Journal of Soil Sciences and Agricultural Engineering

Journal homepage: www.jssae.mans.edu.eg
Available online at: www.jssae.journals.ekb.eg

A Comparison Assessment of Measuring Evapotranspiration in Egypt

Fatma El Zahraa T. Ahmed[1]; Z. E. Ismail[1*]; W. H. Abou El Hassan[2] and M. M. Ibrahim[1]

[1] Agricultural Engineering Department, Faculty of Agricultural, AL Mansoura University.
[2] Water Management Research Institute, National Water Research Center, Egypt.

Cross Mark

ABSTRACT

Scarce water resources management makes accurate measurements of different parameters of water requirements very critical. Therefore, the values for crop evapotranspiration and crop water requirement are identical. Crop water requirements refer to the amount of water that is needed to be supplied efficiently. Therefore, there are many models and tools which were used in this study are used in this study as a practical tool to calculate actual evapotranspiration such as the CROPWAT model. Moreover, Eddy Covariance and ET-Watch model are methods used to estimate evapotranspiration. The main goal of the study was to assess daily and decadal actual evapotranspiration using Eddy covariance and ET-Watch model under arid land conditions then compare results with CROPWAT model result. Egypt was used as an example. Results showed that Eddy covariance ETa values for both crops were lower than ETa values from CROPWAT, while ET-Watch values were somewhat close to CROPWAT values. For cotton, the intercept of the linear relationship for daily ETa were 1.737 and 2.15, respectively between Eddy covariance and CROPWAT. For decadal ETa were ١،٩١, ٢،٠٣٩ ETWatch and CROPWAT. While for wheat crop, the intercept of the linear relationship for daily ETa were 1.09 and 0.663, respectively between Eddy covariance and CROPWAT, ETWatch and CROPWAT. For decadal ETa were 1.101 and 0.69. Its highly recommended to use ETWatch when predicting daily ETa, while for decadal ETa both Eddy covariance and ETWatch could be used with no big differences.

***Keywords*:** Evapotranspiration, Eddy Covariance, CROPWAT, ET-Watch Egypt

INTRODUCTION

Evapotranspiration (ET) is a collective term used to characterize water removal from earth's surface into the atmosphere by the combination of evaporation and transpiration mechanisms Liou and Kar (2014). These two mechanisms occur simultaneously and the distinction between the two phases cannot be rendered easily Allen *et al.* (1998). The FAO Penman–Monteith (FAO-PM) method is suggested as the main reference evapotranspiration (ETo) method based on meteorological data Allen *et al.* (1998); Todorovic *et al.* (2013). In many regions and climates the FAO method was shown to be capable of providing consistent ETo values and it was long accepted worldwide as a good ETo estimator compared to other approaches, particularly in daily calculations Temesgen *et al.* (2005); Xing *et al.* (2008). The evapotranspiration can be calculated either directly with weighting lysimeters or with a technique of eddy correlation or indirectly with the use of surface energy balance Farahani *et al.* (2007). Ragab *et al.* (2017) reported that the actual crop water requirement based on modern technologies could save at least 50% of irrigation water. Another benefit is that these modern technologies do not need the crop coefficient Kc, which for many irrigation practitioners is difficult to obtain. Eddy Covariance (EC) method have been commonly used since the 1990s to measure the biosphere exchange of energy, gases and water vapor Hassan and Bourque (2006). Burba (2013) said that Eddy Covariance is one of the most precise and defensible methods to calculating emission of different gases and water vapor over scales ranging from few hundreds to millions of square meters. Eddy covariance is useful to quantify fluxes since the technique provides direct measuring over a canopy ranging from a few meters to several hundred meters, and calculations on a time scale from hours to years can be made Baldocchi (2014).

Classic methods for the measurement of evapotranspiration (ET) such as Eddy covariance are possible in the field scale, but do not qualify for estimated when interacting with large scales Courault *et al.* (2005).

Remote sensors easily acquire the broad spectrum of regional and global targets knowledge to enable data modeling and recovery of different ecological indicators. Therefore remote sensing has become an essential ecological monitoring approach, especially at a wide or global level Li *et al.* (2020). Courault *et al.* (2005) specify four types of remote sensing models based on empirical direct methods, residual methods of the energy budget, deterministic methods and vegetation index methods. Liou and Kar (2014) outlined various ET models (algorithms) for remote sensing based on Surface Energy Balance approach and mentioned out its input parameters, main assumptions, merits and demerits, these models were Surface Energy Balance Index (SEBI), Surface Energy Balance System (SEBS), Simplified Surface Energy Balance Index (S-SEBI), Surface Energy Balance Algorithm for Land (SEBAL), Mapping Evapotranspiration at High Resolution and with Internalized Calibration (METRIC) and Two-Source Models (TSM). Wu *et al.* (2008) created remote sensing ETWatch detection system which is a chain that begins from pre-processing data to applications items, using spatial information on climatic data, soil type, land usage,

*** Corresponding author.**
E-mail address: ebrahimzi@yahoo.com
DOI: 10.21608/jssae.2021.188651

cover of vegetation, digital elevation, and remotely sensing factors for the land surface. ETWatch is an integration of the ''Residue Approach'' and Penman Monteith (P–M). The energy balance model, is computed from spectral radiances in the cloudless atmosphere. For the first time outside China, the ETWatch model was developed in Egypt in 2017 by El-Shirbeny *et al.* (2018).

To optimize water productivity, the main goal of the study is to find out the best methodology that can be applied for accurate measurement of evapotranspiration. Then comparing ET predictions from these methods with ET calculated from CROPWAT. Eddy covariance (EC) and the MODIS ET product using ETWatch model was verified at Zankalon site at Sharqia, Egypt.

MATERIALS AND METHODS

Study area

The study area was allocated in Zankalon Water Requirements Experimental Station. It is in the eastern part of the Nile Delta, Sharkia Governorate, Egypt. The site is located at 30° 35' N and 31° 30' E with an elevation of about 7 meters above sea level. Cotton was selected (summer crop from 1 May 2014 to 16 October 2014) and wheat (winter crop from 1 December 2014 to 10 May 2015).

Climate data used in this study were based on mainly daily meteorological data including Maximum and Minimum Temperature, Humidity, and Wind speed for years 2014 and 2015 from the automatic weather station in Zankalon weather station, Sharkia Governorate, Egypt. Sunshine hour and rainfall data from (Worldweatheronline) web site.

The soil type in the study area belongs to heavy clay class according to Atta (2007), table (1) describe some soil physical and chemical properties.

Table 1. Some soil physical and chemical properties of the study area, Atta (2007)

Depth (cm)	Particle size (%)				Texture	Bulk density ($gm./cm^3$)	Field capacity (%)	Wilting point (%)	Available water (%)	E.C (dS /m)	pH
	Sand	Silt	Clay	Remainder							
0-15	25.80	28.90	43.51	1.79	clay	1.25	43.51	23.55	19.96	1.40	8.1
15-30	25.12	30.10	42.50	2.28		1.27	40.50	21.06	19.44	1.22	8.0
30-45	26.90	31.50	40.50	1.10		1.32	37.12	17.59	19.53	1.25	8.1
45-60	29.78	31.50	37.12	1.60		1.40	36.25	16.62	19.63	1.05	8.02
Average	26.90	30.50	40.91	1.69		1.32	39.34	11.65	19.64	1.23	8.03

Tested methods

The chosen methods for this study were CROPWAT using (Penman–Monteith equation), Eddy covariance method, and ETWatch model as follow:

CROPWAT model with (P-M) equation

Smith (1992) developed FAO-CROPWAT 8.0 which is a Computer Program for Irrigation Planning and Management. It can calculate Reference evapotranspiration, Crop water requirements, and Crop irrigation requirements. It allows to improving irrigation practices, the planning of irrigation schedules under varying water supply conditions, and the assessment of crop production under rain conditions or deficit irrigation.

$$\mathbf{ETo} = \frac{0.408\Delta(R_n - G) + \gamma\frac{900}{T+273}u_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \qquad \mathbf{1}$$

Where;

ETo = reference evapotranspiration (mm day^{-1}),
Rn = net radiation at the crop surface (MJ m^{-2} day^{-1}),
G = soil heat flux density (MJ m^{-2} day^{-1}),
T = mean daily air temperature at 2 m height (°C),
u_2 = wind speed at 2 m height (m s^{-1}),
e_s = saturation vapour pressure (kPa),
e_a = actual vapour pressure (kPa),
e_s-e_a = saturation vapour pressure deficit (kPa),
Δ = slope vapour pressure curve (kPa $°C^{-1}$),
γ = psychrometric constant (kPa $°C^{-1}$).

Eddy covariance

Eddy Covariance (EC) method is a direct micrometeorological flux measurement, which provides exchange energy fluxes at high temporal resolution (typically 30-min interval). EC system consisted of a three-dimensional sonic anemometer (SAT) used to measure wind speed in three dimensions 10 times per second and virtual temperature, hygrometer measures vapor pressure at a frequency of 10 Hz, and soil heat flux plate. EC data included daily data Net radiation (Rn), Sensible heat flux (H), Soil heat flux (G) and Latent heat flux (**λ**ET) for 2014 and 2015 years from Zankalon tower station with an elevation of about 15 meters.

According to Cleverly *et al.* (2002) ETa from eddy covariance (EC) is calculated from the latent heat flux as:

$$\mathbf{ET_a} = \frac{\mathbf{LE}}{\lambda * \varrho_w} \qquad \mathbf{2}$$

Where:

ETa = actual evapotranspiration (mm/day),
LE = Latent heat flux (W/m^2),
λ = latent heat of vaporization of water (2441kJ/kg),
ϱ_w = density of water (kg/m^3).

ETWatch-Egypt model

ETWatch model was developed by the ETWatch team at the Digital Agriculture, Institute of Remote Sensing and Digital Earth, Chinese Academy of Sciences. It has been installed and operated in National Authority for Remote Sensing & Space Sciences in Egypt (NARSS). It is an evapotranspiration (ET) monitoring system based on remote sensing and sub models developed by the ETWatch team of RADI: net radiation, soil heat flux, sensible heat flux, latent heat flux, gap filling and ET data fusions. It is the first operational platform in the world with well-managed data and extensibility, guarantying the series ET data production. ET is an important parameter for water management and irrigation management departments Wu *et al.* (2012); Wu *et al.* (2016); Wu *et al.* (2017).

ETWatch model description shown in Figure (1). It establishes an ET processing system based on remote sensing technologies and ETWatch model, forms a service flow from remote sensing data preprocessing to evapotranspiration (ET) estimation, and provides an ET monitoring platform, serving for water consumption management in Egypt. Principles of evapotranspiration

Estimation in ETWatch are according to the surface energy balance as the following equation;

$$Rn = \lambda E + H + G \qquad 3$$

Where:

Rn = net (all-wave) radiant energy (W/m^2),
λE = latent heat flux (W/m^2),
H = sensible heat flux (W/m^2),
G = soil heat flux (W/m^2).

ETWatch model required many input data; *1)* Base data: DEM (digital elevation model), slope, aspect, land cover; *2)* RS data: MODIS, FY-2D (Fengyun-2D geostationary meteorological satellite), ARIS (The Atmospheric Infrared Sounder), LANDSAT, MSG (Meteosat Second Generation geostationary meteorological satellite; and *3)* Meteorological data: daily data (air pressure, humidity, minimum and maximum temperature, wind speed). All data needed as (TIF) image format file were included with the support of the National Authority for Remote Sensing & Space Sciences (NARSS).

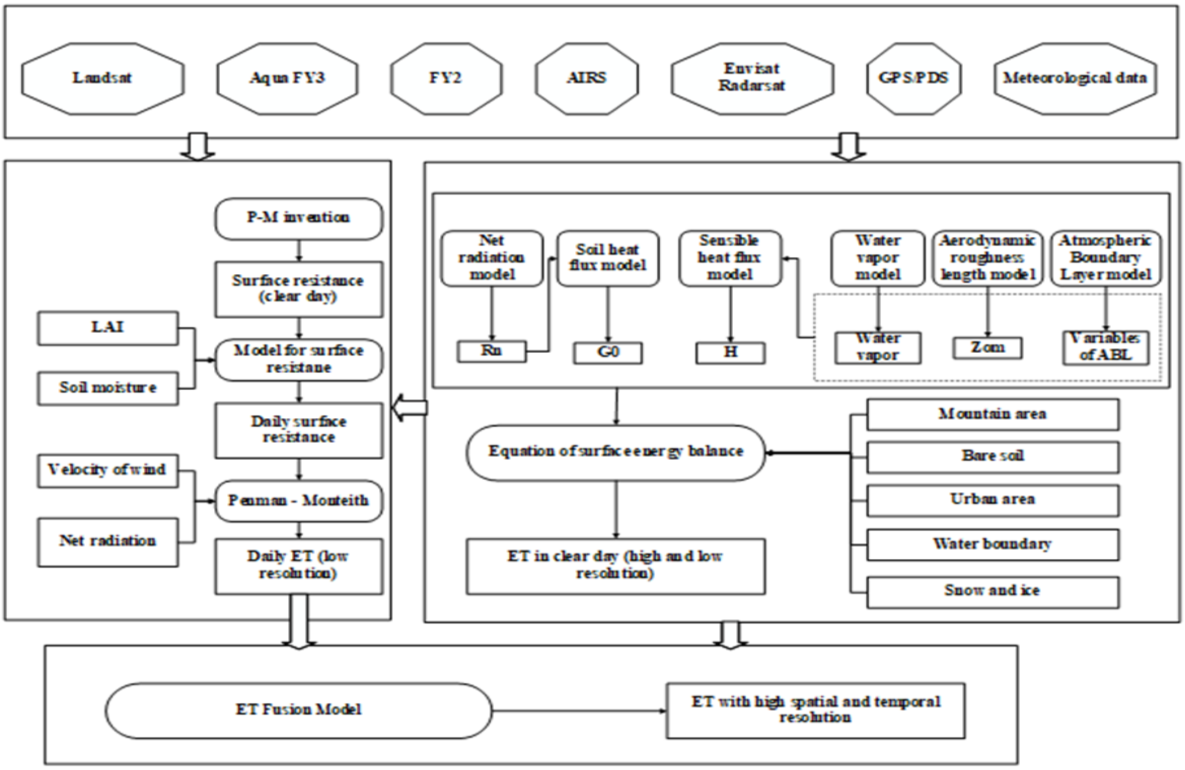


Figure 1. Shows the flow chart describing ETWatch model

ETa comparisons and statistical analysis

FAO CROPWAT model contains procedures of crop water requirements and for irrigation scheduling FAO (2009). It allows the simulation of crop water use under various climate, crop and soil conditions. It is widely used for defining crops water requirements all over the world Surendran *et al.* (2015) because of its simplicity, easiness to use and being linked to less intense data requirements. This model was used for comparison as eddy covariance technique is not widely available in Egypt. It is an expensive method. The measurements are sometimes difficult to explain when atmospheric turbulence is weak, which occurs commonly at night and data may require gap-filling techniques Aubinet (2008); Novick *et al.* (2009).

The comparison between methods of evaluating ETa (such as Eddy covariance and ETWatch model) against CROPWAT model at daily and decadal (approximately every 10 days) basis was determined using statistical tools. The slope, intercept, coefficient of determination (R^2), root mean square error (RMSE) and mean bias error (MBE) were considered in the comparison.

RESULTS AND DISCUSSION

Eddy covariance ETa values were always lower than ETa values from FAO-PM (CROPWAT model), these results agree with Ragab *et al.* (2017) results. In ETWatch model ETa values were slightly higher. ETWatch model isn't an open-source model. It considered complicated and need high experience and time to prepare input data.

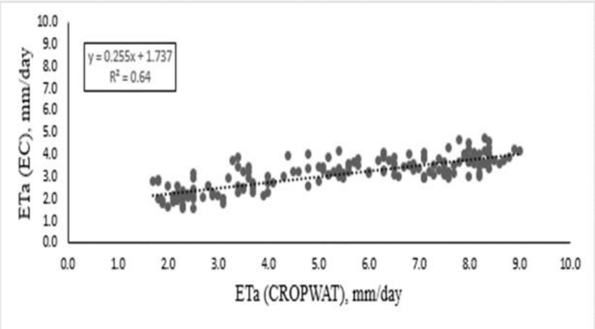
Daily and decadal (ETa) for summer crop (cotton)

The correlation results between the tested methods for cotton daily ETa are indicated in Figure (2). This figure indicated the linear regression analysis for Eddy covariance, ETWatch model to test the accuracy of its results by the range of their closeness to the "best fit" line (1:1). The slopes of Eddy covariance and ETWatch model were 0.26 and .33, respectively. While, for decadal ETa as shown in figure (3) of Eddy covariance and ETWatch model were 0.24 and 0.33, respectively.

From the results, it was observed that ETWatch model had is more reliable than Eddy covariance. The intercept of the linear relationship between values of daily ETa obtained from Eddy covariance and CROPWAT was 1.737. While the corresponding values was 2.15 between ETWatch model and CROPWAT. When replacing daily ETa results with decadal ETa results, the values of intercept of 1.91 and 2.039 were recorded, respectively.

Table (2) indicates a highly significant differences at 1% level between values of daily ETa among the three prediction methods. Calculated F value was 93.847. Table

(3) indicates some descriptive statistics for the values of daily ETa obtained from different methods. For decadal ETa results, a highly significant was found between different methods at 1% level of significance. The F value was 9.651 as in table (4). Some descriptive statistics for decadal ETa are also summarized in table (5). A comparative study was made between Eddy covariance and ETWatch model with respect to both daily and decadal ETa values as shown in table (6). As indicated in the previous table, ETWatch model is more accurate than Eddy covariance method because the first method is accompanied by higher R^2 values with CROPWAT model. The previous conclusion is quite obvious with the results of daily ETa. The arrangement of performance as measured through RMSE was ETWatch model then Eddy covariance for (daily - decadal) ETa; and the arrangement of performance as measured through MBE was the same for (daily - decadal) ETa.



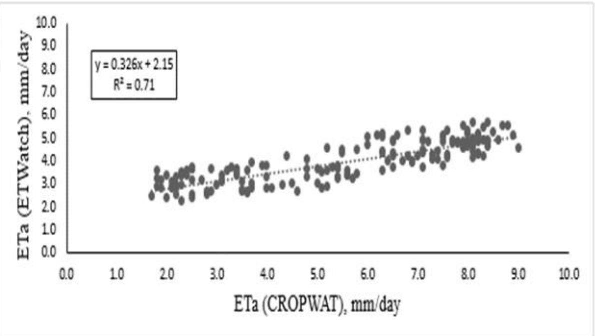


Figure 2. Scatter plot of daily ETa values among CROPWAT model and tested methods for cotton

Table 2. Analysis of variance for relationship among the tested methods on daily ETa values for cotton

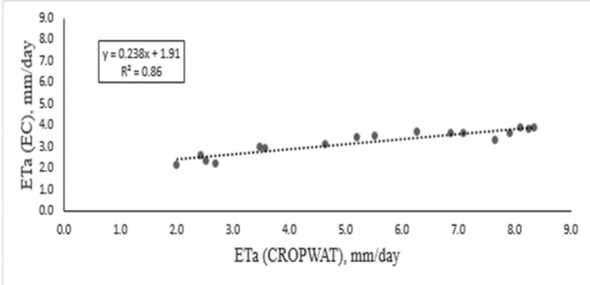
S. V	S.S.	DF	M.S.	F value	Significance
Treat	434.569	2	217.284	93.847	**
Error	1166.912	504	2.315		
Total	1601.481	506			

**** Highly significant at 1% level**

S.V is source of variation, S.S. is sum of squares, DF is degrees of freedom and M.S. is mean squares

Table 3. Means, Std. Deviation and Std. Error from the analysis of variance in the tested methods on daily ETa values for cotton

Calculation method	Mean	Std. Deviation	Std. Error
CROPWAT	5.527	2.2810	0.1755
Eddy covariance	3.323	0.8154	0.0627
ETWatch	3.965	1.0383	0.0799
F = (93.847)		P < 0.01	



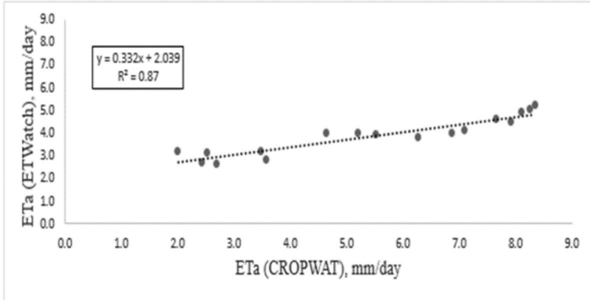


Figure 3. Scatter plot of decadal ETa values among CROPWAT model and tested methods for cotton

Table 4. Analysis of variance for relationship among the tested methods on decadal ETa values for cotton

S. V	S.S.	DF	M.S.	F value	Significance
Treat	41.577	2	20.788	9.651	**
Error	103.391	48	2.154		
Total	144.967	50			

**** Highly significant at 1% level**

S.V is source of variation, S.S. is sum of squares, DF is degrees of freedom and M.S. is mean squares

Table 5. Means, Std. Deviation and Std. Error from the analysis of variance in the tested methods on decadal ETa values for cotton

Calculation method	Mean	Std. Deviation	Std. Error
CROPWAT	5.449	2.3062	0.5593
Eddy covariance	3.300	0.5723	0.1388
ETWatch	3.924	0.9031	0.2190
F = (9.651)		P < 0.01	

Table 6. Statistical performance of EC and ETWatch model for estimating (daily- decadal) ETa for cotton

ETa	R^2		RMSE (mm/day)		MBE (mm/day)	
	EC	ETWatch	EC	ETWatch	EC	ETWatch
Daily	0.64	0.71	2.95	2.25	2.38	1.58
Decadal	0.86	0.87	2.82	2.21	2.24	1.60

R^2 is the correlation coefficient, RMSE is the root mean square error and MBE is the mean bias error

Daily and decadal (ETa) for winter crop (wheat)

The slopes for wheat daily ETa as shown in Figure (4) for Eddy covariance and ETWatch model were 0.20 and 0.51, respectively. While, for decadal for ETa Eddy covariance, ETWatch model as shown in figure (5) were 0.21 and 0.53, respectively. It shows that ETWatch model had high prediction than Eddy covariance. The intercept of the linear relationship for daily ETa were 1.09 and 0.663, respectively between Eddy covariance and CROPWAT, ETWatch model and CROPWAT. While, for decadal ETa were 1.101 and 0.69.

The calculated F value = 88.366 in table (7) was highly significant at 1% level and descriptive statistics are described in table (8) for daily ETa values. For decadal ETa F value = 7.786 in table (9) was highly significant at 1% level and descriptive statistics described in table (10). As shown in table (11) the arrangement of performance as measured through RMSE was ETWatch model then Eddy covariance for (daily - decadal) ETa; and the arrangement of performance as measured through MBE was ETWatch model then Eddy covariance for (daily - decadal) ETa. ETWatch model is accompanied by higher R^2 values with CROPWAT model than Eddy covariance, this is quite obvious with the results of daily ETa.

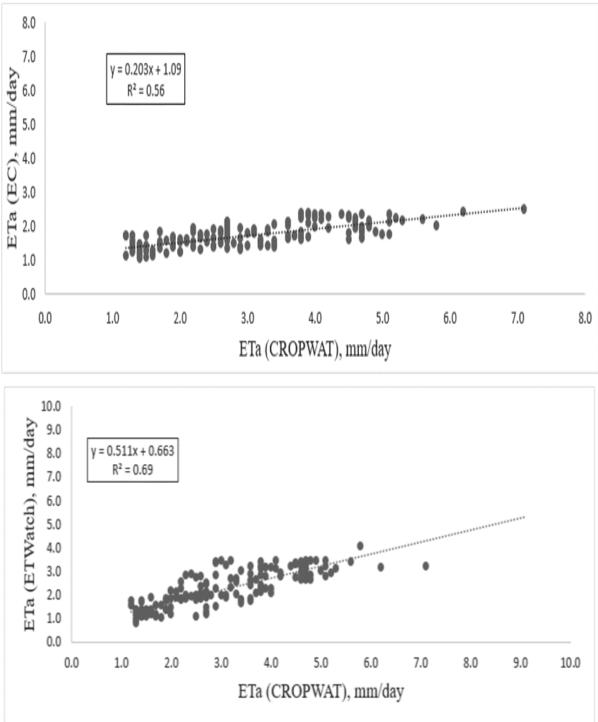


Figure 4. Scatter plot of daily ETa values among CROPWAT model and tested methods for wheat

Table 7. Analysis of variance for relationship among the tested methods on daily ETa values for wheat

S. V	S.S.	DF	M.S.	F value	Significance
Treat	142.722	2	71.361	88.366	**
Error	387.629	480	0.808		
Total	530.351	482			

**** Highly significant at 1% level**
S.V is source of variation, S.S. is sum of squares, DF is degrees of freedom and M.S. is mean squares

Table 8. Means, Std. Deviation and Std. Error from the analysis of variance in the tested methods on daily ETa values for wheat

Calculation method	Mean	Std. Deviation	Std. Error
CROPWAT	3.025	1.2907	0.1017
Eddy covariance	1.705	0.3517	0.0277
ETWatch	2.210	0.7957	0.0627
F = (88.366)		P < 0.01	

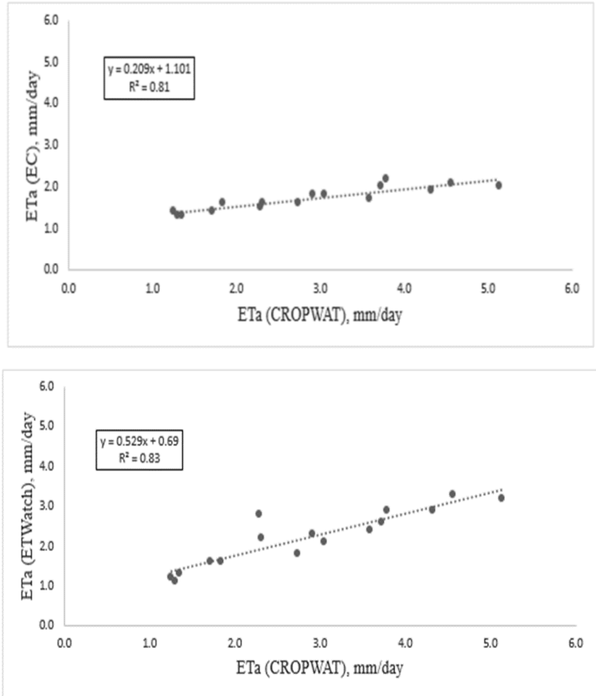


Figure 5. Scatter plot of decadal ETa values among CROPWAT model and tested methods for wheat

Table 9. Analysis of variance for relationship among the tested methods on decadal ETa values for wheat

S. V	S.S.	DF	M.S.	F value	Significance
Treat	10.908	2	5.454	7.786	**
Error	31.520	45	0.700		
Total	42.427	47			

**** Highly significant at 1% level**
S.V is source of variation, S.S. is sum of squares, DF is degrees of freedom and M.S. is mean squares

Table 10. Means, Std. Deviation and Std. Error from the analysis of variance in the tested methods on decadal ETa values for wheat

Calculation method	Mean	Std. Deviation	Std. Error
CROPWAT	2.864	1.2283	0.3071
Eddy covariance	1.700	0.2852	0.0713
ETWatch	2.206	0.7150	0.1788
F = (7.786)		P < 0.01	

Table 11. Statistical performance of EC and ETWatch model for estimating (daily- decadal) ETa for wheat

ETa	R^2		RMSE (mm/day)		MBE (mm/day)	
	EC	ETWatch	EC	ETWatch	EC	ETWatch
Daily	0.56	0.69	1.69	1.12	1.32	0.81
Decadal	0.81	0.83	1.50	0.91	1.16	0.66

R^2 the correlation coefficient, RMSE is the root mean square error and MBE the mean bias error

CONCLUSION

The study is focused on measuring and comparing actual evapotranspiration from two methods Eddy covariance and ETWatch-Egypt model and comparing with CROPWAT model. ETa daily values obtained from EC method was compared with CROPWAT model, the coefficient of determination (R^2) for summer season (cotton) and for winter season (wheat) were equal 0.64 and 0.56, respectively. The calculated R^2 values were reliable as it close to results of Er-Raki *et al.* (2009); Ha *et al.* (2015); Reavis (2017); Ochoa-Sánchez *et al.* (2019). Examining the results of decadal ETa, one can observe that the values of regression of determination (R^2) are becoming higher than daily ETa, also the values of R^2 are becoming closer for the two methods for two seasons.

RECOMMENDATIONS

Eventually, it is recommended to use CROPWAT model if only meteorological data are available for calculating crop water requirements. This is due to its availability and simplicity to use. It also allows the simulation of crop water use under various climate, crop, and soil conditions.

The Eddy covariance is approved to be a powerful method to estimate the surface-atmosphere exchange at the ecosystem scale especially evapotranspiration especially with the decadal ETa results. Unfortunately, it is not widely available in Egypt, it is an expensive method, and the measurements are sometimes difficult to explain when atmospheric turbulence is weak, this occurs mostly at night. In general, it gives lower ETa results than measured with FAO (P-M) equation.

Its highly recommended to use ETWatch when predicting daily ETa, while in predicting decadal ETa both Eddy covariance and ETWatch could be used with no big differences. Due to importance of calculation of actual ET especially where there is shortage of freshwater resources, it is strongly recommended to find an accurate and applicable methodology for the direct measurement of actual ET.

REFERENCES

Allen, R. G., L. S. Pereira, D. Raes and M. Smith. (1998). Crop evapotranspiration-Guidelines for computing crop water requirements-FAO Irrigation and drainage paper 56. Fao, Rome. 300 (9): 1-300.

Atta, Y. (2007). Improving growth, yield and water productivity of some maize cultivars by new planting method. Egyptian Journal of Application Science. 22: 1-16.

Aubinet, M. (2008). Eddy covariance CO2 flux measurements in nocturnal conditions: an analysis of the problem. Ecological applications, 18(6), 1368-1378.

Baldocchi, D. (2014). Measuring fluxes of trace gases and energy between ecosystems and the atmosphere–the state and future of the eddy covariance method. Global change biology. 20 (12): 3600-3609.

Burba, G. (2013). Eddy covariance method for scientific, industrial, agricultural and regulatory applications: A field book on measuring ecosystem gas exchange and areal emission rates, LI-Cor Biosciences.

Cleverly, J. R., C. N. Dahm, J. R. Thibault, D. J. Gilroy and J. E. A. Coonrod. (2002). Seasonal estimates of actual evapo-transpiration from Tamarix ramosissima stands using three-dimensional eddy covariance. Journal of Arid Environments. 52 (2): 181-197.

Courault, D., B. Seguin and A. Olioso. (2005). Review on estimation of evapotranspiration from remote sensing data: From empirical to numerical modeling approaches. Irrigation and Drainage systems. 19 (3-4): 223-249.

El-Shirbeny, M. A., E. Mohamed and A. Negm. (2018). Estimation of crops water consumptions using remote sensing with case studies from Egypt. Conventional water resources and agriculture in Egypt, Springer: 451-469.

Er-Raki, S., A. Chehbouni, N. Guemouria, J. Ezzahar, S. Khabba, G. Boulet and L. Hanich. (2009). Citrus orchard evapotranspiration: comparison between eddy covariance measurements and the FAO-56 approach estimates. Plant Biosystems. 143 (1): 201-208.

FAO. (2009). Cropwat 8.0 for Windows User Guide. Food Agriculture Organization of the United Nations.

Farahani, H. J., T. A. Howell, W. J. Shuttleworth and W. C. Bausch. (2007). Evapotranspiration: progress in measurement and modeling in agriculture. Transactions of the ASABE. 50 (5): 1627-1638.

Ha, W., T. E. Kolb, A. E. Springer, S. Dore, F. C. O'Donnell, R. Martinez Morales, S. Masek Lopez and G. W. Koch. (2015). Evapotranspiration comparisons between eddy covariance measurements and meteorological and remote-sensing-based models in disturbed ponderosa pine forests. Ecohydrology. 8 (7): 1335-1350.

Hassan, Q. K. and C. P.-A. Bourque. (2006). Estimating daily evapotranspiration for forests in Atlantic Maritime Canada: application of MODIS imagery. Proc. ASPRS.

Li, J., Y. Pei, S. Zhao, R. Xiao, X. Sang and C. Zhang. (2020). A review of remote sensing for environmental monitoring in China. Remote Sensing. 12 (7): 1-25.

Liou, Y.-A. and S. K. Kar. (2014). Evapotranspiration estimation with remote sensing and various surface energy balance algorithms—A review. Energies. 7 (5): 2821-2849.

Novick, K. A., Oren, R., Stoy, P. C., Siqueira, M. B. S., & Katul, G. G. (2009). Nocturnal evapotranspiration in eddy-covariance records from three co-located ecosystems in the Southeastern US: implications for annual fluxes. Agricultural and Forest Meteorology, 149(9), 1491-1504.

Ochoa-Sánchez, A., P. Crespo, G. Carrillo-Rojas, A. Sucozhañay and R. J. F. i. E. S. Célleri. (2019). Actual evapotranspiration in the high Andean grasslands: a comparison of measurement and estimation methods. Frontiers in Earth Science. 7: 55.

Ragab, R., J. Evans, A. Battilani and Solimando. (2017). Towards accurate estimation of crop water requirement without the crop coefficient Kc: new approach using modern technologies. Irrigation and Drainage. 66 (4): 469-477.

Reavis, C. (2017). Evaluating methods for quantifying evapotranspiration in Arkansas rice: 1-47

Smith, M. (1992). CROPWAT: A Computer Program for Irrigation Planning and Management: FAO Irrigation and Drainage Paper 46. Food & Agriculture Org, Rome. Italy: 1-57.

Surendran, U., C. Sushanth, G. Mammen and E. Joseph. (2015). Modelling the crop water requirement using FAO-CROPWAT and assessment of water resources for sustainable water resource management: A case study in Palakkad district of humid tropical Kerala, India. Aquatic Procedia. 4: 1211-1219.

Temesgen, B., S. Eching, B. Davidoff and K. Frame. (2005). Comparison of some reference evapotranspiration equations for California. Journal of irrigation drainage engineering. 131 (1): 73-84.

Todorovic, M., B. Karic and L. S. Pereira. (2013). Reference evapotranspiration estimate with limited weather data across a range of Mediterranean climates. Journal of Hydrology. 481: 166-176.

Wu, B., N. Yan, J. Xiong, W. Bastiaanssen, W. Zhu and A. Stein. (2012). Validation of ETWatch using field measurements at diverse landscapes: A case study in Hai Basin of China. Journal of Hydrology. 436: 67-80.

Wu, B., S. Liu, W. Zhu, N. Yan, Q. Xing and S. Tan. (2017). An improved approach for estimating daily net radiation over the Heihe River Basin. Sensors. 17 (1): 1-18.

Wu, B., W. Zhu, N. Yan, X. Feng, Q. Xing and Q. Zhuang. (2016). An improved method for deriving daily evapotranspiration estimates from satellite estimates on cloud-free days. IEEE Journal of Selected Topics in Applied Earth Observations. Remote Sensing. 9 (4): 1323-1330.

Wu, B.-F., J. Xiong, N.-N. Yan, L.-D. Yang and X. Du. (2008). ETWatch for monitoring regional evapotranspiration with remote sensing. Advances in Water Science. 19(5): 671-678.

Xing, Z., L. Chow, F.-R. Meng, H. Rees, L. Steve and J. Monteith. (2008). Validating evapotranspiraiton equations using bowen ratio in New Brunswick, Maritime, Canada. Sensors. 8 (1): 412-428.

تقييم مقارن لقياس البخرنتح في مصر

فاطمة الزهراء طارق أحمد[١]، زكريا إبراهيم اسماعيل[١] ، وليد حسن أبو الحسن[٢] ومحمد ماهر إبراهيم[١]

[١] قسم الهندسة الزراعية - كلية الزراعة - جامعة المنصورة.

[٢] معهد بحوث إدارة المياة - المركز القومي لبحوث المياة - مصر.

أجريت هذة الدراسة لمقارنة وتقييم طريقتين لحساب البخر نتح الفعلى والذى يشير إلى كمية المياه التي يجب توفيرها بكفاءة للمحصول . تم إختيار منطقة الدراسة في محطة الزنكلون. التى تقع في الجزء الشرقي من دلتا النيل ، محافظة الشرقية ، مصر. عند ٣٠,٥٨ درجة شمالاو ٣١,٥ درجة شرقا مع ارتفاع حوالي ٧ أمتار فوق مستوى سطح البحر. تم اختيار القطن (كمحصول صيفي) والقمح (كمحصول شتوي). الهدف الرئيسي من الدراسة هو تقييم البخر نتح الفعلي اليومي وكل ١٠ أيام باستخدام Covariance Eddy ونموذج ET-Watch ثم مقارنة النتائج بنتيجة نموذج CROPWAT. بالنسبة لمحصول القطن كان تقاطع العلاقة الخطية لـ ETa اليومي ١,٧٣٧ و ٢,١٥ على التوالي بين Eddy Covariance و CROPWAT و ETWatch وCROPWAT . بينما كل ١٠ أيام كانت ١,٩١ و ٢,٠٣٩. وللقمح كان تقاطع العلاقة الخطية لـ Eta اليومي ١,٠٩ و ٠,٦٦٣ على التوالي. بينما كل ١٠ أيام كانت ١,١٠١ و ٠,٦٩. أظهرت النتائج أن قيم Eta ل Eddy Covariance كانت أقل من قيم ETa لنموذجCROPWAT وكانت قيم نموذج ET-Watch قريبة إلى حد ما من قيمCROPWAT . نوصى باستخدام نموذج CROPWAT إذا كانت بيانات الأرصاد الجوية متاحة وذلك لبساطته في الاستخدام. يوصى بشدة باستخدام ETWatch عند التنبؤ ب ETa يوميًا ، بينما في التنبؤ كل ١٠ أيام ب ETa يمكن استخدام كل من Eddy covariance و ETWatch بدون اختلافات كبيرة. وأخيرًا نظرًا لأهمية حساب ET الفعلي وكذلك النقص في موارد المياه العذبة ، يوصى بأهمية بإيجاد منهجية دقيقة وقابلة للتطبيق للقياس المباشر لـ ET الفعلي.