J. Agr. Sci. Tech. (2011) Vol. 13: 1135-1145

Seasonal Sensitivity Analysis for Climatic Variables of ASCE-Penman-Monteith Model in a Semi-arid Climate

B. Bakhtiari[1*], and A. M. Liaghat[2]

ABSTRACT

Seasonal variations of climatic parameters are significant in arid and semi-arid regions and sensitivity of each parameter may differ in different seasons. No work has been done in this regard in Iran. Therefore, in this study, sensitivity analysis of the ASCE-Penman-Monteith grass reference evapotranspiration (ET_o) equation was investigated on the basis of variation of mean air temperature (T_{mean}), vapor pressure deficit (VPD), wind speed at 2 meter height (U_2), and short wave solar radiation (R_s) in the semi-arid climate of Kerman, southeast of Iran. The sensitivity coefficients were derived for each variable on a daily basis. The results showed that the computed ET_o was sensitive to VPD in all months, to U_2 during March to November, and to R_s during the summer months. The change in ET_o was linearly related to the change in the climatic variables, with $R^2 \geq 0.976$ in most cases. The sensitivity coefficient for R_s was higher during the summer months and lower during the winter months. Increase in ET_o with respect to the increase in the aforementioned climate variable changed by month. On an annual average, 1 °C increase in T_{mean}, 1 ms^{-1} increase in U_2, and one MJ $m^{-2}d^{-1}$ increase in R_s resulted in, respectively, 0.11, 0.37, and 0.09 mm d^{-1}increases in ET_o. A 0.4 kPa increase in VPD resulted in 0.85 mm d^{-1} increase in ET_o. Generally, various meteorological parameters should be measured with high accuracy in order to use the combination model.

Keywords: Evapotranspiration, Penman-Monteith, Sensitivity analysis

INTRODUCTION

Estimates of evapotranspiration (ET) flux occurring from cropped land surfaces are essential in studies relating to hydrology, climate, and agricultural water management. With increasing pressure on water resources from competing users, large emphasis has been placed on water use efficiency in irrigated fields (Hatfield *et al*., 1996), particularly in arid and semi-arid regions. In these climates where water resources are limited, it is essential to estimate crop ET with the greatest possible precision. The procedure for estimating ET rates of agricultural crops is well established and involves, as a first step, computation of reference evapotranspiration (ET_o) using regularly recorded climatological data. ET_o is defined as 'the rate at which water, if readily available, would be removed from soil and plant surfaces of a specific crop, arbitrarily called reference crop' (Doorenbos and Pruitt, 1975; Jensen *et al*., 1990). The reference crop is usually either grass or alfalfa. The most common procedure for estimating crop ET is to adjust the reference evapotranspiration rate values with the crop coefficient (K_c). One of the challenges associated with the development of many ET_o models is that achieving the unity of transferability of K_c from one location to another has become nearly impossible.

[1] Department of Water Engineering, College of Agriculture, Shahid Bahonar University of Kerman, Kerman, Islamic Republic of Iran.
[*] Corresponding author, Drbakhtiari@mail.uk.ac.ir
[2] Department of Irrigation, College of Agriculture, University of Tehran, Karaj, Islamic Republic of Iran.

[DOR: 20.1001.1.16807073.2011.13.7.20.5]

Besides, researchers use different methods such as temperature, radiation or combination equations that perform differently, depending on the local climatic conditions. Therefore, the need for adopting a specific method as a standardized model has been discussed by ASCE-EWRI (2005). When the required set of climatological data is available for a location, ET_o is often calculated using this combination method. This method might be used to assess the validity of the coefficients in other ET_o models, but the calibration and validation of the coefficients requires that the sensitivity of ET_o to climate variables be determined (Doorenbos and Pruitt, 1975; Jensen *et al*., 1990; Steiner *et al*., 1991). To understand the relative role of each climate variable in calculation of ET_o, sensitivity analysis is required (Saxton, 1975). By definition, sensitivity analysis is the study of how the variation in the output of a model can be apportioned, quantitatively or qualitatively, to variation in the model parameters (Saltelli *et al*., 2004). A sensitivity analysis shows the effect of change of one factor on another (McCuen, 1973). If the change of the dependent variable of an equation is studied with respect to change in each of several independent variables, the sensitivity coefficients will show the relative importance of each of the variables to the model solution. Saxton (1975) derived sensitivity coefficients by differentiating the combination terms for the Penman (1948) method with respect to each variable. Results showed that the equation was most sensitive to net radiation. Smajstrla *et al*. (1987) defined the sensitivity coefficient as the slope of the curve of ET_o versus the climatic variable being studied. Piper (1989) showed that errors in measurement of sunshine hours, wind speed, and wet bulb temperature had the same relative effect on the estimated ET_o. In the same context, Ley *et al*. (1994) conducted sensitivity analysis for the Penman-Wright ET_o model (same as Penman-Kimberly) to errors in parameters and weather data using a factor perturbation simulation approach for Washington State. This model was most sensitive to error in the maximum and minimum air temperatures. Rana and Katerji (1998) analyzed the sensitivity of the original Penman-Monteith equation to climatic and parametric factors in a semi-arid climate for a reference grass surface, grain sorghum, and sweet sorghum in Italy. For grass, available energy and aerodynamic resistance played a major role. For sweet sorghum, the model was most sensitive to vapor pressure deficit. For grain sorghum under water stress, the most sensitive term was canopy resistance. Recently, Irmak *et al*. (2006) calculated the sensitivity coefficient of the standardized daily ASCE-Penman-Monteith equation in different climates of the United States.

No work has been done on sensitivity analysis of ASCE-Penman-Monteith parameters in Iran. Thus, the objective of this study was to quantify the sensitivity of the daily ASCE-Penman-Monteith equation to four climatic variables in a semi-arid region of Iran and derive daily sensitivity coefficients for each variable. Also the seasonal trends of the sensitivity coefficients have been evaluated.

MATERIALS AND METHODS

Site Description and Environmental Conditions

In general, Iran has an arid to semi-arid climate in which most of the relatively scant annual precipitation falls from October through April (Khalili, 1997). Although more than 50 million ha of land in Iran are arable (DehghaniSanij et al., 2004), agricultural activities are limited due to irrigation water scarcity. All agricultural productions in Kerman Province, in southeast of Iran, are irrigation-based. In this region, irrigation water resources are supplied mostly from groundwater, including a limited amount from springs and Qanats. Surface irrigation is the most popular method of irrigation in this area; however, frequent droughts have led farmers to switch over to pressurized irrigation systems to improve water use efficiency and prevent depletion of groundwater resources.

The present study was conducted in an experimental farm of the Shahid Bahonar University of Kerman, located at a latitude of $30^{\circ},15'$N, longitude of $56^{\circ},58'$E, and altitude of 1753.8 m above mean sea level. The farm had a weather station whose floor was covered with reference grass. This grass crop was kept at a height of 0.10 to 0.15 m by weekly mowing. The experimental plot was irrigated by a sprinkler system. The climate of the area is semi-arid based on Extended-De Martonne classification (Khalili, 1997). The average annual rainfall is about 152.9 mm based on 55 years of record (1951-2005) at Kerman synoptic weather station, which is near the study site. Mean air temperature is about $15.8^{\circ}C$, with the average monthly temperature of $4.6^{\circ}C$ in the coldest month (January) and $26.7^{\circ}C$ in the hottest month (July). The annual mean relative humidity is about 32%. The normal monthly climatic variables for this location are shown in Table 1. Land-surface near the study site is surrounded by well-watered clipped alfalfa. An automatic weather station equipped with the necessary sensors was installed in this site to record the meteorological data required for calculating ET_o by the most commonly used equations. Daily air temperature, relative humidity, solar radiation, and wind speed at a height of 2 m, were obtained from this automatic weather station in 2007.

Air temperature and relative air humidity were measured at 2 m, with a sensor specification ranging from, respectively, -30 to 80 ºC (±0.1 ºC) and 0 to 100%, (±0.5%). For net short wave radiation at 2 m, a pyranometer (Lambrecht GmbH, 16131 model) was installe with, sensor specifications ranging from 0.305–2.8 μm, irradiation of 0-2000 W m^{-2} and sensitivity of 9-15 μV W^{-1} m^{-2}. Wind velocity at 2 m was measured by a very sensitive cup anemometer designed for measuring very

Table 1. Normal monthly climatic variables for Kerman synoptic station (1951-2005).

Climatic Variable	January	February	March	April	May	June	July	August	September	October	November	December	Annual
$T_{mean}(^{\circ}C)$	4.6	7.1	11.2	16.3	12.1	25.5	26.7	24.6	21.0	15.8	9.9	6.0	15.8
$\overline{T}_{Max}(^{\circ}C)$	12.1	14.8	18.7	24.3	29.9	34.9	35.7	34.3	31.5	26.0	19.6	14.5	24.7
$\overline{T}_{Min}(^{\circ}C)$	-0.3	-0.5	3.8	8.2	12.2	16.1	17.7	14.8	10.6	5.5	0.3	-2.6	6.9
$RH_{mean}(\%)$	54	47	41	34	26	19	19	20	21	28	37	47	32
$U_2(\mathrm{m\,s^{-1}})$	1.8	2.6	3.1	3.1	2.8	2.7	2.9	2.6	2.2	1.8	1.5	1.6	2.4
$P(mm)$	29.9	26.0	34.0	18.9	11.5	1.2	1.5	0.5	0.4	1.6	5.9	21.5	152.9

T_{mean}: Average of Mean daily temperature, $\overline{T}_{Max}$: Average of maximum temperature, $\overline{T}_{Min}$: Average of minimum temperature, RH_{mean}: Average of relative humidity, U_2: Average of wind speed, P: Monthly total of precipitation.

light wind of 0.2 m s^{-1}, with sensor specifications in the range of 0-40 m s^{-1} (±0.2 m s^{-1} precision). Daily averages of meteorological parameters were calculated based on hourly records.

ASCE-Penman-Monteith Equation for Grass

Equation 1 presents the form of standardized reference evapotranspiration for daily time steps calculation. Allen *et al.* (1998) defined the reference crop as a hypothetical crop with an assumed height of 0.12 m, with a surface resistance of 70 s m^{-1} and an albedo of 0.23, closely resembling the evaporation from an extensive surface of green grass of uniform height, actively growing, and adequately watered. The constant C_d in the denominator is a function of the time step representing bulk surface (r_s) and aerodynamic resistance (r_a) and varies with reference type and C_n in the numerator is a constant for reference type and time step (ASCE-EWRI, 2005).

$$ET_o = \frac{0.408 \times \Delta(R_n - G) + \gamma \frac{C_n}{T + 273} U_2 (e_s - e_a)}{\Delta + \gamma(1 + C_d u_2)} \quad (1)$$

Where, ET_o is the reference evapotranspiration (mm d^{-1}), Δ the slope of saturation vapor pressure curve at T (kPa °C^{-1}), γ the psychrometric constant (kPa °C^{-1}), R_n the net radiation at the grass surface (MJ$m^{-2}d^{-1}$), U_2 the average hourly wind speed at 2 m (ms^{-1}), G the soil heat flux density (MJ$m^{-2}d^{-1}$), e_s the saturation vapor pressure (kPa), e_a is the average actual vapor pressure (kPa), $e_s - e_a$ is vapor pressure deficit (VPD), and C_d and C_n are equal to 0.34 and 900, respectively.

Equations associated with the calculation of the required parameters in Eq. (1) have been standardized and described in a detailed report by the ASCE-EWRI (2005).

Sensitivity Coefficients

In order to derive sensitivity coefficients for climatic variables (T_{mean}, U_2, VPD and R_s), a factor perturbation simulation approach (Smajstrla *et al.*, 1987; Irmak *et al.*, 2006) was used. Sensitivity coefficient for each climatic variable was derived by dividing the amount of increase or decrease in ET_o by the unit of increase or decrease in each climatic variable on a daily basis as (Irmak *et al.*, 2006):

$$C_s = \frac{CH_{ET_o}}{CH_{CV}} \quad (2)$$

Where, C_s is the sensitivity coefficient, CH_{ET_o} is change in ET_o with respect to change in climatic variable, and CH_{CV} is the change in climatic variable (1 unit change for T_{mean}, U_2, R_s and 0.4 kPa for VPD). The average sensitivity coefficient for each month was calculated as daily mean values for each variable. To compute the sensitivity coefficient for each meteorological variable, the amount of increase in ET_o was determined as the difference between the calculated base ET_o and the new ET_o values computed for each day. The difference between these two values was divided by 1, 2, 3, 4 and 5 separately for each day (by 0.4 kPa up to 2 kPa for the VPD). This method was recurrent for the state when the meteorological variables were decreased by 1, 2, 3, 4 and 5 units. Then, the linearity of increase and decrease in ET_o with respect to increase and decrease in each variable was evaluated. When we varied one parameter, the other parameters were fixed to make sure that the sensitivity method was mono-criteria.

RESULTS AND DISCUSSIONS

The mean monthly values of the main climatic parameters in the experimental farm are given in Figure 1. Sensitivity coefficients, as defined by Eq (2), have been calculated on daily basis using data from the grass reference station. The amount of change in ET_o with respect to increase and decrease in each meteorological variable is shown in Figure 2a. The regression coefficients between the changes in ET_o relative to changes in climate variables for the entire 2007 are given in Table 2. The change in ET_o with respect to the unit change in each variable (except vapor pressure deficit for which the changes in ET_o are per 0.4 kPa up to 2 kPa) are given in Table 3 on a monthly and annual basis. In general, ET_o reaction was linear with high coefficient of determination ($R^2 \geq 0.976$) to change in all four climatic variables. The influence of VPD on change in ET_o was the greatest with the slope of 0.85. A 0.4 kPa increase in VPD resulted in 0.85 mm d^{-1} increase in ET_o (see Table 2). Thus ET_o is

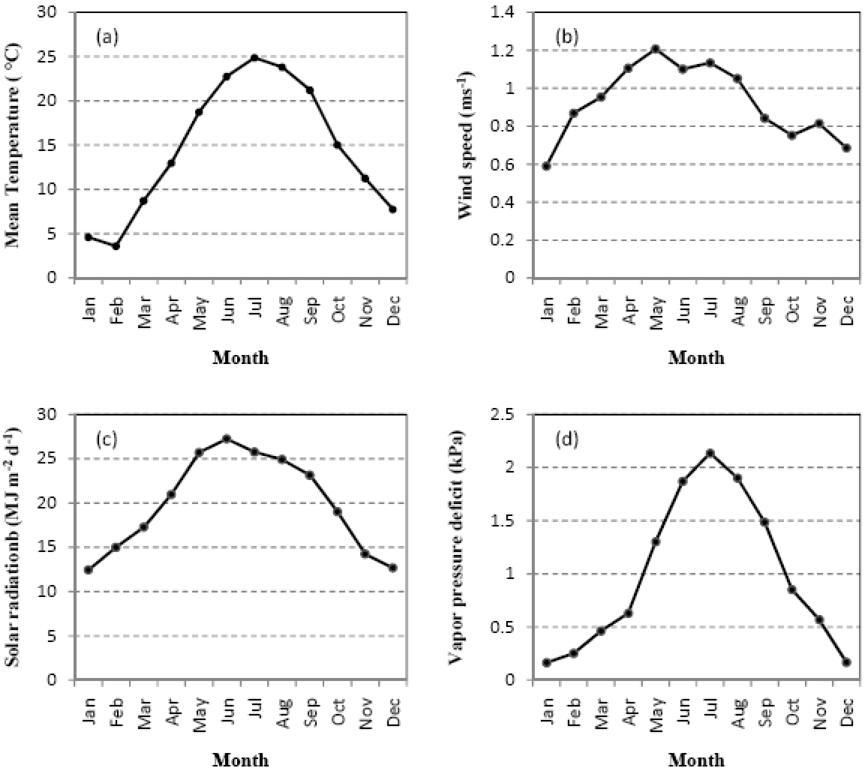

Figure1. Mean monthly variations of the major climatic variables in the experimental farm located in the Shahid Bahonar University of Kerman during 2007.

Table 2. Coefficients of the regression equation between changes in ET_o (mm d^{-1}) and changes in each climatic variable during 2007.

Variable	a	b	R^2
$T_{mean}(^{\circ}C)$	0.11	-0.0104	0.999
VPD (kPa)	0.85	0.0002	1.00
$U_2 (\mathrm{m\,s^{-1}})$	0.36	0.0466	0.976
$R_s (\mathrm{MJ\,m^{-2}\,d^{-1}})$	0.09	-0.0007	0.999

Regression formula: y=ax+b (y=change in ET_o and x= change in climatic variable).

[DOR: 20.1001.1.16807073.2011.13.7.20.5]

Table 3. Average change in ET_o (mm d^{-1}) with respect to change in four climatic variables for different months of 2007.

Variable	January	February	March	April	May	June	July	August	September	October	November	December	Annual
T_{mean} ($^{\circ}C$)	0.22	0.29	0.35	0.43	0.44	0.36	0.38	0.37	0.33	0.30	0.28	0.25	0.33
VPD (kPa)	1.00	1.43	1.31	1.28	1.14	0.77	0.84	0.83	0.75	0.86	1.04	1.01	1.02
U_2 (m s^{-1})	0.11	0.22	0.49	0.53	1.35	2.04	2.22	2.05	1.68	1.11	0.88	0.10	1.06
R_s (MJ m^{-2} d^{-1})	0.12	0.16	0.23	0.30	0.35	0.39	0.38	0.38	0.35	0.26	0.18	0.14	0.27

T_{mean}: Mean daily temperature, VPD: Vapor pressure deficit, U_2: Wind speed at 2 m, R_s: Solar radiation.

linearly and strongly related to VPD on seasonal basis. As illustrated in Figure 2a, the slope of ET_o versus VPD got smaller as the temperature increased (during the summer months). The increase in ET_o with respect to increase in VPD was larger during February to May (Figure 3). Therefore, the effectiveness of vapor pressure deficit on evapotranspiration is greater in low temperatures due to the behavior of the term $1/(\Delta+\gamma)$ in Eq. (1). This term decreases as temperature increases.

Figure 4 shows that the trend of sensitivity coefficients decreases from winter toward summer and increases again during the fall in this semi-arid region.

After VPD, the wind speed at 2 m had the largest effect on ET_o (see Figure 5), but, on annual basis, the wind speed was the first factor effecting ET_o. The annual change in ET_o due to change of U_2 was 1.06 mm d^{-1} while it was 1.02 mm d^{-1} for VPD (see Table 3). The magnitude of increase in ET_o with respect to increase in U_2 was larger during the warm months than the cold months (see Figure 3 and Table 3). In general, when crops transpire water, the surrounding environment of the crop canopy will be moist. In arid and semi-arid climates like the study site, the wind flow most probably replaces this moist air with dry air and causes an increase in ET_o.

Short wave solar radiation has an increasing trend from winter to summer months as illustrated in Figure 1. Smajstrala *et al*. (1987) noticed greater sensitivity of the Penman (1948) model to a unit change in solar radiation during the summer compared with the winter months for Florida. Also, Irmak *et al*. (2006) observed the dominance of R_s during the summer months in several semi-arid climates.

The sensitivity coefficients of T_{mean} was maximum during the spring and summer months and lower during the fall and winter. The T_{mean} coefficients varied from 0.07 in January to 0.15 in May, with annual average of 0.11. Table 4 presents an average of thefour sensitivity coefficients per day and per month.

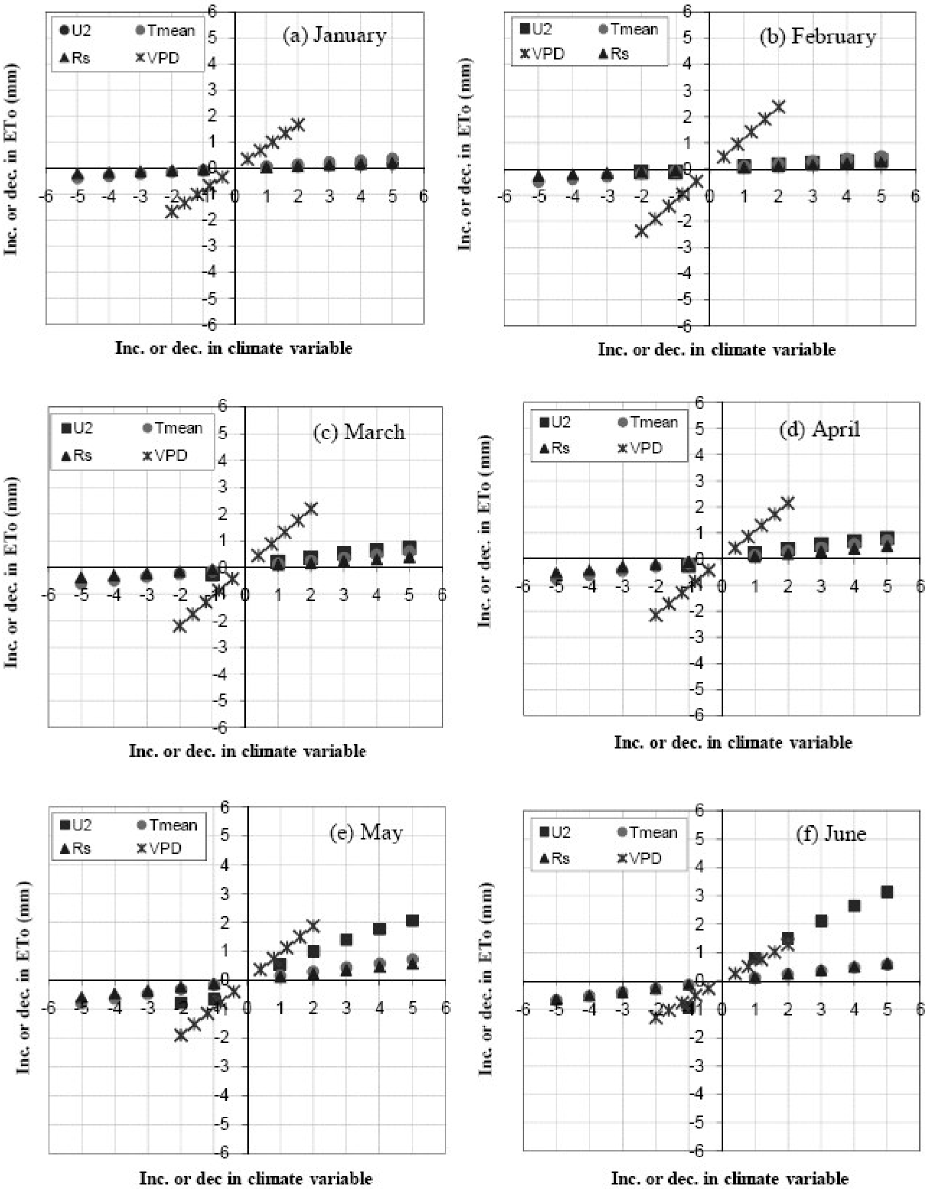

Figure 2. Changes in ET_o (mm d^{-1}) with respect to increase or decrease in four climatic variables (T_{mean} is mean air temperature, VPD is vapor pressure deficit, U_2 is wind speed at 2 m and R_s is solar radiation).

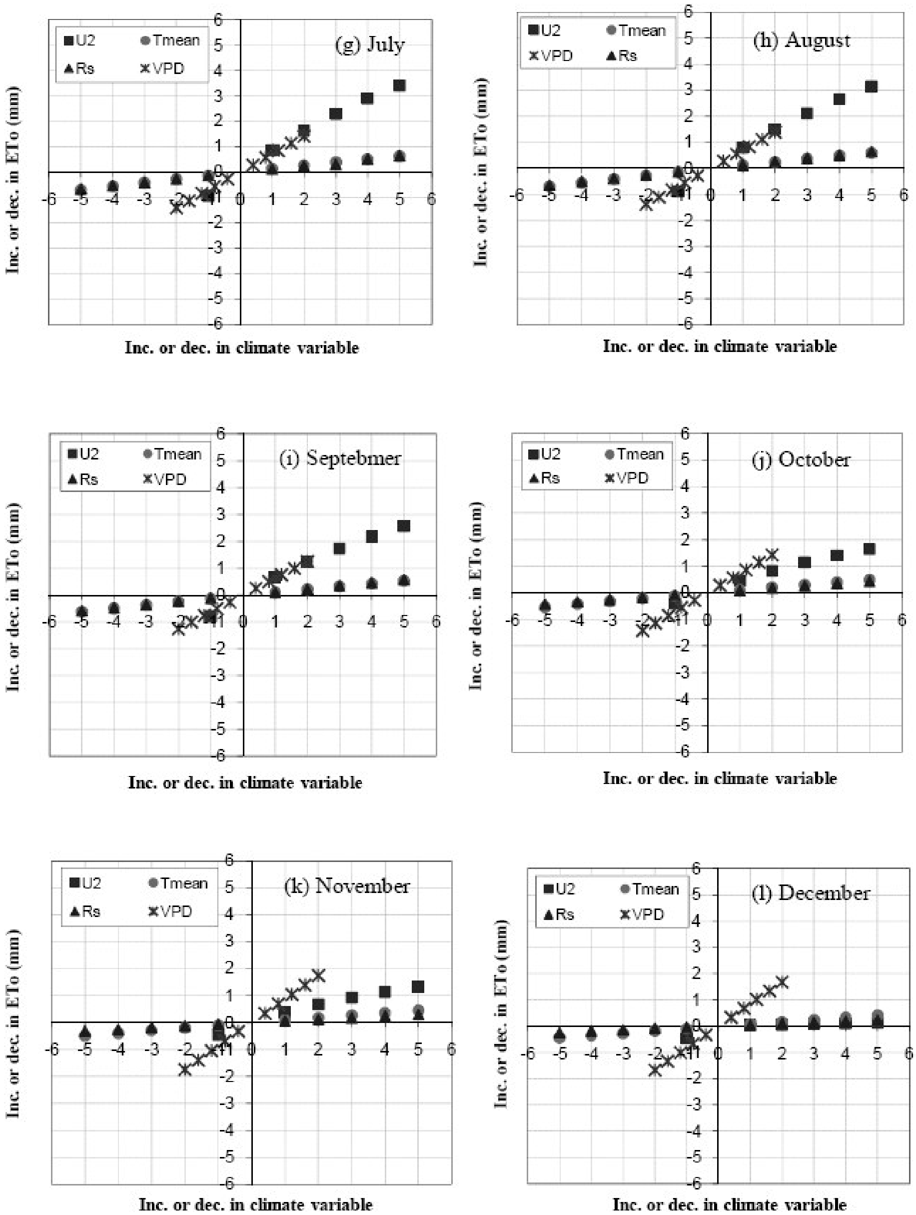

Figure 3. Changes in ET_o (mm d^{-1}) with respect to increase or decrease in four climatic variables during July to December 2007.

Table 4. Average sensitivity coefficients for four climatic variables.

Variable	January	February	March	April	May	June	July	August	September	October	November	December	Annual
T_{mean} ($^{\circ}C$)	0.07	0.10	0.12	0.14	0.15	0.12	0.13	0.13	0.11	0.10	0.09	0.09	0.11
VPD (kPa)	0.83	1.19	1.09	1.07	0.95	0.64	0.70	0.69	0.63	0.71	0.87	0.84	0.85
U_2 (m s^{-1})	0.04	0.08	0.17	0.19	0.47	0.71	0.77	0.71	0.59	0.39	0.28	0.03	0.37
R_s (MJ m^{-2} d^{-1})	0.04	0.10	0.05	0.10	0.12	0.13	0.13	0.13	0.12	0.09	0.06	0.05	0.09

T_{mean}: Mean daily temperature, VPD: Vapor pressure deficit, U_2: Wind speed at 2 m, R_s: Solar radiation

CONCLUSION

The daily ET_o sensitivity of the ASCE-Penman-Monteith model to error in four weather variables i.e.mean air temperature (T_{mean}), wind speed at 2 m (U_2), vapor pressure deficit (VPD), and shortwave solar radiation (R_s), in semi-arid climate of Kerman, Iran, was analyzed using a factor perturbation simulation approach. The sensitivity analyses were carried out using weather data for 2007 collected at a grass reference automated station. Daily sensitivity coefficients were computed for each variable. ET_o was found to be differently sensitive to the climatic variables and to the time of year. The results generally showed that the response of ET_o was linear, with high determination coefficient ($R^2 \geq 0.976$) to changes in all climatic variables. The computed evapotranspiration was most sensitive to VPD, followed by U_2. Shortwave solar radiation and mean air temperature had nearly equal effects over the seasons. The daily sensitivity coefficients showed substantial oscillations over the seasons. Average changes in ET_o (mm d^{-1}) per unit change of a given weather variable were reported. These may be used to estimate potential error in daily ASCE-Penman-Monteith ET_o estimates in areas having climates similar to the study area. The sensitivity coefficients presented in this article can be used to estimate the quality of weather instrumentation required to obtain a specific accuracy level in ET_o calculated by ASCE- Penman-Monteith equation.

REFERENCES

1. Allen, R. G., Pereira, L. S., Raes, D., and Smith, M., 1998. Crop Evapotranspiration. Guidelines for Computing Crop Water Requirements. FAO Irrigation and Drainage. Paper No. 56. FAO, Rome.
2. ASCE-EWRI. 2005. The ASCE Standardized Reference Evapotranspiration Equation. Technical Committee Report to

the Environmental and Water Resources Institute of the American Society of Civil Engineers from the Task Committee on Standardization of Reference Evapotranspiration. ASCE-EWRI, 1801 Alexander Bell Drive, Reston, VA 20191-4400, 173 p.

3. DehghaniSanij, H., Yamamoto, T., and Rasiah, V. 2004. Assessment of evapotranspiration estimation models for use in semi-arid environments. *Agri. Water Manag.*, **64**: 91-106.
4. Doorenbos, J. and Pruitt, W. O. 1975. Guidelines for Predicting Crop Water Requirement. FAO Irrigation and Drainage Paper No. 24, Rome, Italy, 156 p.
5. Hatfield, J. L., Prueger, J. H., and Reicosky, D. C., 1996. Evapotranspiration Effects on Water Quality. In: Proceedings of the ASAE International Conference on Evapotranspiration and Irrigation Scheduling, 3–6 November, San Antonio, TX, pp. 536–546.
6. Irmak, S., Payero, J. O., Martin, D. L., Irmak, A., and Howell, T. A. 2006. Sensitivity Analyses And Sensitivity Coefficients of Standardized Daily ASCE-Penman-Monteith Equation. *J. Irrig. Drain. Eng.*, ASCE, **132(6)**: 564-578.
7. Jensen, M. E., Burman, R. D., and Allen, R. G., 1990. Evapotranspiration and Irrigation Water Requirements. ASAE Manuals *Rep. Eng. Pract.* No. 70, 332p.
8. Khalili, A. 1997. Integrated Water Plan of Iran. Vol. 4: Meteorological studies, Ministry of Energy, Iran.
9. Ley, T. W., Hill, R. W., and Jensen, D. T. 1994. Errors in Penman-Wright Alfalfa Reference Evapotranspiration Estimates: Effects of Weather Sensor Measurement Variability. Trans. ASAE, 37(6): 1863-1870.
10. McCuen, R. H. 1973. The Role of Sensitivity Analysis in Hydrologic Modeling. *J. Hydrol.*, **18**: 37-53.
11. Penman, H. L. 1948. Natural Evaporation from Open Water, Bare Soil and Grass. *Proc. R. Soc.* London, **A193**: 120-146.
12. Piper, B. 1989. Sensitivity of Penman Estimates of Evaporation to Errors in Input Data. *Agri. Water Manag.*, **15**: 279-300.
13. Rana, G., and Katerji, N. 1998. A Measurement Based Sensitivity Analysis of the Penman-Monteith Actual Evapotranspiration Model for Crops of Different Height and in Contrasting Water Status. *Theoret. Appl. Climatol*., **60**: 141-149.
14. Saltelli, A., Chan, K., and Scott, M. 2004. Sensitivity Analysis. John Wiley and Sons Publishers, N. Y.
15. Saxton, K. E. 1975. Sensitivity Analysis of the Combination Evapotranspiration Equation. *Agric. Meterol.*, **15**: 343-353.
16. Smajstrla, A. G., Zazueta, F. S., and Schmidt, G. M. 1987. Sensitivity of Potential Evapotranspiration to Four Climatic Variables in Florida. *Soil and Crop Sci. Soc. of Florida*, **46**: 21-26.
17. Steiner, L., Howell, T. A., and Schneider, A. D. 1991. Lysimetric Evaluation of Daily Potential Evapotranspiration Models for Grain Sorghum. *Agron. J.*, **83**: 240-247.

تحلیل حساسیت فصلی مدل پنمن- مونتیث ASCE نسبت به متغیرهای اقلیمی در یک اقلیم نیمه خشک

ب. بختیاری، و ع .م. لیاقت

چکیده

تغییرات فصلی پارامترهای اقلیمی در مناطق خشک و نیمه خشک معنی‌دار بوده و حساسیت هر پارامتر در فصول مختلف متفاوت است. تا کنون مطالعه‌ای در این زمینه در ایران انجام نگرفته است. بنابراین در این مطالعه، تحلیل حساسیت مدل پنمن- مونتیث ASCE در برآورد تبخیرتعرق مرجع چمن بر اساس متغیرهای اقلیمی میانگین دمای هوا (T_{mean})، کمبود فشاربخار (VPD)، سرعت باد در ارتفاع ۲ متری (U_2) و تشعشع موج کوتاه خورشید (R_s) در اقلیم نیمه خشک کرمان انجام پذیرفته است. ضرایب حساسیت برای هر یک از متغیرها در مقیاس زمانی روزانه محاسبه گردید. نتایج نشان داد که ET_o محاسبه شده در تمامی ماه‌ها به VPD حساس بوده در حالی که به U_2 طی ماه های مارس تا نوامبر و به R_s طی ماه‌های فصل تابستان حساس است. همچنین تغییرات ET_o با تغییرات هر یک از متغیرهای اقلیمی به صورت خطی و در اکثر حالات با $R^2 \geq 0.976$ بستگی داشت. ضریب حساسیت مربوط به R_s طی ماه های تابستان بزرگتر و طی ماه های زمستان کوچکتر بود. مقدار افزایش ET_o با توجه به افزایش هر یک از متغیرهای اقلیمی در هرماه تغییر نمود. در مقیاس متوسط سالانه، یک درجه سانتی گراد افزایش در T_{mean}، یک متر بر ثانیه افزایش در U_2 و یک واحد افزایش در مقدار R_s حسب مگاژول بر متر مربع بر روز به ترتیب منتج به ۰/۱۱، ۰/۳۷ و ۰/۰۹ میلی متر افزایش در ET_o می‌شود. همچنین ۰/۴ کیلوپاسکال افزایش در VPD باعث ۰/۸۵ میلی‌متر افزایش در مقدار ET_o می‌شود. در هر حال، جهت استفاده از مدل ترکیبی باید پارامترهای مختلف هواشناسی با دقت لازم اندازه گیری شوند.

[DOR: 20.1001.1.16807073.2011.13.7.20.5]