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Evaluating estimation methods of potential evaporation-transpiration in Deylam city

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Abstract: The most important duty of agriculture sector is supplying needs and promoting food security besides protecting basic resources permanency. Irrigation planning has been established in order to update water-soil balance and prediction of water future usage based on calculation or measurement of daily evaporation-transpiration amounts in order to predict arrival time to allowed level. In present study, daily evaporation-transpiration amounts and average daily evaporation-transpiration amounts in various months of year by FAO Penman-Monteith (FP-M) method, Blany-Criddle (B-C), Hargreaves-Samani (H-S), and TorrentWhite (T-W) were estimated by synoptic station of Deylam city. Statistical period used in this research is from 2006 to 2013. For lack of lysimeter data in region and suggestions by FAO organization, daily potential evaporation-transpiration amounts calculated by FAO Penman-Monteith method has been considered as control amounts of ET0 and estimated amounts have been compared by Blany-Criddle, Hargreaves-Samani, and Torrent white. Results have shown that Blany-Criddle method among the other methods has the most correlation coefficient and the least standard error amount, it have more accuracy with FAO Penman- Manteith method in estimating potential evaporation-transpiration of Deylam city. In addition, results have shown that Blany-Criddle method, Torrent White, and Hargreaves-Samani have estimated evaporation-transpiration of Deylam city 9, 18, and 38 percent less than evaporation-transpiration amounts by reference method.

Key words: *Deylam; Potential evaporation-transpiration; FAO- Penman- Manteith; Blany-Criddle; Hargreaves-Samani; Torrent White*

1. Introduction

Dry and semidry regions have faced with intensive lack of water resources qualitatively and quantitatively to develop agriculture and provide needed food of incremental population. The main reason of non-utilizing cultivable grounds ability is lack of water (national committee of irrigation and drainage of Iran, 2010). The main and applicable aspect of irrigation is determining water amount and time that should be given to a certain plant. The applicable water should be determined based on level of evaporation-transpiration; therefore, it needs an estimation of this factor. (Hasheminia, 2006) Meteorology parameters, plant factors, agricultural and environmental management are effective factors on each element of evaporation and transpiration. The main effective parameters for meteorology on evaporation and transpiration include radiation, weather temperature, air moisture, and wind velocity. In cultivated plants evaporation and transpiration in vast farms under desirable agricultural management, factors such as type, variety, and plant growth steps should be considered. Resistance differences against evaporation, height, plant thickness, light reflection, ground coverage, and root growing specifications of plant cause evaporation and transpiration to be different in similar conditions. (National committee of irrigation and drainage of Iran, 2008) Many factors such as salinity, low fertility of soil, limited fertilizer usage, and existence of hard and impermeable layer in soil, non-controlling of sicknesses and plant pests, and also agricultural operations' weak management lead to limit plant growth and reduction in evaporation and transpiration. In most methods used to determine evaporation-transpiration, first reference evaporation-transpiration (ET0) is estimated then E-T is calculated. (Alizadeh et al., 2004) In order to estimate ET0, there are many empirical and semi-empirical equations suggested among them, Penman, Blany-Criddle, Hargreaves-Samani, and Torrent Wight have been more applicable and have been used more extensively.

Najafi (2004) calculated potential E-T for 5 provinces by meteorology data by various methods then compared it with Lysimeter data of province. His results have shown that in Shahrekord city, Hargreaves method with error level less than 7% has been selected as the most proper method to estimate E-T. MirzaeiTakhtgahi and Moa'azed (2006) used Hargreaves-Samani, Blany-Criddle methods and evaporation pan in a study in Sanate zone in Kordestan province to estimate potential E-T in comparison to FAO Penman-Manteith which was selected as reference method. Their research results have shown that Blany-Criddle method has more

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precision and accuracy in comparison to 2 other methods to estimate potential E-T. Ghamarnia and Mehri (2007) in a research calculated amount of potential E-T using meteorology data of synoptic stations in Lorestan Province. In 30-year period (1976-2005) monthly and annually potential E-T were modified by 5 methods of Penman, Penman-Manteith, Blany-Criddle Hargreaves-Samani, Mocking, and TurrentWight. Obtained Results showed that in Khoramabad station, mocking method and in Bojnurd and Aligudarz stations, Penman-Manteith methods have been accepted as reference and standard methods and they are the most proper method to estimate potential E-T. Shahinzadeh et al. (2008) in a research used methods of potential E-T estimation in Hufel region in south of Khozestan province and compared to FAO-Penman-Manteith methods as ET0. Obtained results showed that evaporation pan method than other methods have more correlation coefficient with reference method. Garcia et al. (2004) in Bolivia region using Lysimeter data and its comparison to 3 methods of white, Hargreaves-Samani, and Penman-Manteith showed that Penman-Manteith in E-T can have the least error. Castaneda and Rao (2005) in research in south of California used potential E-T estimation methods such as Blany-Criddle, Turk, Torrent white, and mocking then compared to FAO-Penman-Manteith. According to statistical analyses done, methods preferred for better estimation in potential E-T are suggested to be used in South of California by their new calibration. Sumner and Jacobs (2005) in a study on not-irrigated pastureland in Florida understood that both methods of Penman and Manteith and modified Priestly-Taylor need to seasonal calibration parameters, Weib and Menzel(2008) compared Priestley-Taylor, Penman-Manteith, Hargreaves, and evaporation pan to estimate potential E-T in global scope and showed that results of Priestly-Taylor method are nearer to evaporation pan. The purpose of this research is comparing B-C, H-S, and TW methods to estimate potential E-T of Deylam city and evaluating precision of used methods based on FAO-Penman-Manteith method and consequently determining the most proper method to estimate evaporation and transpiration of the mentioned region.

2. Materials and Methods

Deylam city in 2734 km^2 with geographical length of 50° 9' and geographical width of 30° 3' and 10 m altitude is placed in northwest of Bushehr city. It is limited from east to Fars province and from south to Gonaveh city. In Azar, Dey, Bahman months, this city is relatively cold and in other time of year, it is hot and humid. The studies region naturally is divided into 3 parts of mountainous (Zagros Mountains), Mahuri hill, and Livarifertile plain. A part of costal line is salt marsh and sandy.

In this research in order to calculate potential E-T, synoptic station data of Deylam city has been used that specifications are shown in table (1).

Table 1: Deylam synoptic station specifications

Station	Geographical length	Geographical width	Altitude (m)	Statistical period
Deylam	11″ 50°	03″ 50°	10	2006-2013

According to researches done in this field, needed statistics and data to improve research purposes has been gathered from synoptic station of Deylam city. Finally, 7-year statistical period has been used. Methods to estimate potential E-T include B-C, H-S, TW, and FP-M using CropWat. In order to explore precision and determining the most proper method to estimate potential E-T in Deylam city for not having Lysimeter data in this region and FAO organization suggestions, daily potential E-T was calculated by FAO-Penman method as reference method and correlation and standard error of each method were calculated by reference method and compared with each other. Mini tab and Excel software have been used for statistical analysis and related calculations.

2.1. Blany-Criddle Method

This method is usable mostly in dry and semi-dry regions and was developed for dry regions of west US for the first time. In this method, it is assumed that potential E-T is dependent on temperature and light hours a day (Safavi, 2009). General relationships in Blany-Criddle method to calculate potential E-T in Blany-criddle method are as following:

$$ET_0 = a + b[P(0.46T + 8.13)] \quad (2)$$

That:

ET0: reference plant potential evaporation-transpiration (lawn) based on mm in day (mm/d), P: coefficient related to day length or annual percentage of shinning in month that is described daily, T; monthly mean temperature (°C), and a and b are climate coefficients.

2.2. Torrent White Method:

This method was developed for the first time in east US and monthly mean temperature was just used to determine potential E-T. Torrent White relationship is as following: (Safavi, 2009)

$$PET = 1.6L_a\left(\frac{10\overline{T}_a}{I_t}\right)^a \quad (4)$$

That:

PET: is monthly potential evaporation-transpiration (cm0, L_a: is modifying coefficient for number of light hours and month numbers dependent on geographical width, $\overline{T}_a$: it is monthly temperature based on ℃, I_t: is sum of 12 month thermal indexes($I_t = \sum_{m=1}^{12} i_m$).

In addition, thermal index is: $i = \left(\frac{\overline{T}_a}{5}\right)^{1.514}$ (5)

a: empirical constant obtained from following relationship:

$a = 6.75 \times 10^{-7} I_t^3 - 7.71 \times 10^{-5} I_t^2 + 1.792 \times 10^{-2} I_t + 0.4924$ (6)

In Torrent White method, the main hypothesis is that there is a fine correlation among temperature, solar radiations, air humidity, and wind, so just temperature is used to determine potential E-T.

2.3. FAO-Penman- Monteith Method

In May 1390, in gathering of experts of Food and agriculture organization (FAO) on using combination method of Penman-Monteith as a standard updated method to estimate reference E-T. Penman-Monteith method has been estimated by the following way: (journal no. 122 national committee of irrigation and drainage of Iran, 2008):

$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)}$ (7)

ET0: reference evaporation-transpiration (mm/day), G= soil thermal flux (Mjol on m^3 on day), T: daily average of wind velocity (degree Celsius) in 2 meters height, U2: daily average of wind velocity in 2 meters height (m/s), e_s: saturated vapor pressure (kpa), e_a: real vapor pressure (kpa), $e_s - e_a$: lack of saturated vapor pressure (Kpa), Δ: curve slope of vapor pressure (Kpa/ degree Celsius) and γ: psychometric constant coefficient (kpa/ degree Celsius).

2.4. Hargreaves- Samani Method

In this method, it is necessary to calculate average temperature of air (T), maximum and minimum temperature average difference. Then having solar radiation, evaporation and transpiration, E-T is calculated as following:

$EC_0 = 0.0023\ R_a (T + 17.8) TR^{0.5}$ (8)

That

ET0: E-T of reference plant of lawn (mm/day), TR: average difference of Max and Min temperature in mentioned period based on °C, and Ra: out-earth radiation based on water mm.

In order to evaluate the best evaporation and transpiration, least standard estimation error (SEE) and correlation coefficient (R^2) are used. In this way that low standard error and high correlation coefficient according to middle amounts of E-T shows reference method. SEE has been calculated by relation (9).

$SEE = \sqrt{\frac{\sum_{i=1}^{n} (ET_{ab} - \overline{ET})}{n-1}}$ (1)

In above relation, SEE: standard estimation error, ETob: amount of E-T from FAO- Penman- Monteith method, $\overline{ET}$: E-T amounts of each used method and n: total number of data

3. Results

Used psychometric data in this research includes the maximum temperature (Tmax), the mean minimum temperature (Tmin), average temperature (Tmean), average relative humidity, wind average velocity, and sun daily real hours, out-earth radiation (Ra) that are shown in Table 2.

Table 2: Monthly average of climate parameters used in calculation of potential E-T

Parameter/ month	Tmax (℃)	Tmin (℃)	Tmean (℃)	Relative humidity average (%)	Wind average velocity (m/s)	Average daily sunny hours (n)	Maximum average of daily sunny hours (N)	n/M	Out-earth radiation Ra (mm)
Oct	35.25	21.57	28.41	58.43	6.1	8.96	11.5	0.78	11.3
Nov	29.51	18.03	23.77	63.32	6	6.01	10.5	0.56	9.1
Dec	18.79	8.35	13.57	69.73	5.1	5.69	10.2	0.55	7.9
Jan	14.25	7.26	10.75	80.81	5.9	5.58	10.4	0.53	8.5
Feb	19.34	10.12	14.73	77.73	6.1	6.27	11.1	0.56	10.5
Mar	23.2	12.61	17.91	59.67	6.9	7.22	12	0.60	12.7
Apr	28.54	17.13	22.83	57.69	7.2	5.63	12.9	0.44	14.8
May	36.57	24.97	30.77	49.71	6.7	7.43	13.6	0.54	16
Jun	38.7	27.68	33.22	55.53	6.6	10.5	14	0.7	16.5
Jul	39.8	29.05	34.45	49.37	7.1	10.43	13.9	0.75	16.2
Aug	40.19	28.35	34.26	54.09	6.3	10.50	13.2	0.79	15.3
Sep	38.86	25.91	32.38	60.62	6.3	10.02	12.4	0.80	13.5
Annual	30.26	19.25	24.75	61.42	6.3	8.16	12.15	0.64	12.69

Average of monthly and annually potential E-T using FAO-Penman-Monteith, Blany-Criddle, Hargreaves-Samani, and Torrent White using psychometric data has been calculated and offered in Table 3.

Calculated E-T by Blany-Criddle, Hargreaves-Samani and Torrent White were compared with results obtained from E-T by FAO-Penman-Monteith. Obtained amounts from calculation for each method have been drawn than FAO-Penman-Monteith method in one coordinator axis Fig.1. Table (4) shows correlation coefficient, standard error and regressions equations of each method than FAO-Penman-Monteith.

As it is seen from Table 1 and Fig.1, it is indicated that Blany-Criddle method with the most correlation coefficient and the least standard estimation error and nearest slope one by one are the best method

and Torrent White method with the least correlation coefficient and the most standard error and the least slope is the worst method to estimate potential E-T in Deylam region.

Table 3: calculated E-T using various methods

Method/month	FAO- Penman-Monteith	Hargreaves-Samani	Torrent-White	Blany-Criddle
Oct	7.22	4.36	5.75	6.60
Nov	5.22	2.99	2.58	4.61
Dec	3.336	1.98	0.68	2.87
Jan	2.69	1.98	0.41	2.42
Feb	3.27	2.45	0.55	2.85
Mar	5.36	3.49	1.44	4.63
Apr	7.16	4.69	3.20	6.31
May	9.43	5.84	7.83	8.44
Jun	11.16	6.61	11.83	10.51
Jul	10.70	6.51	13.23	9.93
Aug	10.23	6.21	12.99	9.61
Sep	9.11	5.46	9.47	8.36
Annual	7.07	4.38	5.83	6.43

Fig. 2 shows graphic comparison of Blany-Criddle, Hargreaves-Samani, and Torrent White than FAO-Penman-Monteith method. According to figure, the least potential E-T calculated in Deylam City from each of 4 methods related to January month and the most amount of evaporation-transpiration from each of 3 methods FAO-Penman- Monteith, Blany-Criddle, and Hargreaves-Samani related to June month and according to Torrent White method is related to July.

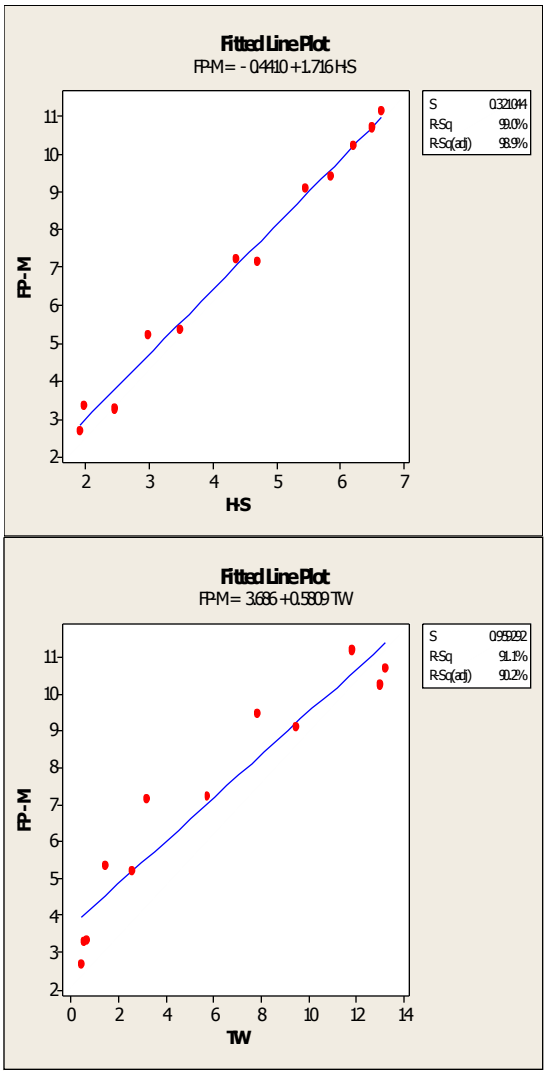
4. Conclusion

According to obtained results, the least potential E-T in Deylam city is related to January month and the most amount of evaporation-transpiration is related to June. In addition, results have shown that Blany-Criddle method estimated potential E-T amount in synoptic station of Deylam 9% less than amount of E-T by Torrent White for synoptic station of Deylam 18% less than calculated E-T by FAO-Penman-Monteith.

Table 4: Comparison of various methods than FAO-Penman Monteith Method

Method	R^2	SEE	Correlation equation
Blany-Criddle	0.999	0.02	0.3644+1.043X=Y
Hargreaves-Samani	0.990	0.10	0.4410+ 1.716X=Y
Torrent White	0.910	0.92	3.6860+0.5609X=Y

Hargreaves-Samani method estimated the least precision in E-T of synoptic station of Deylam have estimated E-T 38% less than E-T estimated by FAO-Penman-Monteith. Totally, according to amount of standard error, correlation coefficient and difference amount in estimating potential E-T it can be stated in this way that E-T calculation by Blany-Criddle method is so near to calculated E-T by FAO-Penman-Monteith that are corresponded by results of Shahedi and Zarei research (2011). Therefore, while lack of needed statistics to utilize FAO-Penman-Monteith method in Deylam city, Blany-Criddle method can be considered as the best index to measure and explore potential E-T and water need in region.



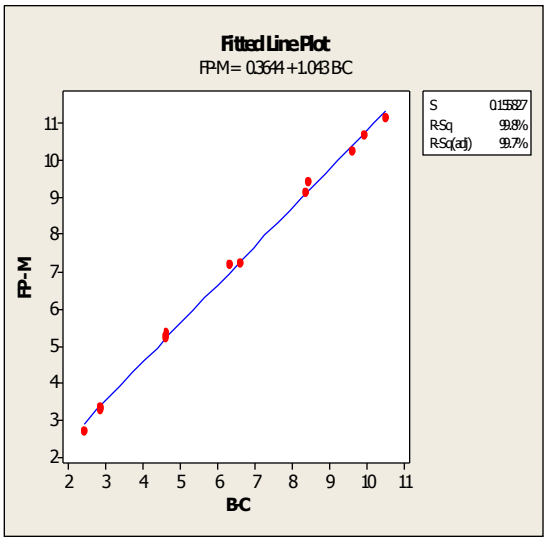


Fig.1: Comparison Results of Various methods by FAO-Penman- Monteith

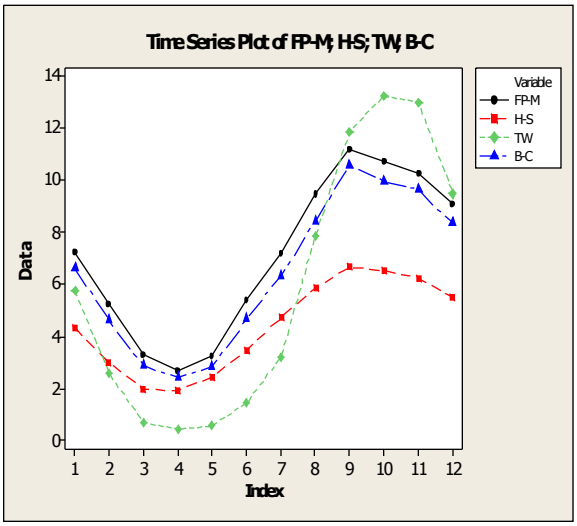


Fig.2: Graphic comparison of B-C, H-S, and TW methods than FP-M method

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