant number	cm^2/ plant	12.5	Was measured
Time to reach maximum canopy cover	day	60	Was measured
Flowering time	day	64	Was measured
Maturity time	day	80	Was measured
Maximum canopy cover	%	85	Was calibrated
The most effective root depth	cm	60	Was measured
Normalized water productivity	g/m^2	35	Was calibrated
Plant transpiration coefficient for complete cover	-	1.15	Was calibrated
Water depletion fraction (lower limit)	-	0.6	Was calibrated
Water depletion fraction (upper limit)	-	0.3	Was calibrated
Reference Harvest Index	-	55	Was calibrated
Lower limit of Sensitivity to salinity stress	dS/m	2	Default
Upper limit of Sensitivity to salinity stress	dS/m	8	Default

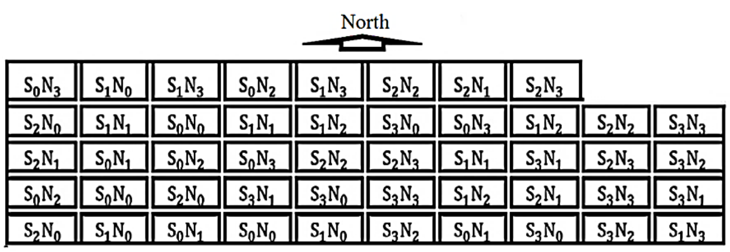

Fig. 1. Network of treatment in the field

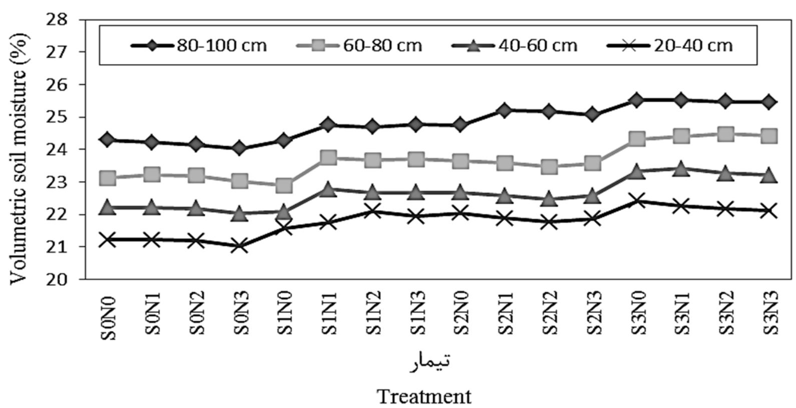

Fig. 2. Moisture changes in different layers of soil profile

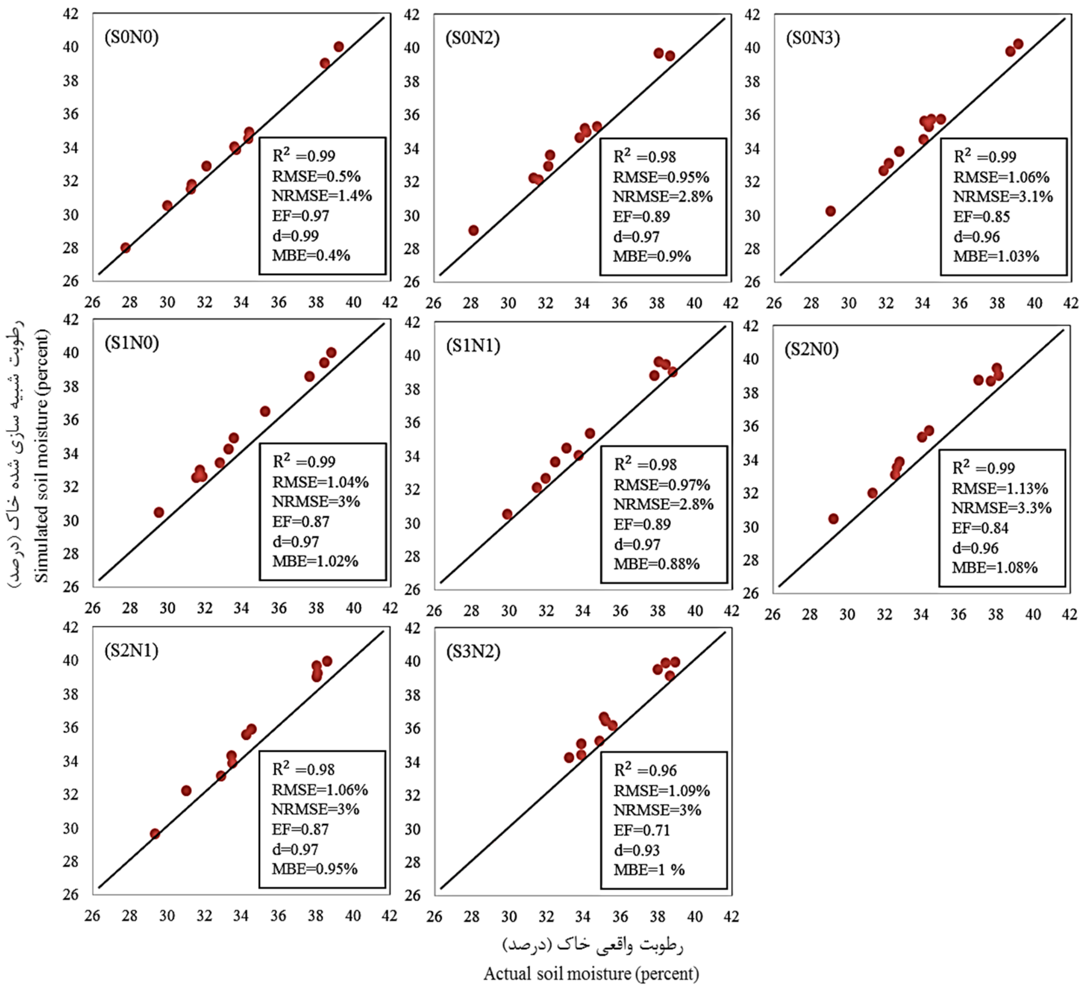

Fig. 3. Calibration of AquaCrop model for estimation of soil moisture

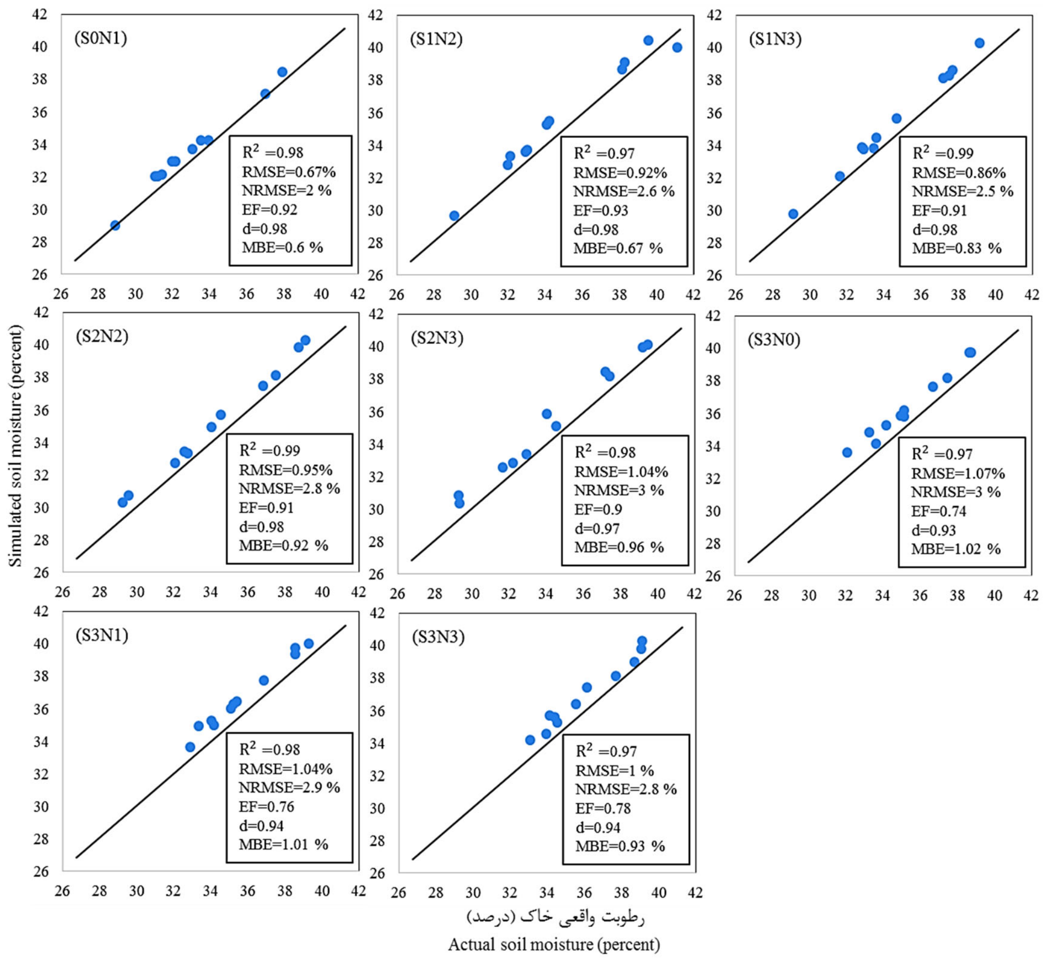

Fig. 4. Evaluating of AquaCrop model in estimation of soil moisture (Validation)

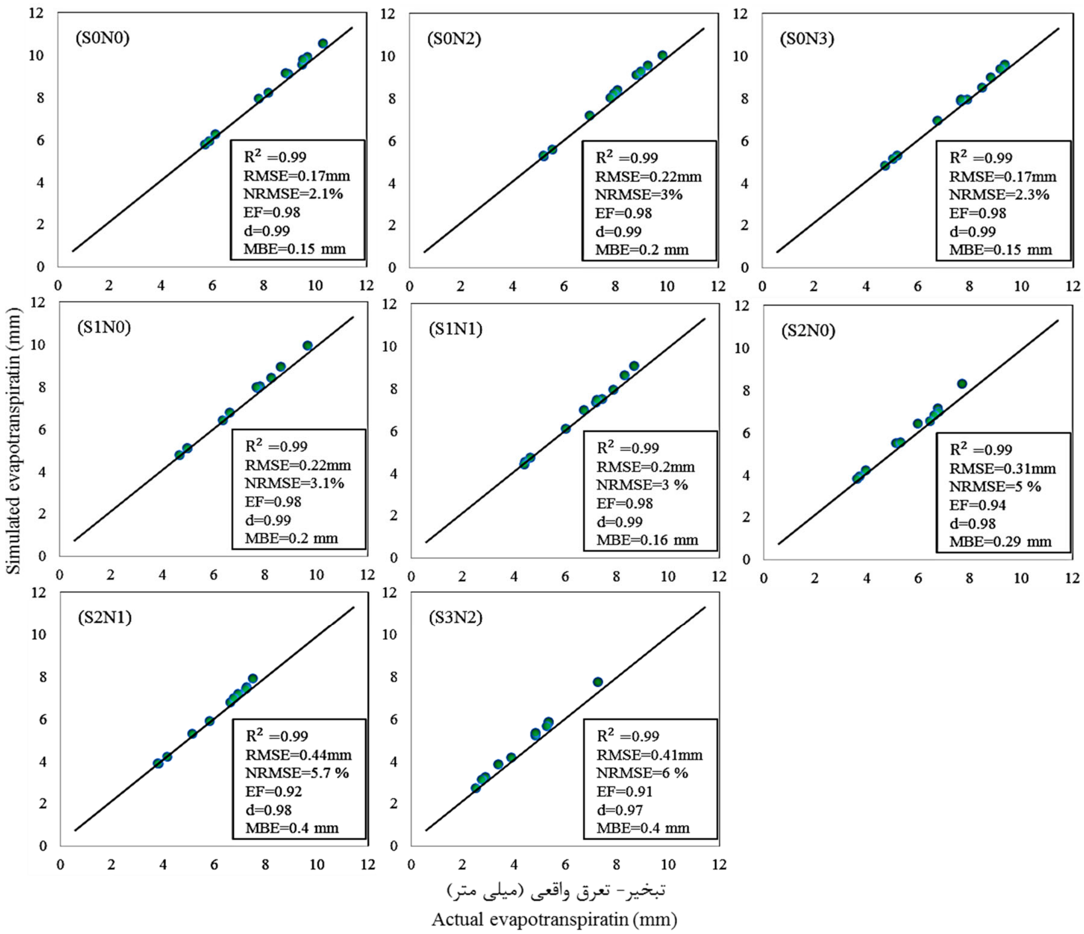

Fig. 5. Calibration of AquaCrop model for estimation of maize evapotranspiration

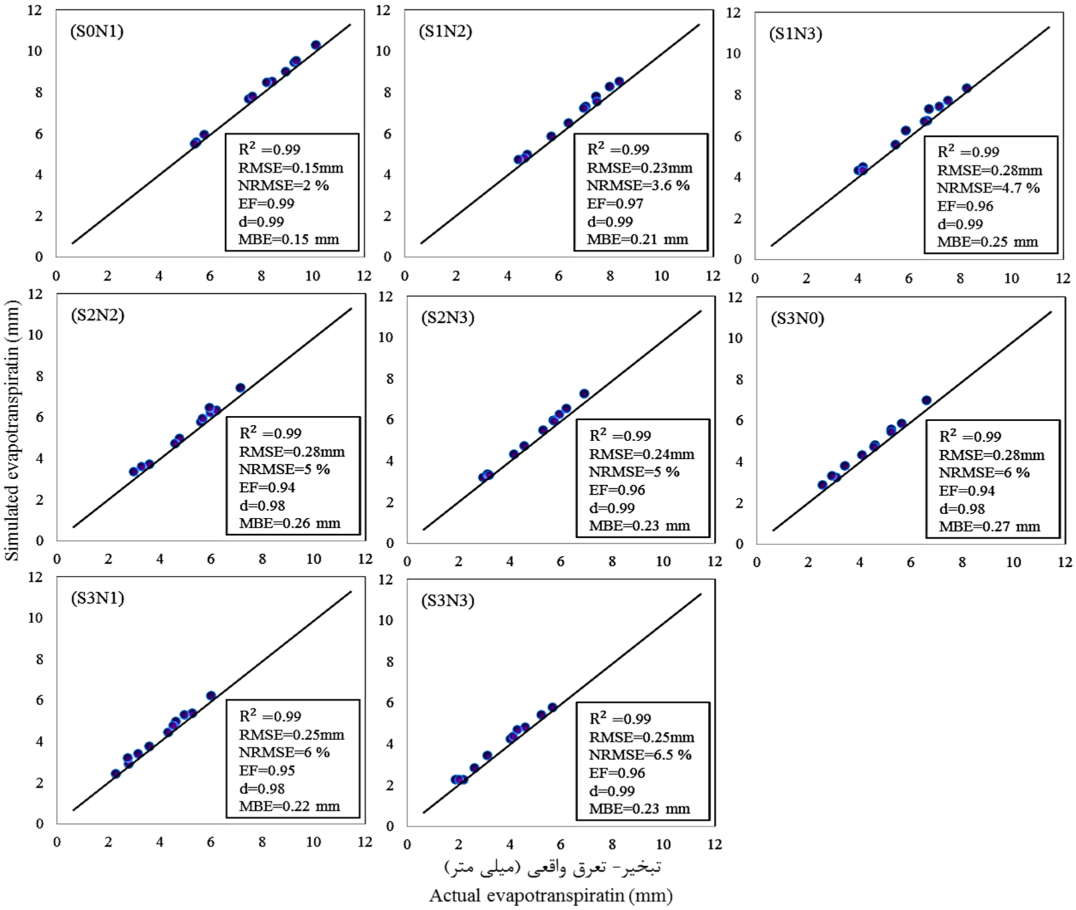

Fig. 6. Evaluating of AquaCrop model in estimation of maize evapotranspiration (Validation)

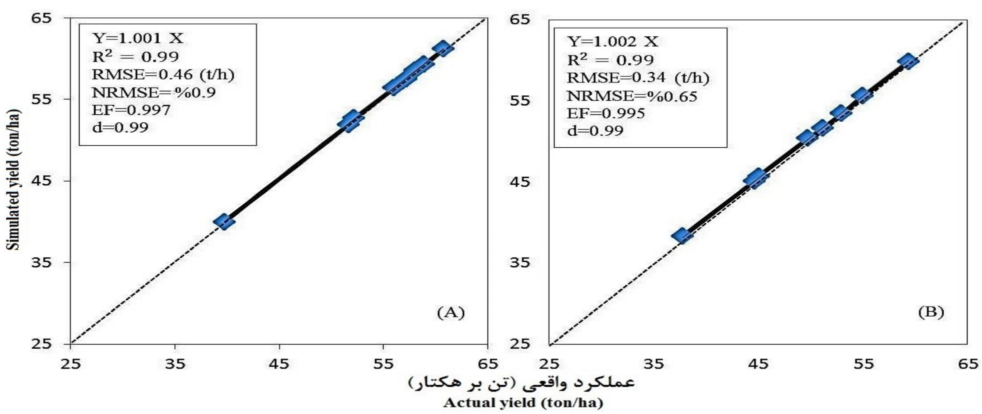

Fig. 7. Comparing the actual yield of maize relative to the simulated yield with AquaCrop model, calibration (A) and validation (B)