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A Comparative Study of Crop Evapotranspiration Estimation by Three methods with Measured Crop Evapotranspiration in Konya Plain.

Sinan SÜHERI[1,*], Peter Addo AMARKAI[1], Duran YAVUZ[1]

[1]Selçuk University, Faculty of Agriculture, Department of Agricultural Structure and Irrigation, Konya, Turkey

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ABSTRACT

Evapotranspiration values are one of the basic data used in the planning, design, construction and operation of irrigation facilities. The irrigation water needs of several plants are calculated by using various empirical equations based on meteorological data and the system is designed according to the month in which the highest irrigation water is needed. The aim of this study is to compare ETc of several crops calculated with different ETc estimation methods as of FAO56-Penman-Monteith, Hergeaves - Samani and Radiation Equation with determined ETc values obtained from previously conducted researches in Konya. In the study, five commonly cultivated crops in Konya Province such as maize, sugar beet, sunflower, potato and wheat were considered. In most of the cases, it was found that radiation equation produced higher ETc values than the measured ETc values in the researches conducted at the region. As a result of this study, Penman-Monteith was close to most of the values obtained from other studies and therefore remains a highly recommendable method for estimating ETc for considered plants in Konya.

1. Introduction

Konya province located in the Central Anatolia has semi – arid climate with hot and dry summers. Annual precipitation in Konya is about 322.4 mm which is relatively low as compared to country average. A bit over 4 percent of the population are engaged in agricultural activities. Most of the crops cultivated in Konya require irrigation because of hot and dry summers.

Agriculture is one of the major ways to obtain nutrient, medicine, and other products for sustaining life and also contributes largely to the gross domestic product of most economies. Livelihood enhancement programs, food security, and other socioeconomic interventions over the years have targeted development in agriculture by increasing crop production through improvement in technology to be able to meet the needs of the world’s increasing population. The World Bank (2018) has projected a world population of 9.7 billion by 2050 that is about 28% increase of the current population of 7.6 billion suggesting that food production in the future must be increased to be able to match this growth. Climate on the other hand is known to affect food production in many ways. Climate is made up of many parameters including wind, air temperature, humidity, solar radiation, atmospheric pressure, and precipitation. All of these parameters are likely to change due to instability in the atmosphere. Variations in these parameters directly or indirectly affect agricultural activities.

Water plays a crucial role in agriculture; however, it is required to meet household, energy, manufacturing and ecological needs. Although the need for water is increasing in other sectors, irrigation continues to be the main consumer of water. According to the FAO (2018), the usage of water for irrigation generally amounts to about 70% of all freshwater withdrawals. Irrigation is a reliable way of providing plants with the water needed for growth and plant yield depends largely on the amount of water available and can be used at a particular period. Additionally, determining the amount of water needed by plants, and the amount that can be used by the plant for growth is necessary to determine the amount of water needed for irrigation to avoid excessive use of water and ensure plant growth.

Efficient management of declining water resources is an essential factor in achieving high irrigation

* Corresponding author email: *ssuheri@selcuk.edu.tr*

efficiency, reducing drainage, decontamination of groundwater and desalination. The irrigation water efficiency can be increased by a proper irrigation program which includes the calculation of plant water consumption or crop evapotranspiration (ETc). Evapotranspiration is simply the amount of water lost through evaporation and transpiration and it can be expressed as a function of reference Evapotranspiration (ETo) and the crop coefficient (Kc).

Evapotranspiration values are one of the basic data used in the planning, design, construction and operation of irrigation facilities. When planning an irrigation system, possible crops that can be cultivated under irrigation are determined and the planting rates in the irrigation area are estimated. The irrigation water needs of these plants are calculated by using various empirical equations based on meteorological data and the system is designed according to the month in which the highest irrigation water is needed.

The aim of this study is to calculate ETc of several crops cultivated in Konya plain by using different ETc estimation methods and to compare estimated ETc values with determined ETc values obtained from previously conducted researches in the region.

2. Materials and Methods

2.1. Study Area

Konya where the research was conducted has arid climate conditions with hot and dry summers. According to long-term meteorological data (1929 – 2017), annual mean temperature, annual mean evaporation , annual mean precipitation are 11.6° C, 1324 mm and 322.4 mm, respectively.

Monthly measured data for 10 years (2000-2010) period were obtained from Konya meteorological station (latitude 37.9837 N, longitude 32.5740 E, elevation 1031 m) for calculation of ETo (reference crop evapotranspiration), (Table 1).

Table 1
Meteorological data of experimental area (2000-2010)

Months	Mean Max Temp (°C)	Mean Min Temp (°C)	Monthly Sunshine duration (n)(Hours/Month)	Monthly average wind speed (u2)	Monthly mean relative humidity (%)
January	5.65	-3.05	103.05	2.12	82.19
February	7.24	-2.39	136.03	2.82	76.87
March	13.79	1.05	196.02	3.22	64.65
April	17.4	4.78	208.6	3.04	63.3
May	23.07	9.26	267.49	2.9	56.64
June	28.1	14.06	296.69	3.36	46.97
July	31.3	17.37	328.17	3.68	41.49
August	31.69	17.6	319.18	3.32	39.5
September	26.43	12.37	266.11	2.75	49.62
October	20.32	7.35	213.3	2.48	62.38
November	13.25	1.42	158.38	2.2	75.73
December	6.75	-2.2	102.12	2.08	83.35

2.2. Reference ETo calculations.

Three ETo calculation methods as of FAO56-Penman Monteith, Hargreaves and Samani, and Radiation equation were used to calculate ETo. The methods used in this study are cited and described in Allen et al. (1998), Hargreaves and Samani (1985) and Doorenbos and Pruitt (1977) respectively.

The FAO56 Penman Monteith method as stated by Allen et al. (1998) is

$$ET_o = \left(\frac{0.408\Delta(R_n - G) + \gamma\frac{900}{T+273}u_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \right)$$

Where; Rn = net radiation at the crop surface [MJ m^{-2} day^{-1}], G = soil heat flux density [MJ m^{-2} day^{-1}], T = mean daily air temperature at 2 m height [°C], u_2 = wind speed at 2 m height [m s-1], es = saturation vapor pressure [kPa], ea = actual vapor pressure [kPa], es – ea = saturation vapor pressure deficit [kPa], Δ = slope vapour pressure curve [kPa $°C^{-1}$], γ = psychrometric constant [kPa $°C^{-1}$].

The Hargreaves and Samani method as stated by Hargreaves and Samani (1985) is,

$$ET_o = 0.0023Ra(T_{max} - T_{min})^{0.5}(T_{mean} + 17.8)$$

Where; Ra = extraterrestrial radiation (MJ m^{-2} day^{-1}/2.45), Tmin = monthly minimum air temperature (°C), Tmax = monthly maximum air temperature (°C), Tmean = monthly mean air temperature (°C).

The radiation method as stated by Doorenbos and Pruitt (1977) is

$$ET_o = c(W * Rs)$$

Where; ETo = reference crop evapotranspiration (mm day^{-1}), Rs = solar radiation in equivalent evaporation (MJ m^{-2} day^{-1}), W = weighting factor which depends on temperature and altitude, C = adjustment factor which depends on mean humidity and daytime wind conditions. W factor was calculated according to formula given by Doorenbos and Pruitt (1977)

$$W = \frac{\Delta}{\Delta + \gamma}$$

Where; Δ = slope of the saturation vapour pressure temperature relationship (kPa °C^{-1}), γ = psychrometric constant (kPa °C^{-1}), C factor was calculated according to formula given by Allen and Pruitt (1991)

$$C = 1.066 - 0.00128RH_{mean} + 0.045U_d - 0.0002RH_{mean}U_d - 0.0000315(RH_{mean})^2 - 0.001103(U_d)^2$$

Where; Rhmean=Mean relative 3umidity (%), Ud = mean wind speed at 2 m

2.3. Determination of Crop Evapotranspiration

The Crop evapotranspiration was calculated with following formula given by (Allen et al., 1998)

$$ETc = Kc \cdot ETo$$

Where; ETc = crop evapotranspiration (mm day^{-1}), Kc = crop coefficient, ETo = reference crop evapotranspiration (mm day^{-1})

The crop evapotranspiration of five different crops; maize (grain), sugar beet, sunflower, potato and wheat which are commonly cultivated on the region were calculated.

The Kc coefficients and planting periods were taken from Anonymous (2016). The Kc coefficients and growth periods of the crops for Konya meteorological stations are given in Table 2.

The Kc coefficients during initial and mid-season were considered as fixed. Kc coefficients for per month were determined graphically as stated by Allen et al. (1998).

Table 2
Kc coefficients and planting periods of the crops for meteorological stations Anonymous (2016).

Crops	Planting date	Planting Time (days)	Plating periods Kc coefficients			Length of growth stages (days)			
			Kc_{ini}	Kc_{mid}	Kc_{end}	I	II	III	IV
Maize	10/05	160	0.23	1.18	1.07	30	40	50	40
Potato	10/04	140	0.25	1.18	0.78	30	35	50	25
Sugarbeet	1/04	185	0.26	1.22	0.71	30	50	70	35
Sunflower	20/04	145	0.29	1.08	0.37	25	30	60	30
Wheat	20/10	270	0.63	1.16	0.27	170	30	40	30

3. Results and Discussion

ETo results calculated using FAO-56 Penman Monteith, Hargreaves and Samani, and Radiation equation as presented in Table 3 shows an annual sum of 41.82, 38.69 and 50.86 mm/day and averages 3.49, 3.22 and 4.24 mm/day respectively.

The Radiation equation produced the highest monthly ETo with a minimum of 0.95 mm/day and maximum ETo of 8.37 mm/day. FAO56-Penman Monteith method recorded a minimum of 0.70 mm/day and a maximum of 7.36 mm/day. Hargreaves and Samani method yielded values which are closer to FAO56-Penman Monteith in most months than the Radiation equation.

The highest ETo was 6.02 mm/day and a minimum value was 0.84 mm/day obtained by using Hargreaves and Samani estimation methods.

Table 3
ETo values (mm/day) calculated with different methods.

Months	FAO56 – Penman Monteith	Hargreaves and Samani	Radiation Equation
January	0.70	0.86	1.01
February	1.12	1.27	1.68
March	2.26	2.38	3.06
April	3.10	3.39	4.19
May	4.47	4.72	5.89
June	6.19	5.71	7.54
July	7.36	6.02	8.37
August	7.05	5.54	7.79
September	4.76	4.02	5.46
October	2.76	2.52	3.22
November	1.33	1.42	1.70
December	0.72	0.84	0.95

The calculated ETo was used to estimate the ETc of maize in this study as shown in Table 4. Maize plant has a growing period of 160 days that is from May to October and crop coefficient Kc of 0.22, 0.42, 1.06, 1.19, 1.16 and 1.10. The total ETc for maize was 817.83, 682.96, and 934.85 mm according to the different methods. The highest ETc was obtained when the radiation equation was used whereas the least value was recorded when the Hargreaves and Samani method was used.

The ETc of the maize crop determined in a research conducted by Kara (2011) in 2009 at Konya. Kara (2011), investigated the effects of four different irrigation levels and 7 day irrigation interval on maize yield and yield components. It was stated that total ETc of maize crop ranged between 590 mm and 781 mm in the study.

The researcher has indicated that the ETc was measured as 727.7 mm for the treatment where maximum yield was obtained.

In the another study conducted during the growing period in 2009 -2010, ETc values of maize were ranged between 555 mm and 779.1 mm for 2009, 602.4 mm and 812.5 mm for 2010. The ETc values of the treatment where the maximum yield obtained were 779,1 mm for 2009 and 812,5 mm for 2010 (Şahin et al., 2015).

Table 4
ETc of Maize calculated with different methods.

Months	Days	Kc	Penman Monteith		Hergeaves Samani		Radiation Equation	
			ETo (mm/day)	ETc (mm/month)	ETo (mm/day)	ETc (mm/month)	ETo (mm/day)	ETc (mm/month)
May	21	0.22	4.47	20.65	4.72	21.81	5.89	27.21
June	30	0.42	6.19	77.99	5.71	71.95	7.54	95.00
July	31	1.06	7.36	241.85	6.02	197.82	8.37	275.04
Aug	31	1.19	7.05	260.07	5.54	204.37	7.79	287.37
Sept.	30	1.16	4.76	165.65	4.02	139.90	5.46	190.01
Oct.	17	1.10	2.76	51.61	2.52	47.12	3.22	60.21
Total	160			817.83		682.96		934.85

When ETc values measured in Kara (2011) were compared with the ETc values estimated in this study, the ETc values calculated with FAO56-Penman-Monteith and Radiation Equation were higher than maximum ETc values calculated in Kara (2011). Hergeaves and Samani method produced closer ETc values to the measured ETc values.

It can be concluded that Radiation Equation overestimated the maize crop ETc in the region.

When ETc values measured in Şahin et al. (2015) were compared with the ETc values estimated in this study, it can be stated that Penman Monteith methods produced closer ETc values to the measured ETc values in the study.

Table 5
ETc of Sugar beet calculated with different methods.

Months	Days	Kc	Penman Monteith		Hergeaves Samani		Radiation Equation	
			ETo (mm/day)	ETc (mm/month)	ETo (mm/day)	ETc (mm/month)	ETo (mm/day)	ETc (mm/month)
April	29	0.26	4.47	34.87	4.72	36.82	5.89	45.94
May	31	0.60	4.47	83.14	4.72	87.79	5.89	109.55
June	30	1.12	6.19	207.98	5.71	191.86	7.54	253.34
July	31	1.23	7.36	280.64	6.02	229.54	8.37	319.15
Aug	31	1.23	7.05	268.82	5.54	211.24	7.79	297.03
Sept.	30	0.97	4.76	138.52	4.02	116.98	5.46	158.89
Oct.	3	0.73	2.76	6.04	2.52	5.52	3.22	7.05
Total	185			1020.01		879.75		1190.96

The ETc of sugar beet calculated in this study were 1020.01 mm, 879.75 mm, and 1190.96 mm using the Penman-Monteith, Hargreaves and Samani, and the Radiation equation as presented in Table 5. The growing period for sugar beet is 185 days. Higher ETc was recorded within the mid-season of the growing period.

Süheri et al. (2007) calculated the seasonal ETc of sugar beet throughout the development stages in 2005 and 2006. It was observed that ETc values ranged from 203 mm to 1177 mm in 2005 and 200 mm to 1002 mm in 2006 for the various seasons. The study also computed the ETc for the vegetative growth stage, root development stage, and ripening stage of sugar beet. ETc was mostly high during the root development stage.

Another study conducted in Konya by Poçan (2008) considered the calculation of seasonal and monthly ETc for sugar beet in 2006 and 2007. The total ETc ranged from 826 mm to 1135 mm in 2006 and 907 mm to 1182 mm in 2007.

Topak et al. (2016) conducted a study to compare partial root-zone drying with conventional deficit irrigation and full irrigation in Konya. The researches indicated that, the measured ETc values of sugar beet were ranged between 591.6 mm and 965.3 mm in the study.

When the total ETc results obtained from full irrigation treatments in this studies were compared with ETc measured with the three methods, the radiation equation was higher than the maximum ETc obtained in Süheri et al. (2007) study, the maximum ETc calculated by Poçan (2008) and the maximum ETc calculated by Topak et al. (2016). . Penman-Monteith and Hargreaves and Samani method had ETc values within the ranges observed in Süheri et al. (2007) , Poçan (2008) and Topak et al. (2016).

Table 6
ETc of Sunflower calculated with different methods.

Months	Days	Kc	Penman Monteith		Hergeaves Samani		Radiation Equation	
			ETo (mm/day)	ETc (mm/month)	ETo (mm/day)	ETc (mm/month)	ETo (mm/day)	ETc (mm/month)
April	10	0.23	4.47	10.28	4.72	10.86	5.89	13.55
May	31	0.36	4.47	49.89	4.72	52.68	5.89	65.73
June	30	1.00	6.19	185.70	5.71	171.30	7.54	226.20
July	31	1.09	7.36	248.69	6.02	203.42	8.37	282.82
Aug	31	0.95	7.05	207.62	5.54	163.15	7.79	229.42
Sept.	12	0.51	4.76	29.13	4.02	24.60	5.46	33.42
Total	145			731.31		626.00		851.13

The results of ETc for sunflower using Penman-Monteith, Hargreaves and Samani, and Radiation have been presented in Table 6. The total growing period for sunflower is 145 days and the planting period started from April and end in September. The total ETc are 731.31 mm, 626 mm, 851.13 mm.

Yavuz et al. (2016) calculated the ETc for sunflower cultivated in Konya with different irrigation interval in 2013 and 2014. The results of the study shows a total mean ETc ranging from 243.8 mm to 748.7 mm in 2013 and 2014.

ETc determined by the radiation equation in this study was higher than maximum ETc measured by Yavuz et al. (2016) The ETc values calculated with Hergeaves and Penman Monteith in this study were lower than maximum ETc values measured by Yavuz et al. (2016). However, Penman Monteith method produced closer ETc values to the ETc values measured by Yavuz et al. (2016).

Table 7
ETc of Potato calculated with different methods.

Months	Days	Kc	Penman Monteith		Hergeaves Samani		Radiation Equation	
			ETo (mm/day)	ETc (mm/month)	ETo (mm/day)	ETc (mm/month)	ETo (mm/day)	ETc (mm/month)
April	20	0.25	4.47	22.35	4.72	23.60	5.89	29.45
May	31	0.44	4.47	60.97	4.72	64.38	5.89	80.34
June	30	1.09	6.19	202.41	5.71	186.72	7.54	246.56
July	31	1.18	7.36	269.23	6.02	220.21	8.37	306.17
Aug	28	1.00	7.05	197.40	5.54	155.12	7.79	218.12
Total	140			752.36		650.03		880.64

Potato has a growing period of 140 days with crop coefficient Kc of 0.25, 0.44, 1.09, 1.18, and 1.00 were used to calculate the ETc using Penman-Monteith, Hargreaves and Samani, and radiation equation. The total ETc calculated using the methods are 752.36 mm, 650.03 mm, and 880.64 mm. In the mid-season stage of potato, the ETc values were high for each of the methods.

Yavuz et al. (2012) also measured seasonal ETc in 2008 and 2009 of different irrigation methods for potato in Konya. The study determined the ETc for a sprinkler irrigation, furrow and drip irrigation system. The seasonal ETc in Yavuz et al. (2012) study were 665.69 mm, 614.64 mm, and 581.54 in 2008 for each of the irrigation methods used. In 2009 the seasonal ETc estimated in Yavuz et al. (2012) study were 674.76 mm, 621.96 mm, and 562.79 mm.

The ETc calculated in this study using Penman-Monteith and the Radiation method had higher ETc for potato than the values obtained in Yavuz et al. (2012) study. The Hargreaves and Samani method was within the range observed in Yavuz et al. (2012) estimation.

Wheat is grown for 270 days and the results of ETc calculated with different methods have been represented in Table 8. Today ETc of wheat with Penman-Monteith method was 588.62 mm, Hargreaves and Samani method was 598.23 mm, and radiation equation was 758.85 mm in Konya. The estimation of ETc was higher when the radiation equation was used. Penman-Monteith method is the method with the least value of ETc for wheat.

Tari (2016) conducted a study to create deficit irrigation strategies for wheat. In the research, 22 experimental treatments were created based on the growth stages of wheat and water-deficit levels in Konya plain. The seasonal ETc was observed to be varied between 206 and 571 mm in the study.

When the results obtained from this study was compared to Tari (2016)'s, it was observed that Penman-Monteith method was about 18 mm higher than ETc determined in Tari (2016) study. The Hargreaves Samani was about 28 mm high when compared with the maximum ETc from Tari (2016) and the radiation equation was over 180 mm higher.

Table 8
ETc of Wheat calculated with different methods.

Months	Days	Kc	Penman Monteith		Hergeaves Samani		Radiation Equation	
			ETo (mm/day)	ETc (mm/month)	ETo (mm/day)	ETc (mm/month)	ETo (mm/day)	ETc (mm/month)
January	31	0.63	0.70	13.67	0.86	16.80	1.01	19.73
February	28	0.63	1.12	19.76	1.27	22.40	1.68	29.64
March	31	0.65	2.26	45.54	2.38	47.96	3.06	61.66
April	30	0.93	3.10	86.49	3.39	94.58	4.19	116.90
May	31	1.16	4.47	160.74	4.72	169.73	5.89	211.80
June	30	0.9	6.19	167.13	5.71	154.17	7.54	203.58
July	7	0.38	7.36	19.58	6.02	16.01	8.37	22.26
October	21	0.63	2.76	36.51	2.52	33.34	3.22	42.60
November	30	0.63	1.33	25.14	1.42	26.84	1.70	32.13
December	31	0.63	0.72	14.06	0.84	16.41	0.95	18.55
Total	270			588.62		598.23		758.85

4. Conclusion

In conclusion, the results of this study suggest that the radiation method is not suitable in estimating plant water consumption in Konya because it produced the highest ETc in most cases, however, comparison with the other studies shows over estimated values which cannot be recommended for irrigation scheduling. Penman-Monteith was close to most of the values obtained from other studies and therefore remains a highly recommendable method for estimating ETc for considered plants in Konya.

5. References

Allen RG, Pruitt WO (1991). FAO-24 reference evapotranspiration factors. *Journal of irrigation and drainage engineering* 117 (5): 758-773.

Allen RG, Pereira LS, Raes D, Smith M (1998). Crop evapotranspiration-Guidelines for computing crop water requirements-FAO Irrigation and drainage paper 56. *FAO, Rome* 300 (9): D05109.

Anonymous (2016). Türkiye'de Sulanan Bitkilerin Bitki Su Tüketimi Rehberi, Tarımsal Araştırmalar ve Politakalar Genel Müdürlüğü. p., Ankara.

Doorenbos J, Pruitt W (1977). Crop water requirements. Irrigation and drainage paper no. 24. *FAO, Rome*

Hargreaves GH, Samani ZA (1985). Reference crop evapotranspiration from temperature. *Applied engineering in agriculture* 1 (2): 96-99.

Kara S (2011). Konya ekolojik koşullarında damla sulama yöntemi ile sulanan mısır bitkisinde su-verim ilişkileri, Selçuk Üniversitesi Fen Bilimleri Enstitüsü

Poçan M (2008). Farklı sulama aralıklarında sulamanın şeker pancarının verim ve kalitesi üzerine etkisi, Selçuk Üniversitesi Fen Bilimleri Enstitüsü

Süheri S, Topak R, Yavuz D (2007). Farklı Sulama Programlarının Şeker Pancarı Verimine Ve Su Kullanım Randımanına Etkisi. *Selçuk Tarım Bilimleri Dergisi* 21 (43): 37-45.

Şahin M, Süheri S, Yavuz D (2015). Damla Sulama ile Sulanan Mısır Bitkisinde Farklı Bitki Sıra ve Lateral Hat Aralıklarının Verim ve Su Kullanım Randımanına Etkisi Selçuk Üniversitesi BAP Projesi. Proje No: 09401066.

Tari AF (2016). The effects of different deficit irrigation strategies on yield, quality, and water-use efficiencies of wheat under semi-arid conditions. *Agricultural Water Management* 167: 1-10.

Topak R, Acar B, Uyanöz R, Ceyhan E (2016). Performance of partial root-zone drip irrigation for sugar beet production in a semi-arid area. *Agricultural Water Management* 176: 180-190.

Yavuz D, Kara M, Suheri S (2012). Comparison of different irrigation methods in terms of water use and yield in potato farming. *J. Selcuk Univ. Nat. Appl. Sci* 2: 1-12.

Yavuz N, Çiftçi N, Yavuz D (2016). The Effects of Deficit Irrigation on Yield of Sunflower. *CHEMTECH'16*: 20.