

COMPARISON OF DIFFERENT DETERMINING METHODS OF REFERENCE ET_0 BASED ON LIMITED WEATHER CONDITIONS IN GAP REGION

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Abstract. Reference crop evapotranspiration (ET_0) is among the most important components of the hydrologic cycle. Standard FAO-Penman-Monteith method is the most frequently used equation to estimate of ET_0 . However, the usability of this method is limited due to its complexity Hargreaves-Samani (HS) and Turc methods that can be operated with limited data such as temperature and solar radiation are used as an alternative to the standard method. In the present study, the reference ET_0 values estimated with FAO-PM as the standard method, Hargreaves-Samani and Turc methods were compared at semi-arid climate conditions. Based on the acquired results; highest R^2 value at the GAP region with semi-arid climate conditions was determined as 0.9872 from the monthly averages of ET_{0-PM} and ET_{0-HS} comparison, whereas the lowest RMSE value was also obtained from the same monthly comparison (0.08). ET_{0-Turc} method yielded a monthly average comparison of 0.981 for the R^2 values comparison. While ET_{0-CAP} put forth the lowest values for all three intervals. It is suggested that HS method can be used instead of Standart Penman-Monteith method (FAO-PM) under GAP region semi arid climate conditions for reference ET_0 estimation if Penman-Monteith can not be calculated. The Turc method is also can be a good alternative to estimate potential evapotranspiration that can be measured by Class A pan. And that ET_0 estimation should be made by determining the K_p value in case CAP based ET_0 estimation is carried out.

Keywords: reference ET_0 , FAO-PM equation, Hargreaves-Samani equation, Turc equation, pistachio

Introduction

Evapotranspiration is the most important component of the hydrologic cycle and occurs with the mutual impact of evaporation and transpiration from the soil and the leaf. In this regard, it is the most important parameter for water source planning, water budget methods and irrigation software used in crop water consumption calculations. Continuity and high yield in agricultural production is possible only by the accurate and timely completion of losses due to evaporation and transpiration. For this purpose, ET_0 should be estimated accurately since it plays a critical role in the accurate estimation of water losses from the soil and the leaf, carrying out the plans accordingly as well as the planning of irrigation systems (Trajkovic, 2008; Çobaner et al., 2016). Evapotranspiration is generally estimated in two stages. It can be determined by estimating the evaporation gap of the air around the plant subject to certain climate parameters as well as by calculating the water consumption of the grass covering the soil surface completely which is used in estimating plant water consumption (ET_c) and multiplying it by a certain coefficient specific to the crop. It is known that there are over 50 methods or models for the estimation of potential evapotranspiration subject to the data sets used (temperature, radiation, Class A Pan, mass transfer etc.), ecological conditions (arid or humid) and assumptions (Lu et al., 2005). Many researchers have tested the compliance of these methods under certain ecological conditions while also carrying out studies for putting forth the performances of difference methods under different climate conditions (Castaneda and Rao, 2005; Tabari et al., 2013).

Empirical equations based on energy and mass transfer in compliance with different climate and environmental conditions have been developed for estimating ET_0 . For this purpose, Allen et al. (1998) developed the FAO-56 Penman-Monteith method (PMF-56) which is the standard method that is widely used all over the world under different climate and agricultural conditions for ensuring that ET_0 estimation is more understandable as well as for ensuring that the information provided is used commonly and frequently (Fisher and Pringle, 2013). This method is widely used for determining reference ET_0 (Çobaner et al., 2016). However, there are difficulties related with the use of this model for estimating ET_0 due to its complexity. Daily data for many meteorological parameters such as temperature, relative humidity, solar radiation, evaporation, wind speed are required for using this model. It is not always possible to obtain this data set in full due to both technological and human based reasons and due to the fact that it is partially costly. On the other hand, calculation of water consumption on has become difficult in Turkey with a surface area of 783.562 km² since there are 275 meteorological stations with one station per each 275 km² (Çobaner et al., 2016). Therefore, researchers have developed easy to use reference ET_0 methods which can be an alternative method for regions where it is not possible to provide the data set in full. Reference ET_0 should be calculated using methods that require less climate data in cases when sufficient climate data are not available. For this purpose, Todorović et al. (2013) suggests the use of the best known Hargreaves-Samani equation and the “Penman Monteith Temperature Method” (PMT) in which the data required for calculation is calculated from the already existing climate data. Hargreaves and Samani (1985) developed an equation that can calculate the reference evapotranspiration value making use of only temperature and radiation data. Similarly, the Turc formula (1961) that uses only radiation, temperature and relative humidity values for determining reference ET_0 was first developed for the regions of Southern France and Northern Africa (Diouf et al., 2016). The fact that the data used can be acquired easily is evaluated as the superiority of this formula for cases when the parameters required by other methods cannot be obtained. In addition, new methods developed which require a smaller data set have been used by many different researchers under different climate conditions for determining their performances in humid (Lu et al., 2005; Fisher and Pringle, 2013; Tabari et al., 2013) and arid regions (Todorovic et al., 2013) and for making a comparison with the FAO-56 PM method (Trajkovic, 2008; Gavilan et al., 2006; Castaneda and Rao, 2005; Shahidian et al., 2012). Since the Turc method is an empirical equation developed for estimating reference ET_0 in humid regions, it uses only temperature and solar radiation as the data set. The radiation term used in this method is solved by the method provided in the Hargreaves-Samani equation. In addition to these methods, methods based on Class A Pan evaporation method as an alternative for many regions in the world where meteorological data cannot be obtained in full are used widely due to their ease of use, low cost and ease of application in irrigation software (Tabari et al., 2013). Different researchers (Kanber et al., 1992; Bilgel et al., 1999; Aydın, 2004) have carried out a limited number of studies on the determination of crop water consumption (ET_c) for pistachio. In these studies, ET_0 -PM method has been used as the standard method for determining reference ET_0 . The Food and Agriculture Organization (FAO) declared in 1990 together with the International Irrigation and Drainage Commission and World Meteorological Organization (WMO) that the FAO-PM (Allen et al., 1998) method can be taken as a reference since it yields more consistent and reliable results in comparison with other methods (Castaneda and

Rao, 2005; Çobaner et al., 2016). Hence, FAO-56-PM method was taken as the standard in this study with which the other methods were compared. Hargreaves-Samani and Turc equations can be used frequently for crop water consumption calculations since they are easy to use, require less data and can be used only with temperature data. Therefore, some empirical methods used for determining reference crop water consumption and CAP evaporation method were evaluated comparatively in this study. The climate data used for this purpose in the study were acquired from the Provincial directorate of meteorology in Siirt. In this study, climate data and FAO-56 Penman Monteith values which are used as reference method were taken from the study carried out in Gaziantep in order to determine crop water consumption (ET_c) in pistachio by Aydın (2004). Gaziantep, one of the most important provinces for pistachio production was selected as the study area. Pistachio is produced in 56 provinces in Turkey (Anonymous, 2001) with the highest amount of production in Gaziantep and Şanlıurfa. Gaziantep is ranked first in Turkey with regard to its pistachio production area and product amount (Aslan, 2017) which is an important economical input for the economy of the province. In the aforementioned study, reference (ET_o) were determined according to FAO-56 Penman Monteith method and ET_c was calculated according to water budget technique. From this point of view, crop coefficients (K_c) were determined for the phenological stages of pistachio. The maximum and minimum values of K_c for the suggested treatment in July and November were calculated as 1.51 and 0.39, respectively. These values range from 0.49 to 1.1 for the Southeast 1st Region (Gaziantep, Şanlıurfa and Diyarbakır) (Anonymous, 2017). However, since it is not always possible to determine the ET_o by the Penman-Monteith method, it is possible to eliminate this deficiency with the Hargreaves-Samani model and to estimate ET_c using the determined K_c coefficients. On the other hand, no studies were conducted to determine pan coefficient (K_p) for Gaziantep and Southeastern Anatolia region. Similarly, Since a new issue in Southeastern Anatolia Region, there is no study about determination of K_p in pistachio. On the other hand, the K_p coefficients, which changed periodically for Pistachio in California conditions, were proposed as 0.96 in June and August (Anonymous, 2019). Therefore, K_p coefficient was accepted as 1 in this study.

The purpose of the present study was to carry out reference ET_o estimation in pistachio production regions, carry out reference ET_o estimations via FAO-PM, Hargreaves-Samani and Turc equations in addition to Class A Pan (CAP) method, evaluate the usability of these methods for alternative reference crop water consumption (ET_o) estimation in the GAP region and the put forth the relations between these methods. In addition, this study aims to contribute to the studies on determination of crop coefficient (K_c), evaporation pan coefficient (K_p) or crop-pan coefficient ($K_{cp-dual}$) in Southeast Anatolia region where pistachio is grown widely.

Materials and methods

Description of study area and weather data

The city of Gaziantep is located in the Southeast Anatolia Region (*Fig. 1*) between $36^\circ 28'$ and $38^\circ 0'$ eastern longitudes and $36^\circ 38'$ and $37^\circ 32'$ northern latitudes in WGS84 system and according to ED-50, 3° Central Meridian (CM): 36 coordinate system was shown in *Table 1*.



Figure 1. Locational view of the study area

Table 1. The place of Gaziantep in ED-50, 3° CM: 36 coordinate system

Points	X	Y
1	541275.4225986	4155978.5921223
2	411633.5530552	4156345.4115202
3	410582.2394373	4056459.2749163
4	541765.9807594	4056095.7171703

Gaziantep has a climate structure with transition characteristics between the Mediterranean and the continental climate. Summers are quite hot and arid, while winters are cold and rainy. Mean annual temperature is + 14.9 °C, with the highest temperature of + 44 °C and lowest temperature of -17.5 °C. The hottest month is July with 27.7, while the coldest month is January with 3.4 and the annual rainfall for the province is 544.3 mm. Rains generally occur during the winter period with less rain during the summer months when evapotranspiration is high and the crops need plenty of water (Aydın, 2004). Thus, irrigation operation and management stands out for pistachio production.

ET₀ estimation methods

FAO-56 PM method was used in this study for comparing the reference ET_0 estimations obtained via Hargreaveas-Samani and Turc equations. For this purpose, the daily ET_{0-PM} values were used which have been calculated in the study on pistachio by Aydın (2004) and Ünlü (2005). The climate data of Gaziantep, located in Southeastern Anatolia Region which is known as the most important pistachio producing region of Turkey were used in the aforementioned study. Climate data for the same province were used in Hargreaveas-Samani and Turc equations used for estimating reference ET_0 .

FAO-56 Penman Monteith method

The FAO-56 Penman Monteith method used for determining reference crop water consumption requires only daily meteorological data. This equation can be written as indicated below (Allen et al., 1998).

$$ET_o = \frac{0.408 \cdot (R_n - G) + \gamma \frac{900}{T + 273} u_2 (e_s - e_a)}{\Delta + \gamma (1 + 0.34 u_2)} \quad (\text{Eq.1})$$

where ET_o: reference evapotranspiration (mm day⁻¹); R_n: net radiation (MJ m⁻²), G: soil heat flux (MJ.m⁻²); T_{mean}: average air temperature (°C); U₂: wind speed at 2 m height (m.sn⁻¹), e_s: saturation vapor pressure (kPa), Δ: slope of vapor pressure curve (kPa.°C⁻¹), γ: psychrometric constant (kPa.°C⁻¹)

The ET_o software developed by FAO-56 was used for determining reference ET_o. All parameters used in this software are data measured daily and acquired from the meteorological station.

Hargreaves-Samani method

The Hargreaves-Samani equation used for determining reference crop water consumption which requires only the maximum and minimum (T_{max}-T_{min}) temperature values and extraterrestrial radiation (global radiation) (R_a) can be indicated as below (Hargreaves and Samani, 1985).

$$ET_{o-HS} = 0.0023 \frac{R_a}{\lambda} \sqrt{(T_{max} - T_{min})(T + 17.8)} \quad (\text{Eq.2})$$

ET_o: Reference evapotranspiration (mm day⁻¹), 0.0023: an empirical coefficient, R_a: extraterrestrial radiation (mm day⁻¹), λ: the latent heat of vaporization (MJ kg⁻¹) for the mean air temperature (T_{mean} in °C) given as:

$$\lambda = 2.501 - 0.002361 * T_{mean} \quad (\text{Eq.3})$$

λ is generally assumed 2.45 MJ.kg⁻¹

Since the temperature, humidity and radiation values used in the equation can be accessed easily, it has been used by many researchers for determining the reference crop water consumption (Todorovic et al., 2013; Fisher and Pringle., 2013; Djaman et al., 2015; Çobaner et al., 2016; Diouf et al., 2016; Yamaç, 2018). The R_a value used for calculating ET_{o-HS} was calculated using the following equation suggested by Fisher and Pringle (2013) for the Turc method which is solved subject to temperature and by making use of the solar radiation data obtained from the meteorology.

$$R_s = 0.16(T_{max} - T_{min})^{0.5} R_a \quad (\text{Eq.4})$$

R_s is the solar radiation (MJ m⁻² day⁻¹).

Turc method

The Turc formula derived by Turc (1961) which is used for calculating the daily potential evapotranspiration can be written as below:

$$ET_{o-Turc} = a * C * (R_G + b) \frac{T}{r+15} \quad (\text{Eq.5})$$

where ET_o: reference evapotranspiration (mm day⁻¹), T: mean daily temperature (°C), R_G: Global radiation (MJ m⁻² day⁻¹), a and b: empirical constants and a = 0.31 (m² MJ⁻¹ mm⁻¹) and b = 2.094 (MJ m⁻² day⁻¹), C: defined by the relative humidity RH, (%) as:

$$C = 1 + \frac{50 - RH}{70} \quad \text{if } RH < 50\% \quad (\text{Eq.6})$$

$$C = 1 \quad \text{if } RH \geq 50\% \quad (\text{Eq.7})$$

Similarly, relative humidity and temperature values were obtained from meteorological records of Provincial Directorate of Meteorology in Siirt. The C value in the ET_{o-Turc} equation used for calculating daily potential evapotranspiration was calculated using the aforementioned equations based on the average relative humidity ratio.

Pan evaporation method (ET_{o-CAP})

The following equation suggested by Allen et al. (1998) was used for calculating reference crop water consumption (ET_o) according to the Class A Pan evaporation method.

$$ET_o = K_p * E_{pan} \quad (\text{Eq.8})$$

where ET_o: Reference evapotranspiration, mm day⁻¹; K_p: pan coefficient (assumed 1 as average value in this study). E_{pan}: pan evaporation, mm day⁻¹. However, the K_p value was not calculated separately in this comparison and was assumed theoretically as 1 and therefore the measured E_{pan} value was assumed to be equivalent to ET_o.

Statistical analysis

The ET_o values calculated daily according to the FAO-PM method were compared statistically with the daily ET_o values. Paired comparisons were made for determining the value of R² which were then subject to linear regression analysis and the R² equation was determined for the obtained curve. The equalities suggested by Djaman (2015) which are provided in *Table 2* were used for a more advanced evaluation of the compared equations.

Results and discussion

The climate data for 1999-2002 obtained from the meteorological records were used in the study. For this purpose, the maximum and minimum temperatures used in the Hargreaveas-Samani and Turc equations along with the relative humidity and radiation values used in the Turc equation were evaluated separately for each year and than converted to monthly average (*Fig. 2a*).

The solar radiation values measured in cal cm⁻² day⁻¹ at the meteorology stations were converted into the unit of MJ m⁻² day⁻¹ after which they were used for solving the equation. The radiation values for the study years are provided in *Figure 2b* as monthly average annually. As can be seen when the figures are examined, while solar radiation values were low in the beginning of the year (January-February) and in the last two months (November-December) of the year, the number of sunny days and sunshine

duration along with the amount of reflected radiation increased parallel to the increase in seasonal temperatures. Cloudy weather that sometimes occurred during measurement days appears as sudden decreases in radiation.

Table 2. Statistical analysis equations

Source	Equation	
Root mean squared error (RMSE)	$RMSE = \sqrt{\sum_{k=0}^n \frac{(P_i - O_i)^2}{n}}$	(Eq.9)
Mean absolute error (MAE)	$MAE = n^{-1} \sum_{i=1}^n (P_i - O_i)$	(Eq.10)
Percentage error (PE)	$PE = \left \frac{P_{ave} - O_{ave}}{O_{ave}} \right 100\%$	(Eq.11)
Mean ratio (MR)	$MR = n^{-1} \sum_{i=1}^n \frac{P_i}{O_i}$	(Eq.12)
Determination coefficient (R ²) (Todorovic et al., 2013)	$R^2 = \left\{ \frac{\sum_{i=1}^n (O_i - \bar{O}) \cdot (P_i - \bar{P})}{\sqrt{\sum_{i=1}^n (O_i - \bar{O})^2} \cdot \sqrt{\sum_{i=1}^n (P_i - \bar{P})^2}} \right\}^2$	(Eq.13)

RMSE: root mean squared error; MAE: mean absolute error; MR: mean ratio; PE: percentage error of estimate; n: number of observations, P_i: estimated ET_o by other equations, O_i: PM-estimated ET_o (actual), P_{ave}: mean of the estimated ET_o, O_{ave}: mean of the O_i. In order to determine R², the pair wise comparisons were made by using linear regression

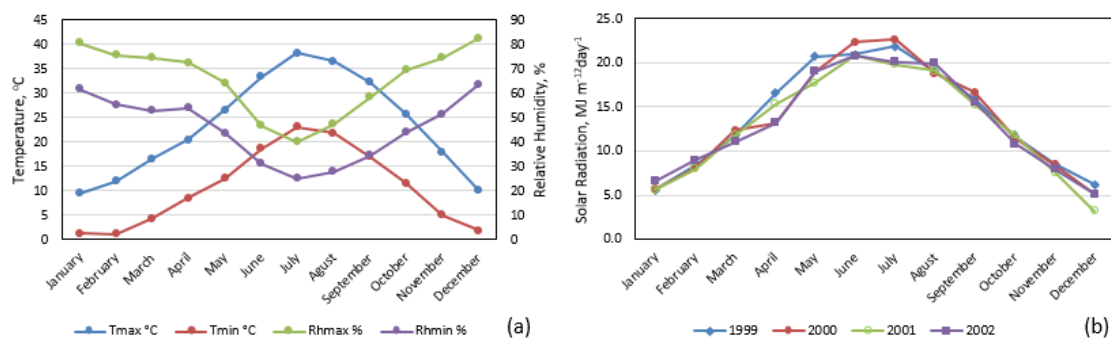


Figure 2. Variation of long-term monthly average temperature and relative humidity (a) and solar radiation during study years (b)

The 4 year mean values were calculated for the reference crop water consumption (ET_o) daily values obtained via the Hargreaveas-Samani (ET_o-HS), Turc (ET_o-TURC) and Pan evaporation methods (ET_o-CAP) compared in the study thereby obtaining long term average and annually total ET_o values which are presented in *Figure 3a* and *b*. As shown in *Figure 3a*, in the months which Class A Pan evaporation values measured were taken into consideration to compare the predicted plant water consumption values estimated by the models with the measured values. The period mentioned is the period in which pistachio is phenologically active and in this term, full bloom period is completed and begins the leafout period. The comparison of estimated and measured evaporation values was made until the end of October, which is the post-harvest period.

Likewise, as shown in *Figure 3b*, the monthly totals of the estimated and measured ET_o values were calculated for the mentioned period.

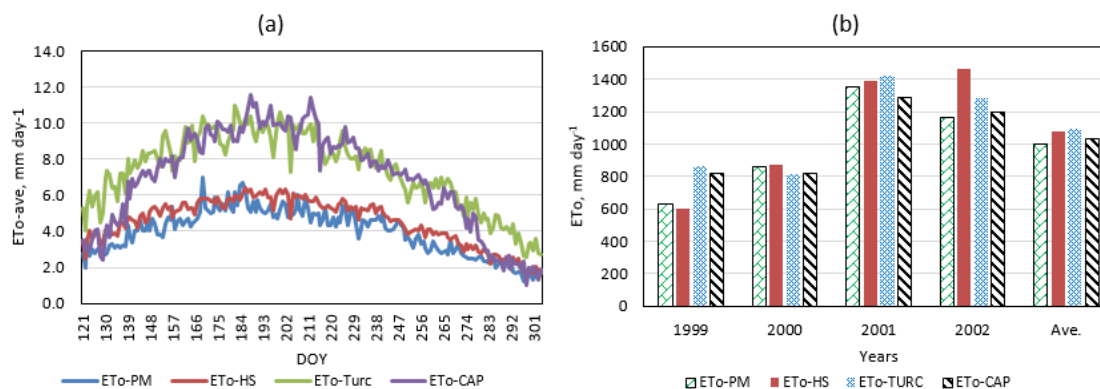


Figure 3. Comparison of 4-year mean daily and total seasonally ET_o calculated from 4 methods during study years for evaporation season

Average daily ET_o changing during study years. Similarly, The long term monthly mean values were calculated by taking the monthly mean ET_o values for the same years which are given in *Figure 4*. As can be seen in *Figure 4*, ET_{o-PM} and ET_{o-HS} values were determined to be close to each other, however the ET_{o-Turc} and ET_{o-Pan} values were observed to be greater than the ET_{o-PM} and ET_{o-HS} they were compared with. Long term mean monthly mean comparisons have yielded similar results as can be seen in *Figure 4*. Evaporation measurements are not carried out during the winter months (from November till April) in the study region, however other climate parameters are measured daily. Hence, it is not possible to calculate the ET_{o-CAP} values for the aforementioned months. Çobaner et al. (2016) carried out a study for determining the best Hargreavas-Samani equation for the Mediterranean region as a result of which they put forth that the Hargreavas-Samani equation calibrated according to the temperature and humidity values put forth similar results with those calculated via Penman-Monteith. These findings of the researchers are in accordance with the results of the present study. Small differences in our results are due to the fact that the HS equation has not been calibrated for the GAP region and that it is used directly. Similarly, Trajkovic (2005) states that the Hargreavas-Samani equation predicts ET_o higher than the actual value. The average values calculated via ET_{o-CAP} and ET_{o-Turc} methods showed a parallel change, similar to the change of radiation by temperature, as shown in *Figure 3a*. The ET_{o-CAP} values increased rapidly during summer months when evaporation is measured.

Diouf et al. (2016) carried out a study for determining reference ET_o via Turc equation due to limited climate data under Senegal conditions as a result of which it was reported that the annual ET_o values were higher for the humid seasons according to the FAO-PM method. The researchers indicated that ET_o is mostly due to radiation and temperature under conditions of high humidity and that humidity does not have any impact on ET_o under any circumstance.

Fisher and Pringle (2013) carried out a study under humid regional conditions for comparing the Hargreavas-Samani and Turc methods with the FAO-56 model operated with reduced data as a result of which it was indicated that the FAO-56 reduced dataset

model yielded better results in comparison with the other two methods. The Turc equation developed for using the measured temperature and radiation value was tested with the equation using estimated radiation values and it was put forth that FAO-56 provides better estimations in comparison with the other methods.

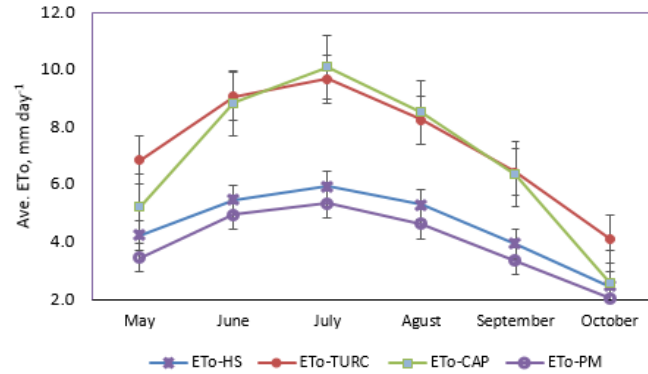


Figure 4. Comparison of 4-year mean monthly ET_o calculated from 4 methods during study years.

Paired comparisons at the daily, 10 days and monthly average value levels were carried out for the reference crop water consumption values calculated in accordance with the methods used and the acquired results are presented graphically in *Figures 5–7*. As can be seen from *Figure 5*, the onset of the curve is at low levels during the first months when evaporation measured is not made in winter months while comparing ET_o -PM and ET_o -CAP values.

The methods used for reference ET_o were compared statistically and the acquired results have been summarized in *Table 3*.

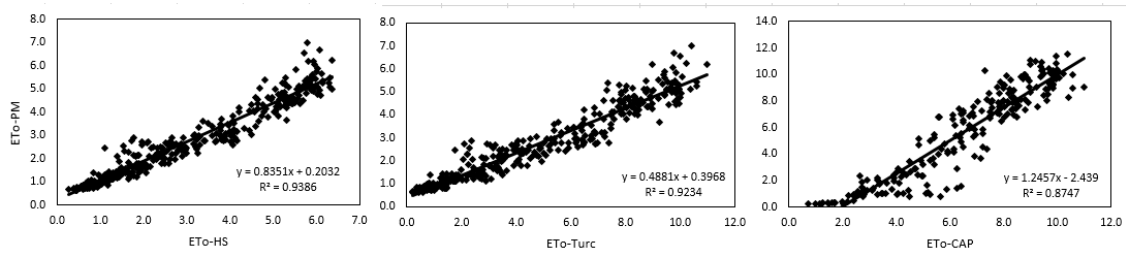


Figure 5. Comparison of daily average ET_o for (1999-2002)

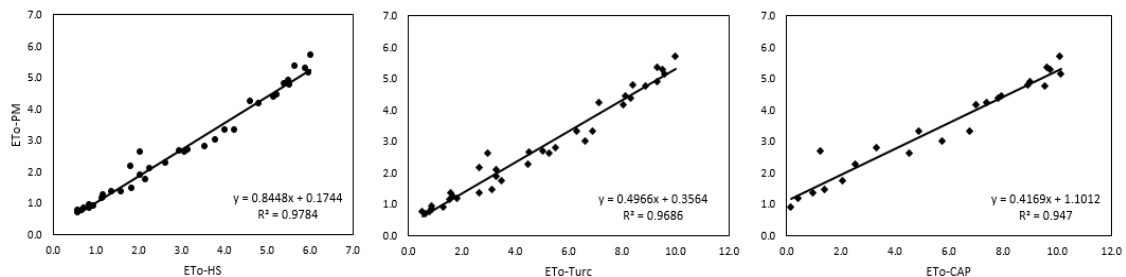


Figure 6. Comparison of 10 days intervals average ET_o for (1999-2002)

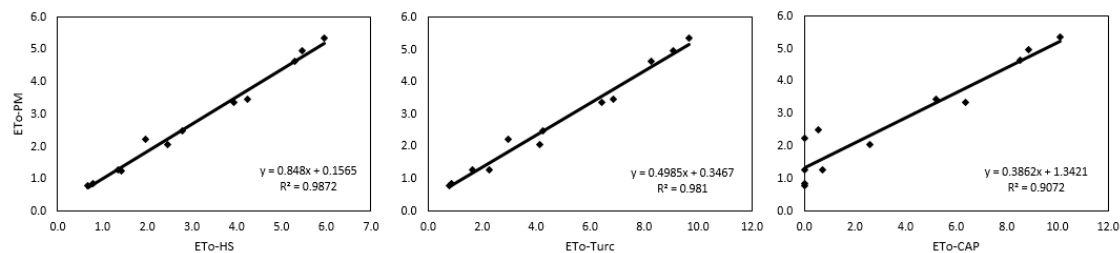


Figure 7. Comparison of monthly average ET_o for (1999-2002)

Table 3. Error values of average daily ET_o estimates on daily basis as compared to FAO-PM method

	Daily			10 days interval			Monthly		
	HS-PM	Turc-PM	CAP-PM	HS-PM	Turc-PM	CAP-PM	HS-PM	Turc-PM	CAP-PM
RMSE (mm/day)	0.58	2.65	2.62	0.15	0.82	0.81	0.08	0.47	0.46
MAE (mm)	0.45	2.11	2.14	0.04	0.21	0.21	0.01	0.07	0.07
MR	1.08	1.63	0.92	0.11	0.16	0.09	0.04	0.05	0.03
PE (%)	10.84	75.09	31.96	10.73	74.80	31.51	11.15	75.07	31.39
R²	0.9386	0.9234	0.8747	0.9784	0.9686	0.947	0.9872	0.981	0.9072

Quantitative methods were applied for carrying out a statistical evaluation of the equations used in ET_o estimation. It is considered that the R^2 value approaching 1 and RMSE, MAE, MR and PE values approaching zero (0) from among the parameters given in Table 3 which are used as criteria for comparing the methods indicate good performance and a high level of accordance between the compared values (Fisher and Pringle, 2013; Kaya et al., 2016).

The R^2 values of the studied methods were determined to be close but different in daily, weekly and monthly performance comparisons. It was determined as a result of the comparison made between reference crop water consumption methods for each of the three period intervals that the highest R^2 value was obtained as 0.9872 for ET_{o-HS} and ET_{o-PM} at the monthly level, while the lowest R^2 value was determined as 0.9386 for the comparison made at the daily level. The lowest R^2 value was also obtained as 0.8747 for the ET_{o-PM} - ET_{o-CAP} method as a result of the comparison made for all three periods. Castaneda and Rao, (2005) compared Thornthwaite, Blaney Criddle, Turc and Makkink methods. It was indicated that the Turc method had the best performance among the compared methods since the values obtained were closest to the estimated values of the ET_{o-PM} method prior to recalibration. They also put forth that other ET_o estimation methods also yield results within acceptable limits close to FAO-PM values in case regional parameters are used and the parameters are calibrated for the region. It will not be misleading to use the HS and Turc methods used in this study for making ET_o estimations in the region. When the compared methods are evaluated according to the RMSE values, lowest RMSE value should be obtained as is the case for other error parameters. As can be seen from the table, while the ET_{o-HS} - ET_{o-PM} pair had the lowest RMSE value for monthly averages with 0.08, highest RMSE value was obtained as 2.65 from the ET_{o-Turc} and ET_{o-PM} paired comparison. Todorovic et al. (2013) carried out a comparison between HS and PMT models for reference ET_o estimation in the

Mediterranean climate region with limited data as a result of which similar HS and PMT values were obtained for the excessively arid and arid regions with those of MSE. While PMT yielded a lower RMSE value in semi-arid and humid regions as a result of which it was indicated to have a better performance in comparison with HS. It was observed as a result of the percentage error (PE) evaluations that the lowest percentage error was obtained as 10.73 for the 10 day interval comparison, while the highest percentage error was obtained as 75.09 for the ET_{o-Turc} and ET_{o-PM} comparison. Djaman et al. (2015) states that calibrated models display a better performance at cold and hot humid regions thereby leading to monthly values at an acceptable level, while the same performance has not been obtained for the semi-arid and tropical humid regions. Since the models are developed for use in the regional climate conditions for which they have been developed, they yield acceptable results only in similar climate conditions.

It was observed as a result of the statistical comparison between the studied methods that the highest R² value and the lowest percentage error value were obtained for the ET_{o-HS}-ET_{o-PM} paired comparison in monthly average ET_o calculation. The results are observed to be in accordance with those of Çobaner et al. (2016) and Todorovic et al. (2013).

Conclusion

It was determined as a result of the study that the Hargreaves-Samani model can be used for reference crop water consumption estimation in regions for Penman-Monteith model which full climate data cannot be obtained due to various reasons since these methods can be operated only with limited climate data and maximum temperature, minimum temperature, mean relative humidity and solar radiation inputs. Likewise the Turc model can also be a good alternative to estimate potential evapotranspiration which can be measured by Class A Pan. Moreover, the Penman-Monteith Temperature based (PMT) method used for ET_o estimation only with temperature data can also be used as an alternative for semi-arid climate conditions such as the GAP region.

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