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# Estimation of Long-Term Reference Evapotranspiration Using Limited Weather Data in Sugar Beet Plantation Area from Middle Anatolian, Turkey

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**Abstract**: The Konya basin, Middle Anatolian region, is one of the most important agricultural area in Turkey. The region is in a semi-arid area with average annual rainfall ranging from 280 to 500 mm. Sugar beet is the vital commercial crop in this area that is the largest producer of Turkey. Water requirement of the sugar beet and evapotranspiration is very high during the growing season in the basin. The Food and Agricultural Organization of United Nations Penman-Monteith (FAO56-PM) equation requires accurate weather data like air temperature, relative humidity, solar radiation and wind speed. Unfortunately, not all these input data are possible to reach easily. Therefore, FAO56 suggested another equation that is Hargreaves – Samani (HS) equation when sufficient weather data are not available to estimate FAO56-PM. This study estimates ETo using by HS equation. For this purpose, daily maximum and minimum temperature data collected along the period 1986-2015 from sugar beet plantation area located in Konya basin. Results demonstrate that long-term annual ETo vary between 1036 mm to 1312 mm. The lowest and the highest annual ETo belonged to Karapınar where it is located in East part of Konya basin. Finally, this study estimates long-term reference evapotranspiration to give the idea of water loss in a semi-arid area

**Key words:** Evapotranspiration, Hangreaves-Samani equation, semi-arid area, sugar beet

## Introduction

Reference Evapotranspiration is an essential parameter in designing irrigation system and managing water under irrigated and rainfed conditions. Many different direct and indirect methods exist to estimate reference evapotranspiration. The direct method are estimated from a reference crop such as a perennial grass and the indirect methods are computed from weather data using temperature, radiation and combination models. The Food and Agricultural Organization of United Nations has been suggested Penman-Monteith (FAO 56-PM) equation (Allen et al., 1998). Many studies worldwide have shown that the FAO 56-PM equation is the most accurate method under different climate (Berengena and Gavilán, 2005; Irmak et al., 2003; Jabloun and Sahli, 2008; Kashyap and Panda, 2001; Temesgen et al., 2005). This method requires all the weather data such as air temperature, relative humidity, solar radiation and wind speed. Unfortunately, not all these needed weather data are complete in many of the area by the missing meteorological data. Therefore, this method limited to use. The Food and Agricultural Organization of United Nations has been suggested another equation which is the Hargreaves – Samani (HS) equation (Hargreaves and Samani, 1895). This method needs only daily avearge, maximum and minimum temperature to estimate reference evapotranspiration.

The Middle Anatolian region is one of the major agricultural production area in Turkey. The climate of the area is usually dry so evapotranspiration is very high in the region. The weather is very hot and dry during the summer, and also less

precipitation during the winter as well. Water scarcity is a significant problem in the area, specifically for agricultural production. Sugar beet (*Beta vulgaris* L.) is a strategic crop for this area that is the biggest producer of the Turkey. However, sugar beet water consuming is very high and water loss due to evapotranspiration is significant reason for sugar beet production in the area (Topak et al., 2011). Water resources are limited and endangered in semiarid areas. It is vital to estimate crop water requirement for accurate management and scheduling. Therefore, the objective of this study is to demonstrate long term behaving evapotranspiration in sugar beet planting area in Konya basin for irrigation management.

## Materials and Methods

The main methodological approaches included the following steps: (a) selecting meteorological stations where sugar beet is planted; (b) computation of the reference evapotranspiration.

All the meteorological daily data were recorded from 1986 to 2015 used for this study obtained from the European Commision MARS database (Micale and Genovese 2004). The climate variables, available on a daily basis, included: maximum air temperature (°C) and minium air temperature (°C). Table 1 and Figure 1 demonstrate position of meteorological stations. Each stations represent district of the sugar beet plantation area. Site elevations ranged from 955 to 1170 m above mean sea level: Longitude, from 31° 40' 48" W to 33° 46' 48" W; and latitude; from 37° 21' 12" N to 39° 2' 24" N. In Table 1, the annual average values of meteorological stations are reported. Annual average temperature is high during the period of 2001 and 2010 almost in all regions. Average annual precipitation ranged from 291 to 335 mm; average annual temperature, from 10 to 12 °C. The area climate is classified as arid. Therefore, irrigation is necessarily prerequisites for the region.

The reference evapotranspiration (ETo) was computed by the Hargreaves-Samani (HS) equation (Hargreaves and Samani, 1985). The HS method requires only maximum temperature ($T_{max}$), minimum temperature ($T_{min}$) and extraterrestrial radiation (Ra) for the estimation of ETo (mm day$^{-1}$). The equation can be written as (Todorovic et al., 2013):

$$ETo = 0.0023 \frac{Ra}{\lambda} \sqrt{(Tmax - Tmin)}\,(T + 17.8) \quad (1)$$

The coefficient 0.0023 is an empirical coefficient, Ra is the extraterrestrial radiation (mm day$^{-1}$) computed according to Allen et al. (1998) and λ is the latent heat of vaporization (MJ kg$^{-1}$) for the mean air temperature T (°C) given as:

$$\lambda = 2.501 - 0.002361\,.T \quad (2)$$

## Results and Discussion

The equation was derived using 30 years (1986-2015) of daily ETo values estimated from HS method using the measured and carefully screened weather data from Konya basin. The results demonstrate in Figure 2. The result of the ETo referred to the potentially sugar beet cultivable area at present.

Annual ETo in Konya basin estimates to range from about 1036 mm in 1990 to 1312 mm in 2010 at Karapınar (Table 2). In general, ETo demonstrate a trend of increasing in all districts. It can be concluded that the increasing trend of ETo depends on rising temperature over 30 years. The year with higher ETo shows in 2001 and 2010 in all regions beside Altınekin in 2001 because this year has high temperature than other years. Seydişehir and Beyşehir (Figure 2a,c) locate to each other. Therefore, the trend of computed ETo in these two districts have almost same behaving. However, opposite trends between 2012, 2013 and 2014 demonstrate in these two districts because of the opposite temperature change between these years. Çumra, Meram and Akören located in South part of the Konya basin. ETo ranged from about 1155 mm year$^{-1}$ at Meram (Figure 2d) and 1140 at Çumra mm year$^{-1}$ (Figure 2e) in 2000 while ETo increased to 1175 mm year$^{-1}$ in 2000 at Akören (Figure 2b) because between annual maximum and minimum temperature differences in Çumra and Meram are not

higher than Akören. Cihanbeyli and Kulu have significant differences between the years in 2002 and 2008 (Figure 2j,k). The reason is that Kullu annual minimum temperature is lower than Cihanbeyli annual minimum temperature between these years. Karapınar, Karatay and Emirgazi (Figure 2f,g,i) almost have same trends because these three districts located in same area which is southeast part of the Konya basin. Altınekin (Figure 2h) has different behaving than all other districts due to geographical location

ETo estimates are also in agreement with the results reported in the literature for different locations. Liang et al. (2010) found that evapotranspiration varied between 1098.67 mm to 1210.25 mm in USA conditions. Oudin et al. (2010) indicated that Southern part of the Europe reached same results. Under different irrigation applications, ETo obtained by Uçan and Gençoğlan (2004) ranged between 1056 mm to 1278 mm in Kahramanmaraş. Zhang et al., 2001 reported that mixed vegetation covers have same agreement with the results. Some result differences are seen because of the methodologies that is used for calculation and climatic data that obtain from another source.

Table 1. Summary of each district weather station site characteristics used in the study

| Station Code | Site | Latitude (°) | Longitude (°) | Altitude (m) | Rainfall (mm year$^{-1}$) | Taverage (C°) |
|---|---|---|---|---|---|---|
| 1 | Seydişehir | 37.50 | 31.84 | 1149 | 312 | 11 |
| 2 | Akören | 37.37 | 32.38 | 1107 | 291 | 12 |
| 3 | Beyşehir | 37.81 | 31.68 | 1170 | 313 | 11 |
| 4 | Meram | 37.59 | 32.46 | 1098 | 311 | 12 |
| 5 | Çumra | 37.52 | 32.73 | 1030 | 311 | 12 |
| 6 | Karapınar | 37.60 | 33.35 | 1000 | 292 | 12 |
| 7 | Karatay | 37.89 | 33.15 | 1060 | 308 | 12 |
| 8 | Altınekin | 38.17 | 32.95 | 1047 | 315 | 12 |
| 9 | Emirgazi | 37.96 | 33.78 | 1090 | 311 | 12 |
| 10 | Cihanbeyli | 38.67 | 32.83 | 1030 | 291 | 12 |
| 11 | Kulu | 39.04 | 33.23 | 955 | 335 | 12 |

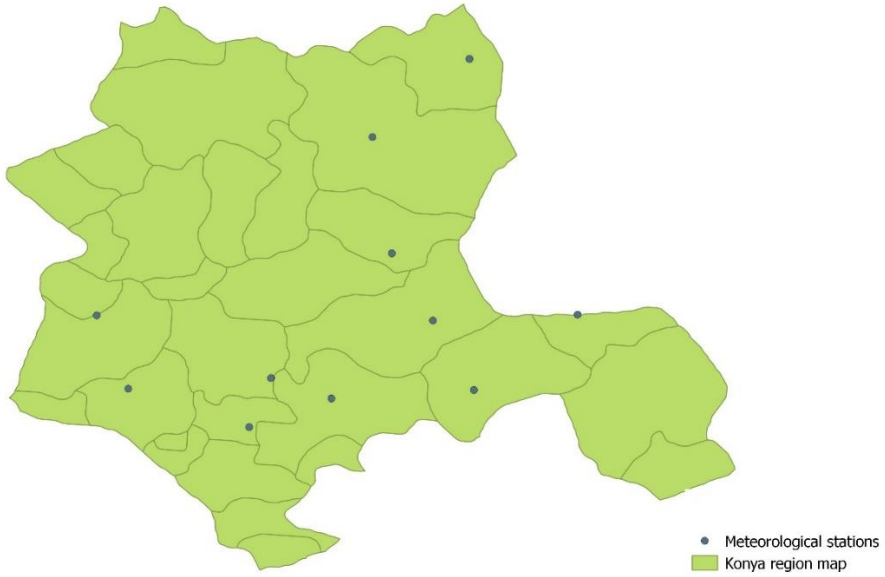


Figure 1. Location of meteorological stations used for ETo calculations in Konya basin.

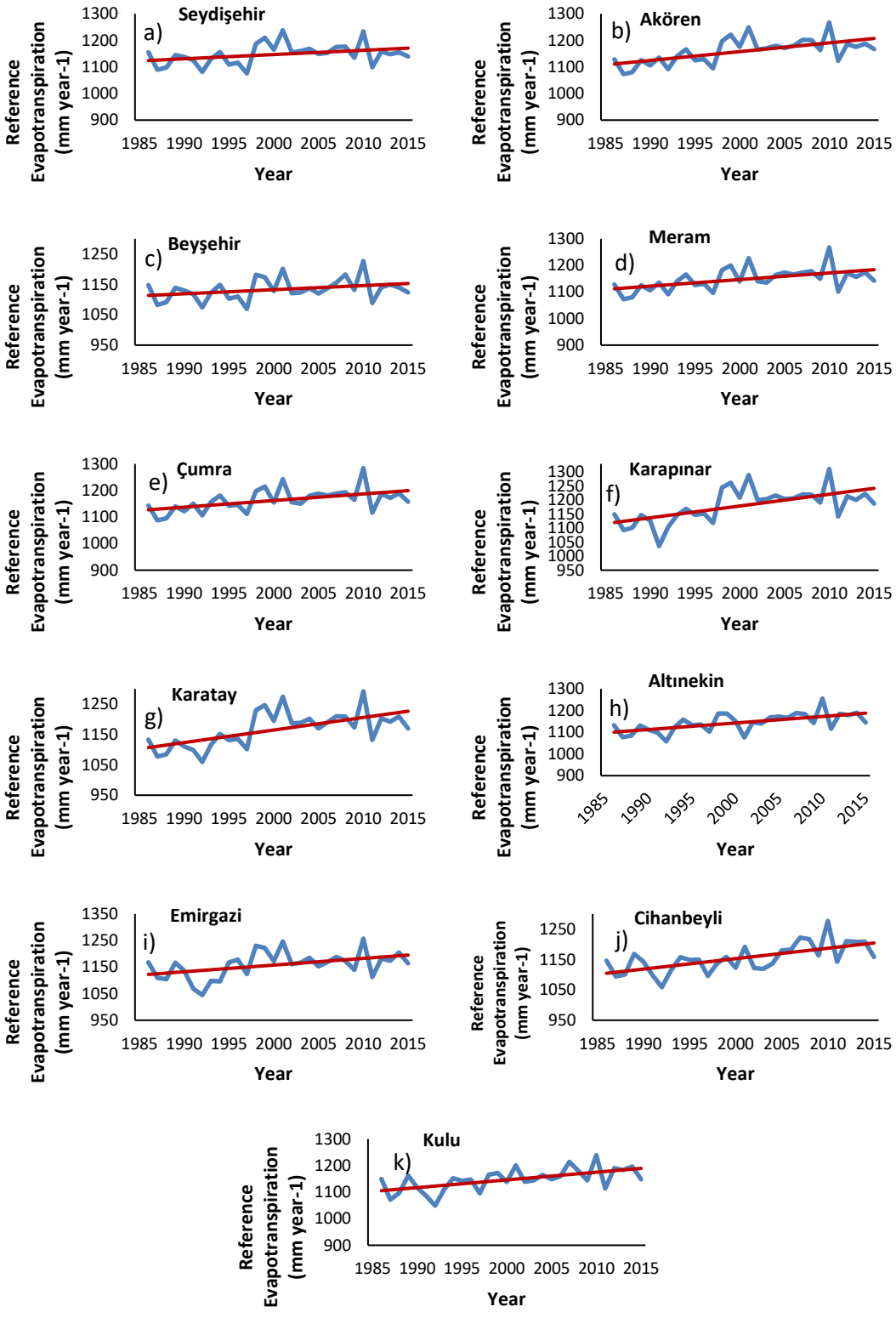


Figure 2. The annual ETo results in different districts of Konya basin.

Table 2. Some information about 30 years of maximum, minimum, average annual ETo and standart deviation in Konya basin ($ETo_{max}$ = Maximum evapotranspiration, $ETo_{min}$ = Minimum evapotranspiration, $ETo_{avg}$ = Average evapotranspiration, Std = Standart deviation)

| Site | $ETo_{max}$ (mm year$^{-1}$) | $ETo_{min}$ (mm year$^{-1}$) | $ETo_{avg}$ (mm year$^{-1}$) | Std |
|---|---|---|---|---|
| Seydişehir | 1238 | 1076 | 1147 | 40 |
| Akören | 1268 | 1073 | 1159 | 47 |
| Beyşehir | 1227 | 1069 | 1133 | 36 |
| Meram | 1268 | 1073 | 1148 | 42 |
| Çumra | 1284 | 1088 | 1163 | 42 |
| Karapınar | 1312 | 1036 | 1181 | 60 |
| Karatay | 1292 | 1059 | 1167 | 57 |
| Altınekin | 1256 | 1058 | 1144 | 43 |
| Emirgazi | 1257 | 1045 | 1159 | 49 |
| Cihanbeyli | 1277 | 1059 | 1154 | 47 |
| Kulu | 1239 | 1049 | 1147 | 42 |

## Conclusion

The FAO 56-PM is the most accurate method for computing daily ETo. However, this method requires air temperature, relative humidity, solar radiation and wind speed but not all these meteorological data is available in this study. Therefore, in this paper, ETo results in Konya basin estimated by HS method based on available daily maximum, minimum and average temperature data.

ETo increasing trend results from 1986 to 2015 demonstrate that future water requirement and water stress could increase in the region. Therefore, controlled and regulated irrigation management and modern irrigation techniques are needed for high sugar beet yields and infinite water resources in Konya basin.

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