Medbiotech Journal

MBTJ, 3(1): 001-004, 2019

Research Paper

Assessment of empirical methods for estimating potential evapotranspiration in Zabol Synoptic Station by REF-ET model

Amir Ahmadipour [a] *, Peyman Shaibani [a], Seyed Abdalreza Mostafavi [b]

[a]Department of Hydrology, University of Zabol, Iran
[b]Department of Environmental Geology, Payam Noor University Taft Branch, IRAN

Received: 14 December 2018 Accepted: 02 February 2019 Published: 01 March 2019

Abstract

Estimates of potential evapotranspiration are essential for planning, designing, and managing irrigation and drainage plans and water resource management. Evapotranspiration involves evaporation from the Earth's surface and water, and plant transpiration, which is of particular importance in irrigated arid and semiarid areas. In this research, nine methods of potential evapotranspiration estimation, including FAO Penman-Monteith (FAO PM), Penman-Kimberley (1996), Penman (1948), Penman-FAO 24, FAO radiation 24, Blanney Criddle-FAO, Hargreaves (1985), Priestly Taylor, and Makkink (1957) were calculated for the Zabol Synoptic Station. The FAO PM is accepted as a standard method by many researchers and international institutes, hence, it was adopted as a reference approach in this study. Estimates of reference evapotranspiration were determined by different empirical methods using the REF-ET model and were then compared with each other. It was found that the Penman (1948), Penman-FAO 24, Hargreaves (1985), Penman-Kimberly (1996), Blanney Criddle-FAO, FAO radiation, Priestly Taylor, and Makkink (1957) were more suitable methods, respectively, in Zabol synoptic station. Also, regression coefficients and linear equations were presented between each method and the FAO PM approach to convert potential evapotranspiration measured by the other methods into the FAO PM method.

Keywords: Reference evapotranspiration; FAO Penman-Monteith; Zabol Synoptic Station; REF-ET model.

How to cite the article:
A. Ahmadipour, P. Shaibani, S. A. Mostafavi, Assessment of empirical methods for estimating potential evapotranspiration in Zabol Synoptic Station by REF-ET model, Medbiotech J. 2019; 3(1): 001-004, DOI: 10.22034/mbt.2019.80823.

1. Introduction

Reference plant evapotranspiration is the potential evapotranspiration for a particular vegetation, usually grass or alfalfa. The plant of interest should uniformly and completely cover a wide area with green and fresh shrubs. The grass and alfalfa should be of 8-15 cm and 20 cm high, respectively (?). Application of a reference plant for determining potential evapotranspiration is that this quantity varies due to differences of plants in terms of vegetation roughness and energy reflection coefficient, or to the variability of different locations in terms of captured solar energy and both the latent and tangible heat reaching from surroundings. However, the environmental conditions are considered constant for the reference grass plant. The methods for the

* Corresponding author email: Amir.ahmadipour1984@yahoo.com

calculation of potential evapotranspiration can be divided into four groups:

1. The so-called aerodynamic methods
2. The so-called energy power
3. Combined methods
4. Experimental methods (Federer et al., 1996)

The combined FAO PM as the standard method for calculating the reference plant evapotranspiration from climatic data as well as for the evaluation of other methods was introduced by the International Commission on Irrigation and Drainage (ICID) and the UN Food and Agriculture Organization (FAO) in 1990. These methods involve empirical equations and/or complex methods based on physical processes. Combined methods relate evaporation changes with net radiation flux and aerodynamic transfer properties to a natural surface (Allen et al., 1998).

There are approximately 50 methods for the estimation of evapotranspiration. These methods and models, however, provide different values because of their various assumptions and the input data requirements, or because they have been developed for specific climatic zones (Grismer et al., 2002). Previous studies on multiple scales suggested that various methods may distinctly yield different results (Alizadeh et al., 2004). Considering that various methods have been recommended for this purpose, one of the problems of making decision in this case is to choose an appropriate method. Reference evapotranspiration (ET_0) is measured either directly (lysimetery) or is estimated indirectly (empirical equation). Potential evapotranspiration can be measured directly by a lysimeter, but it is generally estimated by empirical or theoretical equations or simply by using a standard evaporation container with a coefficient (Grismer et al., 2002). The most accurate method for estimating the amount of evapotranspiration is the use of weighing lysimeter. However, since the establishment of this kind of lysimeter is very costly and, additionally, the statistics of this method is usually not available, experimental methods are often used for estimating evapotranspiration and the standard method to compare the results (Allen et al., 1994).

Studies conducted around the world indicate that the accuracy of evapotranspiration values estimated with the FAO PM relationship are better than lysimeter values measured by other ET_0 estimation equations, hence it is recommended as a standard relationship in conditions were lysimetery data are not available (Hargreaves, 1994). Salami et al. (2010) evaluated 14 different methods of ET_0 estimation methods at Shiraz Synaptic Station. The results showed that, compared to the FAO PM, the most suitable methods were user input resistance ASCE, PM ASCE, Penman-Kimberly (1996), Penman-Kimberly (1972), Priestly Taylor, Hargreaves (1985), Penman-Kimberly (1982), Blanney Criddle-FAO, Makkink (1957), Penman (1948), FAO radiation 24, Penman-FAO 17, and Penman-FAO 24, respectively. Amatya et al. (1995) compared six methods of evapotranspiration, a combined method (PM), three radiation methods (Makkink, Priestly Taylor, and Turc) and two temperature methods (Torrent White-Hargreaves, and Samani) using meteorological data from three stations in northeastern California. They found that the Torrent White and Makkink-Priestly Taylor were the worst and the best methods, respectively, in comparison to the Penman-Monteith equation used as a standard comparison method. Lu et al. (2005) examined six methods of potential evapotranspiration for 36 forests in the southeastern United States. Three methods were based on the temperature (White Toronto, Hamoon and Samani-Hargreaves) and three were radiation methods (Turc, Makkink, and Priestly Taylor). The results showed that the calculated PET values had high correlations with each other (R = 0.85-1). Higher differences were found between temperature-based methods than radiation approaches. In general, the Priestly Taylor, Turc, and Heamoon were the best methods. Nandagiri and M. Kovoor (2006) studied FAO PM and seven common methods in India in four arid, semi-arid, semi-humid, and humid areas and introduced the FAO PM as the most appropriate method in India. Jabloun and Sahli (2007) investigated the FAO PM and the Hargreaves methods in 8 areas in Tunisia and concluded that the FAO PM method to be very appropriate for estimation of mean daily evapotranspiration and that the results obtained in coastal areas by the Hargreaves method were associated with a reduction in estimates.

In this research, nine methods for estimating potential evapotranspiration, including FAO Penman-Monteith (FAO PM), Penman-Kimberley (1996), Penman (1948), Penman- FAO 24, Radiation FAO 24, Blanney Criddle-FAO, Hargreaves (1985), Priestly Taylor, and Makkink (1957) were calculated t Zabol Synoptic Station by the REF-ET model. This study aimed to compare the annual and monthly values of potential evapotranspiration calculated by different methods using the standard reference method (FAO-PM) at Zabol Synoptic Station.

2. Materials and methods

2.1 Determination of potential evapotranspiration

In this paper, the evapotranspiration of the reference plant was calculated by REF-ET software, designed by Richard Gallen (University of Idaho, USA), which calculates grass and alfalfa evapotranspiration as the reference plants. Various versions of the software were designed during the years 1999 and 2000. The algorithm used in REF-ET is derived from the ASCE instruction, reports of Jensen (1990), the FAO 56 Journal (Allen et al., 1998), and reports of the ASCE Committee for evapotranspiration in irrigation and hydrology during 2000. The software can calculate the reference evapotranspiration as monthly, daily, hourly or less (Amatya et al., 1995). The two main objectives of the software development are to provide a standard program for estimating evapotranspiration and their comparison with each other, and also to offer a standard evapotranspiration estimation method capable of using information as files, various units, and different time periods.

2.2 Introduction of the study area

The Zabol Synoptic Station is located in Fars province (28° 58' N, 53° 41' E, 1,288 m above sea level) with an average annual precipitation of 143 mm during the statistical period 2003-2014, and an average monthly temperature of 14.69° C. Table 1 shows some of monthly synoptic information in the Zabol station during the statistical period of 2003-2014.

Table 1. Some monthly synoptic information at the Zabol station (Data from the Zabol Synoptic Meteorological Station (2003-2014)

Month / Variable	Sep.	Aug.	Jul.	Jun.	May	Apr.	Mar.	Feb.	Jan.	Dec.	Nov.	Oct.
Mean Max. Temp. (°C)	34.3	35.3	32.6	26.9	21.7	15.7	11.7	8.8	11.0	16.0	23.9	30.4
Mean Min. Temp. (°C)	16.3	18.7	15.2	11.1	7.7	2.2	-1.5	-3.5	-1.8	1.5	6.5	11.8
Mean Temp. (°C)	25.3	26.9	23.9	19.0	14.7	8.9	5.1	2.7	4.7	8.8	15.2	21.1
Mean Rel. Humidity (%)	21.1	22.7	23.3	30.2	36.5	42.4	47.3	57.5	56.4	45.9	31.9	23.3
Mean Dew point Temp. (°C)	2.0	4.2	2.2	0.9	-0.8	-4.2	-6.0	-5.6	-4.1	-2.9	-1.5	-0.1
Mean vapor pressure (HPA)	7.4	6.8	7.5	6.9	6.1	4.8	4.2	4.2	4.8	5.3	5.7	6.3
Mean wind speed (Knot)	4.4	5.3	5.5	6.6	7.4	6.8	6.1	3.8	3.5	3.8	4.1	4.1
Mean sunny hours	352.5	331.7	343.1	330.2	256.6	258.8	237.2	220.9	211.5	223.4	291.1	318.6
Mean precipitation (mm)	0.4	0.5	2.6	.6	16.9	27.6	17.3	28.3	26.9	13.5	3.3	0.0

2.3 Evaluation of methods for estimation of potential evapotranspiration

The accuracy of different methods was evaluated by three statistical criteria of mean absolute magnitude difference (MAD), mean difference (BIAS) and efficiency factor. Low values of MAD and BIAS represent less error and model accuracy. Ef values closer to 1 indicate the validity and efficiency of the methods. If Ef is zero, it indicates that the model estimation is not more appropriate than the use of mean observational data. However, the amount of Ef may also be negative, which indicates that it is insignificant and far from the outcome of the evaluated issue.

3. Results and discussion

3.1 Evaluation of estimation methods for potential evapotranspiration at Zabol synoptic station

The FAO-PM method was used to determine the most appropriate method for each station. According to the comparison criteria, the most proper and the most improper were ranked low and high per criteria, respectively. By tabulating the results of these criteria, the method ranked lowest in all the criteria can be considered as the most suitable method. Based on the evaluation, the three criteria of BIAS, Ef, and MAD have almost the same outcomes. According to Table 2, the most suitable methods are Penman (1948), FAO-PM 24, Hargreaves (1985), Penman-Kimberley (1996), FAO-Blanney Criddle, FAO radiation 24, Priestly Taylor, and Makkink (1957), respectively.

Table 2. Final ranking of different methods for estimating evapotranspiration at Zabol station

Criterion / Method	Makkink (1957)	Priestly Taylor	FAO radiation 24	Blanney Criddle	Penman-Kimberley	Hargreaves (1985)	FAO-PM 24	Penman 1948
MAD	8	7	6	5	4	3	2	1
EF	8	7	6	5	4	3	2	1
BIAS	8	7	6	5	4	3	2	1
Total	24	21	18	15	12	8	7	3
Rank	8	7	6	5	4	3	2	1

Table 3. Coefficients of the linear and power equations between different methods and the FAO-PM method at Zabol station

Method	Power equation			Linear equation		
	a	b	r^2	a	b	r^2
Penman-Kimberley (1996)	0.95	0.76	1.65	0.92	1.04	0.88
Penman (1948)	0.99	1.10	0.88	0.99	-0.34	1.11
FAO-PM 24	0.99	1.15	0.99	0.98	-0.54	1.26
FAO radiation 24	0.92	0.81	2.14	0.90	0.66	1.52
FAO-Blanney Criddle	0.92	0.58	2.25	0.95	1.07	1.03
Hargreaves (1985)	0.93	0.82	1.27	0.91	-0.78	0.78
Priestly Taylor	0.87	1.13	1.87	0.87	-0.27	2.23
Makkink (1957)	0.87	0.99	3.12	0.85	0.23	2.96

3.2 Regression relationships between the values of the FAO-PM method and other methods at Zabol station

Table 3 shows the values of the linear and power equations between different methods and the values of the FAO-PM method at Zabol station.

4. Conclusion

The study of climatic conditions is of great importance from different viewpoints, especially droughts and determination of water requirement considering the potential evapotranspiration in Fars province, where traditional irrigation is still common. All equations used to calculate potential evapotranspiration do not use identical climatic parameters, therefore, the values calculated with different methods are not consistent. As such, a question arises that which of these equations gives a better estimate of evapotranspiration in each region, which emphasizes the need for regional studies to determine the most appropriate method in a region. The FAO-PM is one of the standard methods recommended for calculating potential evapotranspiration. At Zabol Synoptic Sstation, the highest evapotranspiration occurs in July, August, and April as a result of dry air and intensive insolation. The results of estimation methods for evapotranspiration were evaluated compared with the FAO-PM as a statistical method using statistical indices such as Nash-Sutcliff (efficiency factor), MAD, and BIAS, all of which yielded almost identical results. The results of the three statistical indices show that the most suitable methods are Penman (1948), FAO-PM 24, Hargreaves (1985), Penman-Kimberley (1996), FAO-Blanney Criddle, FAO radiation 24, Priestly Taylor, and Makkink (1957), respectively, at Zabol station. The results of this study are almost consistent with those of previous researchers. Considering that the most appropriate method for estimating the evapotranspiration of the reference plant is the lysimetery examinations, this method is recommended to be tested at Zabol Synoptic Station to compare the results with this research.

References

Hosseini M., S. M. Mirab, S. A. Karami and A. Attapour Fard. 2005. A study on the conventional methods of estimating potential evaporation at Emameh Station, Second National Conference on Watershed, Water and Soil Resources Management, Kerman, pp. 897-904.

Sepaskhah, A. R. 1998. A revision of the Methods for Calculating Evapotranspiration of Crops, Educational Seminar, Faculty of Agriculture, University of Shiraz: pp. 9.

Alizadeh, A. 2010. Designing Irrigation Systems. First Volume, Fourth Print, Mashad: Ferdowsi University Press: 317-323.