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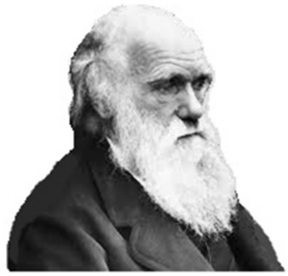

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Estimation of reference evapotranspiration inside fan and pad greenhouse from external climate data

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ABSTRACT

With increasing cultivating areas using greenhouses, estimating reference crop evapotranspiration (ETo) inside a greenhouse has recently gained greater attention for the design of new greenhouses or for improving operation of existing ones. Currently, calculating ETo inside a greenhouse using the Penman-Monteith formula recommended by FAO is difficult because the wind speed in a greenhouse is very low or approximate zero. In addition estimating the inner greenhouse is confronted by lack of all needed climate input variables in many areas especially in developing countries. To simplify calculating the inner greenhouse ETo from the routinely and historically collected data outside the greenhouse in the study area by the Penman-Monteith formula (PM-56), a correction factor is proposed in this study. The parameters for constructing the proposed adjustment factor were taken from ETo values measured using class A evaporation pan, and from ETo determined through meteorological data. The first is used for developing and validating the proposed correction factor where data was collected during three years at three study sites (Abu Halima, Date Palm Shambat Site, and Khartoum University farm) with three greenhouses per site. In the second experiment one house is chosen in Shambat area during the third year and equipped with needed equipments. The second experiment was used for verification purposes. In all cases the fitted values by the correction factor agreed well according to statistical evaluation parameters (Chi-squire test, Mean Absolute Error (MAE), correlation coefficient (r^2), the slope of the regression and the absolute deviation) with a measured value. Hence, the developed correction factor can be used as easy mean of calculating the ETo inside a greenhouse because historically available meteorological factors are needed. The estimations of the greenhouse indoor ETo PM from outdoor ETo

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PM could enhance climate-smart agriculture applications in semiarid environments while minimizing in-greenhouse meteorological data requirements.

***Keywords*:** Greenhouse climate, Reference evapotranspiration, correction factor

1. INTRODUCTION

Irrigation water is a scarce and limited input for crop production in many regions. Therefore, crop water requirement has to be calculated, and irrigation systems have to be designed and operated efficiently. Cultivation under cover has advantages, of the possibility to control the climate conditions and increase the water use efficiency (WUE) (Fernandez,et al 2005, Stanghellini, 2014). Greenhouse cultivation with permanent structures (Katsoulas and Stanghellini, 2019) is widely employed around the world today, but there is no reliable statistical estimates are available. Estimation of the evapotranspiration inside the greenhouse is important for successful plant growth, calculation of irrigation water consumption, and possible and economical rainwater collection and storage. Evapotranspiration is recommended to be calculated by the energy balance FAO–56- Penman–Monteith method as standard method developed for open field conditions (Allen et al. 1998 m stanghellini, 1978).

This procedure requires inputs of many climate variables (Mean max temperature (Tmax), mean min temperature and (Tmin), mean relative humidity(RH), number of sunshine hours (hr), global radiation (Ra), mean wind velocity (U)) and it is constrained by unavailability of such variables in many parts of the world specially developing countries (Mohamed et al ,2016). For greenhouses there is no standard method for estimating ETo such as Penman-Monteith for open field (Martin et al, 2020). However, for design of new or operation of old greenhouse systems the Penman–Monteith equation for determining reference evapotranspiration (ET0), need to be adapted suit the house internal environment. However, the outside climatic variables can be used to estimate inside house ETo if adjusted. This because the inside temperature in cooled greenhouses is normally lower than the outside temperature, and the wind speed and incoming global radiation were reduced (Rahma et al, 2018).

The outside relative humidity (RH) decreases during daytime due to the increasing outside temperature. Daytime RH humidity inside ventilated greenhouse remains at a relatively high level (75–80%) due to the continuous evapotranspiration from crop and soil (Von Zabeltitz, 2011, Diyana, 2014). For determining ETo inside greenhouse using FAO-56-PM the climate data for outside conditions can be taken from adequate references, (climate data tools of FAO - AQUASTAT (www.fao.org/nr/water/ aquastat/gis/index3.stm). The incoming global radiation if is not given, it can be calculated by a method given by Allen et al. (1998). According to Von Zabeltitz (2011) several evapotranspiration models of greenhouse crops have been developed and presented, all based on the Penman–Monteith but some of these models differ in the amount of detail about variables, such as stomatal and aerodynamic conductance, while others are too simplified resulting in reduced accuracy, or site specific resulting in empirical rather than mechanistic model (Katsoulas, and Stanghellini 2019). Reference evapotranspiration can be directly measured by pan, Piche tube or lysimeter methods.

Class A pan method has been one of the most utilized techniques worldwide because of its simplicity, relatively low cost, and yielding of daily evapotranspiration estimates. Greater precision, however, can be obtained when it is utilized for periods of at least five days (Hadi et al, 2014). There is no conclusive result of Pan Coefficient (Kp) prediction studies inside greenhouse. In addition, some producers consider leaving an unproductive area of approximately 10 m^2 occupied by the class A pan inside the greenhouse not viable (Fernandes et al 2003, Rahma et al 2018). To minimize waste of productive area inside the greenhouse by a class A pan, using reduced-size pan is alternative methods (Farias et al., 1994), (Medeiros et al. 1997) verified that evaporation (E) in reduced pan was 15% greater than in class A pan, when both were installed inside a greenhouse. Rahma et al (2018) compared the possibility of using class A pan, lysimeter, and Piche tube to estimate ETo inside greenhouses using the coefficient of simple linear regression (R^2). To estimate the ETo in house they recommended to use lysimeter or Piche tube as alternative to pan method. However, selection of the technique to determine ETo inside the greenhouse is a method of controversy. As such using indirect prediction models seem to be more effective. Farias et al, (1994) reported that ETo inside greenhouses was always lower than that outside and in the range of 45 to 77% of that verified outside. While Fernandes et al., (2003) cited that ETo values of 85 and 80% of ETo outside for greenhouses were given by Braga and Klar (2000). Due to importance of availing the greenhouse inner temperature Mohammed Kheir (2005) developed a mathematical heat transfer model to predict the inside greenhouse temperature at the Palm Technology Company, Agricultural Research Corporation, Shambat-Khartoum North, Sudan. She validated the developed model by comparing measured temperatures data with the predicted ones. The statistical analysis showed that the average model error, the average absolute difference and standard error of estimate for morning period are -0.1250, 0.6000 and 1.2196 respectively, while for the afternoon period they are -3.0000, 0.0750 and 0.4743 respectively. Elmsaad and Abdelnaser (2015), and Mohammed Ahmed et al., (2010) evaluated performance of different types of pads greenhouses and do not object to use pads made from local materials. On diagnosing performance of greenhouses around Khartoum state Boulard, T., et al (2000) reported that the environmental control and design aspects of greenhouses were below expectations. The main objective of this study was to develop a correction coefficient for estimating the ETo inside fan and pad greenhouse from external historical climate data.

2. MATERIALS AND METHODS

2. 1. Greenhouse structure and experimental set up

The study was made in nine greenhouses at three locations: Abu Halima, Date Palm Shambat Site, and Khartoum University farm in Khartoum North -Shambat - Sudan (longitude 32°32' E, latitude 15°40'N and altitude 380 m). The climate is arid in nature with mean annual temperature of 38 °C and mean relative humidity of 25%. The experiment was carried out in a climate controlled single span plastic-house equipped with fan and pad cooling devices. The greenhouse was 38 m long in the north–south direction and consisted of long span of 8.5 m width and 2.5 m mean height and covered with a 100 µm transparent polyethylene film treated against ultraviolet radiation. Tomato plants, c.v. Rondello, were planted in double rows (density 4 plants/m^2) in January and regularly irrigated by drip irrigation systems.

2. 2. Climatic and transpiration measurements

Inside and outside climate variables, (dry and wet bulb temperatures, relative humidity and wind speed) were monitored three times a day (at 8, 12, and 15 o'clock) every three days' time increments for three months (Hesham et al, 2019). The data was collected during three successive years: 2020, 2021 and 2022.

Reference evapotranspiration was determined by means of class-A evaporation pan erected inside and outside each greenhouse. Class A evaporation pan was installed in the center of each greenhouse. The pan was constructed of the nr. 22 galvanized iron sheet, with dimensions, 1.21 m in diameter and 0.250 m in depth. It was installed on a wooden pallet 0.15 m on soil surface (Hadi et al, 2014). Another pan was erected outside of the greenhouse. The ETo, is expressed in mm, and determined by the equation: ETo = Kp.E, where: Kp = pan coefficient taken as 0.7, and, E = pan evaporation (mm).

The temperature was measured with digital thermo-hygrometer (METRAVI HT 3005 model). Three temperature readings were taken per day (one at the pad end, fan end and the middle of each house), at morning, mid-day and evening to give average day value. The wind velocity was measured with the help of a digital anemometer (LUTRON AM-4201 model). The free wind velocity outside of each house was recorded in suitable area free from obstructions (Ganguly and Ghosh, 2007). In each greenhouse fan and pad evaporative cooling system is installed. The system consist of a cellulose cooling pad (14 m surface area, 0.10-m thick) mounted on the north side-wall, two identical exhaust fans (mounted at 0.75 m above the greenhouse floor with 6 m fans spacing). Specifications of each fan are: 350 m^3/min air flow rate, 1.2 m diameter, and 1.1 kW power.

3. RESULTS AND DISCUSSION

3. 1. Development of indoor greenhouse ETo correction factor:

Table 1 a, b shows the collected data of climate elements and ETo values measured by evaporation pan as monthly (6, 7, 8) averages of three houses in each area (Abu Halima, Date Palm, and Khartoum University) for each one of the studied areas. This data is collected during 10 days per month (every three days) for three months per house in three sites with three houses per site to sum up with daily data for 810 days. These daily data is collected outside (Table 1 a) and inside (Table 1 b) each greenhouse.

Table 1a. Average climate elements and ETo measured by Pan method during three years in three study sites for three months per year outside each one of the three greenhouse

Identification	T_{min}	T_{max}	T_{mean}	Ra	ETo Pan	Avg Sunshine monthly duration	Avg daily Wind speed at 2m (U_2)	RH%	ETo Inside
Y1-3H-6	**32.4**	**43.5**	**38.0**	**38.0**	**6.6**	**9.8**	**1.1**	**49.9**	**6.1**
Y1-3H-7	**25.4**	**30.8**	**28.1**	**38.0**	**6.6**	**9.8**	**1.1**	**49.9**	**6.1**
Y1-3H-8	**25.6**	**30.0**	**27.8**	**37.9**	**5.8**	**9.2**	**1.2**	**70.5**	**5.6**

Y2-3H-6	28.6	38.6	33.6	38.0	5.8	9.8	2.0	52.5	6.6
Y2-3H-7	29.9	37.0	33.5	38.0	4.9	8.6	1.8	51.2	6.4
Y2-3H-8	28.5	39.4	33.9	37.9	6.1	9.2	1.4	40.6	6.2
Y3-3H-6	28.6	36.1	32.4	38.0	4.9	9.8	2.4	62.4	6.3
Y3-3H-7	29.9	39.9	34.9	38.0	5.9	8.6	1.8	53.3	6.5
Y3-3H-8	28.5	39.2	33.8	37.9	6.0	9.2	1.5	46.3	6.2

Table 1b. Average climate elements and ETo measured by Pan method during three years in three study sites for three months per year inside each one of the three greenhouse

Identification	T_{min}	T_{max}	T_{mean}	Ra	ETo Pan	Avg Sunshine Monthly duration	Avg Daily Wind Speed 2m (U_2)	RH%	ETo Inside
Y1-3H-6	26.3	32.0	29.1	38.0	4.6	9.8	0.7	58.0	4.9
Y1-3H-7	25.4	30.8	28.1	38.0	4.7	8.6	0.8	70.1	4.8
Y1-3H-8	25.6	30.0	27.8	37.9	4.6	9.2	1.0	73.8	4.9
Y2-3H-6	25.1	29.9	27.5	38.0	4.4	9.8	1.1	80.5	4.8
Y2-3H-7	25.4	28.9	27.2	38.0	3.7	8.6	1.0	76.4	4.7
Y2-3H-8	24.5	30.0	27.2	37.9	4.7	9.2	1.0	74.5	4.9
Y3-3H-6	26.2	29.0	27.6	38.0	3.4	9.8	1.1	83.2	4.7
Y3-3H-7	25.9	29.4	27.6	38.0	3.7	8.6	1.0	72.6	4.8
Y3-3H-8	24.0	29.3	26.7	37.9	4.5	9.2	0.9	68.0	4.9

It is evident from Table 2 that: ETo inside greenhouses was lower than outdoor, and difference in ETo values for years is attributed to differences in climate variables obtained in each year. The differences in ETo at outside and inside greenhouse may be due to the influence of the inside main factors influencing the evaporative demand of the atmosphere (lower wind speed, higher relative humidity and lower direct solar radiation). These results agree with Farias et al., (1994); Martins et al., (1994); Braga and Klar, (2000). Table 2 shows that the average derived correction coefficient based on pan measurement inside the greenhouse is **0.769**, while that estimated on basis of ETo derived by FAo procedure using climate data measured inside the greenhouse is **0.767**. These two correction factors are almost typical. This correction factor enable prediction of the inside greenhouse ETo from that estimated by FAO-56-PM procedure using outside climate elements. The value of the correction coefficient is in agreement with the range of 85 and 80% of ETo outside the greenhouse reported by Braga and Klar (2000), and is slightly above the upper range of 45 to 77% ETo outdoor given by Farias et al, (1994), while Hadi, and Ahmad (2019) stated that under typical ventilated conditions, greenhouse indoor ETo PM was found equal to 60% of outdoor ET.

Table 2. Derivations of ETo Correction Factor

Replication Month – Year	ETo Outside PM	ETo pan out side	ETo Inside` PM	ETo pan Inside Measured	Prediction based on ETo-Pan		Prediction based on in ETo-PM	
					Coef out to in pan	Predicted ETo	Coef. out to in PM-ETo	PM Predicted ETo
Year 1- Month 1	**6.1**	**6.2**	**4.8**	**4.9**	0.8099	**4.68**	0.7934	**4.67**
Year 1- Month 2	**5.9**	**6.0**	**4.5**	**4.7**	0.8029	**4.53**	0.7650	**4.52**
Year 1- Month 3	**5.6**	**5.9**	**4.4**	**4.5**	0.7998	**4.34**	0.7885	**4.33**
Year 2- Month 1	**6.6**	**6.8**	**4.9**	**4.8**	0.7289	**5.09**	0.7474	**5.08**
Year 2- Month 2	**6.4**	**6.5**	**4.7**	**4.7**	0.7444	**4.89**	0.7415	**4.88**
Year 2- Month 3	**6.2**	**6.5**	**4.9**	**4.8**	0.7673	**4.80**	0.7806	**4.79**
Year 3- Month 1	**6.3**	**6.3**	**4.7**	**4.8**	0.7644	**4.85**	0.7484	**4.84**
Year 3- Month 2	**6.5**	**6.4**	**4.9**	**4.7**	0.7295	**4.99**	0.7574	**4.98**
Year 3 - Month 3	**6.2**	**6.0**	**4.9**	**4.8**	0.7726	**4.76**	0.7834	**4.75**
Mean	**6.2**	**6.3**	**4.8**	**4.8**	**0.769**	**4.77**	**0.767**	**4.76**

4. VERIFICATION OF THE CORRECTION FACTOR

4. 1. Variations in Accuracy of predicting ETo inside the greenhouse

For assessing the accuracy in predicting ETo inside the greenhouse it is assumed that: Eto measured by Pan is standard reference value followed by ETo estimated from inside data using

FAO-56-PM procedure. To use Pan for measuring ETo is cumbersome undertaking and it is not always possible especially when designing a new greenhouse in a new area.

As alternative it is more practical to take FAO-56-PM estimate of ETo from outside greenhouse historically recorded data as a tool to predict the inside greenhouse ETo. As given in Table 3 the result of estimating inside ETo on basis of ETo estimated from FAo-56-Pm (R4) results in accuracy almost same as that based on ETo determined by Pan (R3). This is because accuracy of R1 and R2 given in Table 3 are almost the same.

Table 3. Accuracy determination of the data for evaluating the Accuracy of the two Correction factors

Replications - Month - Year over houses and sites	Measured and estimated input ETo data				Accuracy of data determination for evaluating the Accuracy of the two Correction factors			
	ETo pan Inside Measured	ETo - PM Inside`	ETo - pan outside Measured	ETo - PM Outside	R1 = Accuracy of ETo-PM inside to Eto Pan inside	R2 = Accuracy of ETo-PM outside to ETo Pan outside	R3 = Accuracy of correction factor of predicting ETo Pan inside from ETo PM outside	R4 = Accuracy of correction factor of predicting ETo PM inside from ETo PM outside
Year 1- Month 1	**4.9**	**4.8**	**6.2**	**6.1**	**0.98**	**0.98**	**0.81**	**0.8**
Year 1- Month 2	**4.7**	**4.5**	**6.0**	**5.9**	**0.95**	**0.98**	**0.80**	**0.8**
Year 1- Month 3	**4.5**	**4.4**	**5.9**	**5.6**	**0.99**	**0.96**	**0.80**	**0.8**
Year 2- Month 1	**4.8**	**4.9**	**6.8**	**6.6**	**1.03**	**0.98**	**0.73**	**0.7**
Year 2- Month 2	**4.7**	**4.7**	**6.5**	**6.4**	**1.00**	**0.98**	**0.74**	**0.7**
Year 2- Month 3	**4.8**	**4.9**	**6.5**	**6.2**	**1.02**	**0.96**	**0.77**	**0.8**
Year 3- Month 1	**4.8**	**4.7**	**6.3**	**6.3**	**0.98**	**1.00**	**0.76**	**0.7**
Year 3- Month 2	**4.7**	**4.9**	**6.4**	**6.5**	**1.04**	**1.01**	**0.73**	**0.8**
Year 3 - Month 3	**4.8**	**4.9**	**6.0**	**6.2**	**1.01**	**1.03**	**0.77**	**0.8**
Mean	**4.8**	**4.8**	**6.3**	**6.2**	**1.00**	**0.99**	**0.77**	**0.8**

4. 2. Parametric analysis of Accuracy of ETo Prediction:

This is intended to be a verification exercise where the developed correction factor was verified statistically by comparing the results of modeled ETo with the results of the ETo calculated from the observed weather data. The parametric indicators frequently used to assess the variation of the predicted and actual parameters are statistical in nature and includes Root mean square error (RMSE), Nash–Sutcliffe efficiency (NSE), Chi-squire-test (Amatya et al. 1995). Table 4 shows the discrepancy between measured and predicted ETo using these parametric indicators. It is evident from the table that: RMSE is very low indicating good agreement between the predicted and the actual values. This result is in line with that given by Patel et al. (2014), and Valdés et al. (2004). Likewise, determination of the Nash–Sutcliffe efficiency (NSE) results in small error (**0.3156**) indicating agreement between predicted and estimated ETo values for ETo based on pan measurement (Table 4a). However verification of ETo based on estimated ETo resulted in slightly higher NSE value than that based on pan measurement but it is still acceptable (<0.75) and indicate good agreement between predicted and measure ETo. (Table 4b). The analysis using Chi-squire-test for ETo based Pan measurement or PM estimation given in Table 4 reveal that the (calculated values are less than observed value) therefore predicted and observed ETo where represent each other with no significant differences.

Table 4a. Using Root mean square error (RMSE), Nash–Sutcliffe efficiency (NSE), and Chi-squire-test parametric indicators for determining variation of the predicted and ETo pan measured.

Replication Month - Year	ETo pan In side Measured	Predicted Eto	Root mean square error (RMSE)	Nash–Sutcliffe efficiency (NSE)		Chi-squire-test	
						Pan based	PM based
Year 1- Month 1	**4.9**	**4.7**	**0.0623**	**0.0623**	**0.0075**	**0.0126**	**0.0052**
Year 1- Month 2	**4.7**	**4.5**	**0.0402**	**0.0402**	**0.0560**	**0.0085**	**0.0000**
Year 1- Month 3	**4.5**	**4.3**	**0.0305**	**0.0305**	**0.1804**	**0.0068**	**0.0032**
Year 2- Month 1	**4.8**	**5.1**	**0.0700**	**0.0700**	**0.1079**	**0.0145**	**0.0035**
Year 2- Month 2	**4.7**	**4.9**	**0.0242**	**0.0242**	**0.0163**	**0.0051**	**0.0057**
Year 2- Month 3	**4.8**	**4.8**	**0.0001**	**0.0001**	**0.0013**	**0.0000**	**0.0014**
Year 3- Month 1	**4.8**	**4.9**	**0.0008**	**0.0008**	**0.0085**	**0.0002**	**0.0030**
Year 3- Month 2	**4.7**	**5.0**	**0.0654**	**0.0654**	**0.0519**	**0.0138**	**0.0008**

Year 3 - Month 3	**4.8**	**4.8**	**0.0005**	**0.0005**	**0.0000**	**0.0001**	**0.0021**
Mean	**4.8**	**4.8**	**0.1808**	**0.2940**	**0.4297**	**0.0068**	**0.0028**
				0.3156			

Table 4b. Using Root mean square error (RMSE), Nash–Sutcliffe efficiency (NSE), and Chi-squire-test parametric indicators for determining variation of the predicted and ETo estimated by PM-FAO.

Replication Month - Year	ETo Inside` PM	PM Predicted ETo	Root mean square error (RMSE)	Nash–Sutcliffe efficiency (NSE)	
Year1- Month 1	**4.8**	**4.7**	**0.0071**	0.0071	0.0005
Year1- Month 2	**4.5**	**4.6**	**0.0073**	0.0073	0.0303
Year1- Month 3	**4.4**	**4.4**	**0.0026**	0.0026	0.1330
Year 2- Month 1	**4.9**	**5.2**	**0.0452**	0.0452	0.1591
Year 2- Month 2	**4.7**	**5.0**	**0.0585**	0.0585	0.0381
Year 2- Month 3	**4.9**	**4.9**	**0.0001**	0.0001	0.0104
Year 3- Month 1	**4.7**	**4.9**	**0.0385**	0.0385	0.0253
Year 3- Month 2	**4.9**	**5.1**	**0.0207**	0.0207	0.0881
Year 3 - Month 3	**4.9**	**4.8**	**0.0006**	0.0006	0.0046
Mean	**4.8**	**4.8**	**0.1416**	0.1806	0.4894
				0.6311	

5. VALIDATION OF THE CORRECTION FACTOR

For purpose of validating the obtained correction coefficient a fourth greenhouse with typical specifications to those operated in Date Palm Company was assigned for validation purposes. The greenhouse was equipped with all measuring devices in Shambat area to collect climate variables from inside and outside the greenhouse. The data was collected in the 3rd year for a period of three months (6, 7, and 8) and the results are averaged per decade and given in Table 5 a, b. To eliminate bias; the data used in the verification phase were not included in the coefficient development process. As given in Table 5a indicated that RMSE is 0.7149, while

NSE is -1.8838 for the case of ETo prediction based on pan measured ETo. Both indicators show good association. Table 5b indicated Root mean square error of 0.3128, and Nash–Sutcliffe efficiency of 0.3257, which express for the high validity of predicting indoor ETo on basis of ETo estimated by PM-FAO.

Table 5a. Root mean square error (RMSE), and Nash–Sutcliffe efficiency (NSE) parametric indicators for validation of the of the predicted prediction and ETo pan measured.

ETo - Pan based					
Replication: Year -Month -decade	ETo pan In side Measured	Predicted ETo inside	Root mean square error (RMSE)	Nash–Sutcliffe efficiency (NSE)	
Year 1- Month 1 decade 1	6.3	5.0	1.8401	1.8401	0.0392
Year 1- Month 1 decade 2	3.9	4.8	0.7539	0.7539	0.1556
Year 1- Month 1 decade 3	5.2	4.6	0.3603	0.3603	0.3247
Year 1- Month 2 decade 1	5.4	6.1	0.5870	0.5870	0.9264
Year 1- Month 2 decade 2	4.5	5.4	0.7569	0.7569	0.0555
Year 1- Month 2 decade 3	5.6	5.1	0.2439	0.2439	0.0104
Year 1- Month 3 decade 1	5.0	5.2	0.0499	0.0499	0.0034
Year 1- Month 3 decade 2	5.4	5.5	0.0013	0.0013	0.0784
Year 1- Month 3 decade 3	5.2	5.1	0.0070	0.0070	0.0018
Mean	5.2	5.2	**0.7149**	4.6002	1.5952
				-1.8838	

Table 5b. Root mean square error (RMSE), and Nash–Sutcliffe efficiency (NSE), tests for determining validation of the of the of the predicted and ETo estimated by PM-FAO.

ETo-PM- based prediction					
Replication: Year -Month -decade	ETo In side` PM	PM Predicted ETo	Root mean square error (RMSE)	Nash–Sutcliffe efficiency (NSE)	
Year 1- Month 1 decade 1	4.9	4.7	0.0301	0.0301	0.2276

Year 1- Month 1 decade 2	4.8	4.5	0.0746	0.0746	0.4389
Year 1- Month 1 decade 3	5.0	4.8	0.0227	0.0227	0.1457
Year 1- Month 2 decade 1	5.0	5.6	0.3927	0.3927	0.1750
Year 1- Month 2 decade 2	4.9	5.1	0.0470	0.0470	0.0046
Year 1- Month 2 decade 3	5.1	4.8	0.0900	0.0900	0.1492
Year 1- Month 3 decade 1	4.7	4.9	0.0462	0.0462	0.0555
Year 1- Month 3 decade 2	4.7	5.2	0.1739	0.1739	0.0007
Year 1- Month 3 decade 3	4.9	4.9	0.0036	0.0036	0.1092
Mean	4.9	4.9	0.3128	0.8808	1.3063
				0.3257	

6. CONCLUSIONS

At present, prediction of ETo inside a greenhouse for design of new area or in case of no indoor climate elements is not possible. One way to solve this problem is to use a correction factor to estimate ETo from outdoor ETo. Therefore this study is directed to achieve this purpose and it recommended using 0.77 to 0.80 as correction coefficient. This coefficient is developed, validated and verified on basis of greenhouse da collected from real life field experiment made for three years.

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