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Full Length Research Paper

Comparing reference evapotranspiration using actual and estimated sunshine hours in south of Iran

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Reference crop potential evapotranspiration (ET_o) is needed for calculating crop water requirement, however its direct measurement by using lysimeter is difficult and time consuming. Although, many equations have been derived for estimating ET_o, however the Penman-Monteith equation is the most common method that has been used for different climates and locations of the world. However, the Penman-Monteith equation needs full weather data such as solar radiation or sunshine hours, therefore the use of this equation has been limited. In this study, in Fars province in south of Iran, monthly sunshine hours were estimated based on minimum, maximum and mean monthly air temperature, and minimum, maximum and mean monthly air humidity, and the obtained equations were used for estimating monthly ET_o based on the Penman-Monteith equation and the results were compared with the Penman-Monteith equation by using actual sunshine hours data. The results indicated that the derived equations for estimating sunshine hours had high accuracy for estimating monthly ET_o with the Penman-Monteith equation. Therefore, it is possible to estiamte monthly ET_o with Penman-Monteith equation in the study area without using the sunshine hours data.

Key words: Air humidity, air temperature, evapotranspiration, sunshine hours.

INTRODUCTION

Evapotranspiration is an important parameter needed for the management and design of irrigation systems, irrigation scheduling and water resources planning. On the other hand, reference crop potential evapotranspiration (ET_o) is used for calculating crop water requirement. Direct measurement of ET_o can be done by using lysimeter, however it is difficult and time consuming. Therefore, several equations have been proposed for estimating ET_o based on weather data, however there is no universal consensus on the suitability of any given equation for a given climate. So, all proposed equations for estimating ET_o needs rigorous local calibration before applying. Nowadays, the Penman-Monteith equation (Allen et al., 1998) is the standard method for estimating ET_o based on meteorological data, and the suitability of this equation have been confirmed for different climates (Ventura et al., 1999; Kashyap and Panda, 2001; Irmak et al., 2003; Itenfisu et al., 2003; DehghaniSanij et al., 2004; Garcia et al., 2004; Stockle et al., 2004; Temesgen et al., 2005; Allen et al., 2005, 2006; Gavilan et al., 2006; Ge et al., 2006; Cai et al., 2007; Jabloun and Sahli, 2008). However, the Penman-Monteith equation needs full weather data including minimum and maximum air temperature, minimum and maximum relative air humidity, solar radiation or sunshine hours, and wind speed. Therefore, the use of this equation has been limited in different locations of the world.

Fars province with semi-arid and arid climates, is one of the most important agricultural parts of Iran, and is located in the south of this country. ET_o measured data by using lysimeter are scarce in Fars province, and few weather stations with long time and complete data for using the Penman-Monteith equation are available in this region. Some studies have been done in Fars province to use the other equations for estimating ET_o instead of the Penman-Monteith equation, and most of these equations have been calibrated and validated based on the Penman-Monteith equation (Fooladmand and Sepaskhah, 2005; Fooladmand and Haghighat, 2007; Ahmadi and

Fooladmand, 2008; Fooladmand et al., 2008; Fooladmand and Ahmadi, 2009; Fooladmand, 2011a, b).

Solar radiation on the surface of the earth's landmasses is an important factor influencing plant growth through photosynthesis and evapotranspiration and, therefore, indirectly influences the soil water available to plants (Yang et al., 2009a). On the other hand, solar radiation can be estimated based on sunshine hours as reported by Allen et al. (1998). Therefore, many studies have been reported in the literature about estimating solar radiation based on sunshine hours at different locations of the world. However, few studies have been done about estimation of sunshine hours based on other weather data. Tiba and Fraidenraich (2004) analyzed the daily and monthly variability of sunshine hours for a large tropical region in Brazil, and the results showed that daily and monthly average sunshine hours are random variables normally distributed. Chen et al. (2006) reported the decreasing trend of annual sunshine hours at 42 stations in China, and Yang et al. (2009a) reported similar results for north China. Also, Yang et al. (2009b) investigated the possible impact of wind speed on the extent of decline in sunshine hours in three major cities in North China, and the results showed that the smallest and largest decline in sunshine hours were dependent on the city with the highest and lowest wind speed, respectively.

The results of a sensitivity analysis for a soil water balance model for rain-fed vineyard in microcatchments in Bajgah area, Fars province, indicated that sunshine hours were not sensitive in the model (Fooladmand and Sepaskhah, 2007). Also, Wang et al. (2011) reported that ET_o estimation with Penman-Monteith equation is more sensitive to both relative humidity and wind speed than sunshine hours and air temperature in Malawi. Also, the obtained results by Wang et al. (2011) indicated that the proposed procedure by Allen et al. (1998) for estimating ET_o with missing sunshine hours data were similar with the ET_o estimation by using full available weather data.

As mentioned, some studies have been done in Fars province for estimating monthly ET_o with different equations instead of the Penman-Monteith equation. Also, no study has been done for estimating monthly sunshine hours in this region. If sunshine hours can be estimated based on other weather data, it is possible to use the Penman-Monteith equation for estimating monthly ET_o in stations with missing sunshine hours data, and in stations that have no instrument for measuring sunshine hours data. Therefore, the objective of this study was to estimate monthly sunshine hours based on other weather data in Fars province, south of Iran for estimating monthly ET_o with Penman-Monteith equation.

MATERIALS AND METHODS

Fars province is located in the southern part of Iran, at 50°30´ to 55°38´ E longitude and 27°3´ to 31°42´ N latitude, with an arable land area of 1.32 million km². The mean annual precipitation and temperature of the province are about 280.8 mm and 17.8°C, respectively. Since, sunshine hours must be available for calculating solar radiation to estimate monthly ET_o with Penman-Monteith equation, and this weather data are not available in all stations in the study area, therefore it has been estimated based on other weather data such as minimum, maximum and mean monthly air temperature, and minimum, maximum and mean monthly air humidity. To do it, nineteen synoptic stations have been selected in the study area with different statistical data upto 2010. Number of data (months), and the mean annual temperature and mean annual rain of all selected stations have been reported in Table 1.

Ojosu and Komolafe (1987) and Ododo et al. (1995) developed two types of global solar radiation models as a function of relative humidity, sunshine hours and air temperature. In another study, Alizadeh and Khalili (2009) derived an equation for estimating solar radiation based on relative humidity, precipitation, maximum and minimum air temperature, saturation vapor pressure deficit and the ratio of measured to maximum possible duration of sunshine hours. Since, solar radiation is a function of sunshine hours according to the Angstrom-Prescott model (Angstrom, 1956), therefore in this study four equations based on minimum, maximum and mean monthly air temperature, and minimum, maximum and mean monthly air humidity were derived for estimating sunshine hours by using multiple linear regressions.

After deriving the equations for estimating sunshine hours, theses equations were used for estimating monthly ET_o with Penman-Monteith equation. Finally, different derived equations have been compared for determining the best condition for estimating monthly ET_o. For this purpose, the root mean square error (RMSE) has been computed to compare the obtained results of different equations with Penman-Monteith equation based on actual sunshine hours data using the following expression:

$$RMSE = \left[\frac{\sum_{i=1}^{n} (y_i - x_i)^2}{m} \right]^{0.5} \quad (1)$$

where *RMSE* is root mean square error (mm day^{-1}), x_i is the estimated ET_o with Penman-Monteith equation by considering the actual sunshine hours data, y_i is the estimated ET_o with Penman-Monteith equation by considering different equations for estimating sunshine hours data, separately and *m* is the sample size for each station in all statistical years. Therefore, the best equation for estimating ET_o based on estimating sunshine hours can be determined in each station, separately, by comparing the different values of RMSE. It is mentioned that the best condition has minimum RMSE value.

RESULTS AND DISCUSSION

To estimate the monthly sunshine hours, other weather data such as minimum, maximum and mean monthly air temperature, and minimum, maximum and mean monthly air humidity were used. The following equations have been derived by using 2990 data of all months and all stations:

$$n = -0.113\,T_{min} + 0.233\,T_{max} + 4.414 \quad (R^2 = 0.696) \quad (2)$$

Table 1. The information about the selected stations.

Station	Number of data (months)	Average of annual rain (mm)	Average of temperature (°C)
Abadeh	290	134.2	14.3
Arsenjan	48	207.7	18.3
Bavanat	96	205.0	13.6
Darab	192	265.1	22.0
Dorodzan Dam	282	476.6	17.7
Eghlid	190	319.4	12.8
Eizadkhast	144	151.0	13.8
Estahban	58	289.3	17.5
Fasa	312	295.8	19.3
Jahrom	60	286.3	20.5
Kazeron	58	303.9	22.8
Lamerd	48	217.0	25.3
Lar	240	204.0	23.6
Neyriz	132	178.0	19.6
Safashahr	60	195.4	11.7
Sepidan	72	663.5	14.8
Shiraz	312	325.0	18.0
Takhtejamshid	156	299.5	17.3
Zarghan	240	317.7	16.2

$$n = -0.069\ RH_{min} - 0.039\ RH_{max} + 12.987\ (R^2 = 0.702) \quad (3)$$

$$n = -0.076\ T_{min} + 0.142\ T_{max} - 0.032\ RH_{min} - 0.028\ RH_{max} + 8.674\ (R^2 = 0.806) \quad (4)$$

$$n = 0.080\ T_{mean} - 0.066\ RH_{mean} + 10.405\ (R^2 = 0.781) \quad (5)$$

where n is the mean daily sunshine hours in each month (h), T_{min}, T_{max} and T_{mean} are the minimum, maximum and mean monthly air temperature (°C), respectively, and RH_{min}, RH_{max} and RH_{mean} are the minimum, maximum and mean monthly air humidity (%), respectively. It is mentioned that all above equations were significant in 5% level.

Then, the above obtained equations for estimating sunshine hours have been used for estimating monthly ET_o with Penman-Monteith equation. The mean values of ET_o for different stations and different conditions have been presented in Table 2. As shown in this table, the difference between mean monthly ET_o based on Penman -Monteith equations and other conditions are very small, and this results indicated that the low sensitivity of sunshine hours for estimating ET_o which were in agreement with the obtained results by Fooladmand and Sepaskhah (2007) and Wang et al. (2011). In Table 3, the RMSE values of different conditions for estimating sunshine hours compared against the Penman-Monteith equation based on actual sunshine hours data, have been presented for all stations. As shown in this table, the Equation (4) was the best condition for most stations which was in agreement with the highest R^2 value of this equation. Therefore, the combination of T_{min}, T_{max}, RH_{min} and RH_{max} were better that the combination of T_{mean} and RH_{mean}. Figure 1 shows the appropriate scattering of monthly ET_o with the Penman-Monteith equation based on actual sunshine hours data and the Penman-Monteith equation based on estimating sunshine hours data by using the Equation (4) around the line one:one. Therefore, the results of this study indicated that the derived equations for estimating sunshine hours (especially the Equation 4) had high accuracy for estimating monthly ET_o with the Penman-Monteith equation.

Conclusions

Although the Penman-Monteith equation is a standard method for estimating ET_o, however because this equation needs full weather data such as solar radiation or sunshine hours, the use of it has been limited in the world. Therefore, in this study at first sunshine hours have been estimated and then used for estimating monthly ET_o with the Penman-Monteith equation. The results of this study showed the low sensitivity of sunshine hours for estimating ET_o with Penman-Monteith equation. So, the results for the study area (Fars province, south of Iran) demonstrated the high accuracy

Table 2. The mean ET_o values (mm day^{-1}) for different stations and different conditions.

Station	ET_o (Penman-Monteith)	ET_o (Equation 2)	ET_o (Equation 3)	ET_o (Equation 4)	ET_o (Equation 5)
Abadeh	4.29	4.25	4.32	4.29	4.29
Arsenjan	4.76	4.73	4.79	4.78	4.80
Bavanat	4.24	4.19	4.29	4.25	4.25
Darab	5.28	5.30	5.23	5.27	5.28
Dorodzan Dam	4.49	4.47	4.48	4.48	4.50
Eghlid	4.12	4.03	4.15	4.10	4.11
Eizadkhast	4.18	4.13	4.22	4.18	4.20
Estahban	4.73	4.72	4.73	4.74	4.73
Fasa	4.99	5.03	4.96	5.01	4.98
Jahrom	5.19	5.25	5.11	5.19	5.17
Kazeron	5.25	5.34	5.26	5.31	5.33
Lamerd	5.88	6.06	5.89	5.99	5.98
Lar	5.52	5.60	5.44	5.53	5.53
Neyriz	4.88	4.81	4.87	4.85	4.88
Safashahr	4.08	4.06	4.08	4.08	4.05
Sepidan	4.12	4.00	4.09	4.05	4.10
Shiraz	4.78	4.77	4.76	4.77	4.77
Takhtejamshid	4.56	4.54	4.41	4.48	4.44
Zarghan	4.59	4.60	4.55	4.58	4.55

Table 3. The RMSE values (mm day^{-1}) for different stations and different conditions.

Station	ET_o (Equation 2)	ET_o (Equation 3)	ET_o (Equation 4)	ET_o (Equation 5)
Abadeh	0.088	0.075	0.065	0.068
Arsenjan	0.075	0.082	0.066	0.085
Bavanat	0.094	0.085	0.065	0.072
Darab	0.078	0.099	0.069	0.076
Dorodzan Dam	0.192	0.184	0.183	0.184
Eghlid	0.129	0.085	0.079	0.078
Eizadkhast	0.108	0.096	0.081	0.085
Estahban	0.058	0.079	0.058	0.065
Fasa	0.086	0.087	0.074	0.081
Jahrom	0.089	0.118	0.057	0.073
Kazeron	0.126	0.096	0.100	0.120
Lamerd	0.215	0.112	0.155	0.151
Lar	0.123	0.142	0.087	0.093
Neyriz	0.110	0.080	0.076	0.075
Safashahr	0.077	0.078	0.069	0.081
Sepidan	0.170	0.094	0.116	0.077
Shiraz	0.083	0.089	0.070	0.071
Takhtejamshid	0.089	0.217	0.135	0.233
Zarghan	0.067	0.093	0.066	0.084
Average	0.108	0.105	0.088	0.097

for estimating monthly ET_o with the derived equations for estimating sunshine hours. Therefore, it is possible to estimate monthly ET_o in Fars province, south of Iran without using sunshine hours data.

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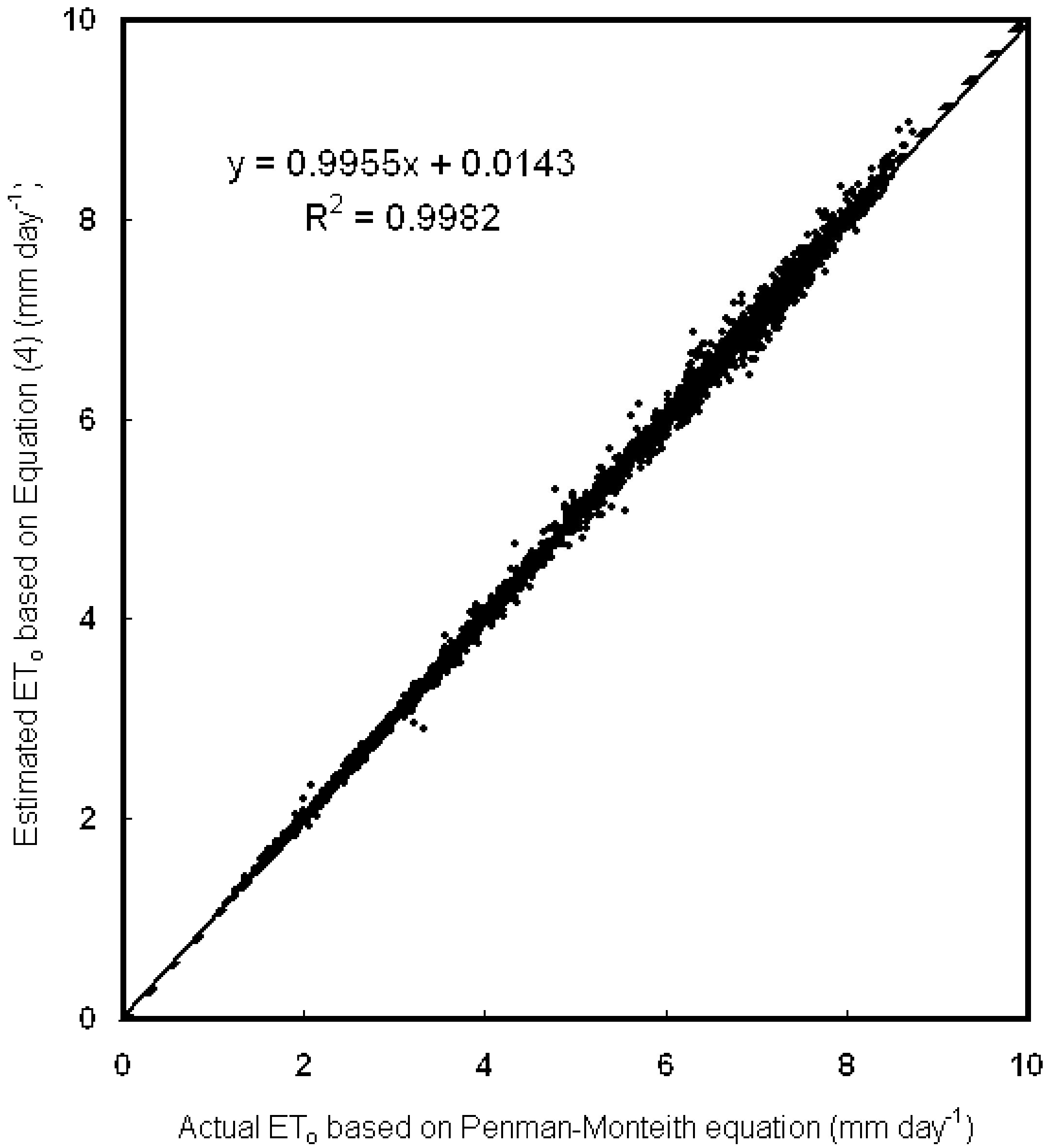

Figure 1. ET_o with actual sunshine hours versus ET_o with estimated sunshine hours by using the Equation (4).

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