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Assessment of Potential Evapotranspiration Estimation Methods in the Fasa Region

Hedieh Ahmadpari[1], Elham Sadat Shokoohi[2], Nasrin Mohammadi Lalabadi[3]*, Maryam Safavi Gerdini [4], Mahboube Ebrahimi[5]

[1]M.Sc. Graduate of Irrigation and Drainage, University of Tehran, Iran.
[2]M.Sc. Graduate of Desert Area Management, University of Tehran, Iran.
[3]M.Sc. Graduate of Agronomy, University of Tehran, Iran.
[4]Ph.D Student of Water Resources, University of Birjand, Iran.
[5]Assistant Professor, Department of Agriculture, Payame noor University, Tehran, Iran.

***Corresponding Author**

Abstract: *The base of irrigation system design is the estimation of Evapotraspiration (ETo) more correctly. According to need to determine of ET correctly in water balance calculations and the lack of suitable meteorological data, collecting ET method or model for simulating Evapotranspiration is essential. The Penman-Monteith FAO is a valid method, which has been presented by Food and Agriculture Organization of the United Nations, for estimating reference evapotranspiration and it provides the precise results in comparison with direct measurements. The mentioned method needs different parameters such as wind speed, air temperature, net radiation and sunshine hours for estimation of reference evapotranspiration. Also, the Penman-Monteith FAO is a suitable method for evaluating empirical methods. In this study reference crop evapotranspiration calculated by Ref-ET software for Fasa, by using Fasa synoptic stations meteorological data during years 2004 to 2018. The results of methods evaluated with Penman-Monteith FAO standard method. The efficiency of all methods were evaluated with Root mean square Error (RMSE), Mean Absolute Error (MAE) statistic parameters. The results showed that ASCE st PM, ASCE PM, ASCE PM, ASCE PMrs, 1972 K Pen, FAO 24Pen, FP 17 Pen, 1996KPen, 1948Pen, 1985 Harg, 1961Turc, FAO 24BC, FAO Pan, Prs -Tylr and 1957Makk methods, respectively, have less MAE and RMSE. So in situation of less data for Penman Monteith FAO method in Fasa, it is possible to use of other methods that needs few hydrological parameters.*

Keywords: Evapotraspiration, Ref-ET software, Fasa region, FAO Penman Monteith, RMSE, MAE

INTRODUCTION

One of the prerequisites for optimal water management in the watershed is the accurate estimation of the water balance components, and potential evapotranspiration is one of the factors affecting the water balance. Accurate estimates of evapotranspiration play an important role in studies such as global climate change, environmental development and water resource control (Liu et al, 2010). The phenomenon of evapotranspiration causes water and moisture losses from the levels of water, soil and vegetation and it is important to calculate it using a suitable method considering the small amount of precipitation and water resources limitation in Iran. The methods of estimating the evapotranspiration of plants are divided into two main groups directly and indirectly (computational). Various methods including lysimetric methods are proposed in the form of direct methods for measuring evapotranspiration, but the use of lysimeter is not feasible due to the lack of affordable and time consuming measurement of data in all regions. For this reason, researchers have tried to use indirect methods of estimating evapotranspiration from evaporation pan values or some meteorological data. In all indirect methods that are used to determine the amount of evapotranspiration, the potential evapotranspiration (ET_O) value is estimated and, using this, the water requirement of the desired plant is calculated. Several methods have been proposed for estimating ET_o, each of them has certain limitations and can be recommended in special condition. All of these methods are a combination of theoretical concepts and empirical results. In experimental methods, the basis of the work is on the temperature parameter and using the ambient temperature, the potential evapotranspiration is calculated. The combined methods for calculating potential evapotranspiration use two processes of energy balance and aerodynamics. In recent years, many experimental methods have been provided by experts to estimate evapotranspiration, each of which is a function of specific climate variables. Most of these methods have been obtained under local calibration and have been shown to have limited global credibility. The International Commission on Irrigation and Drainage (ICID) proposed the Penman- Monteith FAO method as a standard method for calculating potential evapotranspiration and for evaluating other methods of estimating evapotranspiration (Ahmadpari et al, 2017). Considering that at many meteorological stations, all parameters required for the Penman- Monteith FAO method, including radiation reached the ground, should not be measured, therefore, a simpler method should be used to estimate the reference evapotranspiration with high precision and needs less input parameters. Sentelhas et al. (2010) calculated the reference evapotranspiration for Ontario in Canada by different methods and compared with the results of the Penman- Monteith FAO method. Their results showed that Priestley-Taylor and Hargreaves methods could be a good alternative for Penman- Monteith FAO method. Trajkovic and Kolakovic (2009) calculated the reference evapotranspiration for the Balkans region under wet weather conditions by Hargreaves, Priestley-Taylor, Turc, Jensen-Haise and Thornthwaite methods and compared with the results of the Penman- Monteith FAO method. The results showed that the most suitable methods are Turc, Priestley-Taylor, Jensen-Haise, Thornthwaite and Hargreaves respectively. Castaneda and Rao (2005) calculated the reference evapotranspiration for Southern California by Blaney-Criddle, Thornthwaite, Turc and Makkink methods and compared with the results obtained from the Penman- Monteith FAO method. The results showed that the most suitable methods in this region are Turc, Makkink, Blaney-Criddle and Thornthwaite respectively. In Iran, studies to estimate ET_o with different methods and their comparison is done. Valipour (2014) evaluated of different equations to estimate potential evapotranspiration versus Penman Monteith FAO method in 31 provinces of Iran. The results showed that the Albrecht model estimates the potential evapotranspiration better than other models in the most provinces of Iran (23 provinces). Panahi et al. (2016) evaluated of empirical methods for estimating reference evapotranspiration in Tabriz station. In the research, using meteorological parameters of Tabriz station, which is located in semi-arid region, the values of reference evapotranspiration of empirical methods were compared with correspondent FAO-Penman-Monteith values. The obtained results showed that the Hargreaves method with root mean squared error of 0.43 and correlation coefficient of 0.98 provided the precise estimations of reference evapotranspiration in comparison with other empirical methods. Ahmadpari et al. (2018) evaluated of Penman Monteith FAO and alternative methods for estimating reference evapotranspiration with missing data in Eqlid county. The results showed that ASCE st PM, ASCE PM, ASCE PM, ASCE

PMrs, 1972 K Pen, FAO 24Pen, FP 17 Pen, 1948Pen, 1996 KPen, 1985 Harg, FAO 24Rd, FAO 24BC, 1957 Makk, Prs –Tylr, 1961 Turc and FAO Pan methods, respectively, have less mean absolute error (MAE) and root mean square error (RMSE). Ahmadpari et al. (2018) evaluated of evapotranspiration estimation models for use in Arsanjan county. The results showed that Methods based on Penman (ASCE stPM, ASCE PM, ASCE PMrs, 1972KPen, FAO 24Pn, 1948Pen, 1996KPen, FP 17 Pen), respectively, with the RMSE of about 0.011, 0.150, 0.150, 0.225, 0.275, 0.333, 0. 565, 0.601 and with the MAE of about, 0.007, 0.131, 0.131, 0.210, 0.233, 0.264, 0.470, 0.532 appropriate methods for estimating reference evapotranspiration are considered. FAO Pan, Prs –Tylr, 1957 Makk, FAO 24Rd, FAO 24BC, 1961 Turc, 1985 Harg methods, respectively, with the RMSE of about 2.580, 1.726, 1.710, 1.284, 1.064, 0,997, 0.772 and with the MAE of about 2.192, 1.649, 1.604, 1.023, 0.952, 0.876, 0.662 has the least compliance with the FAO Penman-Monteith method. Ahmadpari et al. (2018) compared of different methods to estimate reference evapotranspiration in Bavanat county with Penman-Monteith FAO Standard method. The results showed that ASCE st PM, ASCE PM, ASCE PM, ASCE PMrs, 1972 K Pen, FAO 24Pen, FP 17 Pen, 1948Pen, 1996 KPen, 1985 Harg, FAO 24Rd, FAO 24BC, 1957 Makk, 1961 Turc, Prs -Tylr and FAO Pan methods, respectively, have less MAE and RMSE. Joshani et al. (2017) evaluated of different methods of the estimation of reference evapotranspiration by FAO's evaporation pan method in catchment basin of east and south eastern of the Iran. Based on the results, considering the different time dimensions, the methods Hargreaves-Samani, Blaney–Criddle-FAO 24, Turc and Priestley–Taylor, have the best conformity with reference evapotranspiration values resulted by evaporation pan. Fooladmand and Sepaskhah (2005) evaluated and calibrated of three evapotranspiration equations in a semi-arid region (Bajgah area, Fars province, in Iran). Monthly values of ET_o were estimated with Penman-FAO, Penman-Monteith and Hargreaves equations using the mean monthly weather data from 1986-2002 (17 years). The Penman-Monteith and Hargreaves equations were calibrated based on Penman-FAO method which was recognized as the most appropriate equation for ET_o estimation, according to the previous studies. This study showed that the results of Penman-Monteith and Hargreaves equations are similar to but somehow they underestimate ET_o compared with Penman-FAO method. Behmanesh et al. (2017) evaluated of solar radiation estimation models in estimating reference evapotranspiration in 4 synoptic stations including Urmia, Takab, Salmas and Mahabad in West of Urmia lake catchment. Solar radiation was estimated using seven models including, Hargreaves-Samani, Allen, Self-Calibrating, Samani, Annandale, Bristow-Campbell and Angstrom–Prescott. The evaluation results of the models showed that the Angstrom – Prescott model had the best performance, and the Samani method was the weakest method in the studied stations. Ghamarnia et al. (2013) evaluated and calibrated of reference evapotranspiration models according to calculating periods for a cold semi-arid climate (Sanandaj, in Iran). In this study, daily, ten-day, and monthly calculating periods were studied on accuracy of reference evapotranspiration estimation using FAO Penman Monteith, FAO Radiation, Modified Penman, Hargreaves, Priestley-Taylor and Makkink models. The results showed that the modified Penman method can predict reference evapotranspiration with higher accuracy in all periods and calibration of the equation and has no effects on its accuracy. Also, the results showed that the computational periods have no significant effects on the accuracy of different models prediction. Kahkhamoghadam (2018) evaluated of reference evapotranspiration models for warm arid climate (Zahedan station, in Iran). In this study, 30 commonly used ET_o equations that belonged to four groups: (1) pan evaporation-based methods, (2) temperature-based methods (3) radiation-based methods, and (4) mass transfer-based methods were evaluated against the PMF-56 standard model. In general, the comparative results showed that the mass transfer-based equations had the worst performances, while the radiation-based and temperature-based models (as Turc, Jensen-Haise, Hargreaves- 4 and Blaney-Criddle) were the bestsuited equations for estimating ET_o in this warm arid climate (Zahedan). Assareh and Davoodi (2014) evaluated the methods of estimation potential evapotranspiration in Omidiyeh Town, in Iran. In the study, the FAO-Penman-Monteith (FP-M) method was considered as the reference and accuracy of Blaney Criddle (BC), Torrent White (TW) and Hargreaves-Samani (HS) methods that need fewer climatic parameters was compared to it. The results showed that Blaney-Criddle method, compared to other methods used, with the highest correlation coefficient and the lowest standard error along with FAO Penman-Monteith method were more accurate in estimating potential evapotranspiration in Omidiyeh. According to the literature review, it seems that a comprehensive study on the evaluation of different methods of evapotranspiration in the Fasa region has not been conducted based on the Penman- Monteith FAO method. Therefore, the purpose of this study is to determine the accuracy of different methods for estimating reference evapotranspiration in comparison with the Penman- Monteith FAO method for the Fasa synoptic station and to introduce possible alternative methods in the absence of meteorological data for the reference method.

Materials and Methods

The study area

The study area in this research is Fasa county, Fars Province, Iran, located 1456 meters above sea level. The average annual rainfall of the Fasa county is about 380 mm and in Longitude of 53 ° 19 ' east, latitude of 28 ° 31' north is located. The center of this county is Fasa. Fasa has 11,000 hectares of cultivated land and has the first place to produce wheat in Iran. Fasa has the second place to produce of corn in Iran. Other products of the county are cotton, barley, tomato, eggplant, onion, potato, sugar beet, watermelon and melon, walnut, almond and date palm. The location of this county is shown in Figure 1.

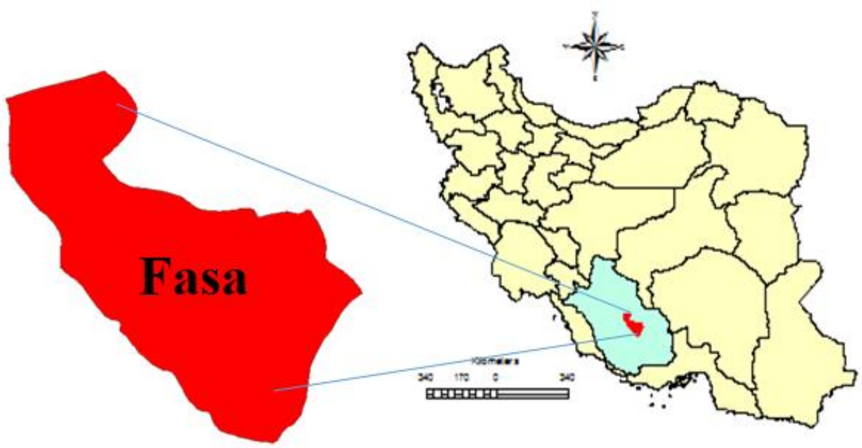


Figure 1: Location of study area in Iran and Fars province

Research method

To conduct this research and calculate the reference plant evapotranspiration, monthly meteorological data including minimum temperature, maximum temperature, average temperature, minimum relative humidity, maximum relative humidity, average relative humidity, rainfall, average evaporation, mean sunny hours and average wind speed of Fasa meteorological station at the statistical years of 2004 to 2018 used. In this study, Ref-ET software has been used to calculate the evapotranspiration of the reference plant. This software calculates 17 different methods of reference plant evapotranspiration. According to available statistics and data, 16 methods were selected and the evapotranspiration calculations were performed using Ref-ET software. Table 1 shows the equations used in this study.

Table 1: Evapotranspiration equations used to evaluate evapotranspiration

Equations based on Penman's method	Other equations
ASCE PM= ASCE Penman-Monteith (full) (grass, rs=f (timestep))	FAO 24 Rd= FAO 24 Radiation
ASCE PMrs= ASCE Penman-Monteith (full) (grass w/user spec.rs)	FAO 24 BC= FAO 24 Blaney-Criddle
ASCE stPM= ASCE Penman-Monteith Standardized	1961 Turc= Turc (1961)
FAO 56 PM= FAO 56 Penman- Monteith	1957 Makk= Makkink (1957)
FP17Pen= FAO Plant Protection Paper 17 Penman	Prs- Tylr= Priestley-Taylor (1972)
FAO 24Pn= FAO 24 Corrected Penman	1985 Harg=1985 Hargreaves (Hargreaves and Samani)
1996 Kpen=1996 Kimberly Penman	FAO Pan= FAO 24 Pan Evaporation
1972 Kpen=1972 Kimberly Penman	
1948 Pen=1948 Penman	

Among these methods, to determine the most suitable method for estimating potential evapotranspiration of Fasa meteorological station, Penman-Monteith FAO method was selected as the reference method and other methods were compared with it.

Statistical indicators

In this study, for the comparison of the results of different models of evapotranspiration, the root mean square error (RMSE) and mean absolute error (MAE) were used. The RMSE value indicates how much the predictions have estimated the measurements more or less and the MAE value represents the accuracy of the method and the mean value of the error. Whatever the value of the indicators is closer to zero, the better (the difference between the predicted and measured values is lower). The statistical indices RMSE and MAE are defined as equations 1 and 2.

$$\mathrm{RMSE} = \left[\frac{\sum_{i=1}^{n}(\mathrm{P}-\mathrm{O})^2}{n}\right]^{1/2} \quad (1)$$

$$\mathrm{MAE} = \frac{\sum_{i=1}^{n}|(P-O)|}{n} \quad (2)$$

In the above relations, p is the predicted value, o the observed value and n is the number of data.

Results and Discussion

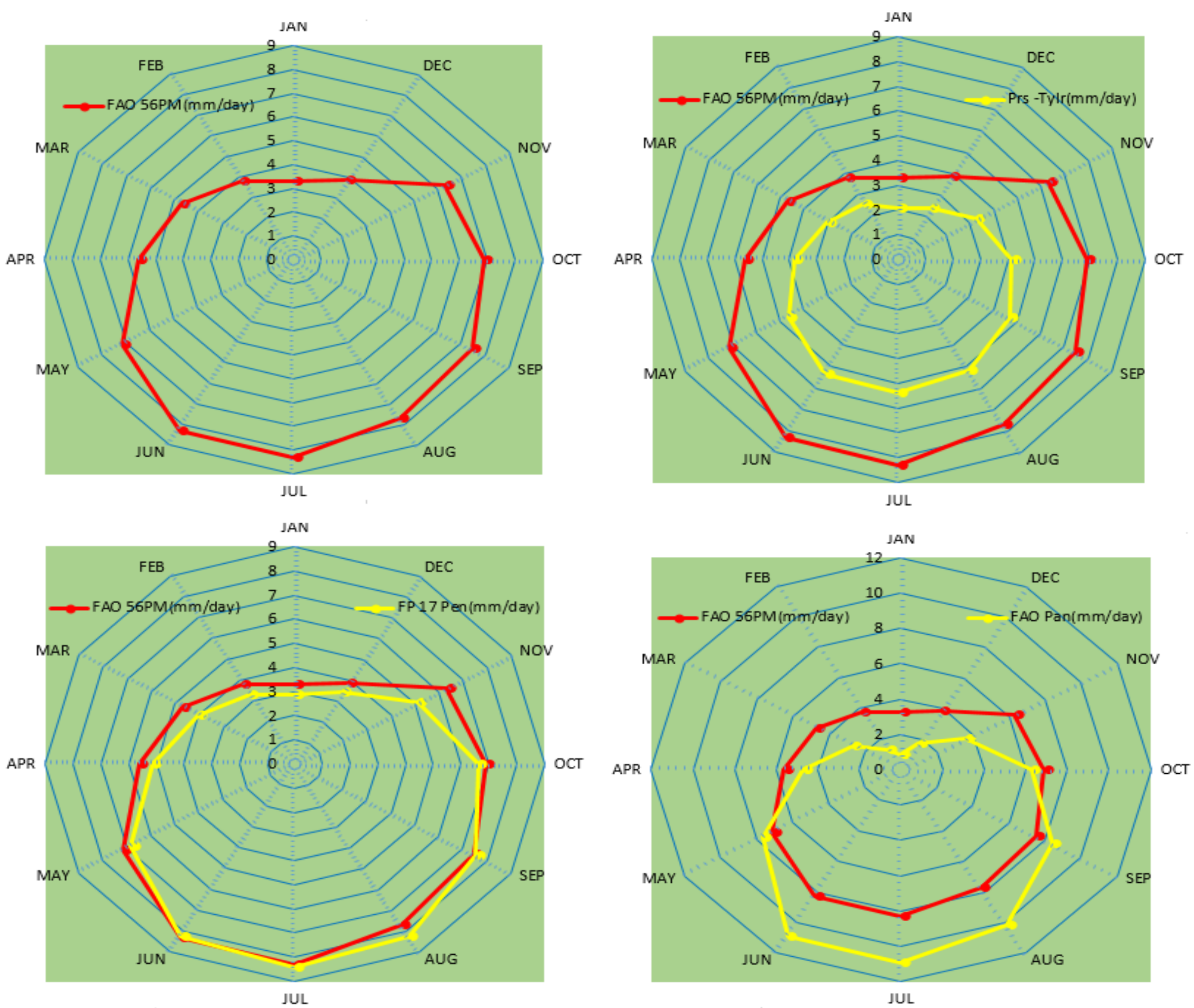
The potential evapotranspiration for the Fasa synoptic station was calculated on a monthly basis in 16 methods. The results for different methods in different months of the year are presented in Table 2 according to millimeters per day.

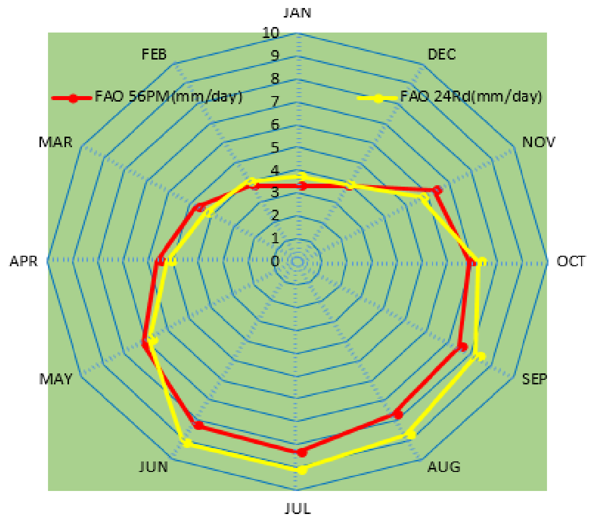
Table 2: Average values of evapotranspiration obtained during the statistical period for the reference plant with different methods according to millimeters per day

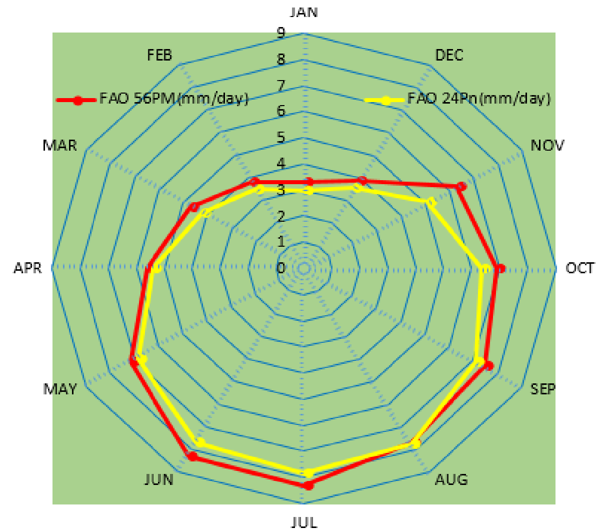
month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
FAO56PM	3.29	3.81	4.72	5.63	7.16	8.27	8.32	7.69	7.47	6.88	6.31	3.85
ASCE PM	3.35	3.82	4.78	5.72	7.34	8.54	8.58	7.9	7.65	7.07	6.49	3.92
ASCE PMrs	3.35	3.82	4.78	5.73	7.34	8.54	8.58	7.9	7.65	7.07	6.49	3.92
ASCE stPM	3.29	3.75	4.68	5.61	7.15	8.3	8.32	7.66	7.43	6.88	6.31	3.85

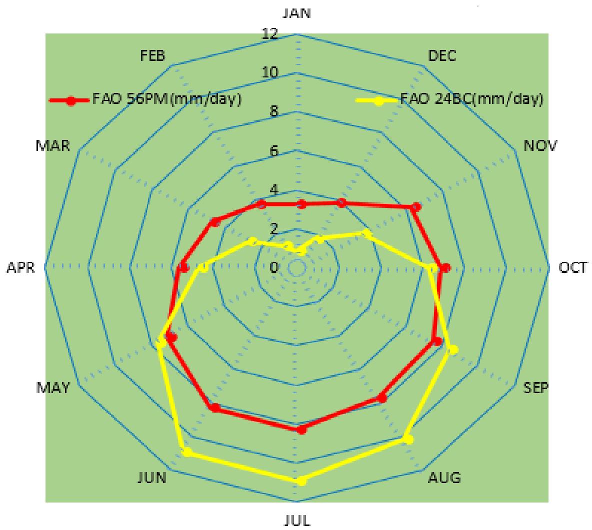
1996 KPen	2.65	3.11	3.71	4.65	6.45	8.53	9.01	8.31	7.74	6.34	5.03	3.13
1972KPen	3.6	4.11	5.01	5.89	7.41	8.53	8.54	7.86	7.76	7.26	6.77	4.19
1948Pen	2.58	2.94	3.62	4.65	6.11	7.37	7.5	7.28	6.65	5.87	4.55	3.11
FAO 24Pn	3	3.5	4.23	5.4	6.88	7.71	7.81	7.73	7.1	6.34	5.1	3.55
FP 17 Pen	2.86	3.29	4.03	5.15	6.83	8.23	8.43	8.25	7.56	6.62	5.12	3.46
FAO 24Rd	3.72	4.06	4.3	5.22	6.88	9.18	9.09	8.75	8.25	7.22	5.65	3.91
FAO 24BC	0.88	1.3	2.69	4.7	7.68	10.9	10.9	10.2	8.38	6.25	3.59	1.69
FAO Pan	0.88	1.3	2.69	4.7	7.68	10.9	10.9	10.2	8.38	6.25	3.59	1.69
1985 Harg	3.13	4.05	5.53	6.91	8.96	10	10.2	9.06	7.96	6.15	5.16	3.17
Prs -Tylr	2.06	2.56	3.03	3.83	4.65	5.34	5.4	5.14	4.68	4.15	3.28	2.41
1957 Makk	2.52	2.74	2.85	3.41	4.39	5.25	5.18	4.94	4.77	4.37	3.64	2.62
1961 Turc	4.14	2.7	3.01	3.7	4.91	5.86	7.24	6.99	6.88	5.84	4.35	2.65

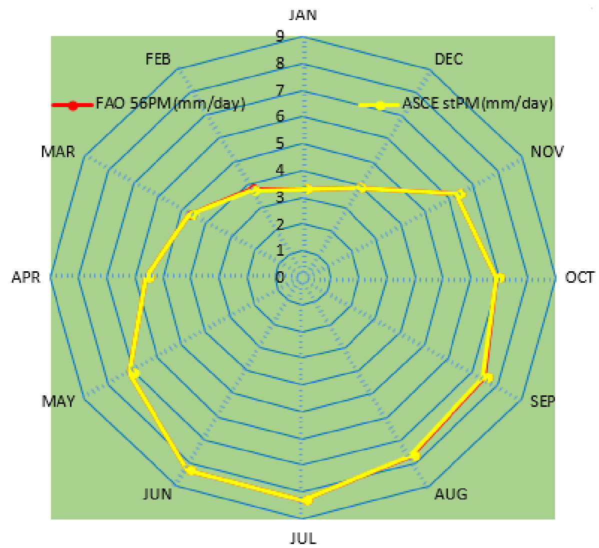
In order to better compare the results of different methods of evapotranspiration, the values calculated by each method were compared with the results of the Penman-Monteith FAO equation as a reference method. In Fig. 2, evapotranspiration calculated by different methods been compared with evapotranspiration obtained from the Penman-Monteith FAO equation.

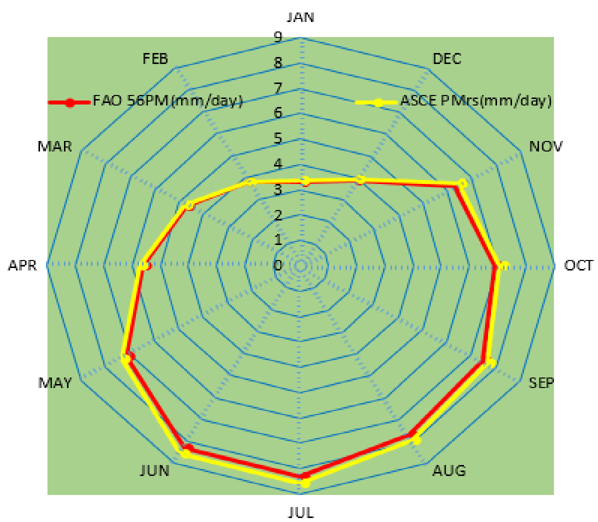


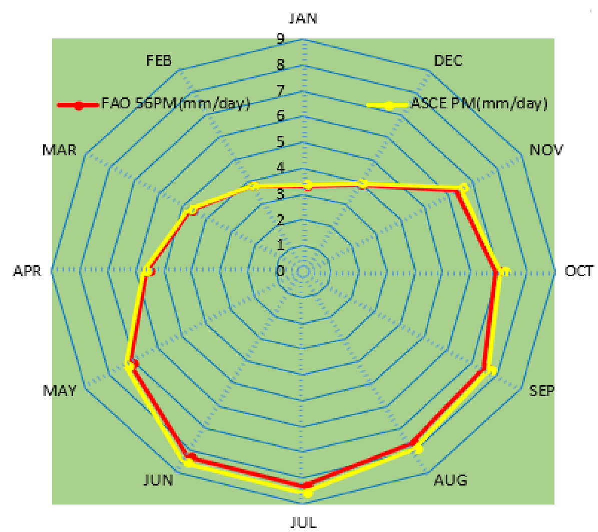

FAO 56PM(mm/day)
FAO 24Rd(mm/day)


FAO 56PM(mm/day)
FAO 24Pn(mm/day)


FAO 56PM(mm/day)
FAO 24BC(mm/day)


FAO 56PM(mm/day)
ASCE stPM(mm/day)


FAO 56PM(mm/day)
ASCE PMrs(mm/day)


FAO 56PM(mm/day)
ASCE PM(mm/day)

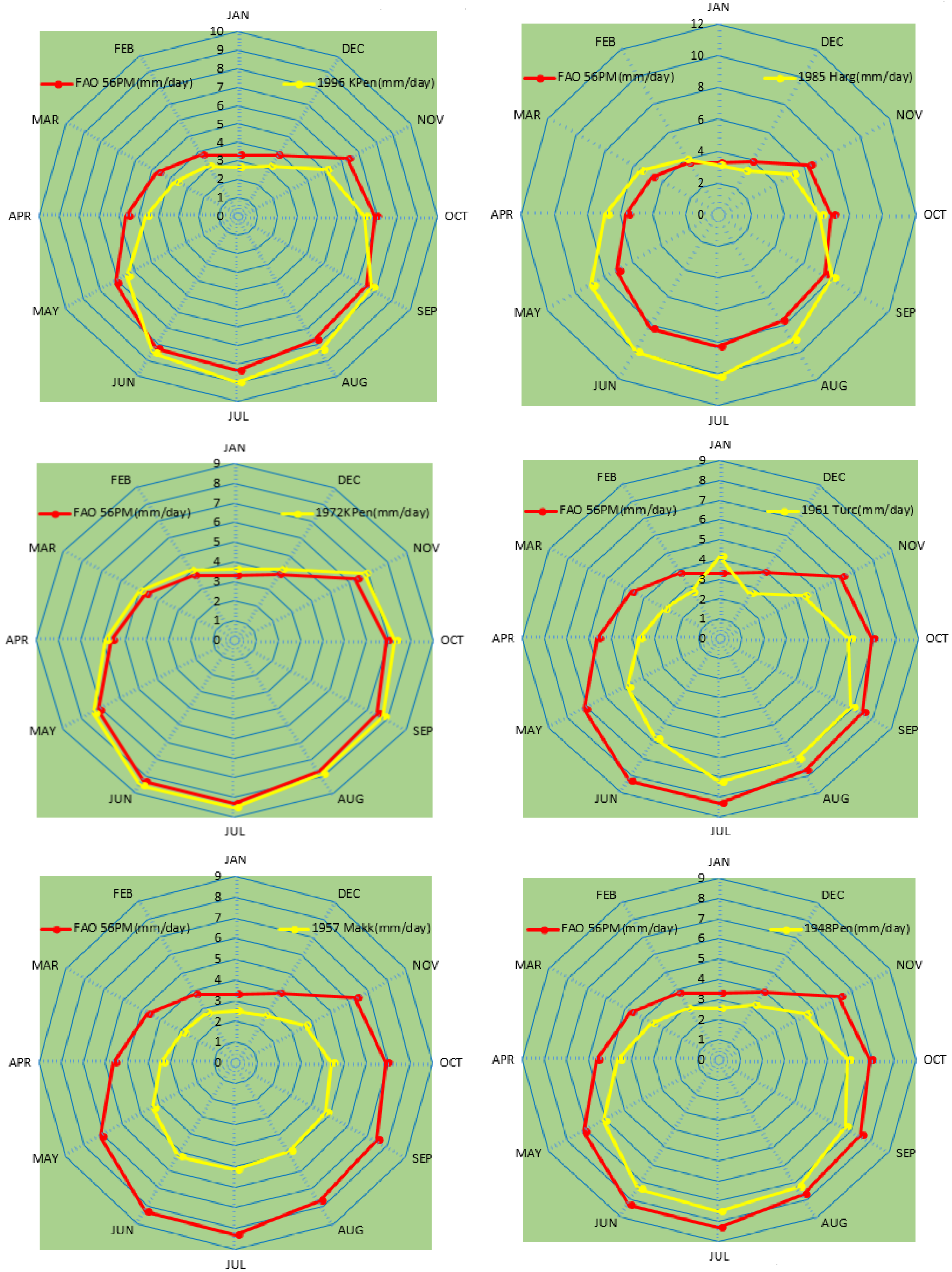


Figure 2: Comparison of evapotranspiration results obtained from the FAO Penman-Monteith method and the investigated methods

monthly estimation of potential evapotranspiration by Penman-Monteith FAO method shows that the lowest and highest potential evapotranspiration is estimated for January and July month, respectively. As shown in fig. 2, The amount of computational evapotranspiration by some methods for some months estimated be more and less than real value. The methods of 1957 Makk, Prs-Tylr and 1961Turc in all months of the year, the amount of potential evapotranspiration estimates less than the reference method. Since the methods of 1957 Makk, Prs-Tylr and 1961Turc estimate the amount of evapotranspiration less than the real value. If the data of these methods are used, the probability of water stress will increase for the plant. Figure 2 shows that methods ASCEstPM, ASCE PMrs, ASCE PM, 1972KPen, FAO 24Pn and FP 17 Pen have good compliance with the Penman-Monteith FAO method. In order to evaluate the accuracy of the methods and compare their results with the values obtained from the reference method (Penman-Monteith FAO method), the statistical indicators of MAE and RMSE have been used. Whatever the difference between the amount of computational evapotranspiration in other methods with the Penman-Monteith FAO method is less, the index values are closer to zero, indicating the high accuracy of the method used. Table 3 shows the results of root mean square error (RMSE) and mean absolute error (MAE) using different methods, compared to the Penman-Monteith FAO method for the Fasa county.

Table 3. Results of statistical indices according to millimeters for different methods compared with the reference method

Evapotranspiration equations	MAE	RMSE
ASCE stPM	0.019	0.028
ASCE PM	0.147	0.168
ASCE PMrs	0.147	0.168
1972KPen	0.294	0.303
FAO 24Pen	0.424	0.509
FP 17 Pen	0.428	0.520
FAO 24Rd	0.531	0.604
1996 KPen	0.702	0.755
1948Pen	0.931	0.980
1985 Harg	1.027	1.175
1961 Turc	1.403	1.523
FAO 24BC	1.878	2.052
FAO Pan	1.878	2.052
Prs-Tylr	2.227	2.338
1957 Makk	2.239	2.356

Statistical analysis shows that methods based on Penman (ASCE stPM, ASCE PM, ASCE PMrs, 1972KPen, FAO 24Pn, FP 17 Pen, 1996KPen, 1948Pen), respectively, with the RMSE of about 0.028, 0.168, 0.168, 0.303, 0.509, 0.520, 0.755, 0.980 and with the MAE of about, 0.019, 0.147, 0.147, 0.294, 0.424, 0.428, 0.702, 0.931 appropriate methods for estimating reference evapotranspiration are considered. FAO 24Rd method has less MAE and RMSE and good compliance with the Penman-Monteith FAO method. 1957 Makk, Prs -Tylr, FAO Pan, FAO 24BC, 1961 Turc, 1985 Harg methods, respectively, with the RMSE of about 2.356, 2.338 ,2.052, 2.052, 1.523, 1.175 and with the MAE of about 2.239, 2.227, 1.878, 1.878, 1.403, 1.027 have the least compliance with the Penman-Monteith FAO method. So in situation of less data for Penman-Monteith FAO method in Fasa, it is possible to use of other methods that needs little hydrological parameters.

Conclusion

Excessive consumption of water in various sectors, especially agriculture, has caused water scarcity to be a serious crisis that threatens human life worldwide. To solve this problem is the need to manage water resources. One of the most important factors in water resources management is the accurate estimation of water balance to be based on there could be proper planning for water resources and various uses. One of the important parameters in water balance is evapotranspiration. The accurate estimation of evapotranspiration in a region and on an annual scale is very difficult and requires a lot of time and cost. Therefore, in this study, we have tried to use the Penman-Monteith FAO method for estimation of evapotranspiration in the Fasa region and then, using its results, we can select the methods that have the best results for the Fasa region. According to the results obtained in this study, it can be said that in the case of lack of statistics for using the Penman-Monteith FAO method at the Fasa synoptic station, ASCE st PM, ASCE PM, ASCE PMrs, 1972KPen, FAO 24Pen, FP 17 Pen, FAO 24Rd and 1996 KPen methods can be considered as the best indicator for measurement and examination of potential evapotranspiration and plant water requirements in the region. According to this study and the importance of potential evapotranspiration in water resource management, the following suggestions are presented:

1) Estimate potential evapotranspiration in the Fasa region with other software like ETo calculator, Cropwat, AGWAT, Netwat, artificial neural network, Geographic Information System (GIS) and Remote Sensing (RS) and comparison with the results of this study.
2) Using climate change models, climate parameters will be estimated for the future and potential evapotranspiration using it will be predicted.
3) Using the results of this research in other research, future studies and decisions in the Fasa region.
4) Similar to this research be done for other regions in the world.

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