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Performance Assessment of the Fao Aquacrop Model for Maize Yield, Biomass and Water Productivity Along the River Nile, Egypt

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ABSTRACT

Different three maize field experiments represent the main agro ecological zones (Sakha, Giza and Qena), including full and deficit irrigation, were conducted in Egypt along the river Nile. The last updated version of AquaCrop model was evaluated with maize yield and water productivity under different irrigation water treatments (1.2, 1, 0.8 and 0.6 from actual evapotranspiration ET_c). The model was evaluated after parameterization using field observations relative to canopy cover (CC), total biomass and yield data as well as using conservative parameters. The treatments show highly agreement between measured and simulated values of CC except the highest severe irrigation treatment (I4). The determination coefficients are higher (R^2>60), thus indicating that the CC model explains significantly the variance of observed CC values. Also, estimated errors are then small, with RMSE ranging between (0.3 to 13%), and d varying between 0.6 and 0.98. Also, the agreement between simulated and observed maize grain yield, final biomass and water productivity were good with R^2, RMSE and d. Results cleared that the model is considered a good decision support tool for exploring irrigation management and maize production in Egypt. Nevertheless, the model showed slightly uncertainty specially under sever deficit irrigation. It is supposed that, AquaCrop would be useful if it included some calibrated parameters about root distribution system in soil, because it is a water driven model and relies mainly on soil water balance and uptake.

Keywords: Water driven model, uncertainty, deficit irrigation, calibrated parameters

INTRODUCTION

Actually, maize (*Zea Mays, L.*) is considered the world's third most important crop especially with rapid population increase, as it can integrate with wheat in decreasing the world decline of food security. Maize is a summer crop in Egypt, it is important to natural economy because it is using as a source of human food and feed as well. In Egypt maize production has significantly increased over the past three decades. The cultivated area of maize in 2015 was about 800.000 ha with an average productivity equal 7.5 ton ha^{-1} (Sameha, 2016). Selecting the best irrigation water scheduling is necessary to improve crop yield and water productivity, that approach implies appropriate prediction of yield relating to water.

Recently, demand for maize is increasing because its importance in producing ethanol as biofuel, being a stable food in many countries as well as its using as a feed for livestock in the form of forage, silage or grain. The strong demand is putting high pressure on production, hence, competition for available water. Improving the WP for maize production is therefore of paramount importance to obtain "more crop per drop" specially with limited worldwide water resources and impacts of temperature due to climate change (Heng *et al*.2009).

Simulation models that quantify the effects of irrigation deficit on yield production at the farm level could be used as a valuable tool in agriculture and water management, (Homayoun far *et al*.,2014 and Singh 2014). In case of maize, many models were tested in this regard, for example, CERES-Maize model (Jones and Kiniry,1986), the Muchow-Sindair-Bennett (MSB)model (Muchow *et al*.,1990),EPIC phase model (Cavero *et al*.,2000), CROPSYST (Stockle *et al*., 2003), and the Hybrid-Maize model (Yang *et al*.,2004). However, most of these models are quite sophisticated, demanding advanced skills for their calibration and mode of operation, as well as requiring large number of parameters; some are so cultivar-specific they are not easily measured or allowed to the end users.

The recent version of FAO AquaCrop model (Raes *et al*.,2012; Steduto *et al*., 2012) is a user friendly and easy to use in high accuracy and robustness, in addition it requires a relatively small number of parameters. AquaCrop has been tested well in different locations on the world (Hsiao *et al*., 2009) and showed a good fitness on simulating CC, biomass development, and grain yield of different cultivars of maize. Also, respecting irrigation management and crop response to deficit irrigation, AquaCrop has been evaluated and parameterized globally (Heng *et al*., 2009; Todorovic *et al*.,2009; Araya *et al*.,2010 a,b; Garcia-Vila and Fereres. 2012; Khoshravesh *et al*., 2013), to enhance the scheduling of deficit irrigation (Andarzian *et al*., 2011; Parades *et al*.,2014), to assess increasing of crop production responding to agricultural field management (Shrestha *et al*., 2013; Mhizha *et al*.2014), to evaluate and assess the impacts of climate change on crop yield production (Vanuytrecht *et al*.,2014b) as well as evaluating the water quality on crop yield (Kumar *et al*.,2014).

There are three main factors that distinguish AquaCrop from other models such as the crop water use emphasis, using CC instead of LAI, and separation of evapotranspiration into soil evaporation and plant transpiration in the frame work of soil water balance in root zone and normalized water productivity (Steduto *et al*., 2009).

However, AquaCrop model is recommended for modeling adaptive agriculture water management for simulating maize production in most semi- arid areas of the world (Nyakudyaa and Stroonsnijder, 2014; Ahmadi *et al*., 2015). Nevertheless, AquaCrop has limited study on crop production in Egypt. Therefore, the main goal of this study is to evaluate the latest updated version of Aqua Crop model (v.5.0) to improve maize yield via irrigation levels along the river Nile of Egypt. The detailed objectives were : (1) to calibrate and validate the model in different agroecological sites in Egypy.,(2) investigate the model fitness with yield, water productivity under different quantities of irrigation levels.

MATERIALS AND METHODS

Study locations:

Three field locations were established along the River Nile from North delta to upper Egypt in order to include different agro ecological conditions in Egypt. The field experiments were conducted in 2014 and 2015 growing summer seasons in Sakha (31˚09′ E, 31˚01′ N, 6 m above sea level), Giza (31˚02′ E, 30˚ 0′ N, 22.5 m above sea level), and Qena at south (32˚ 07′ E, 26˚ 01′ N, 72.6 m above sea level),Fig.1. The sites are representative of the various soil and climate conditions in Egypt, where the first location in North delta and near to Mediterranean Sea climate, the second location in Middle Egypt, while the last location in the south of Egypt where high temperature and low relative humidity.

Layout and management practices:

The experimental layout at each site was a randomized complete block design (RCD) with four replications. Maize cultivar single cross (c.v. SC.10), developed by maize research sector in Egypt and planted on May,15, 2014 and 2015 in different sites. Four irrigation treatments by furrow method were conducted. Seeds were sown in plots having 8 rows each 20 m long, and on furrows 0.75 m apart at a depth of 0.07 m. The crop density of 70.000 plant ha^{-1} was achieved after thinning in both years, which is considered the common and standard density in the region according to the recommendations of Ministry of Agriculture and Land Reclamation in Egypt. Maize plants were harvested at different dates due to the temperature variation from North to South for different locations. So, the harvested days noticed on October 15, October,10 and September,25 for Sakha, Giza and Qena respectively. Maize total biomass and grain yield were harvested over on 10 m long length from the middle of the fourth row (middle row) of each plot. Plots received about 300 kg ha^{-1} nitrogen as ammonia gas injection, and 45 kg ha^{-1} phosphorus as calcium phosphate before planting based on the recommended dose for the region (FAO, 2005). Observed values of CC were derived from LAI as reported by Hsiao *et al*. (2009) as follows:

$$CC = 100.5\left[1 - \exp\left(-0.60\ LAI\right)\right]^{1.2} \qquad (1)$$

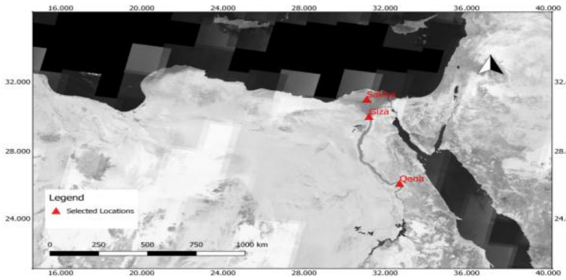

Fig 1. The selected study locations along the River Nile.

Four irrigation treatments were used as a part of actual evapotranspiration (ETc) in each site as I_1,I_2,I_3 and I_4 in both years. Such symbols represent irrigation with 1.2, 1.0, 0.8, and 0.6 from ETc respectively. Irrigation scheduling was controlled and governed by measuring (SWC) of the root zone by Time Domain Reflectometry (TDR), (Scott *et al*.,2002). Irrigation timing was fixed as irrigation at 50 % depletion from soil available water, while irrigation water quantities for each treatment were added under control according to previous treatments using cutthroat flume (20 × 90 cm), (Early, 1975).

Meteorological and soil data:

At each location, automated weather stations were installed to monitor and record daily data of air temperature, wind speed, relative humidity and solar radiation through the growing season (from sowing to maturity). Data in Fig. 2 show the daily maximum temperature, minimum temperature, and solar radiation for both 2014 and 2015 growing seasons under different studied locations. Reference evapotranspiration (ETo) was calculated using the FAO Penman-Monteith equation as described by (Allen *et al*., 1998), Fig.3.

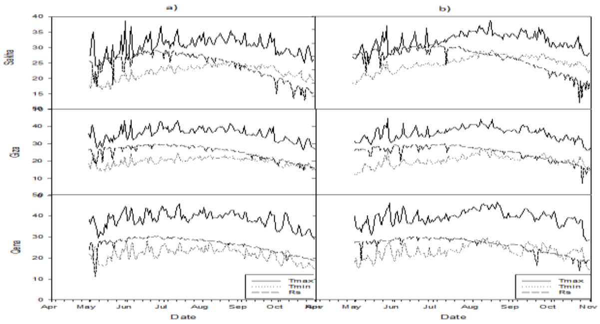

Fig 2. Daily weather data of maximum, minimum temperature (C°) and solar radiation (MJ m^{-2}day^{-1}) for different locations during the growing seasons a) 2014 and b)2015.

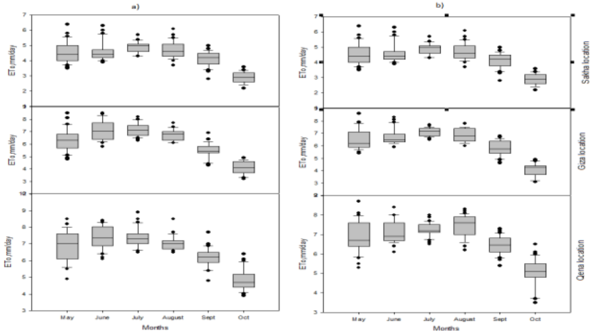

Fig 3. Daily values of potential evapotranspiration for maize in Sakha, Giza and Qena during a) 2014 and b) 2015 growing seasons.

Table 1. Selected soil hydraulic properties for the selected studied locations

Soil layer(m)	θ fc(m^3m^{-3})			θ wp(m^3m^{-3})			θ sat(m^3m^{-3})			Ksat(cm d^{-1})		
	Sakha	**Giza**	**Qena**	**Sakha**	**Giza**	**Qena**	**Sakha**	**Giza**	**Qena**	**Sakha**	**Giza**	**Qena**
0.00-0.10	0.42	0.39	0.37	0.22	0.18	0.16	0.61	0.51	0.44	9.5	10.5	11.7
0.10-0.20	0.42	0.39	0.36	0.21	0.18	0.15	0.61	0.52	0.43	9.3	10.8	11.6
0.20-0.40	0.41	0.38	0.35	0.22	0.17	0.14	0.62	0.50	0.42	9.1	10.0	11.5
0.40-0.60	0.43	0.37	0.35	0.21	0.16	0.14	0.62	0.49	0.41	9.0	9.80	11.2
0.60-0.80	0.43	0.37	0.34	0.21	0.16	0.13	0.60	0.49	0.40	8.8	9.90	11.0
0.80-100	0.42	0.38	0.35	0.22	0.17	0.14	0.60	0.50	0.42	8.7	9.70	10.8

Soil water content was measured to a depth of 100 cm using profile TDR model PICO-T3P, it can measure accurately and quickly as well. In AquaCrop, the soil profile can be divided into five different horizons, each of them with their own physical properties such as, moisture at saturation, field capacity, permanent wilting point and saturated hydraulic conductivity, (Raes *et al*., 2009). In this study, soil profile (0-100 cm) data for each site and depth are shown in Table 1. Water applied quantities with irrigation intervals are detailed in the scheduling irrigation Table 2.

Table 2. Irrigation water scheduling as an average of the two growing seasons for different locations.

Irrigation Treatments	Sakha			Giza			Qena		
	Date	**Intervals (days)**	**Applied water mm**	**Date**	**Intervals (days)**	**Applied water mm**	**Date**	**Intervals (days)**	**Applied water mm**
I1	May,15	-	120	May,15	-	130	May,15	-	140
	May,31	16	105	May,28	13	115	May,26	11	120
	June,17	17	108	June,15	18	120	June,12	17	135
	June,30	13	110	June,27	12	115	June,25	13	125
	July,18	18	105	July,15	18	110	July,18	23	120
	Aug,18	31	100	Aug,16	32	105			110
Total applied water			648			695			750
I2	May,15	-	120	May,15	-	130	May,15	-	140
	May,31	15	85	May,29	14	105	May,25	10	120
	June,15	15	90	June,13	15	110	June,10	15	115
	June,30	15	95	June,28	15	108	June,18	8	100
	July,15	15	85	July,13	15	107	July,5	27	115
	July,30	15	80	July,28	15	60	July,16	11	100
	Aug,15	16	70	Aug,13	15	55			
Total applied water			625			675			690
I3	May,15	-	120	May,15	-	130	May,15	-	140
	May,31	15	60	May,28	13	85	May,25	10	105
	June,10	10	65	June,8	11	80	June,3	9	105
	June,25	15	70	June,22	10	90	June,15	13	85
	July,8	13	67	July,5	13	95	June,20	5	80
	July,15	7	60	July,12	7	60	June,30	10	85
	July,30	15	55	July,25	13	54	July,15	15	80
	Aug,10	11	45	Aug,7	12	50			
Total applied water			542			644			680
I4	May,15	-	120	May,15	-	130	May,15	-	140
	May,28	13	55	May,25	10	80	May,22	7	85
	June,10	13	50	June,5	11	75	June,2	11	98
	June,18	8	59	June,12	7	85	June,8	6	90
	June,28	10	54	June,22	10	90	June,14	6	80
	July,10	12	60	July,5	13	60	June,20	6	65
	July,20	10	50	July,15	10	50	June,30	10	55
	July,30	10	45	July,28	13	40	July,12	12	50
	Aug,8	8	40						
Total applied water			533			610			663
Total of total applied water, mm			2348			2634			2783

FAO AquaCrop description:

The general background and concepts of the model was detailed by (Steduto *et al*., 2012 and Raes *et al*., 2012). The last updated version of AquaCrop model (version 5.0, October 2015) has been used and evaluated in the current study. AquaCrop has four sub-model components: (i) Soil moisture balance; (ii) The crop production enhancement; (iii) The required climatic data(e.g T, Rainfall, ET_o and CO_2) and (iv) The management option (Raes *et al*.,2012). The model inputs as described by (Raes *et al*.,2012) includes:

(1) Daily weather data for T (C°), rainfall, mm, ETo, mm, and annual CO_2,ppm.

(2) Crop data regarding to : (i) Emergency dates, time to reach maximum canopy cover, the attained maximum root depth, time for starting senescence, time to maturity and dates of flowering starts and ends; (ii)The maximum value of transpiration crop coefficient($K_cT_{r,x}$); (iii) Minimum and maximum root depths and root expansion shape factor; (iv) The initial and maximum canopy cover(CCo, CCx), canopy growth coefficient(CGC), and canopy decline coefficient (CDC); (v) adjustment biomass water productivity (BWP*); (vi) reference harvest index (HI_o); (vii) water stress coefficients related to canopy expansion.

(3) Soil data including different layers

(4) Scheduling of irrigation water, both dates and depths of observed irrigation events.

(5) Field management practices referring to salinity, fertility, mulching and run off reduction practices.

Model assessment "goodness – of – fit":

AquaCrop model uses a big number of parameters with several conservative, ones that are expected to change little with time, location or management and were described by Raes *et al*.,(2012). The dates of 2014 and 2015 were used for calibration and validation, respectively. Because crop yield is affected directly by actual evapotranspiration (Doorenbos and Kassam,1979), the model calibration using crop yields provide more confidence in dividing water between actual evapotranspiration and soil storage (Faramarzi *et al*.,2009). The calibrated parameters were primarily adjusted against grain yield and biomass and finally were fine-tuned against soil water content. Calibration process was started with I_1 (1.2 ETc) in the first location (Sakha), then with the other treatments and sites in order to match well parameters applicable for full and deficit irrigation treatments. After finishing the calibration, validation parameters were used without changing the calibrated features. Table 3 describe the summary of the final parameters set in the model. The "goodness-of-fit" of the model was assessed using different statistical indicators as detailed in previous studies (Raes *et al*.,2012; Paredes *et al*.,2014) based on R^2, RMSE, NRMSE, EF and d. Among of these indicators are a determination coefficient (R^2),RMSE and d which could be calculated as follow:

$$R^2 = \frac{\sum_{i=1}^{n}(O_i - \overline{O}) \cdot (S_i - \overline{S})}{\sum_{i=1}^{n}(O_i - \overline{O})^2 \cdot \sum_{i=1}^{n}(S_i - \overline{S})^2} \qquad \textbf{(2)}$$

Table 3. List of calibrated parameters of AquaCrop model for maize in Egypt

Calibrated parameters	**Values under different locations**					
	Sakha		**Giza**		**Qena**	
	2014	**2015**	**2014**	**2015**	**2014**	**2015**
Reference harvest index,%	0.57	0.57	0.52	0.52	0.49	0.48
Plant density, plants ha^{-1}	66000	66000	70000	70000	73000	72000
Time to maximum canopy cover, day	65	66	62	61	58	57
Time to flowering, day	65	66	62	60	57	56
Length of the flowering stage, day	12	11	9	8	7	6
Time to senescence, day	111	110	109	108	103	102
Time to maturity, day	145	145	140	139	130	129
Maximum effective rooting depth, m	1.0	0.98	1.1	1.0	1.3	1.3
Minimum effective rooting depth, m	0.3	0.3	0.4	0.4	0.5	0.5
Shape factor for effective rooting depth	1.2	1.3	1.2	1.1	1.2	1.0

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(O-S)^2}{n}} \qquad \textbf{(3)}$$

$$\mathrm{d} = 1 - \left[\frac{\sum_{i=1}^{n}(Si - Oi)^2}{\sum_{i=1}^{n}(|Si - \overline{O}| + |O - \overline{O}|)^2} \right] \qquad \textbf{(4)}$$

Where n, S, O, $\overline{O}$ and $\overline{S}$ are the number of measurements, simulated, observed, mean observed and mean simulated respectively. R^2 is the relationship measure between both datasets and describes the proportion of the total variance in the observed data that can be explained by the model. It ranges between 0 and 1, with higher values referring to better simulations. Nevertheless, (Loague and Green,1991) reported that these statistics are sensitive to a few errors especially in case of small data sets. RMSE gives the weighted variations in residual error between observed and simulated values. The degree of agreement (Willmott index,d) is a descriptive indicator and has values ranging between 0 and 1, Willmott,(1982). The higher the d value the better the model performance. The d statistic is better than R^2 for testing and evaluating the simulation of soil water, Lgates and McCabe(1999).

RESULTS AND DISCUSSION

Canopy Cover:

As well-known previously, that the most suitable parameterization of CC curve is a major requisite for the model to lead to good estimates of soil evaporation, crop transpiration and biomass, hence good predictions for yield. However, this need is not known by model developers (Hsiao *et al*.,2009; Heng *et al*.,2009; Raes *et al*.,2012) or other authors. The average observed CC plotted against AquaCrop simulations under different levels of irrigation water for both two growing seasons and three locations are shown in Figs 4, 5 and 6. AquaCrop was able to simulate accurately the CC development in different locations and with different irrigation water treatments. However, the good agreement between observed and simulated CC, there is slightly underestimation was noticed in the three locations with deficit irrigation, I4 (0.6 ET_c).

The "goodness-of-fit" indicators for CC curves are presented in Table 4. Except the highest severe irrigation treatment (I4), the other treatments show highly agreement between measured and simulated values of CC. The determination coefficients are higher (R^2>60), thus indicating that the CC model explains significantly the variance of observed CC values. Also, estimated errors are then small, with RMSE ranging between (0.3 to 13%), and d varying between 0.6 and 0.98. The RMSE values obtained with calibration are in the range or lower than those described by (Hsiao *et al*.,2009), with RMSE ranging from 4.8 to 13.6. These results, Table 4 show the necessary for a good calibration of CC curve in order to reach the accurate results.

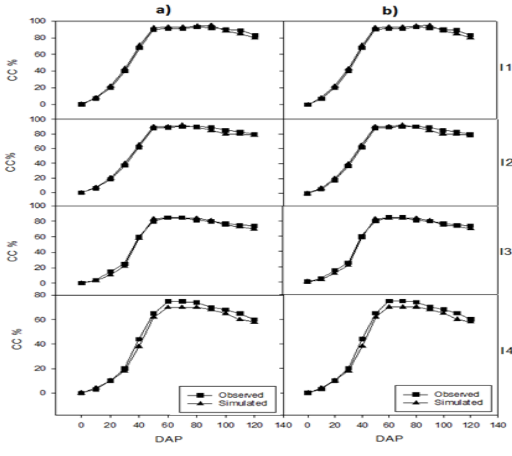

Fig 4. Simulated and observed values of maize canopy cover under different treatments of irrigation levels during a) the first growing season 2014 and b) the second growing season 2015 in Sakha location (DAP, days after planting ,days).

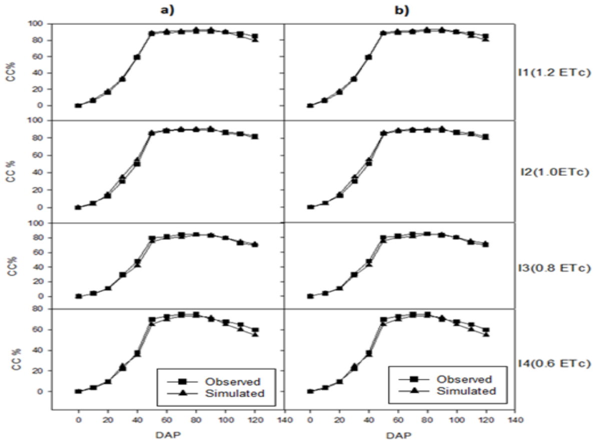

Fig 5. Simulated and observed values of maize canopy cover under different treatments of irrigation levels during a) the first growing season 2014 and b) the second growing season 2015 in Giza location.

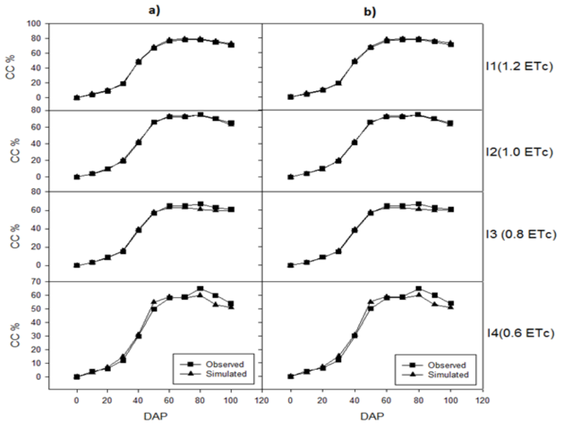

Fig 6. Simulated and observed values of maize canopy cover under different treatments of irrigation levels during a) the first growing season 2014 and b) the second growing season 2015 in Qena location.

Table 4. Statistical indicators relative to canopy cover for maize under different locations, growing seasons and irrigation treatments.

Growing seasons	Irrigation Treatments	CC %					
		Sakha		Giza		Qena	
		Observed	Simulated	Observed	Simulated	Observed	Simulated
2014	I1	64.7	64.4	61.8	62.2	47.5	49.4
	I2	61.7	61.2	58.7	57.8	45.1	45.4
	I3	58.7	56.9	54.5	53.5	41.7	40.7
	I4	45.3	46.5	50.2	47.8	37.6	35.9
2015	I1	65.6	66.5	63.5	63.8	47.7	48.6
	I2	62.8	62.8	60.9	61.8	44.9	44.7
	I3	57.0	56.0	56.2	55.0	40.3	39.2
	I4	48.4	45.6	48.5	46.5	36.2	35.6
Statistical indicators	R2	0.99		0.99		0.98	
	RMSE	1.35		1.32		1.2	
	d	0.99		0.98		0.98	

Final grain yield, total biomass and water productivity:

The main strategic and economic organs of different crops are grain yield, total biomass and water productivity in which the models are aimed at achieving high acceptance simulations. Data in Figs 7, and 8 show simulated and observed values of maize grain yield, and total biomass for different studied locations and two growing seasons. It was indicated that simulated and observed values of maize grain yield and total biomass decreased with deficit irrigation. Also, Sakha location achieved the highest values of grain yield and total biomass followed by the other studied locations Giza and Qena respectively. This decline in yield is mainly due to increasing temperature accompanied with deficit irrigation, as well as increasing soil fertility and clay content in Sakha location as compared with other locations. Deficit irrigation of maize should be avoided during the different following stages in maize, the flowering stage (tasseling), the stage of cob formation, the late vegetative stage (Farre and Faci,2009; Geerts and Raes,2009). However, in the current study deficit irrigation treatments (I3 and I4) were implemented through the growing season, the yield and total biomass did not affect sharply. The lowest yield with the highest deficit irrigation I4 was ranging from 6200 to 7000 kg ha^{-1} for different locations. I attributed this to two main reasons. The first is soil texture (clay texture) as well as the level of soil water table which ranged from 0.4 to 0.8 m below soil surface through the growing season. Ground water contributed to crop water requirements and hence decreased the drought effect of high deficit irrigation treatments T3 and T4. Investigating the potential of ground water contribution to crop water requirements may be helpful in reducing water demand from the river (Yilwo and Sophocleous,2010).

Actually, the model achieved low uncertainity with grain and biological yield,Figs 7 and 8 and Table 4 show the performance of Aquarop in simulating total biomass and grain yield for all locations and two growing seasons. The R^2 and d values of grain yield and and biomass simulation periods ranged from 0.83 to 0.99 in Sakha, and from 0.75 to 0.99 in case of Giza location and finally, in Qena location such values constrained between 0.89 to 0.99. Such values meaning excellent agreement of the model in predicting grain yield and biomass under deficit irrigation along the river Nile. Similar results of simulated AquaCrop for maize grain yield and biomass under full and deficit irrigation were reported by Paredes *et al*.,2014 ; Ahmadi *et al*.,2015. There are different modeling studies resulted that AquaCrop model had a good performance in simulating maize yield and biomass as well, Heng *et al*.,2009; Hsiao *et al*.,2009; Abedinpour *et al*.,2012; Garcia-Vila and Fereres 2012; Katerji *et al*.,2013; Mebane *et al*.,2013; Saad *et al*.,2014). Table 4 shows also that RMSE values in total biomass were lower and ranged between 3.4 and10.1. The RMSE values according to Heng *et al*.,2009 for low irrigation are larger.

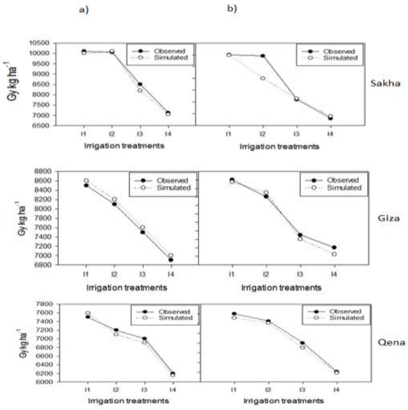

Fig 7. Simulated and observed values of maize grain yield in different locations through both 2014 and 2015 growing seasons.

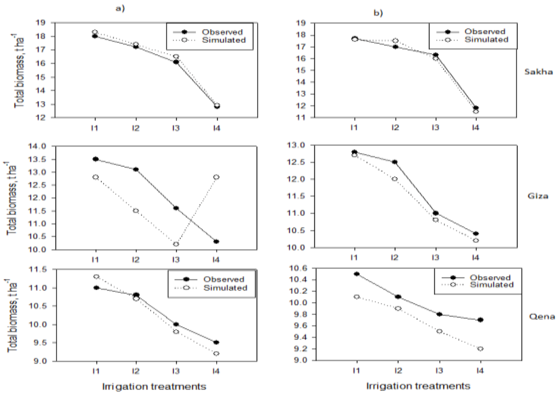

Fig 8. Simulated and observed values of above ground biomass in different locations through both a) 2014 and b) 2015 growing seasons.

As mentioned before in Fig. 3, that ET values were larger in season 2015 specially in Qena location. Therefore, values of WP were lower in location and also in the second growing season. This may be attributed to climate variation in this season as compared with the first growing season 2014. The simulated and observed values of water productivity for all irrigation treatments and two growing seasons and three study locations were plotted in Fig.9. The highest value of WP was achieved under I_2 treatment. These results were similar with those obtained by Di Paolo and Rinaldi.,2008. They reported that irrigation at about 0.75 – 0.80 of full irrigation maximized WP of maize in a Mediterranean environment.

Statistical indicators of model evaluation were detailed in Table 5. Overall, it was noticed from R^2,RMSE and d values that WP predictions for all irrigation treatments, two growing seasons and three locations were in line with observed data. It was also noticed that AquaCrop is a water driven model, and assessment of production simulation depends on the simulation of soil water dynamic. (Lynch,2011) reported that root characters are specific cultivars and are considered the key below ground traits for accurate root water uptake, which are currently missing in AquaCrop (V.5.0). Therefore, we recommend with including more inputs of root growth calibrations in the next updated version of AquaCrop.

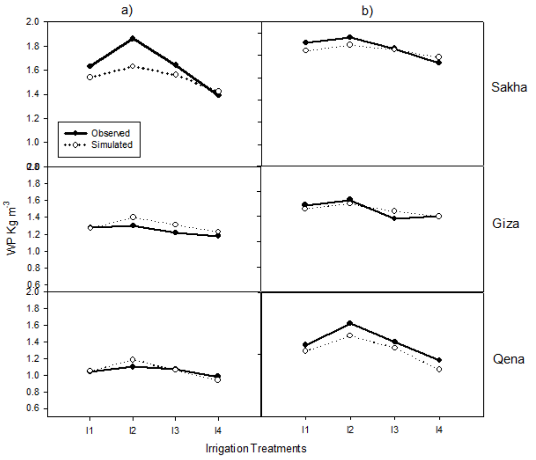

Fig 9. Simulated and observed values of WP in different locations through both a) 2014 and b) 2015 growing seasons.

Table 5. Statistical indicators relative to grain yield, total biomass and water productivity for maize under different locations, growing seasons and irrigation treatments.

Goodness of fit indicators	Gy kg ha⁻¹ Sakha	Gy kg ha⁻¹ Giza	Gy kg ha⁻¹ Qena	Total biomass,t ha⁻¹ Sakha	Total biomass,t ha⁻¹ Giza	Total biomass,t ha⁻¹ Qena	WP kg m⁻³ Sakha	WP kg m⁻³ Giza	WP kg m⁻³ Qena
R^2	0.99	0.85	0.86	0.88	0.89	0.85	0.92	0.90	0.89
RMSE	71.1	153.6	179.1	3.5	3.6	4.1	3.5	4.1	6.3
d	0.98	0.86	0.85	0.85	0.83	0.80	0.88	0.90	0.85

In this connection, some of previous studies suggested to improve AquaCrop efficiency by including more cultivar specific information for root data. Similar to this statements and with respect to sensitivity analysis, Vanuytrecht *et al*., (2014) declared that, the parameters characterizing crop responses to water stress were not usually among those showing the highest sensitivity whereas certain and soil parameters were in fluently under different conditions.

CONCLUSIONS

Three maize field experiments were implemented during the two growing seasons of 2014 and 2015 to calibrate and evaluate the latest version of FAO AquaCrop model (v 5.0) along the river Nile in Egypt. In-season canopy cover, biological yield and water productivity using four levels of irrigation including high and low quantities from actual evapotranspiration showed a high agreement of model efficiency. Overall, the agreement between simulated and observed maize canopy, grain yield, final biomass and water productivity were good with R^2, RMSE and d.

Respecting the simplicity and small number of parameters in AquaCrop compared to other different crop models, we can conclude that, the calibrated model (V 5.0) could be used as a decision support tool for a wide range of predicting maize yield, water productivity and water management strategies under water-saving irrigation management in the arid and semi-arid regions of Egypt. Nevertheless, the model performance has to be calibrated, validated and fine-tuned under a wide range of crops in Egypt. Also, we recommend with calibrating other models in this area such as IXIM-Maize and CERES-Maize along with Aquacrop. Multi-models help in decreasing uncertainty specially under deficit irrigation conditions.

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تقييم اداء برنامج الفاو اكواكروب لانتاجيه محصول الذره والمحصول البيولوجى وانتاجيه وحده المياه على امتداد نهر النيل بمصر

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اقيمت ثلاث تجارب حقليه تمثل ثلاث مناطق مناخيه زراعيه مختلفه على امتداد نهر النيل وتشمل معاملات رى مختلفه . تم استخدام احدث اصدار من برنامج الاكواكروب للتنبؤ بانتاجيه محصول الذره وكذا انتاجيه وحده المياه تحت معاملات رى مختلفه وهى (١,٢ و ١ و ٠.٨ وايضا ٠.٦ من البخر نتح الفعلى). تم تقييم البرنامج من خلال استخدام البيانات الحقليه من الغطاء النباتى والمحصول البيولوجى ومحصول الحبوب وذلك باجراء معايره واختبار صلاحيه البرنامج. وقد اوضحت النتائج التوافق الجيد بين القيم الحقليه والنظريه (مخرجات البرنامج) وذلك مع الغطاء النباتى عدا معامله الرى الاخيره (٠.٦) حيث ان قيمه معامل التقدير R^2 كانت اقل من ٦٠ % ، جذر متوسط مربع الخطأ تراوحت قيمه بين ٠.٣ الى ١٣ % وايضا معامل التوافق كانت قيمه بين ٠.٦ و ٠.٩٨ . وفى هذا السياق ايضا اوضحت هذه القيم توافق جيد بين القيم الحقليه والنظريه من البرنامج وذلك لانتاجيه الذره والمحصول البيولوجى وكذا انتاجيه وحده المياه. وعلى الرغم من ان هذا البرنامج يحتاج تعديل طفيف لتحسين التنبؤ بانتاجيه المحصول خصوصا تحت ظروف ندره المياه والاجهاد المائى العالى فى المراحل المتاخره من نمو المحصول ، اوضحت النتائج ان هذا البرنامج يعتبر اداه دعم قرار جيده فى مجال اداره المياه والرى ونمو محصول الذره فى مصر. ايضا من المفترض ان يكون هذا البرنامج جيد جدا لو انه تم اضافه بعض المقاييس المعايره الخاصه ب توزيع الجذور فى التربه لانه برنامج مائى ويعتمد اساسا على امتصاص الماء من التربه وهذه توصيتنا تجاه هذا الموديل.