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SELÇUK ÜNİVERSİTESİ
FEN BİLİMLERİ ENSTİTÜSÜ

İKLİM PARAMETRELERİNDEKİ DEĞİŞİMİN BİTKİ SU TÜKETİMİNE ETKİSİ (EFFECT OF CHANGES IN CLIMATIC PARAMETERS ON PLANT WATER REQUIRMENTS)

Peter Addo AMARKAI

YÜKSEK LİSANS
Tarımsal Yapılar ve Sulama Anabilim Dalını

Nisan-2019
KONYA
Her Hakkı Saklıdır

ÖZET

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Peter Addo AMARKAI

Selçuk Üniversitesi Fen Bilimleri Enstitüsü
Tarımsal Yapılar ve Sulama Anabilim Dalı

Danışman: Dr. Öğr. Üyesi Sinan SÜHERİ

2019, 80 Sayfa

Jüri
Prof. Dr. Bilal ACAR
Doç. Dr. Ali ÜNLÜKARA
Dr. Öğr. Üyesi Sinan SÜHERİ

Bu çalışmada, Konya ovasında dört meteoroloji istasyonundan 10 yıllık periyotta toplanan verileri kullanarak, iklim parametrelerindeki değişimlerin ovada yetiştirilen bazı bitkilerin su tüketimi üzerine etkileri araştırılmıştır. Sonuçlar FAO Penman-Monteith metodu ile diğer metotların her biri arasında istatistiksel olarak anlamlı bir farklar olduğunu göstermiştir. Çalışmada bölgede yaygın olarak yetiştirilen şeker pancarı, mısır (tane), ayçiçeği, kuru fasulye ve buğday olmak üzere beş farklı ürünün su tüketimi hesaplanmıştır. Radyasyon eşitliğine göre hesaplanan ETc değerlerinin, istasyonların çoğunda diğer yöntemlere göre hesaplanan ETc değerlerinden daha yüksek olduğu görülmüştür. Akşehir'de Radyasyon denklemi kullanılarak elde edilen kuru fasulye ETc değeri 501 mm ile 679 mm, Beyşehir'de 544 mm ile 727 mm, Cihanbeyli'de 679 mm ile 738 mm, Ereğli'de 725 mm ile 767 mm arasında değiştiği bulunmuştur. Tüm istasyonlarda 10 yıllık periyot boyunca en düşük ETc değerleri ASCE Penman-Monteith eşitliği ile hesaplanan ETc değerlerinden elde edilmiştir. Büyük ölçüde minimum ve maksimum bağıl neme bağlı olan Blaney Criddle formülü ile hesaplanan ETc değerleri, birçok lokasyonda FAO 56 Penman-Monteith ve Hargreaves - Samani eşitliklerii ile hesaplanan ETc değerlerinden daha yüksek çıkmıştır. Sonuç olarak, bitkilerin su ihtiyacını belirlemek için standart bir yaklaşım olarak kabul edilen FAO Penman-Monteith'i hesaplamak için meteorolojik verilerin yeterli olmadığı alanlarda radyasyon eşitliği önerilebilir.

Anahtar Kelimeler: ASCE Penman Monteith, Blaney Criddle, Bitki katsayısı, Evapotranspiration, FAO Penman-Monteith, Hargreave-Samani, Radyasyon eşitliği

ABSTRACT

MS THESIS

EFFECT OF CHANGE IN CLIMATIC PARAMETERS ON PLANT WATER REQUIREMENTS

Peter Addo AMARKAI

THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCE OF SELÇUK UNIVERSITY
THE DEGREE OF MASTER OF SCIENCE
IN AGRICULTURAL STRUCTURE AND IRRIGATION

Advisor: Yrd. Doç. Dr Sinan SÜHERİ

2019, 80 Pages

Jüri
Prof. Dr. Bilal ACAR
Doç. Dr. Ali ÜNLÜKARA
Dr. Öğr. Üyesi Sinan SÜHERİ

This study was aimed to investigate the effects of changes in climate parameters on the crop water requirements in the Konya plain over a period of 10 years using data collected from four meteorological stations. The result showed a significant differences between the FAO Penman-Monteith method and each of the other methods. The water requirements of five different crops; sugarbeet, maize (grain), sunflower, drybean and wheat which are commonly cultivated on the region were calculated. It was also observed that the ETc values calculated according to the Radiation equation was higher at most of the stations than ETc values calculated by the other methods. In Akşehir the ETc of dry bean obtained by using Radiation equation ranges from 501 mm to 679 mm, in Beyşehir it ranges from 544 mm to 727 mm, in Cihanbeyli 679 mm to 738 mm, and Ereğli ranges from 725 mm to 767 mm. The ASCE Penman-Monteith recorded the least ETc in all the meteorological station for the 10 year period. Plant water requirement calculated with the Blaney Criddle formula which depends largely on the minimum and maximum relative humidity has higher ETc values than ETc values calculated by the FAO 56 Penman-Monteith and Hargreaves - Samani in most of the locations. From the results, The radiation equations can be recommended for areas where meteorological data are not enough to calculate FAO Penman-Monteith which is considered as a standard approach of determining the water requirement of plants.

Keywords: ASCE Penman Monteith, Blaney Criddle, Crop Coefficient, Evapotranspiration, FAO Penman-Monteith, Hargreave-Samani, Radiation equation

PREFACE

My sincere gratitude goes to my advisor, Dr. Sinan Süheri for critically examining the work and for his constructive suggestions, without him I would not have completed this study successfully. I am highly indebted to the entire staff of Agricultural structure and irrigation department for helping me academically, socially and all other ways during my period of studies. To the Turkish government, thank you for the opportunity and support.

I am also grateful to my beloved wife and family for their counsel, motivation, and all the resources they have spent to get me this far. Finally to all friends and acquaintances, I appreciate every effort and time you have spent to get this work done.

Peter Addo AMARKAI
KONYA-2019

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SYMBOLS AND ABBREVIATIONS

Symbols

ETo = reference evapotranspiration (mm day^{-1}),

ETc = crop evapotranspiration (mm day^{-1}),

Rn = net radiation at the crop surface (MJ m^{-2} day^{-1}),

Ra = extraterrestrial radiation (MJ m^{-2} day^{-1}/2.45),

Rs = solar radiation in equivalent evaporation (MJ m^{-2} day^{-1}),

Rso = clear-sky solar radiation,

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 vapour pressure (kPa),

ea = actual vapour pressure (kPa),

es - ea = saturation vapour pressure deficit (kPa),

$e^0(T_{min})$ = saturated vapour pressure at daily minimum temperature (kPa),

$e^0(T_{max})$ = saturated vapour pressure at daily maximum temperature (kPa),

Δ = slope of the saturated vapour pressure curve (kPa $°C^{-1}$),

γ = psychrometric constant (kPa $°C^{-1}$),

RH_{max} = maximum relative humidity (%),

RH_{min} = minimum relative humidity (%),

RH_{mean}= mean relative humudity (%),

ρ_a= mean air density at constant pressure (kg m^{-3}),

C_p = specific heat of the air (MJ kg^{-1} $^oC^{-1}$),

rs = (bulk) surface resistances (s m^{-1}),

ra = aerodynamic resistances (s m^{-1}),

λ = latent heat of vaporization (MJ kg^{-1}),

k_{time} = unit revolution (86 400 s day^{-1}),

W = weighting factor,

C = adjustment factor,

P= mean daily percentage of total annual daytime hours,

n = actual duration of sunshine (hour),

N = maximum possible duration of sunshine or daylight hours (hour),

U_d = mean wind speed (m/sn),

T_{min} = monthly minimum air temperature (^oC),

T_{max} = monthly maximum air temperature (^oC),

K_c = crop coefficient.

Abbreviations

FAO: Food and Agriculture Organization (United Nations)

ASCE: American Society of Civil Engineers

ASCE P-M: ASCE Penman Monteith

RAD.: Radiation equation

HA-SA.: Hargreave-Samani method

BL-CR.: Blaney-Criddle method

1. INTRODUCTION

The first sign of Agricultural activities is believed to have been seen over 350 thousand years ago since the existence of homo sapiens in which humans belong. Evidence suggests that production of food and animals for clothing, fiber, food, and many other purposes began in the fertile crescent located in Western Asia area. Before the invention of metal tools, crops such as flax, wheat, peas, lentils, peas, barley, and bitter vetch were being cultivated basically to sustain the needs of the farmers. Agricultural practices or farming has evolved from the use of rudimentary tools to the use of sophisticated technologies which include the development of complex irrigation systems. Irrigation started in Egypt and the Mesopotamian plain simply as a process of flooding fields by digging canals to regulate the flow of rivers. Since the last century, there have been a significant improvement in technology and practices in agriculture.

However, the sector among others faces competition because there are limited resources to be used by a constantly growing population. Consequently, the unending competition over available natural resources requires that food production is increased per unit area without causing further damages to the environment. Plants need water to grow and irrigation has proven to be one of the main consumers of water. There have been many innovations and technologies to improve irrigation practices and also ensure the efficiency of irrigation systems. As a result, several irrigation methods have been developed over the years to improve or replace already existing systems to suit different conditions and climates. Traditional irrigation methods such as furrow, basin, strip and the use of cans are gradually replaced by water efficient methods such as drip and sprinkler methods. In most developed countries, irrigation systems are controlled by smart devices that are sensitive to environmental changes instead of the traditional systems which operate on preset schedules. These developments follow the attempt to reduce wastage of water and increase productivity in crops.

Weather conditions, often unpredictable, on the other hand, continues to affect most developmental interventions purposed to increase food production. Temperature, atmospheric pressure, humidity, precipitation, solar radiation, and wind speed are periodically changing and the variations in these parameters affect the amount of water that will be available for plants to grow. Due to these reasons, an efficient and sustainable management of water resources is required to be able to provide plants the water they need for growth and also increase productivity of plants.

Sustainability of irrigated agriculture is primarily achieved by effective management of irrigation water. Irrigation water management involves good monitoring and controlling of the water required for plant growth. The water requirements of plants can be estimated by using periodic weather data.

A number of studies have been carried out to determine the plant water requirement and a number of methods have been developed for predicting plant water requirement by using various weather data. According to Hargreaves and Samani (1985), all the methods used in estimating ET are to some degree empirical and have been derived and/or calibrated from evapotranspiration determined using the lysimeter or soil moisture depletion by a reference crop. The FAO Penman-Monteith (Allen et al., 1998) is one of the most widely used methods for calculating evapotranspiration. The actual evapotranspiration of a crop is derived by multiplying the referenced evapotranspiration with the crop coefficient kc when using the FAO Penman-Monteith method. The FAO Penman-Monteith method was derived from the original Penman-Monteith equation, surface resistance, and the aerodynamic equation (Allen et al., 1998). The Penman-Monteith equation also requires weather data such as air temperature, solar radiation, relative humidity, and wind speed. The Hargreaves Evapotranspiration equation is an alternative to the Penman-Monteith method, which requires only air temperature and solar radiation or extraterrestrial radiation and it is also as accurate as Penman-Monteith equation (Watanabe et al, 2004).

Another widely used temperature method for estimating evapotranspiration is the FAO Blaney-Criddle method. Allen and Pruitt (1986) reported that the FAO Blaney-Criddle method is comparatively easier to use and also capable of predicting reference evapotranspiration accurately. This method unlike the other temperature method (original Blaney-Criddle formula, the Soil Conservation Service (SCS) Blaney-Criddle formula) can be adjusted to suit local weather or climatic conditions (Allen and Pruitt, 1986). Due to this, major recalibration or adjustment is not required when using the FAO Blaney-Criddle method.

The sustainability of irrigation projects can be affected if an appropriate model for estimating the amount of water plants required is not adopted. For every location, a suitable method for calculating the amount of water needed by crops from planting to the final stage of development is required. Daily changes in weather when measured can be helpful in planning and designing an Irrigation Project. In most developing countries irrigation projects have been narrowed to one or some of the following; the

improvement of irrigation technology, irrigation water efficiency, and effective managerial systems. However, the failure to track variations that occur in climate or weather and changes in cropping patterns over long periods of cultivation hinders the effectiveness of most projects. When an irrigation system is under operation, the plant pattern estimated in the planning stage differs according to the planted years, which affects the system performance and also the initial estimation of the amount of water to supply crops changes over time due to climate changes.

Studies have shown that the potential for development in irrigation is higher in sub-Saharan Africa countries because of the relative abundance of natural resources such as lakes, rivers, and sufficient underground water. Despite the great potential for improvement in irrigation in these countries, about 7% of arable lands are irrigated and barely 3.7% of arable lands are irrigated in sub-Saharan Africa (Nyong'o et al, 2002). Data on plant pattern in irrigated areas, plant water consumption, the amount of water supplied in irrigation areas are difficult to obtain and therefore the determination of irrigation modules and irrigation efficiencies of irrigation areas is relatively difficult.

Conversely, Turkey has about 28 million ha of arable land with approximately 26 million ha irrigable land and irrigated area of about 6 million ha. The first biggest irrigation system in Turkey is the Konya-Çumra system completed in 1913. This system allows the irrigation of 50 thousand ha of land. Irrigation systems have been established in many parts of the country since 1913 till today and these systems have been managed by different organizations throughout the years. The annual potential underground and surface water for irrigation in Konya is about 4.5 billion m^3 and about 500 thousand hectares irrigable land. The irrigated land constitutes about 38% of the total cultivated land in Konya (DSİ, 2018). Although the forms of management of irrigation facilities are different in Turkey, annual monitoring and evaluation of irrigation water consumption, irrigation outputs and plant patterns of these networks are carried out by the governing organization. However, further studies are required in Konya to assess the effectiveness of old irrigation systems and to analyze the effects of climate changes on plant water requirement of cultivated plants in the region.

The aim of this study is to investigate the effects of changes in climate parameters on the water requirements of plants in selected areas in Konya plain over a 10 year period. Climate change in the scope of this study refers to the changes in weather properties or weather parameters. Plant water consumption of the selected meteorological stations determined by using 5 methods of calculating plant water

requirement (ASCE Penman-Monteith, FAO 56 Penman-Monteith, FAO 24 Blaney-Criddle, Hargreaves and Samani Method, Radiation Method), has been investigated.

2. LITERATURE REVIEW

An important aspect of irrigation scheduling is the determination of the amount of water needed by plants and the amount of irrigation water plants require to grow. The amount of water needed by plants is affected by several factors including changes in plant pattern and meteorological parameters. This chapter reviews literature of the various techniques used for the determination of evapotranspiration and highlights similar researches on how the changes in climatic on affect evapotranspiration.

Beyribey et al. (1995), defined monitoring in irrigation systems as continuous or periodic observation and gathering of information at each stage of project management in order to ensure that input distributions, work schedules, targeted outputs and other necessary activities are performed in a planned manner and also defined evaluation is also the process of systematically and objectively comparing the appropriateness, effectiveness, and results of irrigation activities or their performance with project objectives.

Beyribey et al. (1997), also stated that water management in irrigation schemes include stages of general irrigation planning, planned water distribution and evaluation of irrigation results. In general irrigation planning studies, plant water consumption and irrigation water requirement are estimated by using meteorological data over a long period of time. In Beyribey et al. (1997) evaluation studies, average climatic data for 10 years were used to determine the irrigation water requirement by using Blaney - Criddle method. Due to the significant variation in precipitation between regions in Turkey, the use of average climatic parameters in evaluation did not give actual results. The irrigation water requirement calculated using both average and annual data were determined in 118 irrigation schemes of 21 regions. It was concluded that for an economic monitoring and evaluation system, estimation of crop water requirement using climatic factors over longer periods and calculation of irrigation water requirements using annual precipitation were determined to be advantageous.

Doorenbos and Kassam (1979), in their study on plant yield response to water, indicated that water performance indicators are the main performance indicators in water management evaluation in irrigation systems. Important parameters in the calculation of water use are plant water consumption and irrigation water requirement. Plant water consumption is a parameter used to calculate irrigation water requirement in most irrigation projects, to estimate the amount of water to be stored annually and to

plan irrigation time. Before calculating the crop evapotranspiration, meteorological data should be well appraised to ensure accuracy of available data, and then all relevant data to the crop type and development stages, and agricultural practices should be collected. In determining crop water requirement, Doorenbos and Kassam (1979) modified the Blaney-Criddle, Radiation and Penman method by using mean climate data.

Altındağ (2007) indicated that the use of long-term averages of reference evapotranspiration ETo model outputs in determining irrigation water needs in irrigation projects cause a lot of fluctuations (i.e. decrease, increase or widespread tendency) in output for most methods over many years. Under these circumstances, it was reported that the selection of the method of determining the irrigation water need and analysis of the obtained ETo values are important. Altındağ (2007) calculated and determined the trend components of reference crop water (ETo) values using long term monthly weather data (temperature, humidity, solar radiation, wind speed, sunshine duration, and evaporation) from nine meteorological stations located in the South-eastern Anatolian Project (GAP) area of Turkey. Thirteen (13) different ETo methods (ASCE Penman-Monteith; FAO 56 Penman-Monteith; 1996 Kimberly Penman; 1963 Penman Original; FAO 24 Corrected Penman; FAO Penman; FAO 24 Radyasyon; FAO 24 Blaney-Criddle; FAO 24 Pan evaporation; Hargreaves and Samani; Priestley-Taylor; Makkink; Turc) were used. ETo values tend to increase over the years, indicating that the water consumption of the plant will increase accordingly in the GAP region.

Ünlükara et al. (2011) conducted a study to test change of montly ETo series by using FAO56 Penman-Monteith equation in Konya and Karaman provinces. In the study, meteorological component between 1975 and 2006 for Konya, 1975 and 2009 for Karaman were considered to calculate ETo values by using FAO56 Penman-Monteith equation. The ETo values evaluated according to the parametric (Unit Root) and nonparametric (Mann-Whitney U and Levene) tests. As a results of the tests, it was stated that there was no changes with regards to ETo between years.

Benli and Erözel (1980) estimated the water consumption in relation to the optimum water use for State Irrigation Systems with Penman, Blaney-Criddle, Jensen-Haise, and Christiansen-Hargreaves methods and the results were compared with the Blaney-Criddle method values which were based on monthly and yearly values at the first phase of the study. It was emphasized that no statistically significant difference was found according to the results obtained after the comparison. However, the Jensen-Haise method provided very high values especially in June, July, and August, indicating

that the Jensen-Haise method could be used more safely than the Blaney-Criddle method for the basis of projection.

Yürekli et al. (2017) investigated the impact of global warming in Ankara, Konya, Kayseri, Karaman, and Afyon provinces in Central Anatolia of Turkey. The reference plant water consumption (ET_O) which covers a considerable part of climate elements was used. The minimum and maximum average temperature values, relative humidity, solar radiation, and wind speed were used to determine the changes in monthly ETo between the years 1970 and 2012. The FAO Penman-Monteith equation was used in determining the ETo values. Trend analysis of the monthly ETo results obtained was analyzed using the Holt and Mann-Kendal methods and the results show that an increasing trend in ETo values in Konya.

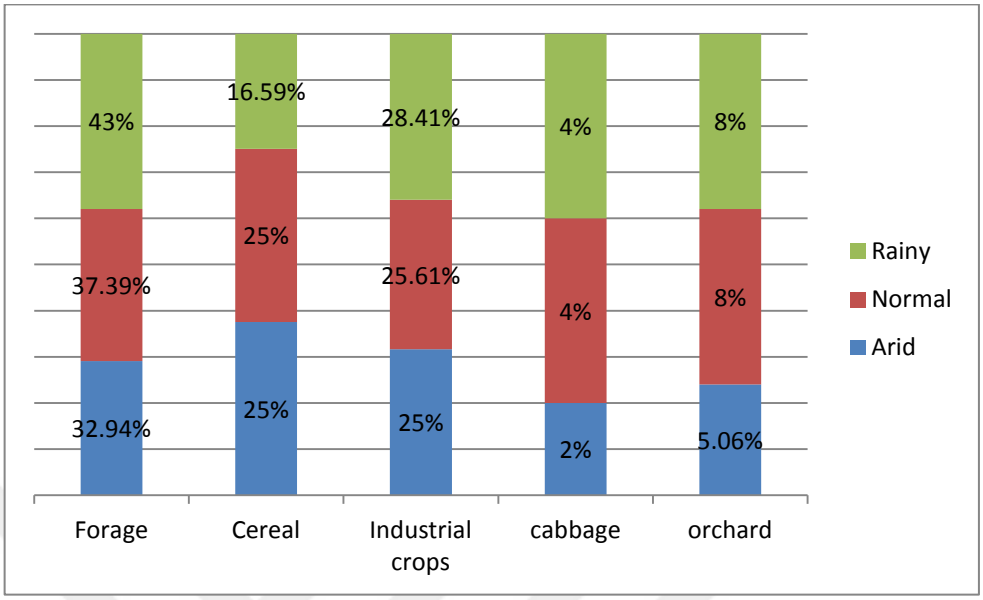
Bayramoğlu (2013) conducted a study to calculate the reference plant water consumption between 2009 and 2012 by using the Penman-Monteith equation and determined the changes in ETo values in Trabzon province. The climate data from 2009-2012 were taken from the Regional Directorate and was used to evaluate the reference plant water consumption in terms of changing climatic values over the years. It was concluded that ETo increases relative to increasing temperature and changes in other data within the period of evaluation.

Karaca et al. (2017) determined the temporal and spatial changes of reference crop evapotranspiration (ETo) values in Antalya which has high agricultural potential. Climate parameters measured from 20 meteorological stations were selected. Fifteen meteorological stations in the provinces and districts of Antalya were selected and the other 5 meteorological stations in the surrounding province and district centers were selected. CROPWAT software developed by FAO was used to calculate ETo values using long-term data obtained from these meteorological stations. ArcGIS software was also used to generate the necessary maps by evaluating ETo values obtained temporally and spatially. In conclusion, the monthly mean ETo values calculated using the long-term mean climatic parameters obtained from different meteorological stations showed 0.90 mm/day in January as the lowest average daily ETo value in the districts of Antalya and the highest was 6.59 mm/day in July. As a result, it was stated that the tables and maps created with the help of long-term climatic data can be used in the studies of plant water consumption and irrigation scheduling based on the reference plant water consumption if the actual data are not available.

Alınoğlu ve Öztürk (1995), using Blaney-Criddle FAO, Blaney-Criddle SCS adaptation, Modified Penman and Penman-Monteith methods of calculating plant water requirement determined the effects of changes in plant pattern on the water needs of plants of 5 irrigation systems related to DSİ V Regional Directorate. Results of each method used for determining the total irrigation water needs were compared over a 10 year period and for all the areas considered for the study. Furthermore, the irrigation modules relating to all the study areas were determined. In the study, significant differences were found between the irrigation modules and the amount of water required for irrigation when the method of calculating plant water requirement and plant pattern was changed.

Faryap and Kızıloğlu (2010), determined optimal crop pattern in sustainable irrigation project area of 8328 hectare in the Demirdöven Irrigation Project Area for the arid, normal and rainy years by considering the seasonal water requirements, irrigation area, water sources, maximum or minimum cropped area and total and net income per unit area by using a linear programming method. In the study, perennial meteorological values were used to calculate plant water consumption with the FAO Modify Penman equation. According to the result of the study, the crop pattern resulting in the highest income values was 32.94% forage crops, cereal of 25%, industrial crops of 25%, cabbage of 2% and orchard of 5.06% for the arid years. The values for the normal year were as follows; forage crops 37.39%, cereal 25%, industrial crops 25.61%, cabbage 4% and orchard 8% and rainy year recorded 43% for forage crops, 16.59% for cereals, 28.41% for industrial crops, 4% for cabbage and 8% for orchards. At arid years, 90% of cultivable areas were found to be sustainable whereas 10% of the area was uncultivable. Apart from the arid years, all other years were 100% cultivable. They concluded that to increase the irrigation rate for an irrigated area, the ecological, social and economic condition of the area must be taken into consideration at the project planning stage and also the optimal pattern of the crop be realized to attain the highest income level as possible. The results are represented in figure 2.1 below;

Figure 2.1 showing plant patterns for rainy, normal and arid areas. (Computed from Faryap and Kızıloğlu (2010) studies)

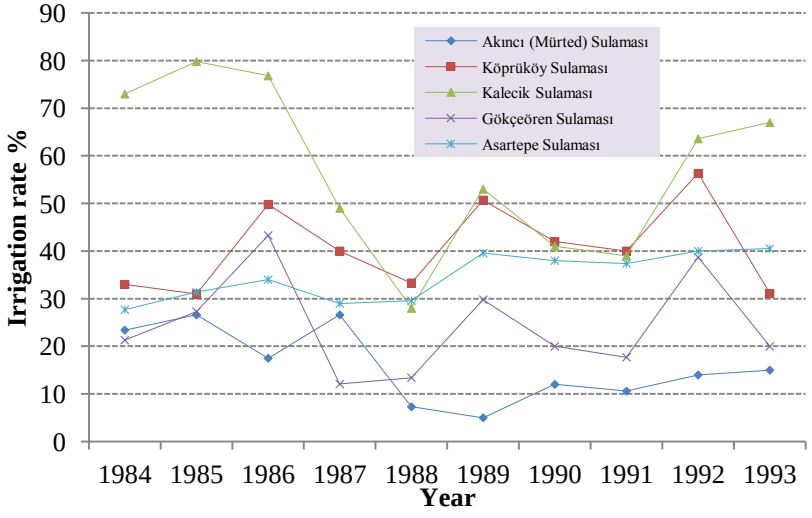


Kızıloğlu et al. (2010), also determined optimal crop pattern in the 9907.5-hectare project area in the Erzurum Daphan plain for arid, normal and rainy years by taking into consideration seasonal water requirements, irrigation area size, water sources, maximum or minimum cropped area sizes and total and net income per unit area. The CROPWAT computer program developed by FAO was used to determine the water consumption of irrigated plants, irrigation water and the amount of irrigation water supplied to plant. Calculations were made for normal, arid and rainy years. In the study, the FAO Modified Penman equation with perennial meteorological data was used to calculate plant water consumption. The optimal crop pattern was determined using QSBWIN packed program. The results of the study show that crop patterns that resulted in the highest income values in arid years are as follow; 50% of forage crops, cereals 19.4%, industrial crops of 26.6%, cabbage 2% and orchard of 2%. The values of normal and rainy years were determined as follows; forage crops 45%, cereals 19.45, industrial crops 31.6%, cabbage 2% and orchards 2%. There was no significant difference between the areas of cultivation in normal and rainy year. However, a difference of 2.63% between normal and rainfall year incomes occurred because of the changes in water prices and the changes in expenditure level and variable costs. Kızıloğlu et al. (2010)'s study is consistent with Faryap and Kızıloğlu (2010)'s. Both studies used a similar methodology in determining plant water consumption, irrigation water

requirement, and optimal plant pattern and concluded that to attain the highest income for an irrigation area, cropping pattern must be determined at an optimal level.

Çınar (2001), determined the effects of the changes in plant pattern on water needs in five irrigation project of DSI V Regional Directorate, between the years 1989 and 1993. In addition, the amount of water used for irrigation between the 5 year period was compared with the irrigation module. The total irrigation water needs from 1989 to 1993 for Asartepe compared in the study revealed the following results; Penman-Monteith method between 10,018.3 and 11,086.8 m^3/ha, Penman (Modified) method was between 12,251.5 and 13,373.3 m^3/ha, FAO Blaney-Criddle was between 12,307.7 and 13,852.0 m^3/ha, Blaney-Criddle SCS method was 8,604.8 and 9,753.9 m^3/ha. In Kalecik FAO Blaney-Criddle recorded the highest maximum irrigation module of 1.32 lt/s/ha, followed by Modified Penman of 1.20 lt/s/ha and Penman-Monteith with 0.98 lt/s/ha and lastly Blaney-Criddle SCS of 0.96 lt/s/ha. Köprüköy also recorded 0.76 lt/s/ha, 0.83 lt/s/ha, and 0.67 lt/s/ha, 0.75 lt/s/ha for FAO Blaney-Criddle, Modified Penman, Penman-Monteith and Blaney-Criddle SCS respectively. The irrigation rate in all five irrigation projects was found to be rather low during the research period due to the fact that farmers were tended to grow crops likely to yield more profit due to their economic conditions instead of complying with the proposed crop pattern at the planning stage. Çınar (2001) recommended a long year average of climate data for determining plant water requirement for an irrigation project and also Penman-Monteith methods for calculating the plant water requirement. Figure 2.2 shows the 10-year irrigation rate for the five different irrigation areas.

Figure 2.2. 10 year period irrigation rate for different irrigation areas



Source: Çınar (2001)

The optimal plant pattern level in the Central and Çumra province of Konya was determined by Güneş and Erkuş (1975) for an area of land from 15 ha to 25 ha. The results from the study were as follows; 32.4% wheat, 3.20% sugar beets, 0.64% potatoes, 0.38% soya, 0.57% beans, 21.81% lentils, 1.73% clover, 0.03% vetch, 9.89% berries, 28.51% fallow, 0.36% orchard, 0.33% vineyard, 0.12% for other purposes.

Kodal et al. (1992), calculated the irrigation water requirement for the normal, dry and rainy years and determined the irrigation module separately according to monthly data. Also, the same method was used for calculating the irrigation module for normal, dry and rainy years was calculated by using the planned irrigation time. The monthly irrigation water requirements and irrigation modules calculated according to irrigation time were compared.

3. MATERIALS AND METHODS

This chapter presents details on the materials used and the methods applied for the determination of crop water requirements for selected areas along the Konya plain.

3.1. Materials

3.1.1. Research Area

Konya is the largest province of Turkey with 41.000 km^2 area located in central Anatolia. The population of the city is about 2.18 million. The total number of farmers registered in Ministry of Agriculture and Forestry Farmer Registration System is about 91.3 thousand. The total arable land in the city is about 2.6 million ha which corresponds to 65% of the total area of the city. Irrigated area is about 0.54 million ha which corresponds to 30% of the total arable land of the city (Yıldırım et al., 2017). Konya has arid to semi-arid climate. Annual rainfall is about 322.4 mm and mean temperature is 11.6 °C with minimum mean temperature of -4.6 °C in January and maximum mean temperature of 30.1 in July and August. The long-term meteorological data averages of Konya Province (1958 – 2017) were given Table 3.1 (MGM, 2018)

Table 3.1 Long-term meteorological data of Konya Province

KONYA	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Annual
	Periods (1929 - 2017)												
Mean Temp (°C)	-0.2	1.4	5.5	11.0	15.8	20.1	23.5	23.1	18.5	12.5	6.3	1.7	11.6
Mean Max. Temp. (°C)	4.6	6.8	11.7	17.5	22.2	26.6	30.1	30.1	25.9	19.8	13.0	6.5	17.9
Mean Min. Temp. (°C)	-4.2	-3.3	-0.2	4.3	8.5	12.5	15.7	15.5	10.9	5.7	0.7	-2.3	5.3
Mean Sunshine duration (saat)	3.3	4.6	5.9	7.1	8.9	10.6	11.6	11.2	9.5	7.2	5.3	3.2	88.4
Mean Precipitation (mm)	37.4	28.7	28.9	32.2	43.5	24.7	6.3	4.9	12.4	29.7	32.1	41.6	322.4

3.1.2 Meteorological Stations

The meteorological data were collected from four meteorological stations where periodic records required to calculate ETo are available from 2009 - 2018. The meteorological stations are Akşehir, Beyşehir, Cihanbeyli, and Ereğli in Konya

province. The various characteristics of the meteorological stations were given in Table 3.2 and the locations of the station were shown in Figure 3.1.

Table 3.2 Characteristics of Meteorological Stations

Station	Latitude (N)	Longitude (E)	Elevation (m)	Climate Type
Akşehir	38.3688	31.4297	1002	Col
Beyşehir	37.6777	31.7463	1141	Mountain Slope
Cihanbeyli	38.6503	32.9226	969	Central Anatolia
Ereğli	37.5255	34.0485	1046	Central Anatolia

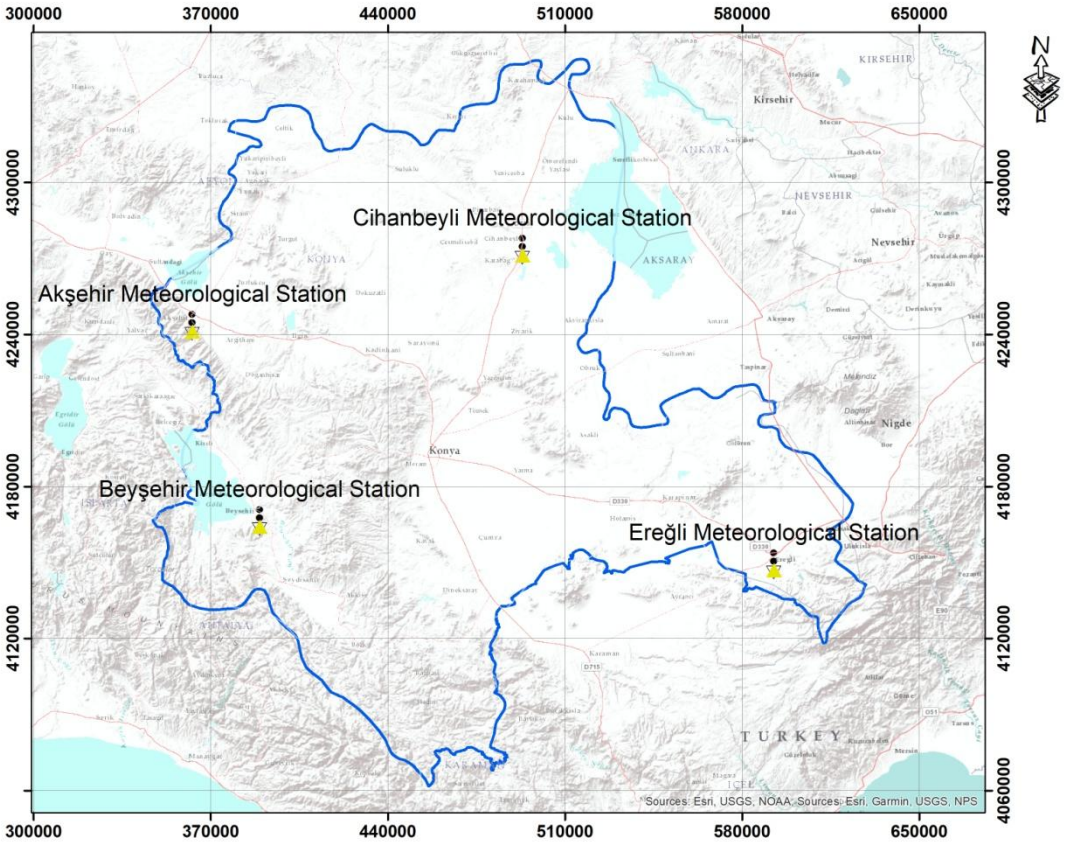


Figure 3.1. Location of Meteorological Stations.

3.2. Methods

Meteorological data for a period of 10 years between 2009 and 2018 years were collected and organized for each meteorological station. The data collected from the stations were used to determine the crop water requirements for a 10 year period.

3.2.1. Determination of Reference Evapotranspiration

3.2.1.1. FAO-56 Penman-Monteith Method

The FAO Penman-Monteith method was derived from the original Penman-Monteith equation and the equations of the aerodynamic and surface resistance (Allen et al., 1998). The equation uses standard climatological data of solar radiation (sunshine), air temperature, humidity and wind speed (Allen et al., 1998). The equation is given as;

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

where,

ETo = reference evapotranspiration (mm day^{-1}),

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 vapour pressure (kPa),

ea = actual vapour pressure (kPa),

es - ea = saturation vapour pressure deficit (kPa),

Δ = slope of the saturated vapour pressure curve (kPa $°C^{-1}$),

γ = psychrometric constant (kPa $°C^{-1}$).

Rn, es, Δ and γ were calculated according to procedures stated in Allen et al., (1998). The formula below was used in Rso (Clear-sky solar radiation) calculation, because calibrated values for *as* and *b*s were not available.

$Rso = (0.75 + 2 \cdot 10^{-5} \cdot z)Ra$ where z is station elevation above sea level (m). In calculation of G, the formula $G_{month,i} = 0.07(T_{month,i+1} - T_{month,i-1})$ where, Tmonth,i+1 is main temperature of previous month (°C) and Tmonth,i-1 is main temperature of next month (°C) was used.

Actual vapour pressure was calculated by using the formula below.

$$e_a = \frac{RH_{mean}}{100} \left[\frac{e^0(T_{min}) + e^0(T_{max})}{2} \right]$$

e^0(Tmin) = saturation vapour pressure at daily minimum temperature (kPa),

e^0(Tmax) = saturation vapour pressure at daily maximum temperature (kPa),

RH_{mean}= mean relative humidity (%)

3.2.1.2. ASCE Penman-Monteith Method

The Penman-Monteith technique as shown below incorporates all parameters that govern energy exchange and corresponding latent heat flux (evaporation) from uniform expanses of vegetation (Jensen and Allen, 2016). Most of the parameters are estimated or can be determined from meteorological data. The equation can be utilized for the direct calculation of any crop evapotranspiration as the surface and aerodynamic resistances are crop specific (Jensen and Allen, 2016). The ASCE Penman-Monteith equation is given as;

$$ET_o = \left(\frac{1}{\lambda}\right)\left[\left(\frac{\Delta(R_n - G) + K_{time}\rho_a C_p \frac{(e_s - e_a)}{r_a}}{\Delta + \gamma(1 + \frac{r_s}{r_a})}\right)\right]$$

Where,

ETo= Reference evapotranspiration (mm day^{-1}),

Rn= net radiation (MJ m^{-2} day^{-1}),

G = soil heat flux (MJ m^{-2} day^{-1}),

$e_s - e_a$= vapour pressure deficit of the air (kPa),

e_s = saturation vapour pressure (kPa),

e_a = actual vapour pressure (kPa),

ρ_a= mean air density at constant pressure (kg m^{-3}),

C_p = specific heat of the air (MJ kg^{-1} $^oC^{-1}$),

Δ = slope of the saturation vapour pressure temperature relationship (kPa $^oC^{-1}$),

γ = psychrometric constant (kPa $^oC^{-1}$),

rs = (bulk) surface resistances (s m^{-1}),

ra = aerodynamic resistances (s m^{-1}),

λ = latent heat of vaporization (MJ kg^{-1}),

k_{time} = unit revolution (86 400 s day^{-1}).

3.2.1.3. Radiation method

The Radiation Method is modification of the Makkink (1957) formula. This method is suggested for areas where climatic data such as measured air temperature and

sunshine, cloudiness or radiation are available, excluding measured wind and humidity (Doorenbos and Pruitt 1977). Knowledge of general levels of humidity and wind is required, and these are to be estimated using published weather descriptions, extrapolation from nearby areas or from local sources (Doorenbos and Pruitt 1977). The relationship is expressed as:

$$ET_o = c(W \times Rs)$$

where:

ETo = reference crop evapotranspiration (mm day^{-1}),

Rs = solar radiation in equivalent evaporation (MJ m^{-2} day^{-1}),

W = weighting factor depends on temperature and altitude,

C = adjustment factor depends on mean humidity and daytime wind conditions.

W 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 $^oC^{-1}$),

γ = psychrometric constant (kPa $^oC^{-1}$),

C was calculated according to formula suggested 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,

RH_{mean}= mean relative humudity (%)

U_d = mean wind speed at 2 m

3.2.1.4. FAO 24 Blaney-Criddle method

The original Blaney–Criddle method (Blaney and Criddle, 1962) was modified by Doorenbos and Pruitt (1977) to improve the definition of the effect of climate on crop water requirements while employing the Blaney-Criddle temperature and day length related f factor. This method for calculating ETo considers general levels of minimum relative humidity, wind speed and sunshine (Doorenbos and Pruitt, 1977). The FAO 24 Blaney–Criddle formula is as follows:

$$ET_o = a + bf$$

$$f = p(0.46T + 8.13)$$

where:

ETo = reference crop evapotranspiration (mm day^{-1}),

T = mean daily temperature (^oC),

P= mean daily percentage of total annual daytime hours for given months and latitude,

P values of the meteorology station were found by interpolation depending on it's latitude (Lyon et al., 2015).

The *a* and *b* are correction factors which adjust the ET estimate base on measured or estimated mean daily minimum relative humidity in percent (RH_{min}), mean ratio of actual to possible sunshine hours (N_{ratio}), and mean daytime wind speed in meters per second (Allen and Pruitt, 1986).

a and *b* were calculated with below formulas given by Allen and Pruitt (1986).

$$a = 0.0043(RH_{min}) - \frac{n}{N} - 1.41$$

$$b = 0.8197 - 0.0040922(RH_{min}) + 1.0705\left(\frac{n}{N}\right) + 0.065649(U_d)$$

$$- 0.0059684(RH_{min})\left(\frac{n}{N}\right) - 0.0005967(RH_{min})(U_d)$$

Where,

RH_{min}= minimum relative humidity (%)

n = actual duration of sunshine (hour),

N = maximum possible duration of sunshine or daylight hours (hour),

U_d = mean wind speed (m/sn)

ETo values for Blaney Criddle method were calculated for 7 years period between 2012 and 2018 because there was no available RH_{min} records for previous years for the meteorological stations.

3.2.1.5. Hargreaves-Samani method

The Hargreaves-Samani method for calculating evapotranspiration is a representative version of one of the older methods of calculating evapotranspiration (Hargreaves and Allen, 2003). The method is computationally simple and applicable to a variety of climates using only commonly available meteorological data and has

similar conceptual versions as the older ones (Hargreaves and Samani, 1985). The creation of the Hargreaves-Samani method was intended to simplify the previous version of Hargreaves (1975) further by using only air temperature and extraterrestrial radiation (Ra) as a substitute for measured sunshine or radiation data (Hargreaves and Allen, 2003). The equation was developed using 8 years of daily lysimeter data from Davis, California and was used to estimate the values of reference evapotranspiration for other locations and comparisons with other methods indicated that Hargreaaves-Samani's method is reliable and usable as the other ETo estimating methods (Hargreaves and Samani, 1985). The equation is as follows:

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

Where;

ETo = reference evapotranspiration (mm day^{-1}),

Ra = extraterrestrial radiation (MJ m^{-2} day^{-1}/2.45),

Tmin = monthly minimum air temperature (^oC),

Tmax = monthly maximum air temperature (^oC),

Tmean = monthly mean air temperature (^oC).

3.2.2. Comparison of ETo values

Statistic methods were used to determine the differences among the ETo values using the FAO 56 Penman-Monteith method as a benchmark. According to Allen et al. (1998) the FAO 56 Penman-Monteith is a modification of the FAO Penman method and has values consistent with actual crop water use data worldwide.

Basic statistics of minimum and maximum ETo, mean, standard deviation, and paired t test were used to determined the differences in mean of the ETo methods against FAO 56 Penman-Monteith method. According to Ferro et al (2005), paired sample t-test is a suitable statistical technique that is used to compare two population means in the case of two samples that are correlated. For the methods comparison the null hypothesis assumes that the mean of ETo determined by FAO 56 Penman-Monteith and other methods are equal. IBM SPSS Statistical 22 programme was used for the analysis.

3.2.3. Determination of Crop Evapotranspiration

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

$$ETc = Kc \cdot ETo$$

ETc = crop evapotranspiration (mm day^{-1})

Kc = crop coefficient

ETo = reference crop evapotranspiration (mm day^{-1})

The crop evapotranspiration of five different crops; sugarbeet, maize (Grain), sunflower, dry bean 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 the meteorological stations are given in Table 3.3.

The four growth stages as intial (I), crop development (II), mid-season (III) and late season (IV) was considered in Kc calculation as shown on Figure 3.2.

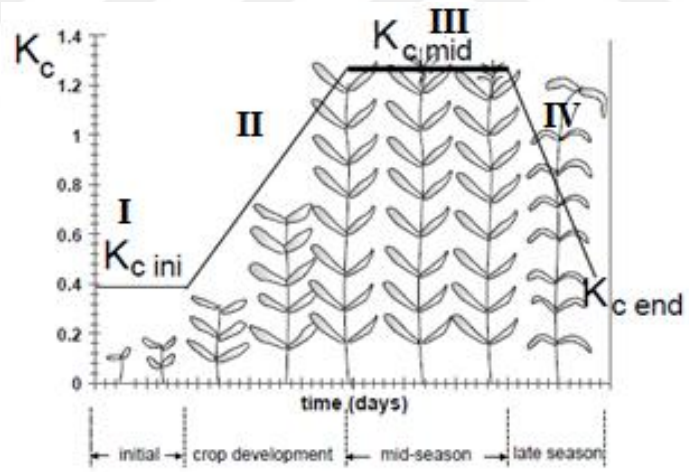


Figure 3.2 Growth periods of the crops and Kc coefficients (Allen et al., 1998).

The Kc coefficients during initial and mid season was considered as fixed. Kc coefficients for per month were determined graphically as stated by Allen et al. (1998). ETo values of the previous year fall months were considered in ETc calculation of wheat crop.

Table 3.3. Kc coefficients and planting periods of the crops for meteorological stations (Anonymous, 2016).

Meteorological Station	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
Akşehir	DryBean	20/05	120	0.24	1.06	0.92	20	35	45	20
	Maize	20/04	160	0.28	1.17	1.06	30	40	55	35
	Sugarbeet	20/03	185	0.44	1.20	0.70	30	50	70	35
	Sunflower	20/04	144	0.36	1.07	0.36	25	30	59	30
	Wheat	10/10	264	0.78	1.16	0.26	30	162	42	30
Beyşehir	Dry bean	1/05	124	0.25	1.05	0.36	23	33	44	24
	Maize	20/04	158	0.27	1.21	1.07	30	40	54	34
	Sugarbeet	20/03	185	0.45	1.21	0.71	30	50	70	35
	Sunflower	20/04	145	0.34	1.06	0.36	25	30	60	30
	Wheat	10/10	267	0.80	1.18	0.26	159	37	41	30
Cihanbeyli	Dry bean	20/05	125	0.16	1.10	0.39	20	35	50	20
	Maize	10/05	160	0.18	1.23	1.11	30	40	50	40
	Sugarbeet	1/04	185	0.30	1.25	0.74	30	50	70	35
	Sunflower	20/04	145	0.20	1.12	0.42	25	30	60	30
	Wheat	20/10	270	0.67	1.18	0.30	170	30	40	30
Ereğli	Dry bean	20/05	125	0.21	1.07	0.36	20	35	50	20
	Maize	10/05	160	0.23	1.18	1.07	30	40	50	40
	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	0.62	1.16	0.27	170	30	40	30

4. RESULTS AND DISCUSION

4.1. Reference crop evapotranspiration (ETo)

4.1.1. ETo calculated according to FAO-56 Penman-Monteith Method

The reference evapotranspiration mm/day results from 2009 to 2018 calculated using the FAO-56 Penman-Monteith Method have been represented in table 4.1. The ETo values calculated between 2009 and 2018 were high in June, July, and August. The values in January, and February were relatively low. January recorded the least ETo values ranging from 0.55 mm to 0.93 mm/day. The maximum ETo value was recorded in July 2012 with 5.95 mm/day. There were inadequate data for the calculation of ETo in November and December 2018. The average ETo for the years are 2.92, 2.76, 2.67, 2.95, 3.05, 2.88, 2.76, 3.13, 2.83, and 2.69 mm/day that is from 2009 to 2018 respectively.

Table 4.1 ETo mm/day results calculated according to FAO-56 Penman – Monteith Method for Akşehir Station

Months	Years									
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
January	0.93	0.56	0.68	0.55	0.86	0.65	0.74	0.88	0.57	0.82
February	1.26	1.27	0.96	0.77	1.39	1.41	1.01	1.66	1.05	1.48
March	1.98	1.83	1.61	1.62	2.44	2.03	1.81	2.32	2.04	2.69
April	2.72	2.51	2.49	3.92	2.96	3.46	2.86	3.92	3.01	3.52
May	3.86	3.95	3.15	3.53	4.43	3.84	3.91	3.84	3.64	3.63
June	5.38	4.07	4.32	5.32	5.57	4.64	3.74	5.3	4.31	4.64
July	5.6	5.51	5.81	5.95	5.46	5.7	5.44	5.83	5.74	5.39
August	5.22	5.58	5.14	5.16	5.37	5.51	4.88	5.24	4.6	3.8
September	3.4	4.15	4.04	4.18	3.95	3.41	4.35	3.9	4.12	3.95
October	2.65	1.64	2.14	2.42	2.22	2.03	2.2	2.43	2.3	2.38
November	1.15	1.28	0.91	1.12	1.35	1.04	1.52	1.56	1.39	-
December	0.91	0.75	0.83	0.89	0.62	0.87	0.64	0.63	1.17	-
Total	35.06	33.10	32.08	35.43	36.62	34.59	33.1	37.51	33.94	32.30

Table 4.2 shows results of ETo calculated according to FAO 56 Penman Monteith method using meteorological data of Beyşehir station from 2009 to 2018. The month July shows the highest ETo values for most of the period with 6.91 mm/day as the highest ETo values over the 10 year period. According to the results obtained,

minimum ETo value for the entire period was 0.49 mm in the month of January over the 10 year period. The total ETo for the various years ranges from 33.85 mm to 39.67 mm.

Table 4.2 ETo mm/day results calculated according to FAO-56 Penman – Monteith Method for Beyşehir Station

Months	Years									
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
January	0.89	0.90	0.75	0.63	0.81	0.55	0.75	0.87	0.51	0.49
Februar	1.10	1.52	1.02	0.83	1.31	1.32	1.15	1.5	0.87	1.46
March	1.78	2.59	1.79	1.71	2.29	2.09	1.71	2.22	1.86	2.55
April	2.80	3.10	2.59	3.59	3.09	3.53	2.92	3.79	3.10	3.59
May	4.15	4.38	3.32	3.73	4.47	4.06	4.16	3.76	3.77	3.77
June	5.89	4.65	4.83	5.84	5.96	4.92	4.28	5.55	4.58	4.83
July	6.27	6.30	6.56	6.91	6.43	6.37	5.98	6.43	6.45	6.06
August	5.77	6.25	4.07	5.96	6.19	6.02	5.6	5.97	5.22	4.4
September	3.78	4.72	4.62	4.75	4.52	3.93	4.69	4.19	4.52	4.38
Octorbeer	2.76	2.26	2.42	2.36	2.54	2.27	2.49	2.91	2.56	2.43
November	1.28	1.72	1.1	1.28	1.39	1.15	1.63	1.73	1.19	1.81
December	0.87	0.9	0.78	0.83	0.67	0.83	0.84	0.65	0.87	0.90
Total	37.34	39.29	33.85	38.42	39.67	37.04	36.2	39.57	35.5	36.67

The ETo mm/day results of data collected from Ceyhanbeyli station from 2009 to 2018 was calculated using the FAO-56 Penman-Monteith Method as represented in table 4.3. The highest ETo value calculated between 2009 and 2019 was in July 2012 with 7.70 mm/day and the lowest ETo is 0.45 mm/day in January 2018.

Table 4.3 ETo mm/day results calculated according to FAO-56 Penman – Monteith Method for Cihanbeyli Station

Month	Years									
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
January	0.61	0.69	0.6	0.59	0.66	0.58	0.61	0.78	0.47	0.45
Februar	1	1.4	1.2	0.74	1.29	1.55	1.09	1.54	1.01	1.38
March	1.67	2.34	1.57	1.66	1.95	2.18	1.78	2.36	2.11	2.69
April	2.68	3	2.47	4.06	2.94	3.86	2.8	4.4	3.08	4.13
May	4.06	4.89	3.52	3.99	5.08	4.35	4.55	4.01	3.75	4.66
June	5.99	5.36	4.91	6.44	6.42	5.39	4.32	6.69	4.7	5.98
July	6.43	7.03	7.03	7.7	6.99	7.17	7.07	7.47	7.1	7.25
August	6.39	7.05	6.47	6.6	6.8	6.91	6.55	7.28	6.8	7.12
September	3.91	6.07	5.01	5.18	4.7	4.36	5.34	4.84	5.66	5.18
Octorbeer	3.21	2.15	2.46	2.66	2.69	2.42	2.69	3.3	2.91	2.85
November	1.04	1.65	1.08	1.12	1.53	1.11	1.96	1.81	1.19	-
December	0.65	0.89	0.81	0.71	0.65	0.74	0.62	0.65	0.89	-
Total	37.64	42.52	37.13	41.45	41.7	40.62	39.38	45.13	39.67	41.69

The ETo mm/day results of data collected from Ereğli station from 2009 to 2018 was calculated using the FAO-56 Penman-Monteith Method as represented in table 4.4. The highest ETo value was recorded in the month July with 6.79 mm/day and the lowest ETo according to the result is 0.47 mm/day in the month December. The minimum total ETo with the period is 33.77 mm and the maximum total ETo is 40.50 mm.

Table 4.4 ETo mm/day results calculated according to FAO-56 Penman – Monteith Method for Ereğli Station

Month	Years									
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
January	0.87	0.9	0.71	0.72	0.75	0.69	0.8	0.66	0.6	0.5
Februar	1.35	1.39	1.07	0.84	1.3	1.44	1.13	1.42	1.09	1.43
March	2.21	2.43	1.79	1.73	2.09	2.25	1.87	2.53	1.97	2.74
April	3.17	3.02	2.53	3.95	2.9	3.83	2.88	4.15	3.33	3.72
May	4.67	4.70	3.68	4.00	4.51	4.73	4.35	4.34	4.22	4.49
June	6.53	5.43	5.27	6.05	6.09	5.6	4.8	5.85	5.35	5.72
July	6.34	6.45	6.29	6.59	6.51	6.55	6.09	6.54	6.79	6.51
August	6.34	6.18	4.39	5.82	5.99	6.22	5.79	5.95	5.71	6.06
September	4.03	4.73	4.17	4.45	4.16	4.3	4.48	4.07	4.61	4.48
Octorbeer	2.87	2.21	2.48	2.23	2.25	2.22	2.33	2.74	2.69	2.48
November	1.18	1.48	0.92	1.06	1.33	1.08	1.42	1.45	1.17	-
December	0.94	1.02	0.47	0.78	0.57	0.86	0.61	0.62	0.97	-
Total	40.50	39.94	33.77	38.22	38.45	39.77	36.55	40.32	38.5	38.13

4.1.2. ETo results calculated according to ASCE Penman-Monteith Method

The ETo results calculated according to ASCE Penman-Monteith method using data from Akşehir meteorological station from 2009 to 2018 has been represented in the Table 4.5 below. The highest ETo value calculated between 2009 and 2018 was recorded in the month July with 4.92 mm/day and the lowest ETo according to the result is 0.46 mm/day in the month January.

The ETo results calculated according to ASCE Penman-Monteith method using data from Beyşehir meteorological station from 2009 to 2018 has been represented in the Table 4.6 below. The highest ETo value calculated between 2009 and 2018 was recorded in the month July with 5.15 mm/day and the lowest ETo according to the result is 0.39 mm/day in the month January.

Table 4.5 ETo mm/day results calculated according to ASCE Penman – Monteith Method for Akşehir Station

Month	Years									
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
January	0.60	0.47	0.56	0.46	0.57	0.48	0.54	0.52	0.41	0.55
Februar	0.86	0.93	0.81	0.65	1.00	1.03	0.73	1.15	0.76	1.00
March	1.41	1.55	1.34	1.22	1.69	1.52	1.40	1.68	1.49	1.85
April	2.20	2.34	2.03	2.81	2.40	2.64	2.25	2.97	2.33	2.84
May	3.24	3.49	2.74	2.99	3.56	3.13	3.25	3.11	2.89	3.07
June	4.36	3.75	3.75	4.46	4.40	3.84	3.37	4.25	3.72	3.90
July	4.53	4.92	4.79	4.85	4.40	4.64	4.50	4.68	4.67	4.41
August	4.21	4.77	4.22	4.19	4.30	4.39	4.12	4.34	3.81	2.88
September	2.79	3.56	3.24	3.31	3.15	2.83	3.47	3.13	3.21	3.19
Octorbeer	2.00	1.51	1.75	1.93	1.69	1.70	1.81	1.91	1.77	2.02
November	0.92	1.05	0.74	0.92	1.04	0.83	1.12	1.10	0.95	-
December	0.65	0.66	0.56	0.65	0.49	0.65	0.51	0.48	0.73	-
Total	27.77	29.00	26.53	28.44	28.69	27.68	27.07	29.32	26.74	25.71

Table 4.6 ETo mm/day results calculated according to ASCE Penman – Monteith Method for Beyşehir Station

Months	Years									
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
January	0.59	0.61	0.56	0.47	0.55	0.45	0.52	0.53	0.39	0.55
Februar	0.80	1.01	0.82	0.66	0.95	1.02	0.76	1.06	0.68	1.00
March	1.34	1.79	1.40	1.27	1.61	1.54	1.33	1.60	1.38	1.77
April	2.25	2.46	2.02	2.68	2.41	2.64	2.21	2.88	2.31	2.76
May	3.28	3.54	2.77	3.09	3.59	3.30	3.35	3.10	2.98	3.12
June	4.44	3.82	3.92	4.66	4.54	4.00	3.63	4.40	3.83	3.94
July	4.69	4.98	5.06	5.15	4.79	4.92	4.68	4.93	4.86	4.62
August	4.35	4.76	4.38	4.40	4.57	4.57	4.37	4.62	4.03	3.04
September	2.89	3.56	3.34	3.49	3.32	3.04	3.53	3.18	3.31	3.34
Octorbeer	2.02	1.71	1.82	1.89	1.80	1.77	1.94	2.11	1.86	2.00
November	0.95	1.18	0.80	0.97	1.04	0.85	1.13	1.14	0.89	-
December	0.63	0.66	0.53	0.61	0.49	0.61	0.57	0.47	0.64	-
Total	28.23	30.08	27.42	29.34	29.66	28.71	28.02	30.02	27.16	26.14

The ETo results calculated according to ASCE Penman-Monteith method using data from Cihanbeyli meteorological station from 2009 to 2018 has been represented in the Table 4.7 below. The highest ETo value calculated between 2009 and 2018 was recorded in the month July with 5.35 mm/day and the lowest ETo according to the result is 0.33 mm/day in the month January. ETo results were not calculated in November and December because of inadequate Meteorological data.

Table 4.7 ETo mm/day results calculated according to ASCE Penman – Monteith Method for Cihanbeyli Station

Months	Years									
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
January	0.43	0.49	0.47	0.43	0.45	0.42	0.45	0.45	0.33	0.47
Februar	0.72	0.9	0.84	0.57	0.9	1.05	0.74	1.03	0.69	0.95
March	1.2	1.62	1.2	1.17	1.49	1.52	1.35	1.59	1.48	1.8
April	2.17	2.32	1.89	2.76	2.24	2.76	2.1	3.06	2.51	2.98
May	3.23	3.58	2.83	3.1	3.79	3.35	3.47	3.06	3.14	3.65
June	4.41	4.06	3.84	4.68	4.6	4.06	3.44	4.64	4.03	4.5
July	4.72	5.13	5.1	5.35	4.92	5.11	4.99	5.27	5.15	5.12
August	4.54	4.97	4.6	4.61	4.76	4.88	4.66	5.12	4.75	4.85
September	2.88	3.9	3.46	3.55	3.28	3.14	3.72	3.38	3.79	3.47
Octorbeer	2.13	1.6	1.77	1.98	1.79	1.81	1.94	2.16	1.97	2.11
November	0.83	1.1	0.75	0.86	1.05	0.81	1.21	1.13	0.86	-
December	0.51	0.63	0.52	0.53	0.45	0.56	0.46	0.4	0.55	-
Total	27.77	30.3	27.27	29.59	29.72	29.47	28.53	31.29	29.25	29.9

The ETo results calculated according to ASCE Penman-Monteith method using data from Ereğli meteorological station from 2009 to 2018 has been represented in the Table 4.8 below. The highest ETo value calculated between 2009 and 2018 was recorded in the month July with 5.23 mm/day and the lowest ETo according to the result is 0.44 mm/day in the month January. ETo results were not calculated in November and December because of inadequate Meteorological data.

Table 4.8 ETo mm/day results calculated according to ASCE Penman – Monteith Method for Ereğli Station

Months	Years									
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
January	0.57	0.64	0.59	0.55	0.56	0.51	0.60	0.47	0.44	0.52
Februar	0.92	0.98	0.89	0.70	1.01	1.08	0.84	1.05	0.82	1.05
March	1.48	1.76	1.44	1.34	1.54	1.64	1.50	1.81	1.53	1.93
April	2.46	2.53	2.09	2.91	2.39	2.79	2.32	3.09	2.64	2.95
May	3.62	3.84	3.11	3.34	3.72	3.65	3.56	3.53	3.40	3.66
June	4.85	4.48	4.40	4.83	4.78	4.53	4.19	4.70	4.37	4.74
July	4.88	5.23	5.09	5.21	5.06	5.12	4.89	5.14	5.21	5.14
August	4.76	4.86	4.66	4.60	4.67	4.88	4.70	4.78	4.64	4.75
September	3.06	3.67	3.35	3.51	3.26	3.46	3.54	3.26	3.50	3.47
Octorbeer	2.10	1.79	1.91	1.91	1.76	1.87	1.95	2.08	2.00	2.05
November	0.95	1.12	0.75	0.91	1.07	0.85	1.12	1.10	0.93	-
December	0.68	0.76	0.55	0.62	0.47	0.67	0.51	0.49	0.70	-
Total	30.33	31.66	28.83	30.43	30.29	31.05	29.72	31.50	30.18	30.26

4.1.3. ETo results calculated according to Radiation method

The ETo results calculated according to Radiation method using data from Akşehir meteorological station from 2009 to 2018 has been represented in the Table 4.9. The highest ETo value calculated between 2009 and 2018 was recorded in the month July with 8.28 mm/day and the lowest ETo according to the result is 0.61 mm/day in the month January. ETo results were not calculated in November and December because of inadequate Meteorological data.

Table 4.9 ETo mm/day results calculated according to Radiation Method for Akşehir Station

Months	Years									
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
January	1.11	1.08	0.91	0.72	1.11	1.10	0.61	1.22	0.80	1.13
Februar	1.44	2.07	1.59	1.37	2.09	2.20	1.19	2.45	1.59	1.85
March	2.71	3.21	2.42	2.55	3.17	2.90	2.48	3.20	2.72	3.39
April	3.88	4.32	3.43	5.32	4.32	4.94	4.25	5.49	4.13	5.19
May	5.60	6.19	4.30	4.81	6.30	5.33	5.54	5.18	4.73	4.76
June	7.48	6.17	6.09	7.84	7.70	6.48	4.97	7.29	5.93	6.25
July	7.31	8.16	8.27	8.28	7.54	8.09	7.69	7.99	7.87	7.29
August	6.97	7.95	7.20	7.12	7.54	7.46	6.67	7.07	5.93	3.70
September	4.60	5.93	5.72	6.12	5.58	4.31	5.97	5.38	5.17	5.30
Octorbeer	3.38	2.49	2.83	3.23	3.13	2.66	2.75	3.38	2.78	3.03
November	1.62	2.27	1.44	1.41	1.96	1.45	2.13	1.93	1.81	-
December	0.97	1.12	1.19	1.08	0.90	0.68	1.05	0.77	1.21	-
Total	47.07	50.96	45.39	49.85	51.34	47.60	45.30	51.35	44.67	41.89

The ETo results calculated according to Radiation method using data from Beyşehir meteorological station from 2009 to 2018 has been represented in the Table 4.10. The highest ETo value calculated between 2009 and 2018 was recorded in the month July with 9.05 mm/day and the lowest ETo according to the result is 0.67 mm/day in the month December.

Table 4.10 ETo mm/day results calculated according to Radiation Method for Beyşehir Station

Months	Years									
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
January	1.28	1.17	1.15	0.86	1.16	1.00	0.61	1.26	0.78	1.14
Februar	1.39	2.00	1.63	1.46	2.01	2.20	1.35	2.31	1.57	1.97
March	2.64	3.52	2.78	2.81	3.15	3.04	2.43	3.22	2.69	3.30
April	4.09	4.55	3.65	5.26	4.47	5.09	4.36	5.43	4.25	5.09
May	6.04	6.28	4.69	5.28	6.35	5.77	5.94	5.24	5.14	5.02
June	8.07	6.42	6.81	8.40	8.22	6.92	5.89	7.79	6.28	6.56
July	8.11	8.55	8.96	9.05	8.54	8.69	8.18	8.66	8.50	7.81
August	7.59	8.04	7.56	7.65	8.15	7.72	7.30	7.73	6.40	3.79
September	4.92	6.01	5.89	6.38	5.89	4.88	6.01	5.47	5.40	5.72
Octorbeer	3.44	2.77	3.18	3.13	3.47	2.95	3.15	3.95	3.10	3.21
November	1.86	2.40	1.56	1.67	1.98	1.53	2.24	2.09	1.64	-
December	1.06	1.03	1.15	1.15	1.01	0.67	1.37	0.86	1.13	-
Total	50.49	52.74	49.01	53.10	54.40	50.46	48.83	54.01	46.88	43.61

The ETo results calculated according to Radiation method using data from Cihanbeyli meteorological station from 2009 to 2018 has been represented in the Table 4.11 below. The highest ETo value calculated between 2009 and 2018 was recorded in the month July with 8.95 mm/day and the lowest ETo according to the result is 0.74 mm/day in the month January. ETo results were not calculated in November and December because of inadequate Meteorological data.

Table 4.11 ETo mm/day results calculated according to Radiation Method for Cihanbeyli Station

Months	Years									
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
January	0.96	0.94	0.88	0.79	0.87	0.92	0.81	1.05	0.74	0.90
Februar	1.45	1.76	1.76	1.20	1.83	2.28	1.50	2.14	1.59	1.95
March	2.40	3.05	2.27	2.53	2.70	2.86	2.53	2.98	2.86	3.46
April	3.90	4.22	3.34	5.21	4.03	5.17	4.09	5.58	4.60	5.65
May	5.74	6.35	4.76	5.24	6.66	5.80	6.25	5.10	5.20	6.23
June	7.58	6.68	6.45	8.13	7.90	6.91	5.52	7.82	6.45	7.70
July	7.76	8.57	8.60	8.95	8.43	8.71	8.61	8.80	8.71	8.60
August	7.86	8.06	7.72	7.73	8.16	8.04	7.68	8.09	7.78	8.07
September	4.72	6.15	5.80	6.12	5.51	4.93	6.07	5.57	6.32	5.64
Octorbeer	3.38	2.41	2.83	3.13	3.21	3.01	3.06	3.73	3.34	3.41
November	1.47	2.10	1.44	1.26	1.93	1.38	2.15	1.96	1.63	-
December	0.80	0.98	1.06	0.94	0.85	0.94	0.81	0.74	1.01	-
Total	48.02	51.27	46.91	51.23	52.08	50.95	49.08	53.56	50.23	51.61

The ETo results calculated according to Radiation method using data from Ereğli meteorological station from 2009 to 2018 has been represented in the Table 4.12 below. The highest ETo value was recorded in the month July with 9.42 mm/day and the lowest ETo according to the result is 0.75 mm/day in the month December. ETo results were not calculated in November and December because of inadequate Meteorological data.

Table 4.12 ETo mm/day results calculated according to Radiation Method for Ereğli Station

Months	Years									
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
January	1.14	1.23	1.06	0.93	1.06	1.19	1.12	1.12	0.95	0.92
Februar	1.68	1.73	1.76	1.35	2.03	2.36	1.57	2.19	1.79	2.22
March	2.92	3.20	2.64	2.81	2.74	3.05	2.69	3.57	2.91	3.55
April	4.63	4.46	3.52	5.58	4.17	5.10	4.26	5.91	4.94	5.45
May	6.75	6.89	5.22	5.60	6.48	6.45	6.27	6.08	5.96	6.21
June	8.72	7.62	7.58	8.54	8.56	8.03	6.78	8.33	7.59	8.10
July	8.16	9.07	8.84	9.10	9.05	9.23	8.66	9.24	9.42	9.07
August	8.43	8.51	8.15	8.03	8.46	8.61	8.14	8.47	7.91	8.42
September	5.31	6.33	5.93	6.50	5.76	5.82	6.33	5.75	6.37	6.25
Octorbeer	3.57	2.81	3.27	3.01	3.25	3.07	3.03	3.90	3.57	3.10
November	1.70	2.44	1.34	1.31	1.85	1.34	2.16	2.14	1.77	-
December	1.11	1.28	1.25	1.02	0.75	1.15	0.86	0.82	1.38	-
Total	54.12	55.57	50.56	53.78	54.16	55.40	51.87	57.52	54.56	53.29

4.1.4. ETo results calculated according to FAO 24 Blaney-Criddle method

The ETo results calculated according to FAO 24 Blaney-Criddle method using data from Akşehir meteorological station from 2012 to 2018 has been represented in the Table 4.13 below. The highest ETo value calculated from 2012 to 2018 was recorded in the month July with 8.02 mm/day and the lowest ETo according to the result is -0.20 mm/day in the month January.

Table 4.13 ETo mm/day results calculated according to FAO 24 Blaney-Criddle Method for Akşehir Station

Months	Years						
	2012	2013	2014	2015	2016	2017	2018
January	-0.20*	0.40	0.53	0.09	0.42	-0.17*	0.99
Februar	0.02	1.32	1.34	0.51	1.82	0.62	1.49
March	1.33	2.30	1.89	1.58	2.28	1.92	2.92
April	4.29	3.15	3.89	2.88	4.47	3.09	3.97
May	4.00	5.36	4.35	4.59	4.24	3.97	4.39
June	7.09	7.03	5.77	4.37	6.77	5.20	6.06
July	8.02	6.94	7.82	7.18	7.68	7.67	6.70
August	6.64	7.11	7.36	6.32	6.90	5.80	3.96
September	5.85	5.09	4.03	5.98	5.02	5.11	4.57
Octorbeer	3.10	2.64	2.31	2.53	3.13	2.40	2.53
November	0.96	1.59	0.96	1.82	1.53	1.15	-
December	0.53	-0.07	0.38	0.11	-0.06	1.08	-
Total	42.03	42.86	40.63	37.96	44.32	38.18	37.58

*negative sign were not considered for the calculation of the total ETo

The ETo results calculated according to FAO 24 Blaney-Criddle method using data from Beyşehir meteorological station from 2012 to 2018 has been represented in the Table 4.14 below. The highest ETo value calculated from 2012 to 2018 was recorded in the month July with 8.38 mm/day and the lowest ETo according to the result is -0.35 mm/day in the month January.

Table 4.14 ETo mm/day results calculated according to FAO 24 Blaney-Criddle Method for Beyşehir Station

Months	Years						
	2012	2013	2014	2015	2016	2017	2018
January	-0.09	0.34	0.20	0.03	0.32	-0.35	0.90
Februar	0.00	1.09	1.23	0.58	1.42	0.23	1.26
March	1.31	2.14	1.94	1.42	2.13	1.70	2.54
April	4.00	3.23	3.71	2.94	4.20	3.08	3.95
May	4.13	5.25	4.61	4.78	4.19	4.12	4.38
June	7.32	7.13	5.90	5.03	6.85	5.57	5.86
July	8.38	7.63	8.03	7.40	7.97	7.83	7.17
August	6.89	7.40	7.34	6.92	7.31	6.10	3.84
September	5.83	5.15	4.51	5.83	4.88	5.13	5.17
Octorbeer	2.80	2.72	2.45	2.82	3.53	2.55	2.75
November	1.18	1.45	0.92	1.72	1.56	0.87	-
December	0.49	-0.06	0.31	0.38	-0.07	1.08	-
Total	42.42	43.47	41.15	39.85	44.43	38.61	37.82

*negative sign were not considered for the calculation of the total ETo

The ETo results calculated according to FAO 24 Blaney-Criddle method using data from Cihanbeyli meteorological station from 2012 to 2018 has been represented in the Table 4.15 below. The highest ETo value calculated from 2012 to 2018 was

recorded in the month July with 8.84 mm/day and the lowest ETo according to the result is -0.30 mm/day in the month January.

Table 4.15 ETo mm/day results calculated according to FAO 24 Blaney-Criddle Method for Cihanbeyli Station

Months	Years						
	2012	2013	2014	2015	2016	2017	2018
January	-0.13	0.16	0.25	0.02	0.31	-0.30	0.86
Februar	0.01	1.12	1.46	0.71	1.58	0.47	1.34
March	1.31	1.84	2.06	1.65	2.25	2.05	2.73
April	4.27	3.14	4.19	2.83	4.65	3.33	4.58
May	4.54	5.93	4.94	5.22	4.53	4.37	5.53
June	7.64	7.42	6.36	5.16	7.45	5.89	7.18
July	8.84	7.94	8.48	8.32	8.59	8.52	8.39
August	7.41	7.75	8.05	7.59	8.22	7.66	7.51
September	5.94	5.04	4.78	6.23	5.33	6.05	5.52
Octorbeer	3.06	2.68	2.66	2.89	3.51	2.82	3.09
November	0.82	1.48	0.87	1.84	1.44	1.09	-
December	0.32	-0.14	0.44	-0.07	-0.13	1.12	-
Total	44.29	44.36	44.54	42.53	47.99	43.67	46.73

*negative sign were not considered for the calculation of the total ETo

The ETo results calculated according to FAO 24 Blaney-Criddle method using data from Ereğli meteorological station from 2012 to 2018 has been represented in the Table 4.16 below. The highest ETo value calculated from 2012 to 2018 was recorded in the month July with 9.00 mm/day and the lowest ETo according to the result was -0.23 mm/day in the month January.

Table 4.16 ETo mm/day results calculated according to FAO 24 Blaney-Criddle for Ereğli Station

Months	Years						
	2012	2013	2014	2015	2016	2017	2018
January	0.15	0.32	0.59	0.33	0.28	-0.10	0.69
Februar	0.15	1.27	1.46	0.74	1.51	0.72	1.60
March	1.52	1.93	2.30	1.78	2.63	1.96	2.89
April	4.45	3.15	4.17	2.96	4.79	3.69	4.40
May	4.69	5.58	5.49	5.26	5.22	4.98	5.51
June	7.84	7.70	7.18	5.99	7.59	6.85	7.58
July	8.63	8.27	8.73	8.08	8.63	9.00	8.59
August	7.39	7.75	8.33	7.85	8.16	7.50	7.77
September	6.11	5.18	5.42	6.33	5.26	6.11	5.92
Octorbeer	2.84	2.67	2.62	2.84	3.61	3.12	2.84
November	0.81	1.44	0.87	1.73	1.61	0.96	-
December	0.42	-0.23	0.67	-0.02	-0.09	1.47	-
Total	45.00	45.49	47.83	43.91	49.38	46.46	47.79

*negative sign were not considered for the calculation of the total ETo

4.1.5. ETo results calculated according to Hargreaves-Samani method

The ETo results calculated according to Hargreaves-Samani method using data from Akşehir meteorological station from 2009 to 2018 has been represented in the Table 4.17 below. The highest ETo value calculated between 2009 and 2018 was recorded in the month July with 6.38 mm/day and the lowest ETo according to the result is 0.64 mm/day in the month December. ETo results were not calculated in November and December in the year 2018 because of inadequate Meteorological data.

The ETo results calculated according to Hargreaves-Samani method using data from Beyşehir meteorological station from 2009 to 2018 has been represented in the Table 4.18 below. The highest ETo value calculated between 2009 and 2018 was recorded in the month July with 6.20 mm/day and the lowest ETo according to the result is 0.63 mm/day in the month January. ETo results were not calculated in November and December in the year 2018 because of inadequate Meteorological data.

Table 4.17 ETo mm/day results calculated according to Hargreaves - Samani Method for Akşehir Station

Months	Years									
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
January	0.90	0.94	0.80	0.66	0.83	0.88	0.84	0.86	0.66	0.92
Februar	1.13	1.47	1.22	0.93	1.46	1.56	1.16	1.77	1.25	1.64
March	1.81	2.43	1.99	1.83	2.24	2.15	2.00	2.34	2.27	2.61
April	2.97	3.34	2.91	3.73	3.31	3.59	3.00	4.05	3.34	4.07
May	4.14	4.76	3.98	4.23	4.80	4.21	4.50	4.28	4.25	4.95
June	5.53	5.14	5.12	5.82	5.77	5.28	4.75	5.75	5.21	5.63
July	5.72	6.38	6.13	6.36	5.72	6.24	5.88	6.27	6.29	6.17
August	5.37	6.18	5.43	5.31	5.42	5.84	5.31	5.69	5.38	5.70
September	3.67	4.45	4.20	4.45	3.94	3.69	4.56	4.04	4.71	4.20
Octorbeer	2.78	2.22	2.24	2.67	2.43	2.27	2.43	2.63	2.43	2.65
November	1.38	1.83	1.06	1.27	1.53	1.26	1.58	1.53	1.43	-
December	0.93	1.04	0.91	0.87	0.65	0.94	0.75	0.64	1.00	-
Total	36.33	40.18	35.99	38.13	38.10	37.91	36.76	39.85	38.22	38.54

Table 4.18 ETo mm/day results calculated according to Hargreaves - Samani Method for Beyşehir Station

Months	Years									
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
January	0.92	1.00	0.86	0.68	0.84	0.86	0.84	0.86	0.63	0.87
Februar	1.18	1.49	1.25	0.96	1.44	1.62	1.16	1.67	1.15	1.62
March	1.85	2.51	2.06	1.82	2.30	2.28	1.98	2.27	2.17	2.59
April	3.16	3.38	2.89	3.69	3.43	3.59	3.04	3.98	3.37	4.00
May	4.33	4.82	3.99	4.19	4.85	4.41	4.59	4.26	4.24	4.83
June	5.81	5.08	5.27	5.77	5.77	5.20	4.96	5.72	5.28	5.49
July	5.78	6.17	6.12	6.13	5.70	5.98	5.98	6.05	6.20	5.91
August	5.46	6.10	5.36	5.23	5.39	5.61	5.37	5.62	5.34	5.53
September	3.68	4.39	4.16	4.39	3.96	3.80	4.58	4.00	4.59	4.19
Octorber	2.78	2.30	2.25	2.56	2.36	2.28	2.50	2.77	2.45	2.57
November	1.41	1.80	1.11	1.41	1.50	1.28	1.59	1.57	1.33	-
December	0.92	0.97	0.86	0.90	0.71	0.95	0.89	0.66	0.96	-
Total	37.28	40.01	36.18	37.73	38.25	37.86	37.48	39.43	37.71	37.60

The ETo results calculated according to Hargreaves-Samani method using data from Cihanbeyli meteorological station from 2009 to 2018 has been represented in the Table 4.19 below. The highest ETo value calculated between 2009 and 2018 was recorded in the month July with 6.84 mm/day and the lowest ETo according to the result is 0.60 mm/day in the month January. ETo results were not calculated in November and December in the year 2018 because of inadequate Meteorological data.

Table 4.19 ETo mm/day results calculated according to Hargreaves - Samani Method for Cihanbeyli Station

Months	Years									
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
January	0.86	0.91	0.81	0.69	0.78	0.90	0.73	0.85	0.60	0.84
Februar	1.24	1.51	1.34	0.94	1.52	1.69	1.22	1.86	1.22	1.69
March	2.01	2.58	2.03	1.97	2.39	2.40	2.09	2.56	2.38	2.65
April	3.31	3.58	3.19	4.10	3.60	3.91	3.06	4.49	3.57	4.12
May	4.57	5.31	4.42	4.67	5.31	4.74	4.80	4.71	4.72	5.18
June	6.21	5.99	5.61	6.39	6.27	5.68	5.24	6.25	5.85	5.99
July	6.15	6.76	6.66	6.84	6.23	6.64	6.38	6.65	6.75	6.48
August	5.58	6.51	5.74	5.69	5.73	5.95	5.77	6.19	5.80	5.84
September	3.96	4.65	4.28	4.53	4.12	3.94	4.79	4.14	4.83	4.30
Octorber	2.93	2.27	2.34	2.73	2.45	2.34	2.49	2.70	2.46	2.69
November	1.35	1.76	1.11	1.25	1.55	1.24	1.60	1.50	1.33	-
December	0.90	0.97	0.90	0.84	0.63	0.91	0.66	0.61	0.95	-
Total	39.07	42.80	38.43	40.64	40.58	40.34	38.83	42.51	40.46	39.78

The ETo results calculated according to Hargreaves-Samani method using data from Ereğli meteorological station from 2009 to 2018 has been represented in the Table 4.20. The highest ETo value calculated between 2009 and 2018 was recorded in the month July with 6.73 mm/day and the lowest ETo according to the result is 0.67 mm/day in the month December. ETo results were not calculated in November and December in the year 2018 because of inadequate Meteorological data.

Table 4.20 ETo mm/day results calculated according to Hargreaves - Samani Method for Ereğli Station

Months	Years									
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
January	1.03	1.14	0.91	0.87	0.97	1.08	0.98	0.94	0.76	0.86
Februar	1.45	1.70	1.44	1.10	1.72	1.81	1.38	1.84	1.41	1.83
March	2.17	2.72	2.23	1.97	2.46	2.57	2.27	2.64	2.33	2.93
April	3.47	3.56	3.17	4.21	3.55	4.09	3.28	4.36	3.64	4.17
May	4.71	5.36	4.36	4.64	5.16	5.01	4.93	4.78	4.65	5.18
June	6.26	5.81	5.63	6.35	6.12	5.76	5.40	5.91	5.85	5.98
July	6.10	6.72	6.52	6.68	6.27	6.60	6.47	6.46	6.73	6.42
August	5.77	6.43	5.73	5.69	5.69	6.05	5.85	6.09	5.76	5.95
September	4.02	4.73	4.32	4.67	4.19	4.01	4.92	4.22	4.92	4.51
Octorbeer	3.04	2.53	2.54	2.77	2.56	2.50	2.65	2.91	2.71	2.71
November	1.46	2.01	1.10	1.32	1.62	1.36	1.67	1.62	1.47	-
December	1.12	1.16	1.01	0.95	0.67	1.10	0.75	0.70	1.20	-
Total	40.60	43.87	38.96	41.22	40.98	41.94	40.55	42.47	41.43	40.54

4.1.6. Comparison of ETo values calculated according to different methods.

The range, minimum, maximum, sum, mean, mean standard error, standard deviation, and variance of ETo calculated using FAO 56 Penman-Monteith, ASCE Penman-monteith, Radiation, Hargreaves-Samani and Blaney-Criddle has been represented in Appendix I. The ETo values calculated with the Radiation equation recorded the highest mean in most cases and ETo values calculated with the ASCE Penman Monteith recorded the lowest mean in most of the years and stations. The lowest means of ETo calculated with the ASCE Penman-Monteith equation was 1.79mm/day in 2014 at the Eregli station. The highest mean was 4.79 mm/day in 2016 at Eregli meteorological station using the Radiation method.

The different methods used to calculate the ETo for Akşehir, Beyşehir, Cihanbeyli and Eregli meteorological stations were compared against the FAO 56 Penman-Monteith method. The differences between ETo mean of the various methods and stations from 2009 to 2018 were tested statistically using paired t test at 95% confidence level with the FAO 56 Penman-Monteith as a benchmark model. If $p<0.05$, the hypothesis - mean of ETo calculated with the FAO 56 Penman-Monteith is not different from other methods, was rejected. The results shows statistical significant differences between most of the ETo means from 2009 to 2018. At Akşehir meteorological station, several ETo evaluation methods showed significant differences against the FAO 56 Penman-Monteith method except Blaney-Criddle with mean ETo values which were 0.33 to 0.52 mm/day higher than the means of FAO 56 Penman Monteith method in 2012, 2014, 2015 and 2017. The differences between the mean ETo at Beyşehir station calculated with Hargreaves-Samani and Blaney-Criddle in 2009 to 2018 were generally not statistically different from ETo mean calculated with FAO 56 Penman-Monteith. Appendix I shows results if statistical analysis.

4.2. Plant coefficient Kc

Figure 4.1 show results of plant coefficients of drybean, maize, sugarbeet, sunflower and wheat for Akşehir meteorological station using the graphical approach by Allen et al. (1998). The Kc_{ini}, Kc_{mid} and Kc_{end} for drybean were 0.24, 1.06 and 0.92 respectively. The Kc_{ini}, Kc_{mid} and Kc_{end} for maize, sugarbeet, sunflower and wheat were represented in Figure 4.1.

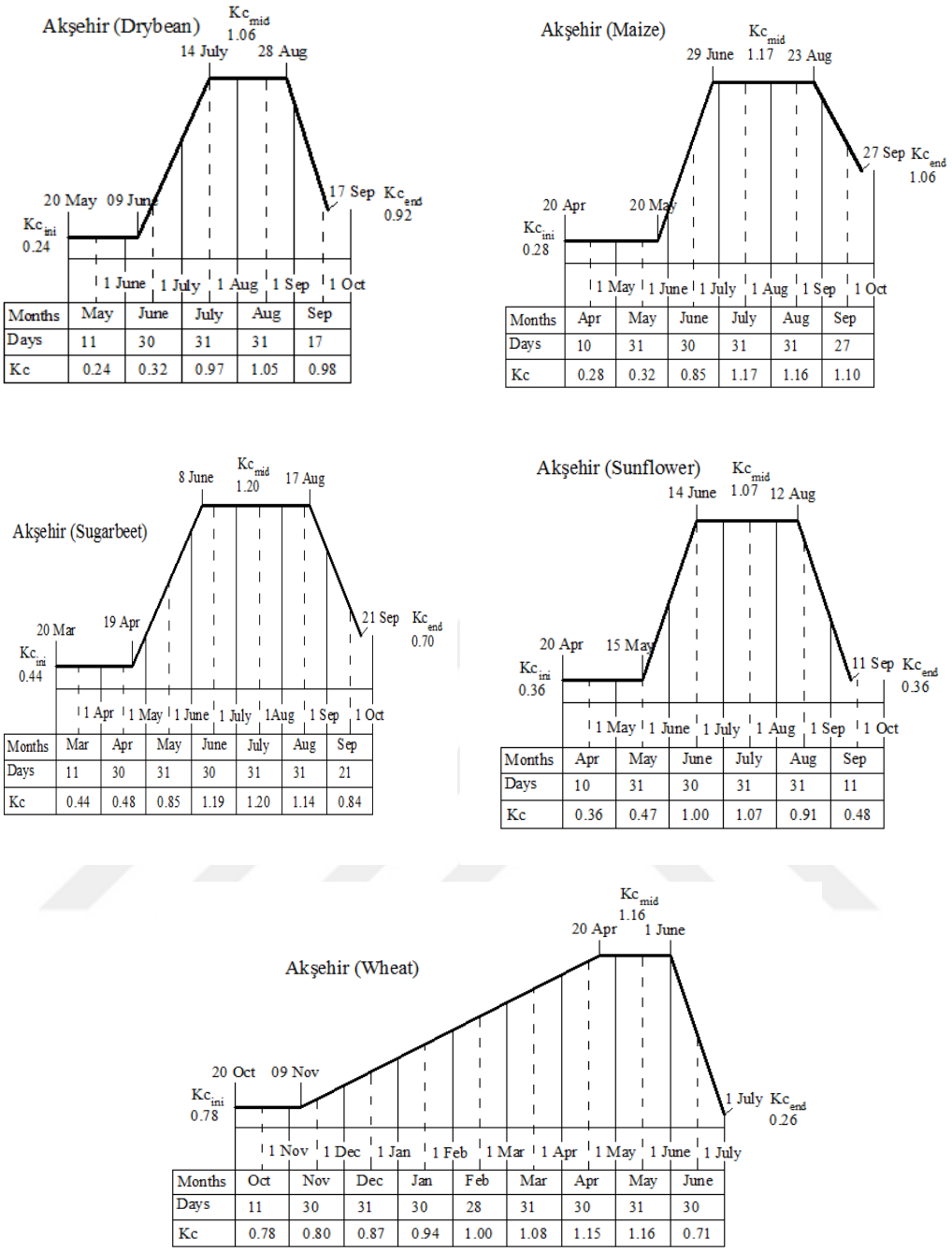


Figure 4.1 Plant coefficients for Drybean, Sugarbeet, Sunflower, Maize and Wheat at Akşehir Meteorological Station

Figure 4.2 show results of plant coefficients of drybean, maize, sugarbeet, sunflower and wheat for Beyşehir meteorological station. The Kc_{ini}, Kc_{mid} and Kc_{end} for drybean were 0.25, 1.05 and 0.36 respectively. The Kc_{ini}, Kc_{mid} and Kc_{end} for maize, sugarbeet, sunflower and wheat were represented in Figure 4.2.

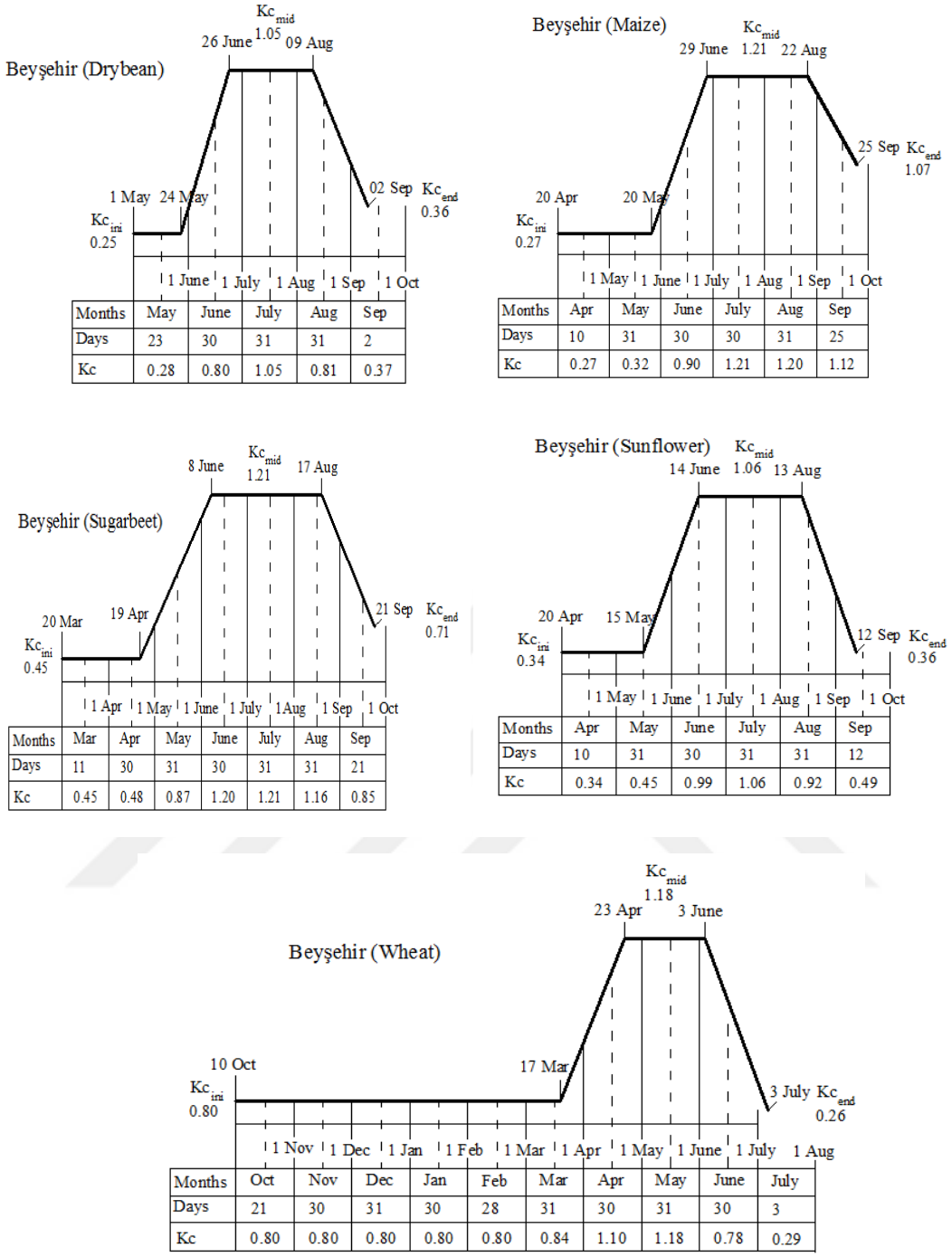


Figure 4.2 Plant coefficients for Drybean, Sugarbeet, Sunflower, Maize and Wheat at Beyşehir Meteorological Station

Figure 4.3 show results of plant coefficients of drybean, maize, sugarbeet, sunflower and wheat for Cihanbeyli meteorological station. The Kc_{ini}, Kc_{mid} and Kc_{end} for drybean were 0.16, 1.10 and 0.39 respectively. The Kc_{ini}, Kc_{mid} and Kc_{end} for maize, sugarbeet, sunflower and wheat have been represented in Figure 4.3 below.

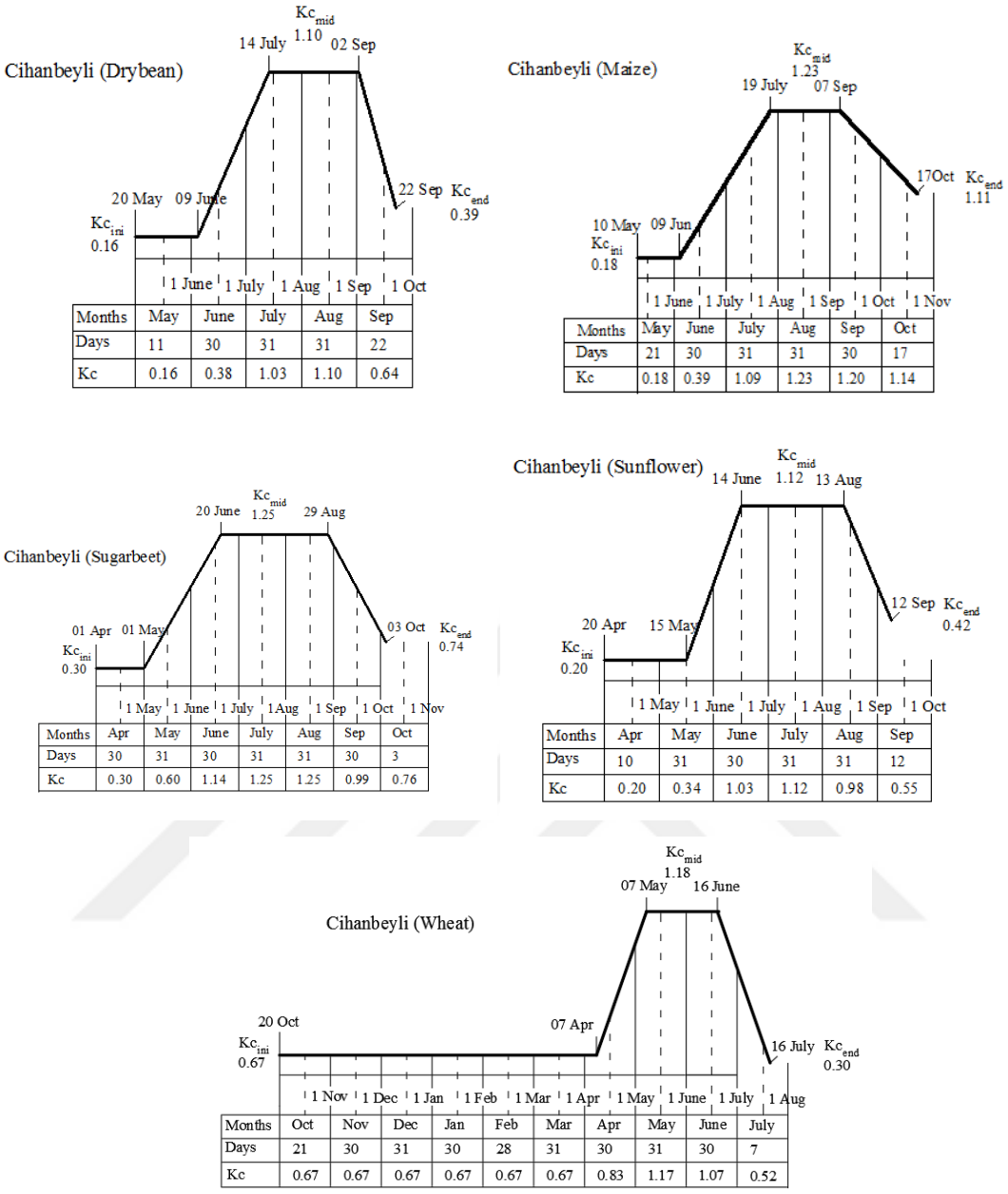


Figure 4.3 Plant coefficients for Drybean, Sugarbeet, Sunflower, Maize and Wheat at Cihanbeyli Meteorological Station

Figure 4.4 show results of plant coefficients of drybean, maize, sugarbeet, sunflower and wheat for Ereğli meteorological station. The Kc_{ini}, Kc_{mid} and Kc_{end} for drybean were 0.21, 1.07 and 0.36 respectively. The Kc_{ini}, Kc_{mid} and Kc_{end} for maize, sugarbeet, sunflower and wheat were represented in Figure 4.4.

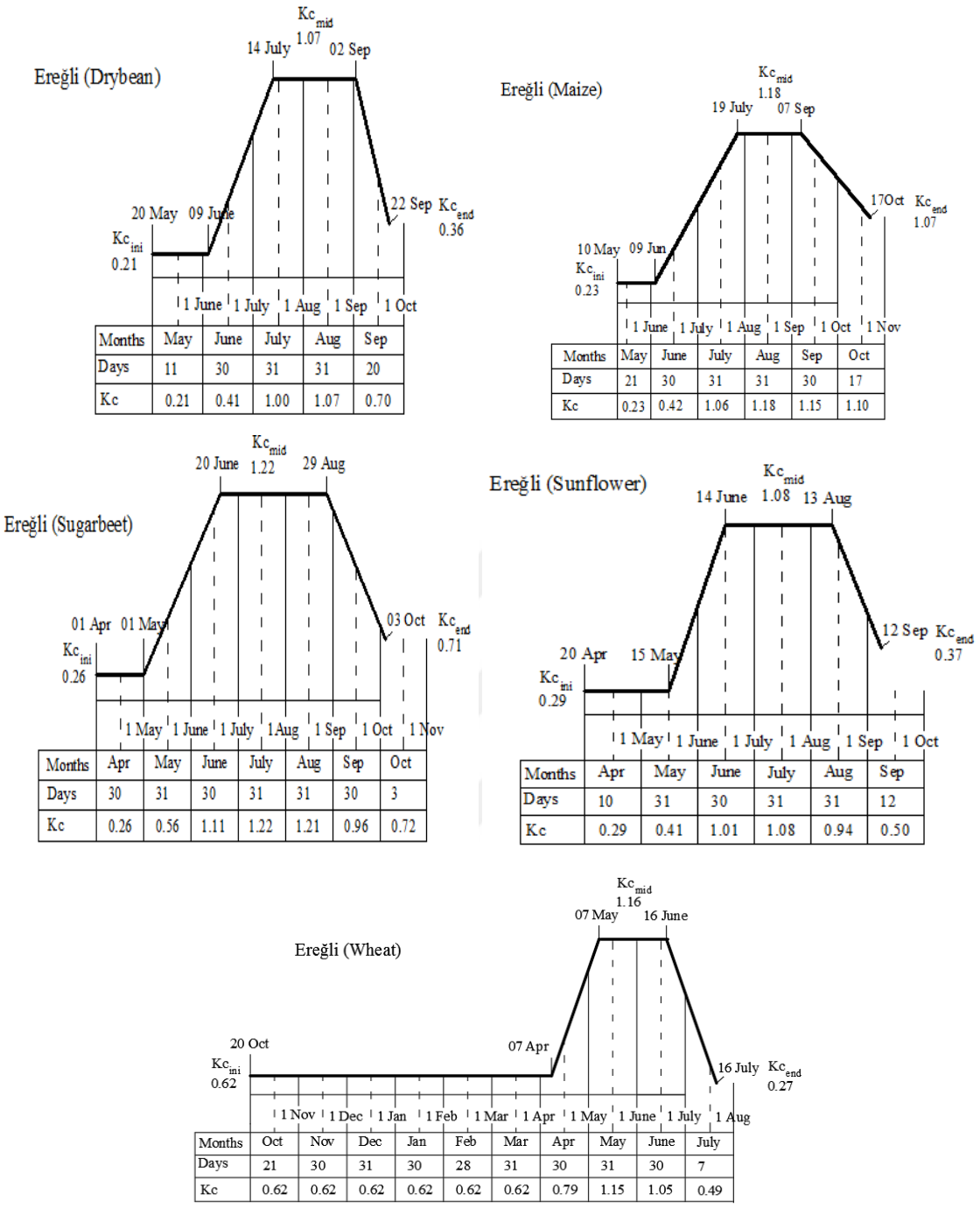


Figure 4.4 Plant coefficients for Drybean, Sugarbeet, Sunflower, Maize and Wheat at Ereğli Meteorological Station

4.3. Crop evapotranspiration ETc

4.3.1. Akşehir Meteorological Station ETc Results

4.3.1.1 Dry bean

The total crop evapotranspiration for each year over the 10 year period was calculated for drybean in Akşehir using FAO 56 Penman-Monteith, ASCE Penman Monteith, Radiation, Hargreaves-Samani and Blaney-Criddle methods. According to the results the radiation method recorded the highest ETc value of 500.8 mm up to 678.5 mm. The ASCE Penman Montieth method recorded the least ETc value over the period in Akşehir. The ETc for Blaney-Criddle and Hargreaves Samani method yielded a ETc values for drybean higher than the FAO56 Penman Monteith method. The FAO56 Penman Monteith method recorded ETc ranging from 405.8 mm to 477mm for drybean. The results shows that water requirement of drybean was high in 2010 and low in 2018. However, when the Hargreaves-Samani method was used the water requirement for drybean was higher in 2018 than subsitquent years. Table 4.21 highlights the total water requirement of drybean plant in Akşehir obtained by using the five methods.

Table 4.21 Akşehir Meteorological stations annual ETc values for drybean

Drybean	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
FAO 56 Penman Monteith	456.7	466.1	459.0	477.0	470.2	462.3	441.2	471.8	442.1	405.8
Hergeaves Samani	471.9	528.9	490.6	505.5	482.0	501.3	482.9	507.8	503.9	508.3
Radiation Equation	610.0	678.5	648.3	670.7	655.8	634.2	610.2	643.6	585.3	500.8
ASCE Penman Motheith	370.2	407.7	378.7	388.0	376.3	375.0	368.0	383.2	361.1	325.3
Blaney Criddle	-	-	-	633.5	606.7	608.6	575.3	615.3	565.2	476.2

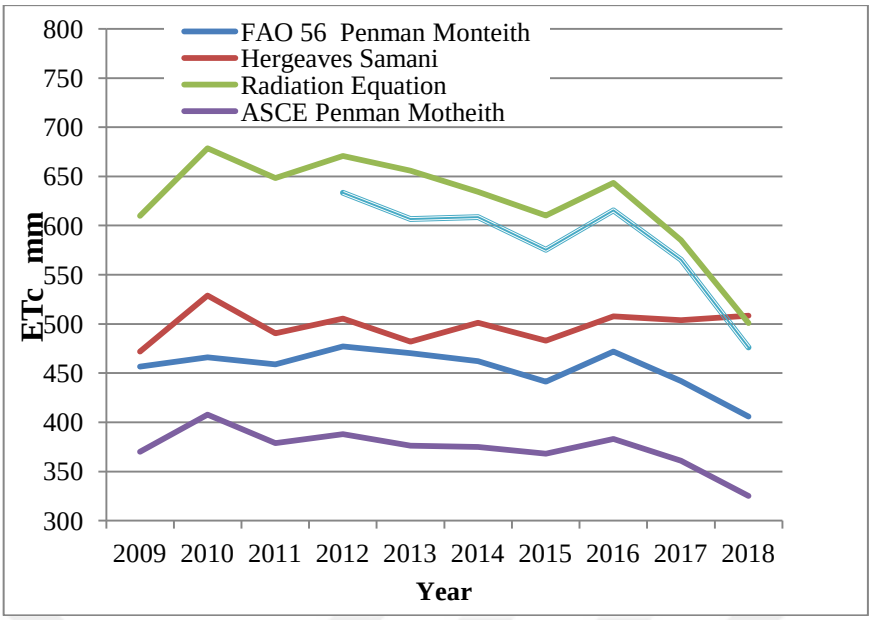


Figure 4.5Akşehir Meteorological stations annual ETc values for drybean

4.3.1.2 Maize

The total crop evapotranspiration for each year over the 10 year period was calculated for maize in Akşehir using FAO 56 Penman-Monteith, ASCE Penman Monteith, Radiation, Hargreaves-Samani and Blaney-Criddle methods. According to the results the radiation method recorded the highest ETc for maize of at least 761.9 mm and at most 985.8 mm. The ASCE Penman Montieth method recorded the least ETc value for maize over the period. The ETc for Blaney-Criddle and Hargreaves Samani method yielded ETc values for maize higher than the FAO56 Penman Monteith method. The FAO 56 Penman Monteith method recorded ETc that range from 603.9 mm to 696.3 mm for maize for the 10 year period.

Table 4.22 Akşehir Meteorological stations annual ETc values for maize

Maize	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
FAO 56 Penman Monteith	667.1	666.9	656.8	696.3	694.7	662.6	636.2	688.9	642.1	603.9
Hergeaves Samani	691.6	763.9	712.2	744.5	714.0	722.7	705.3	741.4	736.3	746.4
Radiation Equation	898.8	976.6	926.9	985.8	969.5	907.8	877.9	941.0	850.5	761.9
ASCE Penman Motheith	542.0	585.8	544.6	568.3	555.2	539.5	532.4	558.0	524.9	488.5
Blaney Criddle	-	-	-	924.0	891.2	858.2	822.3	890.4	810.8	719.1

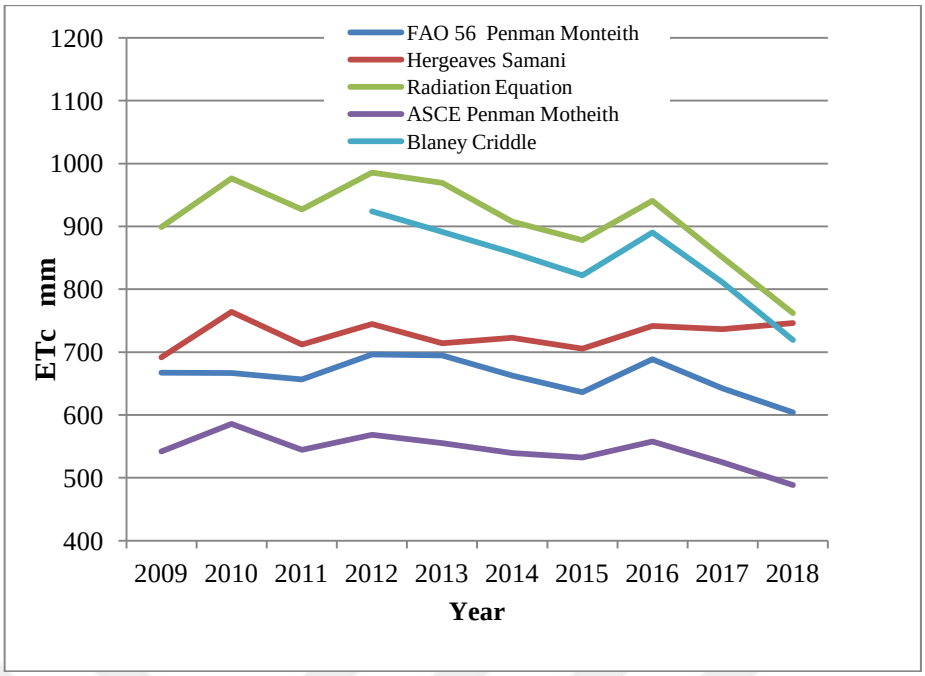


Figure 4.6 Akşehir Meteorological stations annual ETc values for maize

4.3.1.3 Sugarbeet

The total crop evapotranspiration for each year over the 10 year period was calculated for sugarbeet in Akşehir using FAO 56 Penman-Monteith, ASCE Penman Monteith, Radiation, Hargreaves-Samani and Blaney-Criddle methods. According to the results the radiation method recorded the highest ETc for sugarbeet of at least 844.3 mm and at most 1086.6 mm. The ASCE Penman Montieth method recorded the least ETc value for sugarbeet over the period. The ETc for Blaney-Criddle and Hargreaves Samani method yielded ETc values for sugarbeet higher than the FAO56 Penman Monteith method. The ETc range of the FAO56 Penman Monteith method recorded was from 665.9 mm to 778.3 mm for sugarbeet that is from 2009 to 2018.

Table 4.23 Akşehir Meteorological stations annual ETc values for sugarbeet

Sugarbeet	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
FAO 56 Penman Monteith	746.3	725.0	706.0	760.6	778.3	733.7	688.1	761.1	698.6	665.9
Hergeaves Samani	773.7	843.0	781.6	822.3	806.2	803.5	774.9	824.0	805.0	836.8
Radiation Equation	1014.2	1072.3	994.0	1074.5	1086.6	1012.4	950.7	1038.7	929.9	844.3
ASCE Penman Motheith	607.7	640.0	590.7	624.9	622.0	597.7	580.1	616.3	573.6	542.5
Blaney Criddle	-	-	-	994.9	991.7	942.6	872.9	971.5	870.9	801.6

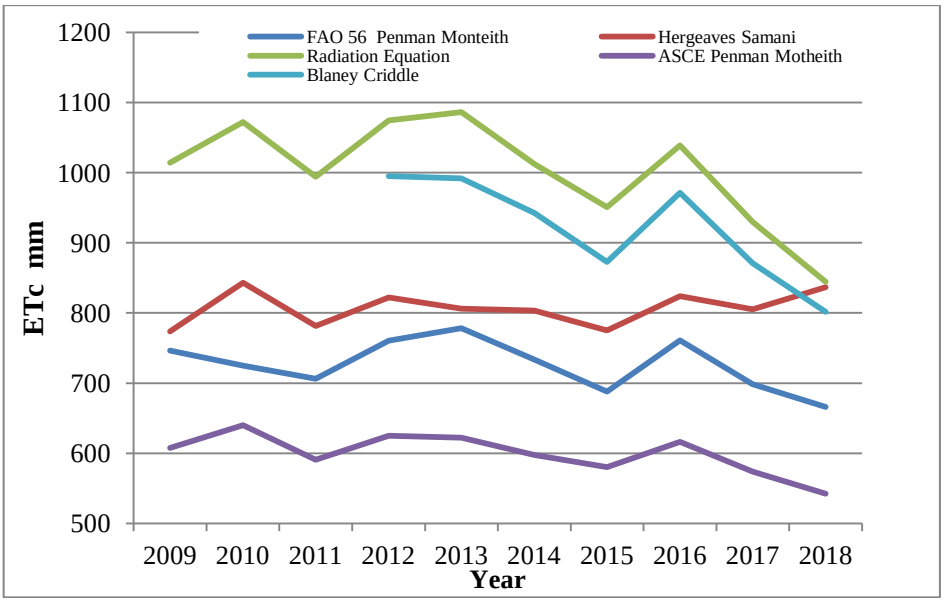


Figure 4.7 Akşehir Meteorological stations annual ETc results of sugarbeet

4.3.1.4 Sunflower

The total crop evapotranspiration for each year over the 10 year period was calculated for sunflower in Akşehir using FAO 56 Penman-Monteith, ASCE Penman Monteith, Radiation, Hargreaves-Samani and Blaney-Criddle methods. According to the results the radiation method recorded the highest ETc for sunflower of at least 631.3 mm and at most 815.3 mm. The ASCE Penman Montieth method recorded the least ETc value for sunflower over the periods considered. The ETc for Blaney-Criddle and Hargreaves Samani method also yielded ETc values for sunflower higher than the FAO56 Penman Monteith method. The FAO56 Penman Monteith method recorded ETc range from 499 mm to 585.3 mm for sunflower for the 10 year period.

Table 4.24 Akşehir Meteorological stations annual ETc values for sunflower

sunflower	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
FAO 56 Penman Monteith	568.4	541.9	534.4	576.2	585.3	557.7	510.3	576.6	524.3	499.0
Hergeaves Samani	586.8	632.9	590.2	620.8	606.4	611.3	576.8	625.0	603.4	628.9
Radiation Equation	769.5	801.4	753.1	813.3	815.3	773.6	704.7	787.1	702.4	631.3
ASCE Penman Motheith	461.9	479.8	447.6	474.0	467.7	453.8	432.2	467.0	432.8	406.4
Blaney Criddle	-	-	-	755.3	746.9	724.6	646.0	740.8	659.0	603.7

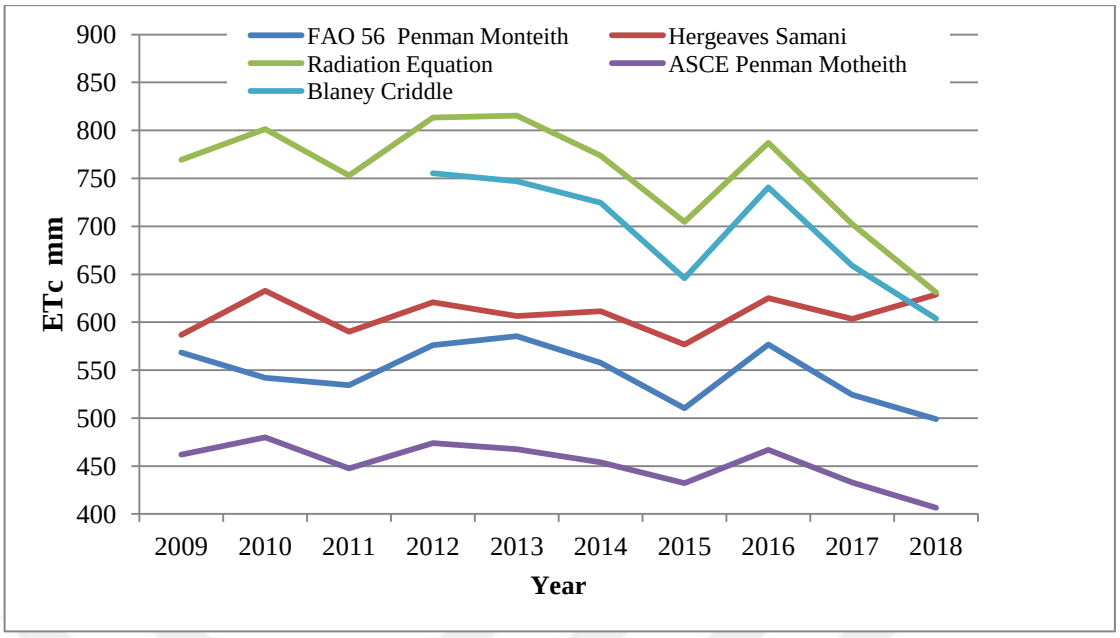


Figure 4.8 Akşehir Meteorological stations annual ETc values for sunflower

4.3.1.5 Wheat

The total crop evapotranspiration for each year over the 10 year period was calculated for wheat in Akşehir using FAO 56 Penman-Monteith, ASCE Penman Monteith, Radiation, Hargreaves-Samani and Blaney-Criddle methods. The lowest ETc recorded for wheat using the radiation method was 660.9 mm and the highest was 844.9 mm. The ASCE Penman Montieth method recorded the least ETc value for wheat over the periods considered. The ETc for Blaney-Criddle and Hargreaves Samani method also yielded ETc values for wheat higher than the FAO56 Penman Monteith method. The FAO56 Penman Monteith method recorded ETc ranging from 456.7 mm to 608.8 mm for wheat for the period considered.

Table 4.25 Akşehir Meteorological stations annual ETc values for wheat

Wheat	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
FAO 56 Penman Monteith	545.5	503.0	456.7	530.1	597.0	550.6	495.3	608.8	515.6	590.5
Hergeaves Samani	561.8	628.1	567.7	580.5	626.4	604.3	565.6	648.2	586.2	680.5
Radiation Equation	751.0	793.8	660.9	759.1	827.1	789.2	661.8	844.9	694.1	781.3
ASCE Penman Motheith	428.0	434.4	388.4	419.5	461.7	431.9	401.6	464.5	401.9	455.2
Blaney Criddle		-	-	565.1	640.6	588.5	480.4	658.5	498.7	669.6

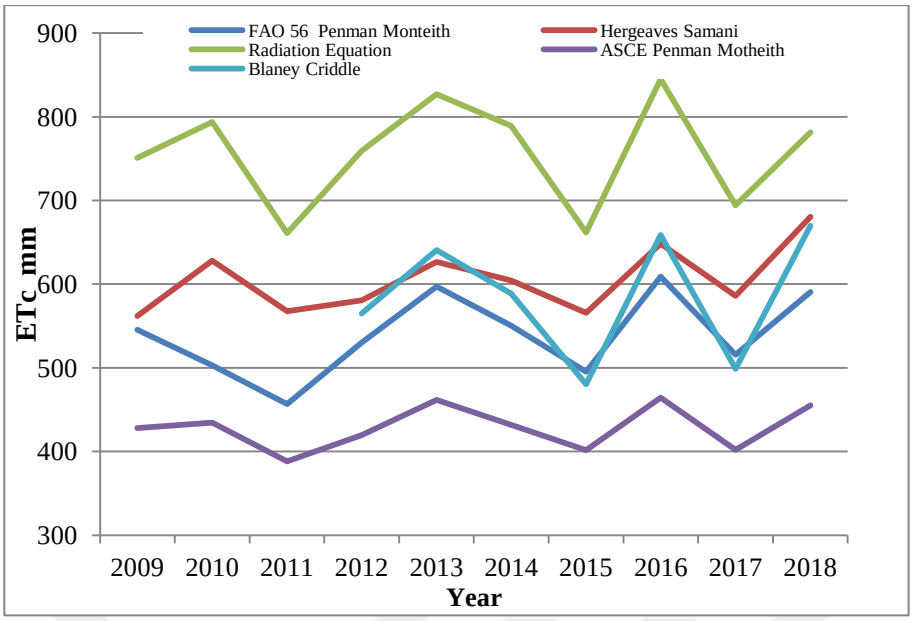


Figure 4.9 Akşehir Meteorological stations annual ETc values for wheat

4.3.2. Beyşehir Meteorological Station ETc Results

4.3.2.1. Dry bean

The total crop evapotranspiration for each year over the 10 year period was calculated for drybean in Beyşehir using FAO 56 Penman-Monteith, ASCE Penman Monteith, Radiation, Hargreaves-Samani and Blaney-Criddle methods. According to the results the radiation method recorded the highest ETc for drybean of at least 543.5 mm and at most 726.9 mm. The ASCE Penman Montieth method recorded the least ETc value for drybean over the periods considered. The ETc for Hargreaves Samani method also yielded ETc values for drybean were closer to FAO56 Penman Monteith ETc values in most years.

Table 4.26 Beyşehir Meteorological stations annual ETc values for drybean

Drybean	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
FAO 56 Penman Monteith	520.0	505.4	498.3	542.2	540.0	505.8	468.2	519.5	478.6	451.3
Hergeaves Samani	495.2	510.2	489.0	499.5	493.5	491.6	481.3	505.6	493.4	497.5
Radiation Equation	690.7	679.0	679.7	726.9	725.1	683.6	633.5	700.6	625.2	543.5
ASCE Penman Motheith	391.7	398.8	389.1	412.6	405.4	394.5	373.4	404.3	373.0	344.1
Blaney Criddle	-	-	-	652.6	642.7	620.1	570.5	638.0	572.0	502.4

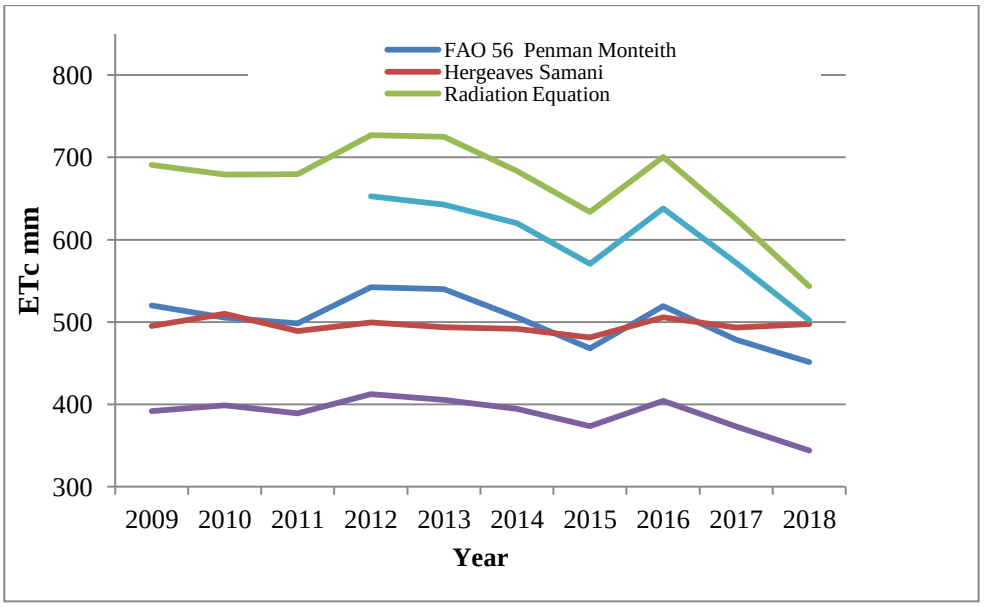


Figure 4.10 Beyşehir Meteorological stations annual ETc values for drybean

4.3.2.2. Maize

The total crop evapotranspiration for each year over the 10 year period was calculated for maize in Beyşehir using FAO 56 Penman-Monteith, ASCE Penman Monteith, Radiation, Hargreaves-Samani and Blaney-Criddle methods. According to the results the radiation method recorded the highest ETc for maize of at least 821.2 mm and at most 1081.8 mm. The ASCE Penman Montieth method recorded the least ETc value for drybean over the periods considered. The ETc for Hargreaves Samani method also yielded ETc values for maize were closer to FAO56 Penman Monteith ETc values in most years.

Table 4.27 Beyşehir Meteorological stations annual ETc valuess for maize

Maize	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
FAO 56 Penman Monteith	755.9	770.2	752.0	808.6	803.4	746.1	720.6	767.5	723.9	681.4
Hergeaves Samani	722.6	766.1	727.2	744.6	729.1	723.7	731.5	744.6	744.4	741.2
Radiation Equation	1002.0	1023.6	1012.9	1081.8	1073.2	994.0	964.4	1027.6	928.7	821.2
ASCE Penman Motheith	571.1	601.9	579.6	611.2	601.0	580.6	568.3	595.2	558.0	517.5
Blaney Criddle	-	-	-	972.9	950.0	905.2	881.5	934.1	855.4	758.1

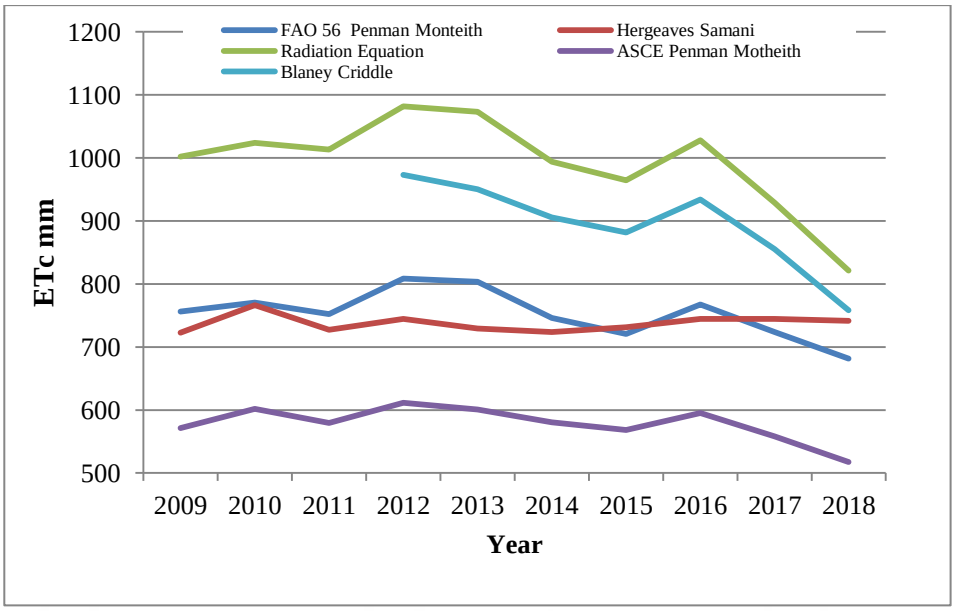


Figure 4.11 Beyşehir Meteorological stations annual ETc values for maize

4.3.2.3. Sugarbeet

The total crop evapotranspiration for each year over the 10 year period was calculated for sugarbeet in Beyşehir using FAO 56 Penman-Monteith, ASCE Penman Monteith, Radiation, Hargreaves-Samani and Blaney-Criddle methods. According to the results the radiation method recorded the highest ETc for sugarbeet of at least 935.2 mm and at most 1199.2 mm. The ASCE Penman Montieth method recorded the least ETc value for sugarbeet over the periods considered. The ETc for Hargreaves Samani method also yielded ETc values for sugerbeet were closer to FAO56 Penman Monteith ETc values in most years in Beyşehir.

Table 4.28 Beyşehir Meteorological stations annual ETc values for sugarbeet

Sugarbeet	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
FAO 56 Penman Monteith	845.8	860.1	838.4	895.9	896.2	828.9	813.5	861.4	814.6	768.5
Hergeaves Samani	813.4	856.3	810.5	835.4	816.9	807.5	825.4	837.1	835.3	834.4
Radiation Equation	1119.4	1139.1	1126.4	1199.2	1199.1	1102.0	1085.4	1154.0	1039.9	935.2
ASCE Penman Motheith	639.1	670.7	644.8	679.6	669.4	645.7	640.2	665.8	624.8	587.4
Blaney Criddle	-	-	-	1075.9	1053.1	996.9	990.5	1044.7	950.7	857.8

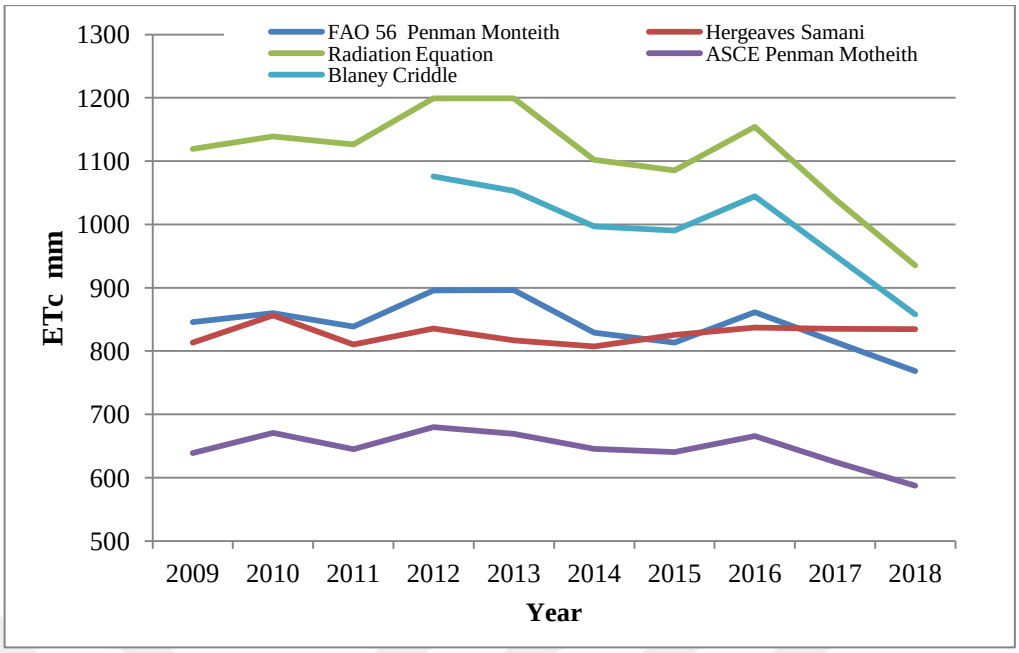


Figure 4.12 Beyşehir Meteorological stations annual ETc values for sugarbeet

4.3.2.4. Sunflower

The total crop evapotranspiration for each year over the 10 year period was calculated for sunflower in Beyşehir using FAO 56 Penman-Monteith, ASCE Penman Monteith, Radiation, Hargreaves-Samani and Blaney-Criddle methods. According to the results the radiation method recorded the highest ETc for sunflower of at least 663.3mm and at most 880.4 mm. The ASCE Penman Montieth method recorded the least ETc value for sunflower over the periods considered. The ETc for Hargreaves Samani method also yielded ETc values for sunflower were closer to FAO56 Penman Monteith ETc values in most years in Beyşehir.

Table 4.29 Beyşehir Meteorological stations annual ETc values for sunflower

sunflower	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
FAO 56 Penman Monteith	625.7	612.4	596.0	650.4	653.9	607.0	568.8	623.2	576.1	546.5
Hergeaves Samani	600.1	620.7	590.6	606.2	603.3	594.8	587.7	611.8	599.1	607.3
Radiation Equation	835.7	823.7	812.6	876.1	880.4	820.6	770.0	841.5	751.8	663.3
ASCE Penman Motheith	472.8	483.2	465.9	496.9	492.4	474.9	453.7	486.3	449.4	419.0
Blaney Criddle	-	-	-	781.5	776.9	739.0	690.9	761.0	684.2	610.5

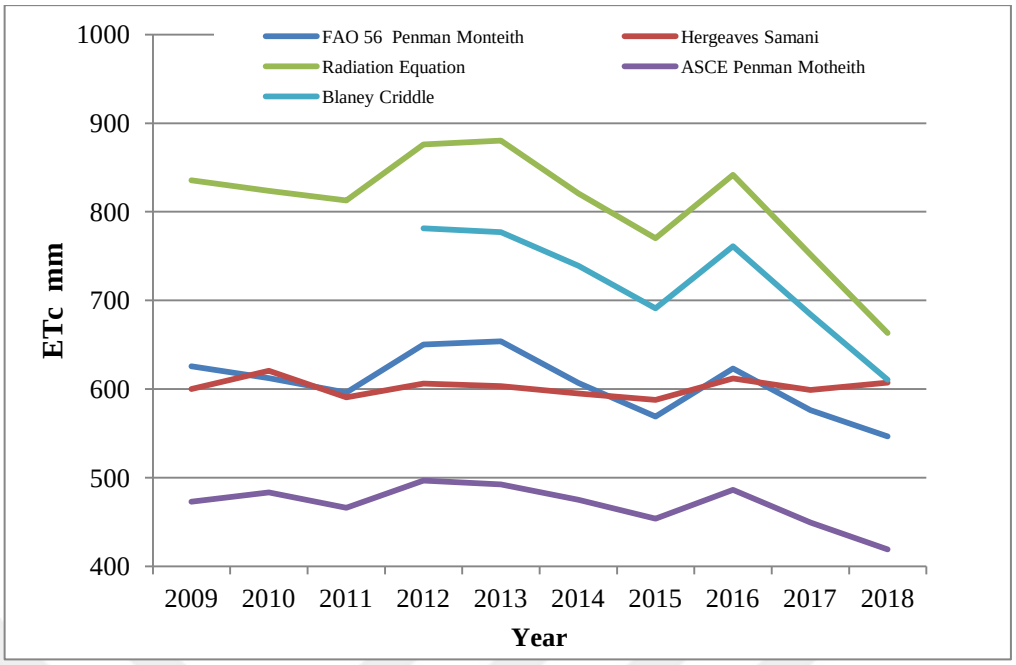


Figure 4.13 Beyşehir Meteorological stations annual ETc values for sunflower

4.3.2.5. Wheat

The total crop evapotranspiration for each year over the 10 year period was calculated for wheat in Beyşehir using FAO 56 Penman-Monteith, ASCE Penman Monteith, Radiation, Hargreaves-Samani and Blaney-Criddle methods. According to the results the radiation method recorded the highest ETc for wheat of at least 710.7 mm and at most 848.9 mm. The ASCE Penman Montieth method recorded the least ETc value for wheat over the periods considered.

Table 4.30 Beyşehir Meteorological stations annual ETc values for wheat

Wheat	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
FAO 56 Penman Monteith	553.6	594.0	509.6	556.6	605.2	570.2	524.0	607.2	534.1	584.6
Hergeaves Samani	590.3	633.9	573.4	581.5	637.4	611.5	575.1	641.1	588.6	659.4
Radiation Equation	794.4	824.5	717.9	809.9	848.9	825.1	710.7	860.3	737.4	782.6
ASCE Penman Motheith	431.8	456.7	401.5	432.9	464.2	443.1	410.1	464.3	410.1	447.7
Blaney Criddle	-	-	-	597.3	641.5	591.4	511.1	645.3	518.2	635.0

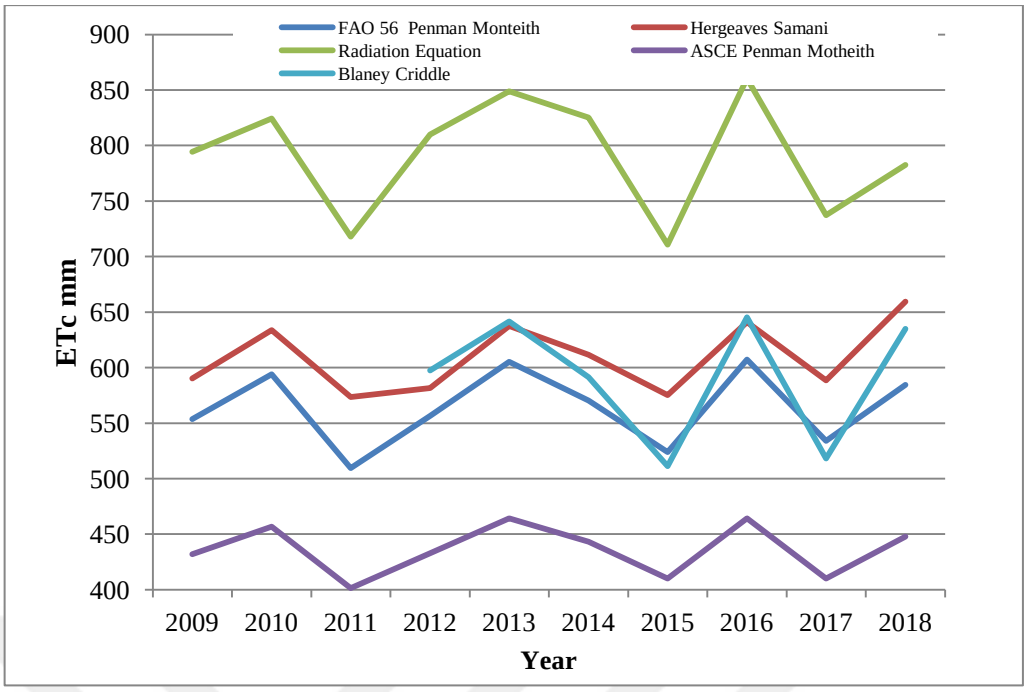


Figure 4.14 Beyşehir Meteorological stations annual ETc values for wheat

4.3.3.Cihanbeyli Meteorological Station ETc Results.

4.3.3.1. Dry bean

The total crop evapotranspiration for each year over the 10 year period was calculated for drybean in Cihanbeyli using FAO 56 Penman-Monteith, ASCE Penman Monteith, Radiation, Hargreaves-Samani and Blaney-Criddle methods. According to the results the radiation method recorded the highest ETc for drybean of at least 678.8 mm and at most 737.5 mm. The ASCE Penman Montieth method recorded the least ETc value for drybean over the periods considered. The ETc values for drybean were lower in 2009 for all methods in Cihanbeyli.

Table 4.31 Cihanbeyli Meteorological stations annual ETc values for drybean

Drybean	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
FAO 56 Penman Monteith	553.8	620.3	577.9	624.3	603.3	595.0	581.7	638.1	598.5	623.4
Hergeaves Samani	521.2	580.8	540.4	557.1	533.1	543.4	536.2	561.3	556.2	544.3
Radiation Equation	678.8	722.5	701.4	737.5	727.0	710.6	696.1	733.4	715.1	727.9
ASCE Penman Motheith	401.9	441.0	417.4	437.0	424.7	425.7	416.1	448.9	431.2	435.3
Blaney Criddle	-	-	-	713.8	684.0	693.8	680.2	722.7	693.2	693.5

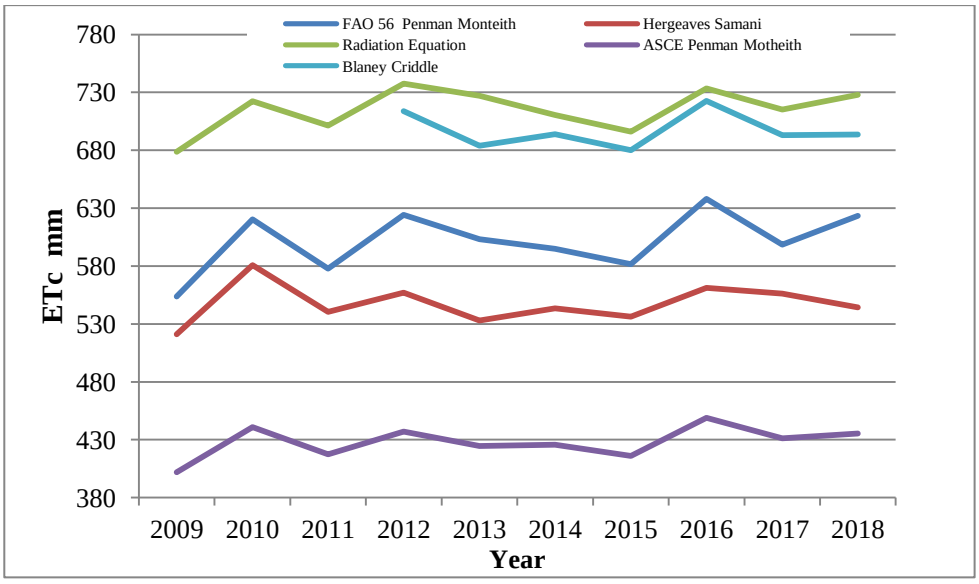


Figure 4.15 Cihanbeyli Meteorological stations annual ETc values for drybean

4.3.3.2. Maize

The total crop evapotranspiration for each year over the 10 year period was calculated for maize in Cihanbeyli using FAO 56 Penman-Monteith, ASCE Penman Monteith, Radiation, Hargreaves-Samani and Blaney-Criddle methods. According to the results the radiation method recorded the highest ETc for maize of at least 911.2 mm and at most 996.4 mm. The ASCE Penman Montieth method recorded the least ETc value for maize over the periods considered. The FAO 56 Penman-Monteith recorded a range of 752.6 mm to 864.8 mm for ETc values of maize in the years 2009 to 2018 for Cihanbeyli meteorological station.

Table 4.32 Cihanbeyli Meteorological stations annual ETc values for maize

Maize	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
FAO 56 Penman Monteith	752.6	850.1	785.6	843.0	813.8	791.6	803.8	864.8	831.4	848.6
Hergeaves Samani	712.7	780.4	728.2	759.1	720.8	725.1	738.3	756.0	759.5	741.3
Radiation Equation	911.2	969.9	945.0	996.4	977.8	942.5	952.7	993.3	981.7	984.6
ASCE Penman Motheith	543.3	597.0	564.3	591.5	570.5	568.6	573.4	605.2	590.9	592.2
Blaney Criddle	-	-	-	964.2	909.5	913.1	933.9	971.6	940.5	936.6

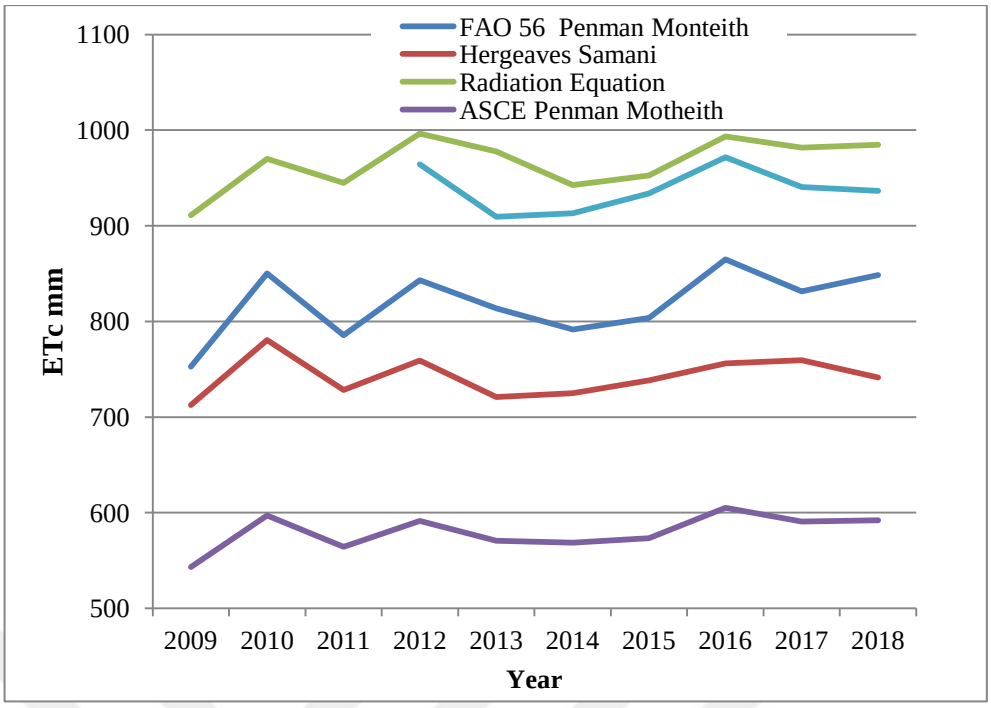


Figure 4.16 Cihanbeyli Meteorological stations annual ETc values for maize

4.3.3.3. Sugarbeet

The total crop evapotranspiration for each year over the 10 year period was calculated for sugarbeet in Cihanbeyli using FAO 56 Penman-Monteith, ASCE Penman Monteith, Radiation, Hargreaves-Samani and Blaney-Criddle methods. According to the results the radiation method recorded the highest ETc for sugarbeet of at least 1119.3 mm and at most 1211 mm. The ASCE Penman Montieth method recorded the least ETc value for sugarbeet over the periods considered.

Table 4.33 Cihanbeyli Meteorological stations annual ETc values for sugarbeet

Sugarbeet	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
FAO 56 Penman Monteith	900.7	1005.4	911.0	1008.6	994.1	945.8	925.2	1025.8	943.9	1008.2
Hergeaves Samani	876.1	960.9	887.1	931.6	904.6	892.5	887.4	928.2	923.2	912.8
Radiation Equation	1119.3	1179.3	1120.3	1211.0	1208.1	1146.4	1123.4	1190.7	1151.7	1200.5
ASCE Penman Motheith	659.8	716.6	667.0	714.0	704.5	685.2	671.2	723.9	697.0	715.7
Blaney Criddle	-	-	-	1159.0	1128.2	1098.1	1081.7	1157.0	1095.7	1135.8

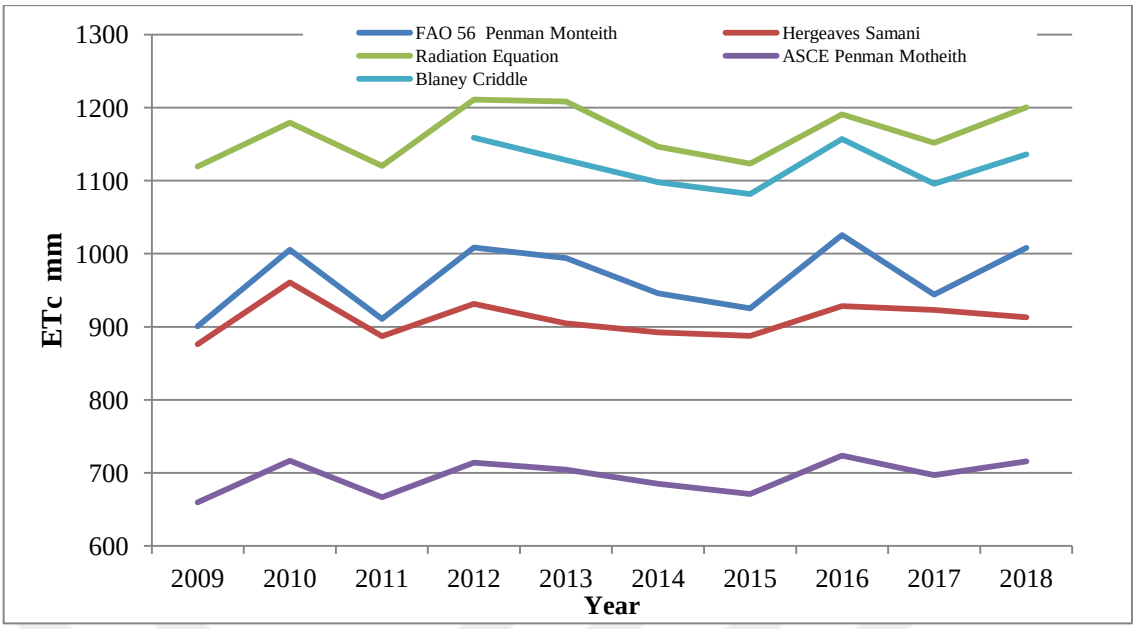


Figure 4.17 Cihanbeyli Meteorological stations annual ETc values for sugarbeet

4.3.3.4. Sunflower

The total crop evapotranspiration for each year over the 10 year period was calculated for sunflower in Cihanbeyli using FAO 56 Penman-Monteith, ASCE Penman Monteith, Radiation, Hargreaves-Samani and Blaney-Criddle methods. According to the results the radiation method recorded the highest ETc for sunflower of at least 808.6 mm and at most 892.6 mm. The ASCE Penman Montieth method recorded the least ETc value for sunflower over the periods considered. The ETc for sunflower calculated using Hargreaves-Samani equations recorded closer ETc values for sunflower for most years.

Table 4.34 Cihanbeyli Meteorological stations annual ETc values for sunflower

sunflower	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
FAO 56 Penman Monteith	671.1	715.8	662.7	743.1	732.3	699.9	661.4	761.1	675.4	735.8
Hergeaves Samani	649.1	704.0	653.8	686.9	667.2	662.6	641.1	689.2	673.0	670.8
Radiation Equation	834.2	856.4	820.9	892.6	891.4	853.7	808.6	883.4	834.7	884.5
ASCE Penman Motheith	490.9	518.3	488.4	526.8	519.2	506.7	482.4	536.7	505.7	525.4
Blaney Criddle	-	-	-	855.2	836.4	819.2	775.0	861.3	796.5	836.3

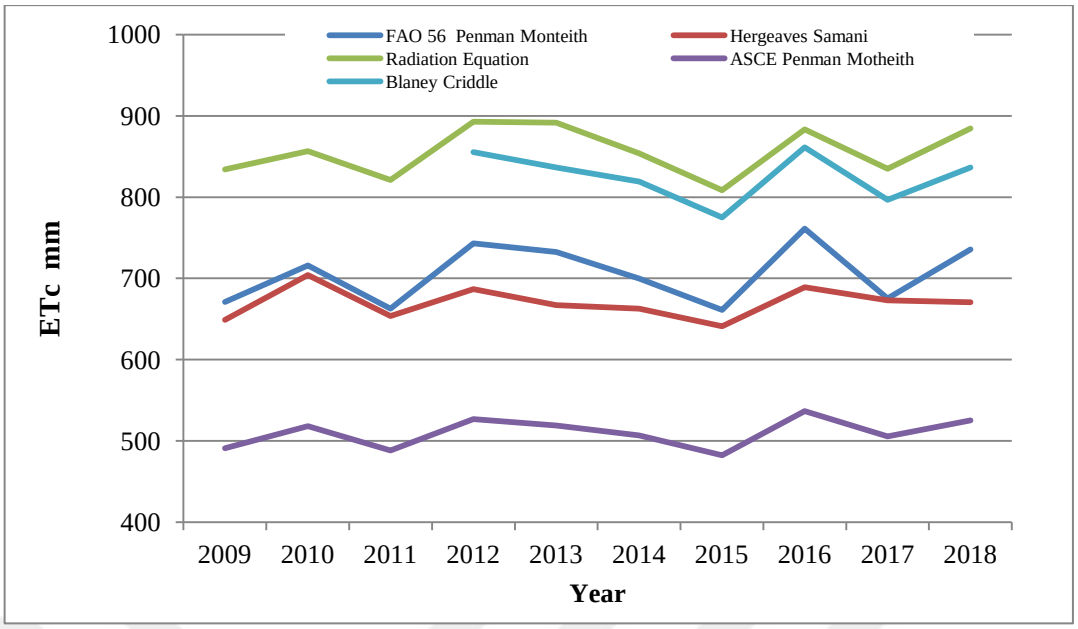


Figure 4.18 Cihanbeyli Meteorological stations annual ETc values for sunflower

3.3.3.5. Wheat

The total crop evapotranspiration for each year over the 10 year period was calculated for wheat in Cihanbeyli using FAO 56 Penman-Monteith, ASCE Penman Monteith, Radiation, Hargreaves-Samani and Blaney-Criddle methods. According to the results, the radiation method recorded the highest ETc for wheat with at minimum of 536.6 mm and a maximum of 677.8 mm. The ASCE Penman Montieth method recorded the least ETc value for wheat over the periods considered. The values of ETc for wheat calculated using Blaney-Criddle equation were closer to FAO 56 Penman-Monteith values in most of the years.

Table 4.35 Cihanbeyli Meteorological stations annual ETc values for wheat

Wheat	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
FAO 56 Penman Monteith	379.7	467.3	378.8	440.5	458.0	478.8	415.7	507.8	427.4	511.8
Hergeaves Samani	444.7	524.1	460.7	479.0	512.7	505.9	454.4	535.6	480.8	536.5
Radiation Equation	536.6	607.8	504.6	581.4	601.7	636.1	571.1	635.2	583.9	677.8
ASCE Penman Motheith	294.2	341.3	288.5	317.0	341.8	345.8	312.7	356.8	326.3	372.4
Blaney Criddle	-	-	-	412.3	471.8	484.0	411.7	510.9	414.3	568.2

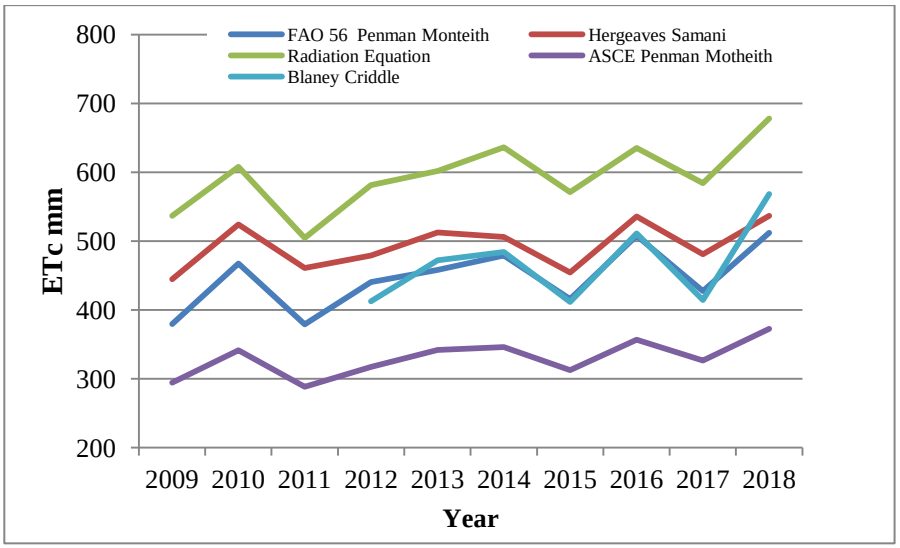


Figure 4.19 Cihanbeyli Meteorological stations annual ETc values for wheat

4.3.4. Ereğli Meteorological Station ETc Results.

4.3.4.1. Dry bean

The total crop evapotranspiration for each year over the 10 year period was calculated for drybean in Eregli using FAO 56 Penman-Monteith, ASCE Penman Monteith, Radiation, Hargreaves-Samani and Blaney-Criddle methods. According to the results the radiation method recorded the highest ETc for drybean in most years between 2009 and 2018. The ASCE Penman Montieth method recorded the least ETc value for drybean over the periods considered. ETc values fell in most of the methods used except Hargreaves-Samani which remain stable with little changes over the years.

Table 4.36 Eregli Meteorological stations annual ETc values for drybean

Drybean	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
FAO 56 Penman Monteith	554.4	549.1	517.2	543.1	543.9	549.2	512.8	539.3	540.0	546.3
Hergeaves Samani	524.6	571.7	532.3	549.9	529.0	544.0	541.5	544.9	551.1	545.0
Radiation Equation	729.9	761.8	732.6	757.3	762.0	766.8	725.0	764.5	751.0	761.8
ASCE Penman Motheith	420.1	438.6	420.9	430.2	425.0	433.0	417.0	429.5	426.1	432.3
Blaney Criddle	-	-	-	705.4	693.4	723.8	685.4	717.3	709.1	713.0

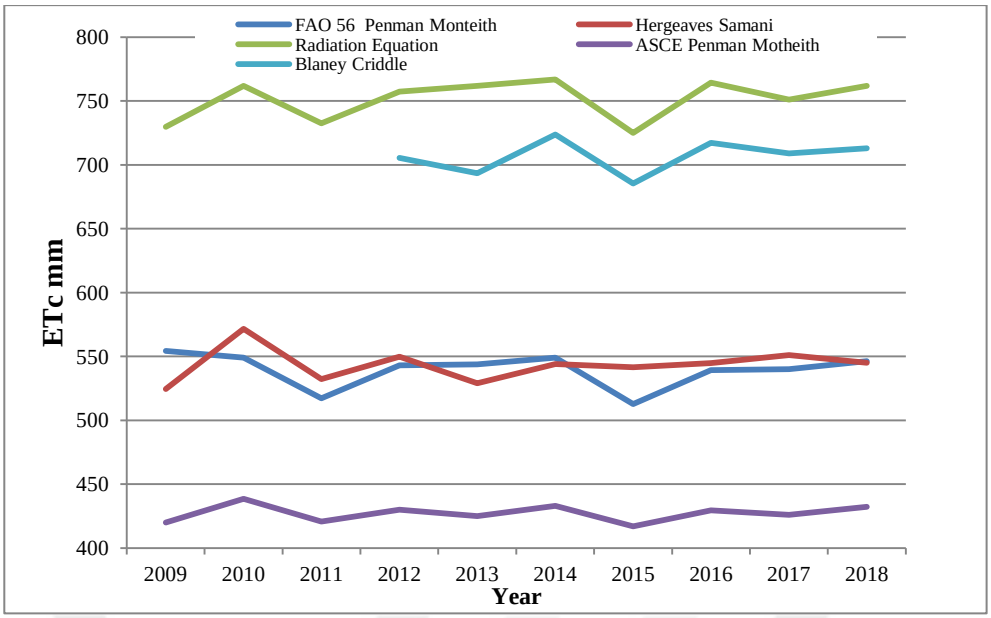


Figure 4.20 Eregli Meteorological stations annual ETc values for drybean

4.3.4.2. Maize

The total crop evapotranspiration for each year over the 10 year period was calculated for drybean in Eregli using FAO 56 Penman-Monteith, ASCE Penman Monteith, Radiation, Hargreaves-Samani and Blaney-Criddle methods. According to the results the radiation method recorded the highest ETc for drybean in most years between 2009 and 2018. The ASCE Penman Montieth method recorded the least ETc value for drybean over the periods considered. ETc values fell in most of the methods used except Hargreaves-Samani which remain stable with little changes over the years.

Table 4.37 Eregli Meteorological stations annual ETc values for maize

Maize	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
FAO 56 Penman Monteith	737.7	733.9	691.1	720.0	717.0	725.9	691.7	719.2	729.1	730.2
Hergeaves Samani	708.5	765.5	712.8	742.9	708.7	720.3	738.0	732.5	748.3	735.3
Radiation Equation	969.0	1009.7	975.0	1007.9	1005.5	1008.7	973.2	1019.3	1010.2	1011.4
ASCE Penman Motheith	558.1	584.7	560.0	573.1	560.9	575.7	561.4	571.4	570.7	578.1
Blaney Criddle	-	-	-	939.1	907.9	944.5	925.1	952.1	949.6	946.0

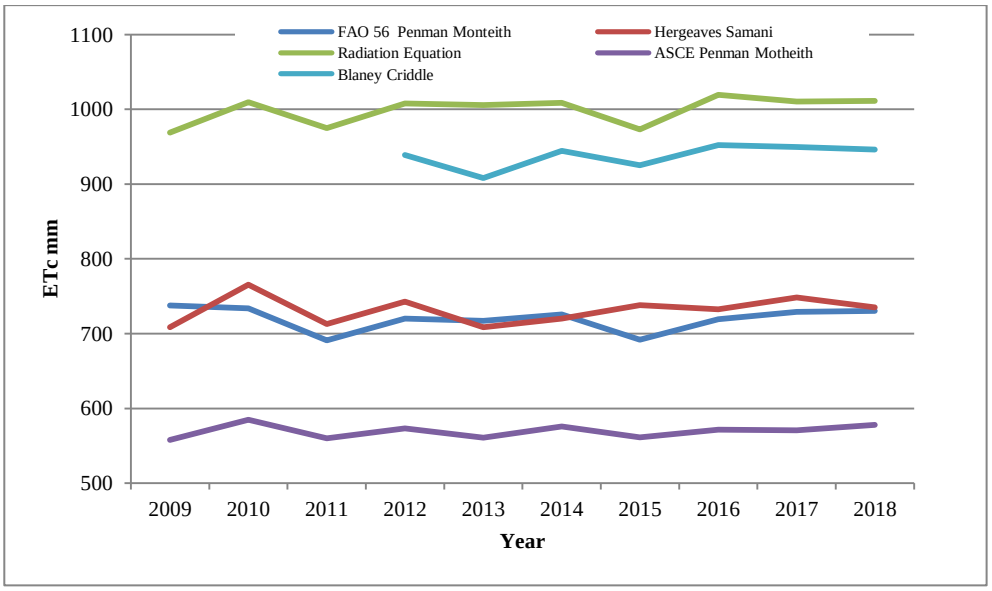


Figure 4.21 Eregli Meteorological stations annual ETc values for maize

4.3.4.3. Sugarbeet

The total crop evapotranspiration for each year over the 10 year period was calculated for sugarbeet in Eregli using FAO 56 Penman-Monteith, ASCE Penman Monteith, Radiation, Hargreaves-Samani and Blaney-Criddle methods. According to the results the radiation method recorded the highest ETc for sugarbeet in most years between 2009 and 2018. The ASCE Penman Montieth method recorded the least ETc value for sugarbeet over the periods considered.

Table 4.38 Eregli Meteorological stations annual ETc values for sugarbeet

Sugarbeet	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
FAO 56 Penman Monteith	898.3	879.4	818.0	871.2	876.4	878.0	817.0	864.2	860.9	876.3
Hergeaves Samani	859.4	923.6	855.1	898.5	870.2	876.5	877.3	880.0	893.4	890.8
Radiation Equation	1193.2	1224.2	1160.8	1220.5	1230.0	1225.5	1156.4	1224.2	1200.7	1222.9
ASCE Penman Motheith	680.3	705.5	669.0	693.5	688.3	694.4	669.0	689.9	680.8	698.3
Blaney Criddle	-	-	-	1128.1	1111.6	1138.9	1079.3	1135.3	1118.9	1141.1

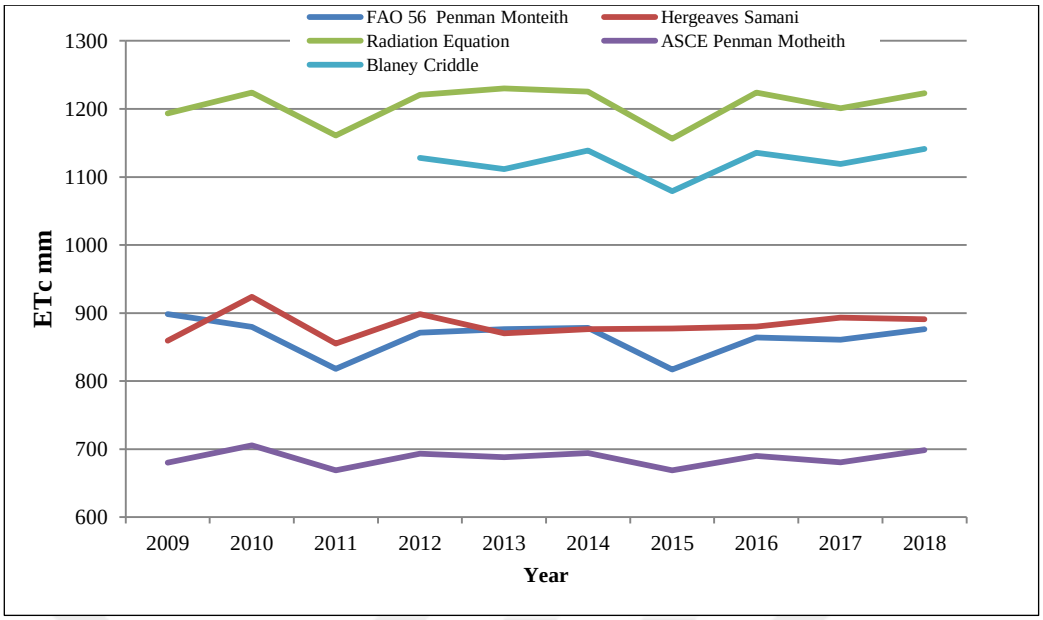


Figure 4.22 Eregli Meteorological stations annual ETc values for sugarbeet

4.3.4.4. Sunflower

The total crop evapotranspiration for each year over the 10 year period was calculated for sunflower in Eregli using FAO 56 Penman-Monteith, ASCE Penman Monteith, Radiation, Hargreaves-Samani and Blaney-Criddle methods. According to the results the radiation method recorded the highest ETc for sunflower in most years between 2009 and 2018. The ASCE Penman Montieth method recorded the least ETc value for sunflower over the periods considered.

Table 4.39 Eregli Meteorological stations annual ETc values for sunflower

sunflower	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
FAO 56 Penman Monteith	678.4	648.9	609.3	651.0	659.1	655.9	600.3	649.4	637.0	651.9
Hergeaves Samani	645.8	685.0	637.5	668.8	652.0	659.7	643.1	658.6	658.8	662.4
Radiation Equation	900.9	908.2	865.0	907.4	925.8	920.0	850.3	920.4	890.2	910.7
ASCE Penman Motheith	513.5	523.3	499.5	518.2	517.4	517.9	494.3	518.3	506.3	521.5
Blaney Criddle	-	-	-	838.1	837.9	854.9	785.7	854.7	827.4	849.3

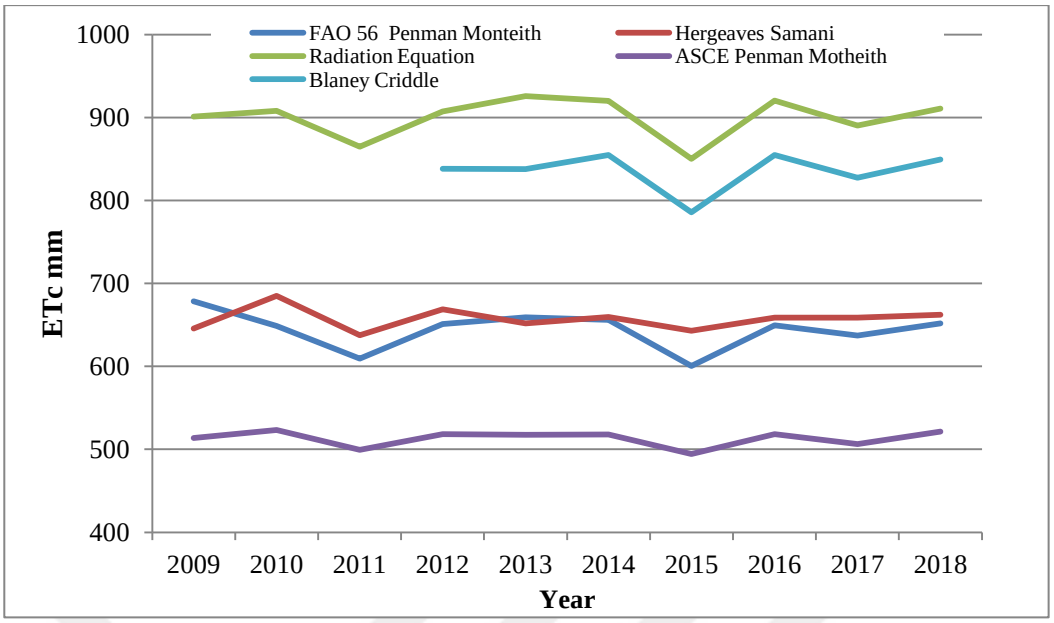


Figure 4.23 Eregli Meteorological stations annual ETc values for sunflower

4.3.4.5. Wheat

The total crop evapotranspiration for each year over the 10 year period was calculated for wheat in Eregli using FAO 56 Penman-Monteith, ASCE Penman Monteith, Radiation, Hargreaves-Samani and Blaney-Criddle methods. According to the results, the radiation method recorded the highest ETc for wheat in most years between 2009 and 2018. The ASCE Penman Montieth method recorded the least ETc value for wheat over the periods considered.

Table 4.40 Eregli Meteorological stations annual ETc values for wheat

Wheat	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
FAO 56 Penman Monteith	573.8	575.4	499.6	552.7	562.4	582.3	510.9	592.0	540.7	593.8
Hergeaves Samani	581.5	650.4	586.1	611.8	635.6	635.1	589.2	640.5	601.5	662.1
Radiation Equation	791.1	806.1	716.6	787.6	791.0	817.3	725.6	843.4	780.6	835.9
ASCE Penman Motheith	430.9	459.6	412.5	438.0	451.3	450.7	421.8	465.3	430.0	471.5
Blaney Criddle	-	-	-	637.3	641.5	658.8	562.7	689.7	604.2	722.8

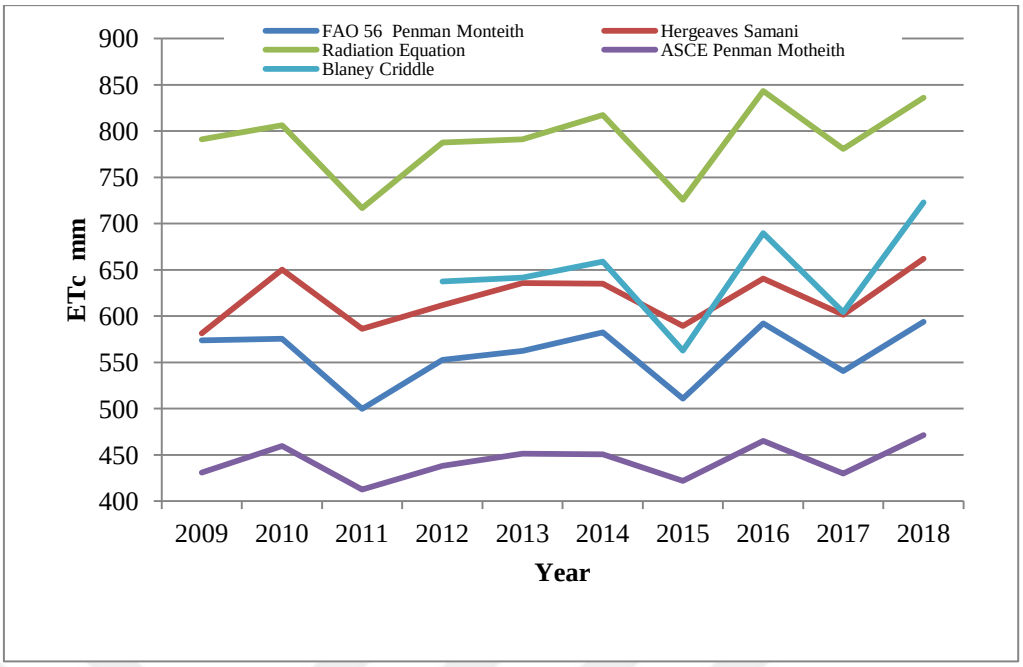


Figure 4.24 Eregli Meteorological stations annual ETc values for wheat

5. CONCLUSIONS AND RECOMMENDATIONS

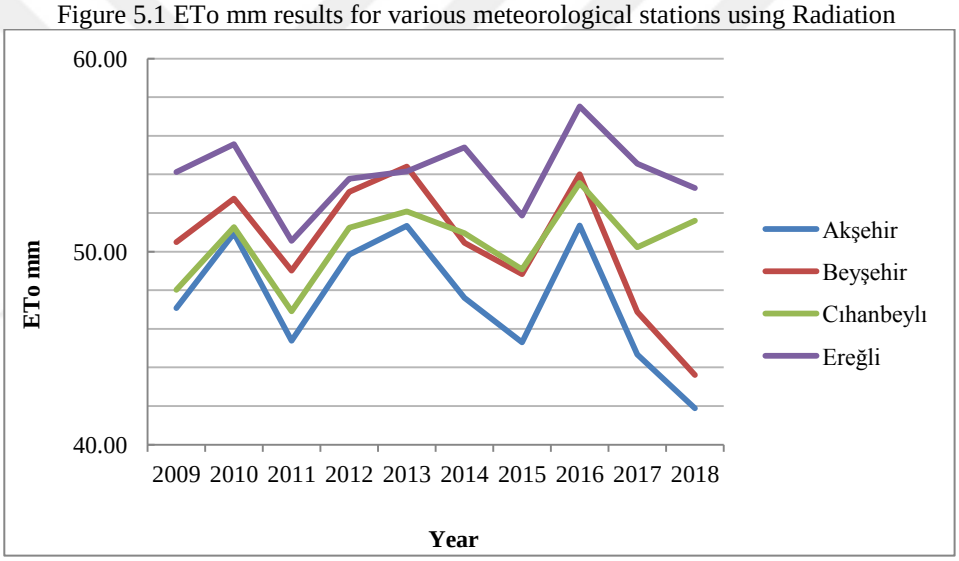
5.1. Conclusions

To be able to design a good irrigation schedule for a particular area of land, the water needs of the plant is one of the major factors to consider. Estimating water needs also depends largely on changes in climate parameters such as temperature, wind speed, humidity, and solar radiation. These parameters are not constant; they vary according to days, months and years requiring continuous evaluation of these parameters to determine the effect of their variations on estimations of water needs of plants in order to find a suitable approach for a specific crop and area. This study was mainly aimed at determining the effect of changes in climate parameters on the water needs of plants in Konya province that is Akşehir, Beyşehir, Cihanbeyli, and Eregli meteorological stations from 2009 to 2018. The FAO 56 Penman-Monteith, ASCE Penman-Monteith, Radiation, Hargreave-Samani, and Blaney-Criddle methods were used to estimate the water need of drybean, maize, sugarbeet, sunflower, and wheat.

Crop evapotranspiration which is also known as the crop water requirement can be estimated with the given formula; $ETc = Kc \times ETo$, where ETc is the crop evapotranspiration, Kc is the crop coefficiency and ETo is the reference evapotranspiration. In determining the ETo, the FAO 56 Penman-Monteith, ASCE Penman-Monteith, Radiation, Hargreave-Samani, and Blaney-Criddle were used. The FAO 56 Penman-Monteith according to Allen et al., (1998) method was derived from the original Penman-Monteith and uses standard climatologic data of solar radiation (sunshine), air temperature, humidity and wind speed. Similar to the FAO56 Penman-Monteith is the ASCE Penman-Monteith technique. Jensen and Allen, (2016) developed this approach to incorporates all parameters that govern energy exchange and corresponding latent heat flux (evaporation) from uniform expanses of vegetation. The Makkink (1957) formula was modified to develop the radiation method. The radiation equation is useful in areas where data on wind and humidity are not available. Doorenbos and Pruitt (1977) also modified the original Blaney and Criddle (1962) method to improve the definition of the effect of climate on crop water requirements while employing the Blaney-Criddle temperature and day length related f factor. Finally, the Hargreaves-Samani (1985) formula uses extraterrestrial radiation, the maximum and minimum temperature for calculating reference evapotranspiration.

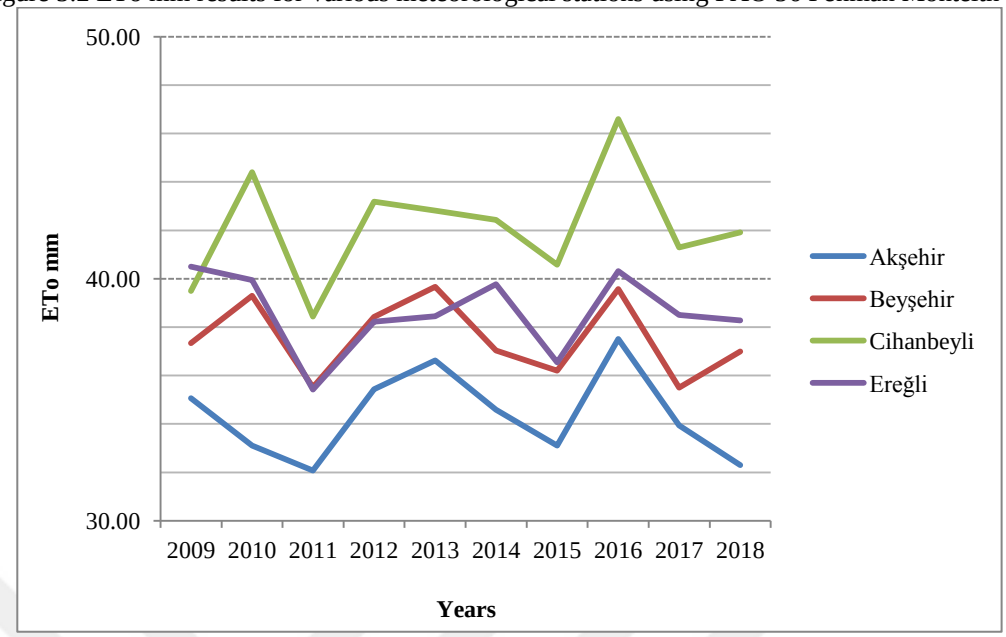
Data obtained from the meteorological stations shows annual variations for all years resulting in changes in the ETo values for each station and year. The results of the Radiation equation recorded the highest ETo in Akşehir, Beyşehir, Cihanbeyli, and Eregli meteorological stations in all the years. Periodic data of sunlight or sunshine for all the stations were available and as a result higher levels of ETo values were obtained with the Radiation formula. Variation in the parameters explains the unsteadiness of ETo in all the stations such that higher ETo values were estimated in months with long hours of sunshine corresponding to Bayramoğlu (2013) study which concluded that ETo values increase relatively to increase in climate parameters such as temperature and others with the period of evaluation. Therefore according to the results, there were longer monthly hours of sunshine in Eregli meteorological station than most of the stations within the 10 year period.

Figure 5.1 ETo mm results for various meteorological stations using Radiation



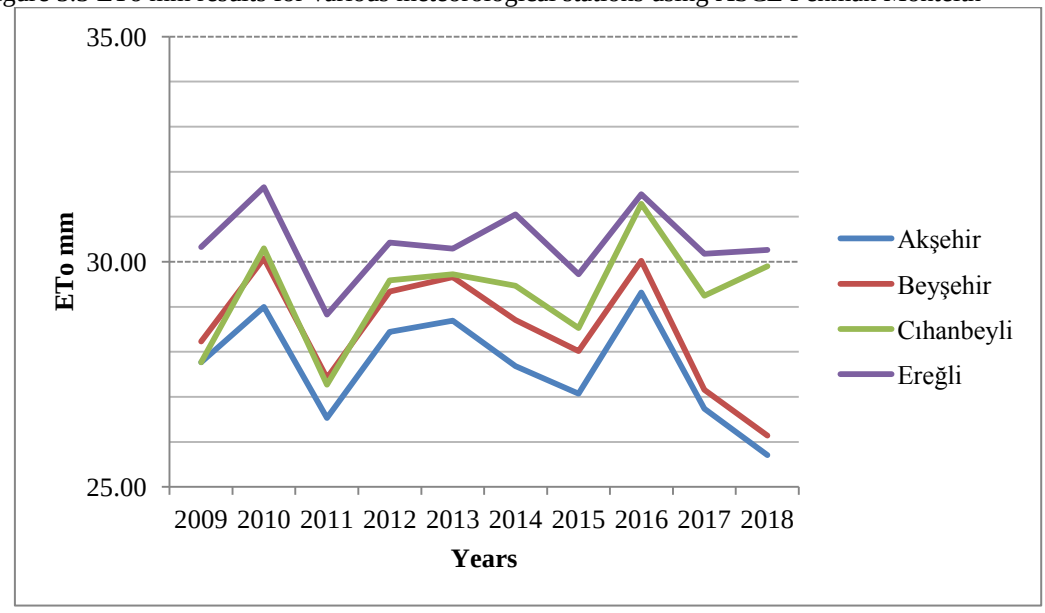
Akşehir station recorded the least ETo values in most of the years whereas Cihanbeyli recorded maximum ETo for most years when the FAO 56 Penman-Monteith equation was used for the estimation. It was observed that changes in most input parameters over the years had an effect on the model. The FAO 56 Penman-Monteith equation uses standard climate data (Allen et al., 1998) which were available in all the stations. According to the results, the year 2016 shows a higher change in ETo values from 2015 suggesting that most there was an increase or decrease of the parameters. Lum et al., (2017) estimated reference evapotranspiration from climatic data and according to their observation, the variations of some input parameters influenced the performances of the models.

Figure 5.2 ETo mm results for various meteorological stations using FAO 56 Penman Monteith



The ETo results estimated with the ASCE Penman-Monteith equation was the least in all stations. In Akşehir the annual minimum ETo within the period 2012 and 2018 was 25.71 mm and the annual maximum ETo was 29.32 mm, in Beyşehir the minimum was 26.14 mm and a maximum value of 30.30 mm, minimum ETo in Cihanbeyli was 27.27 mm and a maximum of 31.50 mm, and in Eregli the minimum was 28.83 mm and the maximum was 31.66 mm.

Figure 5.3 ETo mm results for various meteorological stations using ASCE Penman Monteith



Parameters considered in Hargreaves Samani equation are minimum relative humidity, wind speed and sunshine (Doorenbos and Pruitt, 1977) and data were

available for the 10 year period in all stations. The Hargreaves Samani method recorded higher ETo values than ASCE Penman-Monteith and the FAO 56 Penman-Monteith in most of the meteorological stations. The FAO 24 Blaney-Criddle method results were computed from 2012 to 2018 because meteorological data for all the stations were not available. With the FAO 24 Blaney-Criddle a minimum of -0.35 mm ETo values were estimated in Beyşehir in January 2017 and maximum ETo values of 9 mm in Eregli in July 2017. The total ETo values computed for Akşehir, Beyşehir, Cihanbeyli, and Eregli for the 10 year period are represented in table 5.1 below.

Table 5.1 Annual ETo mm values calculated with FAO 24 Blaney-Criddle

	2012	2013	2014	2015	2016	2017	2018
Akşehir	42.03	42.86	40.63	37.96	44.32	37.18	37.58
Beyşehir	42.42	43.47	41.15	39.85	44.43	38.61	37.82
Cihanbeyli	44.29	44.36	44.54	42.53	47.99	43.67	46.73
Eregli	45.00	45.49	47.83	43.91	49.38	46.46	47.79

Another consideration for this study was to measure whether there were significant differences between the methods in each meteorological station. Descriptive statistics of ETo calculated with the FAO 56 Penman-Monteith, ASCE Penman-monteith, Radiation, Hargreaves-Samani, and Blaney-Criddle were computed with SPSS Statistical software. The differences between ETo mean of the various methods and stations from 2009 to 2018 were tested statistically using paired t-test at 95% confidence interval with the FAO 56 Penman-Monteith as a benchmark model according to Allen et al., (1998) and the results show statistically significant differences between most of the ETo means from 2009 to 2018.

When calculating ETc the characteristics and effects of evaporation of the crop are one of the factors considered (Allen et al., 1998). The crop characteristics measured by the Kc coefficient were determined graphically as stated by Allen et al., (1998) for dry bean, maize, sunflower, sugarbeet, and wheat in Akşehir, Beyşehir, Cihanbeyli, and Eregli. The Kc_{ini}, Kc_{mid}, and Kc_{end} were represented in the crop coefficient curves. The planting and harvesting period for drybean, maize, sugarbeet, sunflower, wheat were 4 months, 6 months, 7 months, 6 months, 9 months respectively. The Kc_{ini}, Kc_{mid}, and Kc_{end} of drybean, maize, sunflower, sugarbeet, and wheat for Akşehir, Beyşehir, Cihanbeyli, and Eregli has been represented in Table 5.2 below.

Table 5.2 Kc coefficient for selected crops

	Kc	Akşehir	Beyşehir	Cihanbeyli	Ereğli
Drybean	Kc_{ini}	0.24	0.25	0.16	0.21
	Kc_{mid}	1.06	1.05	1.10	1.07
	Kc_{end}	0.92	0.36	0.39	0.36
Maize	Kc_{ini}	0.28	0.27	0.18	0.23
	Kc_{mid}	1.17	1.21	1.23	1.18
	Kc_{end}	1.06	1.07	1.11	1.07
Sunflower	Kc_{ini}	0.36	0.34	0.20	0.29
	Kc_{mid}	1.07	1.06	1.12	1.08
	Kc_{end}	0.36	0.36	0.42	0.37
Sugarbeet	Kc_{ini}	0.44	0.45	0.30	0.26
	Kc_{mid}	1.20	1.21	1.25	1.22
	Kc_{end}	0.70	0.71	0.74	0.71
Wheat	Kc_{ini}	0.78	0.80	0.64	0.62
	Kc_{mid}	1.16	1.18	1.18	1.16
	Kc_{end}	0.26	0.26	0.30	0.27

The ETc of drybean, maize, sunflower, sugarbeet, and wheat was calculated using the respective Kc coefficients and ETo in the function ETc = Kc × ETo for the four meteorological stations considered. ETc results show a linear relationship with ETo that is the higher the ETo, the higher the ETc in most cases, similar with Farias et al, (2017) conclusion on the relationship between ETc and ETo. Since the changes in the parameters used in estimating ETo have been observed to have an effect on ETo, it can be deduced that changes in the climatic parameters can influence ETc.

The water requirement of drybean calculated using the FAO Penman-Monteith method in Akşehir ranges from 406 mm to 477 mm, in Beyşehir it ranges from 451 mm to 542 mm, in Cihanbeyli 554 mm to 638 mm, and lastly, Ereğli ranges from 513 mm to 554 mm as shown in figüre 5.4. The water requirement of drybean calculated using the Radiation equation in Akşehir ranges from 501 mm to 679 mm, in Beyşehir it ranges from 544 mm to 727 mm/month, in Cihanbeyli 679 mm to 738 mm, and Ereğli ranges from 725 mm to 767 mm as shown in figure 5.5.

Figure 5.4 ETc of Drybean mm for various meteorological station using FAO Penman-Monteith

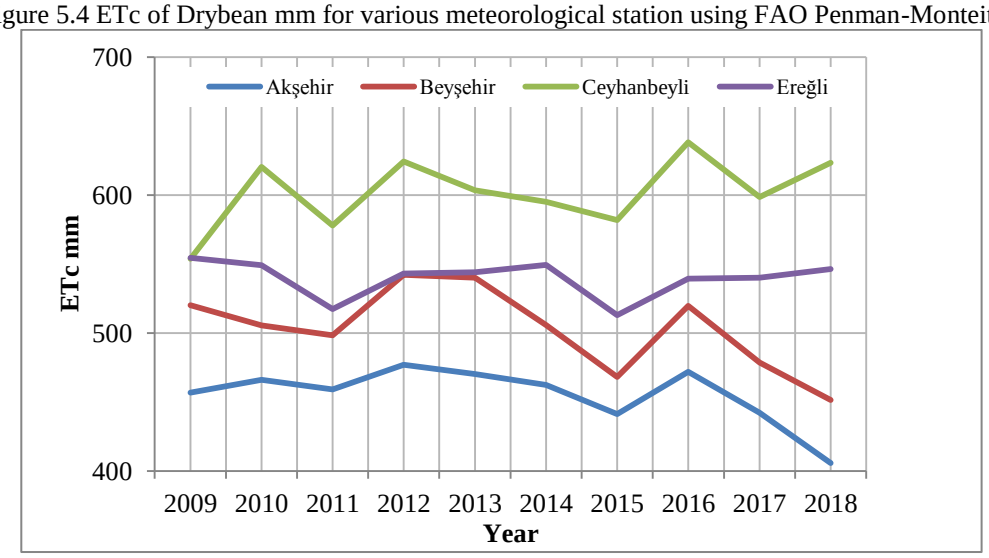
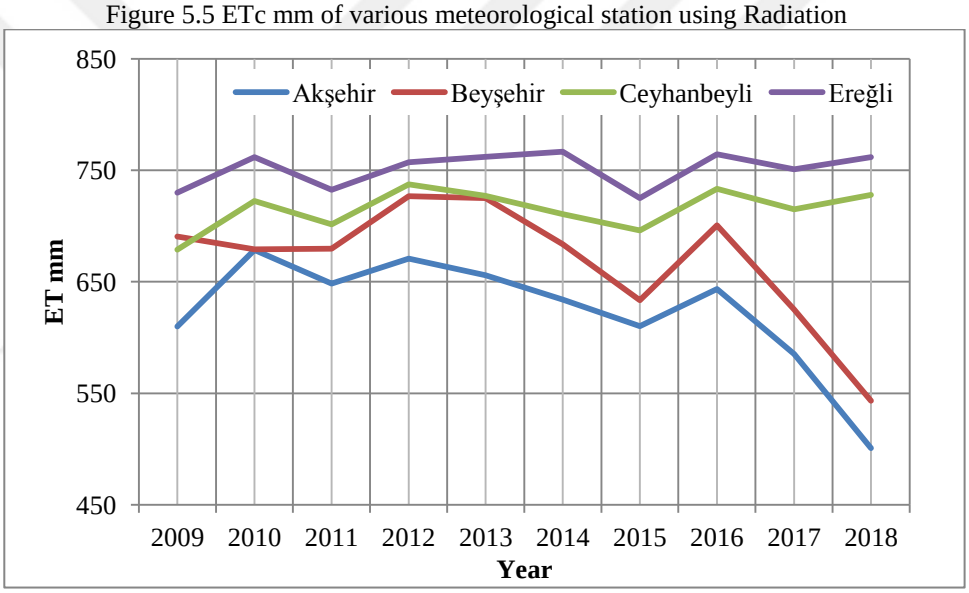


Figure 5.5 ETc mm of various meteorological station using Radiation



It was also observed that the ETc calculated according to the Radiation equation was higher at most of the stations than the other equations. The ASCE Penman-Monteith recorded the least ETc in all the meteorological station for the 10 year period. The Blaney Criddle formula which depends largely on the minimum and maximum relative humidity yielded higher ETc values than the FAO 56 Penman-Monteith, Hargreaves Samani and FAO Blaney Criddle methods in most of the locations.

5.2. Recommendations

The FAO 56 Penman-Monteith equation is a standard equation to determine the water needs of a plant in various climates around the world. In this study the FAO 56

Penman-Monteith method produced an average level of ET in most areas and therefore can be recommended for ET calculation in the region. The radiation method recorded higher values in most of the meteorological stations, however, this method requires further comparison with other emperical methods in order to ascertain its suitability for the calculation of ETc in the region. The Hargreaves Samani equations the FAO 56 Penman-Monteith method were close in most cases inferring that both methods can be used in similar climate conditions. The FAO Blaney Criddle can also be recommended for areas where data on minimum relative humidity are readily available.

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APPENDICES

Appendix I Statistical Analysis of ETo mm/day

A. Descriptive statistics of ETo in Akşehir Meteorological station using FAO 56 Penman-Monteith method

Year	N	Range	Minimum	Maximum	Sum	Mean	Mean Std, Error	Std. Deviation	Variance
2009	12	4.6900	0.9100	5.6000	35.0600	2.9217	0.5114	1.7716	3.1385
2010	12	5.0200	0.5600	5.5800	33.1000	2.7583	0.5226	1.8104	3.2774
2011	12	5.1300	0.6800	5.8100	32.0800	2.6733	0.5193	1.7988	3.2359
2012	12	5.4000	0.5500	5.9500	35.4300	2.9525	0.5671	1.9644	3.8587
2013	12	4.9500	0.6200	5.5700	36.6200	3.0517	0.5342	1.8506	3.4246
2014	12	5.0500	0.6500	5.7000	34.5900	2.8825	0.5187	1.7967	3.2282
2015	12	4.8000	0.6400	5.4400	33.1000	2.7583	0.4837	1.6757	2.8081
2016	12	5.2000	0.6300	5.8300	37.5100	3.1258	0.5168	1.7903	3.2051
2017	12	5.1700	0.5700	5.7400	33.9400	2.8283	0.4780	1.6557	2.7413
2018	12	5.3900	0.0000	5.3900	32.3000	2.6917	0.5150	1.7841	3.1831

B. Descriptive statistics of Beyşehir Meteorological station using FAO 56 Penman-Monteith method

Year	N	Range	Minimum	Maximum	Sum	Mean	Standard Error	Std. Deviation	Variance
2009	12	5.4000	0.8700	6.2700	37.3400	3.1117	0.5880	2.0370	4.1493
2010	12	5.4000	0.9000	6.3000	39.2900	3.2742	0.5608	1.9426	3.7737
2011	12	5.8100	0.7500	6.5600	35.5100	2.9592	0.5882	2.0376	4.1520
2012	12	6.2800	0.6300	6.9100	38.4200	3.2017	0.6492	2.2490	5.0580
2013	12	5.7600	0.6700	6.4300	39.6700	3.3058	0.6182	2.1415	4.5862
2014	12	5.8200	0.5500	6.3700	37.0400	3.0867	0.5817	2.0150	4.0600
2015	12	5.2300	0.7500	5.9800	36.2000	3.0167	0.5396	1.8693	3.4941
2016	12	5.7800	0.6500	6.4300	39.5700	3.2975	0.5720	1.9813	3.9257
2017	12	5.9400	0.5100	6.4500	35.5000	2.9583	0.5658	1.9601	3.8421
2018	12	5.2400	0.8200	6.0600	37.0000	3.0833	0.4839	1.6764	2.8102

C. Descriptive statistics of Cihanbeyli Meteorological station using FAO 56 Penman-Monteith method

	N	Range	Minimum	Maximum	Sum	Mean	Mean Std. Error	Std. Deviation	Variance
2009	12	5.8200	0.6100	6.4300	39.4900	3.2908	0.6084	2.1074	4.4412
2010	12	6.3600	0.6900	7.0500	44.4000	3.7000	0.6528	2.2615	5.1145
2011	12	6.4300	0.6000	7.0300	38.4400	3.2033	0.6266	2.1705	4.7111
2012	12	7.1100	0.5900	7.7000	43.1800	3.5983	0.7077	2.4517	6.0108
2013	12	6.3300	0.6600	6.9900	42.8100	3.5675	0.6669	2.3102	5.3371
2014	12	6.5900	0.5800	7.1700	42.4300	3.5358	0.6282	2.1763	4.7362
2015	12	6.4600	0.6100	7.0700	40.5800	3.3817	0.6185	2.1426	4.5908
2016	12	6.6900	0.7800	7.4700	46.6000	3.8833	0.6667	2.3094	5.3334
2017	12	6.6300	0.4700	7.1000	41.2900	3.4408	0.6404	2.2183	4.9209
2018	10	6.5700	0.6800	7.2500	41.9200	4.1920	0.7197	2.2759	5.1799

D. Descriptive statistics of Ereğli Meteorological station using FAO 56 Penman-Monteith method

	N	Range	Minimum	Maximum	Sum	Mean	Mean Std. Error	Std. Deviation	Variance
2009	12	5.6600	0.8700	6.5300	40.5000	3.3750	0.6302	2.1830	4.7654
2010	12	5.5500	0.9000	6.4500	39.9400	3.3283	0.5947	2.0603	4.2447
2011	12	5.5800	0.7100	6.2900	35.4200	2.9517	0.5878	2.0363	4.1465
2012	12	5.8700	0.7200	6.5900	38.2200	3.1850	0.6426	2.2259	4.9545
2013	12	5.9400	0.5700	6.5100	38.4500	3.2042	0.6275	2.1738	4.7255
2014	12	3.6200	0.6900	4.3100	30.2700	2.5225	0.3875	1.3423	1.8019
2015	12	5.4800	0.6100	6.0900	36.5500	3.0458	0.5697	1.9736	3.8950
2016	12	5.9200	0.6200	6.5400	40.3200	3.3600	0.6055	2.0974	4.3993
2017	12	6.1900	0.6000	6.7900	38.5000	3.2083	0.6089	2.1092	4.4486
2018	10	5.8600	0.6500	6.5100	38.2800	3.8280	0.6279	1.9855	3.9423

E. Descriptive statistics of Akşehir Meteorological station using ASCE Penman-Monteith method

	N	Range	Minimum	Maximum	Sum	Mean	Mean Std. Error	Std. Deviation	Variance
2009	12	3.9300	0.6000	4.5300	27.7700	2.3142	0.4305	1.4914	2.2244
2010	12	4.4500	0.4700	4.9200	29.0000	2.4167	0.4653	1.6117	2.5977
2011	12	4.2300	0.5600	4.7900	26.5300	2.2108	0.4350	1.5069	2.2706
2012	12	4.3900	0.4600	4.8500	28.4400	2.3700	0.4645	1.6090	2.5887
2013	12	3.9100	0.4900	4.4000	28.6900	2.3908	0.4381	1.5175	2.3029
2014	12	4.1600	0.4800	4.6400	27.6800	2.3067	0.4271	1.4795	2.1888
2015	12	3.9900	0.5100	4.5000	27.0700	2.2558	0.4152	1.4383	2.0688
2016	12	4.2000	0.4800	4.6800	29.3200	2.4433	0.4348	1.5062	2.2687
2017	12	4.2600	0.4100	4.6700	26.7400	2.2283	0.4101	1.4205	2.0179
2018	12	4.4100	0.0000	4.4100	25.7100	2.1425	0.4294	1.4875	2.2128

F. Descriptive statistics of Beyşehir Meteorological station using ASCE Penman-Monteith method

	N	Range	Minimum	Maximum	Sum	Mean	Mean Std. Error	Std. Deviation	Variance
2009	12	4.1000	0.5900	4.6900	28.2300	2.3525	0.4485	1.5538	2.4143
2010	12	4.3700	0.6100	4.9800	30.0800	2.5067	0.4544	1.5741	2.4777
2011	12	4.5300	0.5300	5.0600	27.4200	2.2850	0.4572	1.5837	2.5080
2012	12	4.6800	0.4700	5.1500	29.3400	2.4450	0.4918	1.7037	2.9024
2013	12	4.3000	0.4900	4.7900	29.6600	2.4717	0.4704	1.6295	2.6553
2014	12	4.4700	0.4500	4.9200	28.7100	2.3925	0.4552	1.5767	2.4860
2015	12	4.1600	0.5200	4.6800	28.0200	2.3350	0.4378	1.5166	2.2999
2016	12	4.4600	0.4700	4.9300	30.0200	2.5017	0.4594	1.5915	2.5330
2017	12	4.4700	0.3900	4.8600	27.1600	2.2633	0.4387	1.5199	2.3100
2018	10	4.0700	0.5500	4.6200	26.1400	2.6140	0.4045	1.2790	1.6358

G. Descriptive statistics of Cıhanbeyli Meteorological station using ASCE Penman-Monteith method

	N	Range	Minimum	Maximum	Sum	Mean	Mean Std. Error	Std. Deviation	Variance
2009	12	4.2900	0.4300	4.7200	27.7700	2.3142	0.4698	1.6276	2.6490
2010	12	4.6400	0.4900	5.1300	30.3000	2.5250	0.4942	1.7121	2.9313
2011	12	4.6300	0.4700	5.1000	27.2700	2.2725	0.4754	1.6467	2.7118
2012	12	4.9200	0.4300	5.3500	29.5900	2.4658	0.5183	1.7955	3.2239

2013	12	4.4700	0.4500	4.9200	29.7200	2.4767	0.4947	1.7136	2.9363
2014	12	4.6900	0.4200	5.1100	29.4700	2.4558	0.4813	1.6671	2.7792
2015	12	4.5400	0.4500	4.9900	28.5300	2.3775	0.4681	1.6215	2.6291
2016	12	4.8700	0.4000	5.2700	31.2900	2.6075	0.5073	1.7574	3.0885
2017	12	4.8200	0.3300	5.1500	29.2500	2.4375	0.4943	1.7123	2.9319
2018	12	5.1200	0.0000	5.1200	29.9000	2.4917	0.5404	1.8719	3.5041

H. Descriptive statistics of Cıhanbeyli Meteorological station using ASCE Penman-Monteith method

	N	Range	Minimum	Maximum	Sum	Mean	Mean Std. Error	Std. Deviation	Variance
2009	12	4.3100	0.5700	4.8800	30.3300	2.5275	0.4845	1.6785	2.8174
2010	12	4.5900	0.6400	5.2300	31.6600	2.6383	0.4895	1.6958	2.8757
2011	12	4.5400	0.5500	5.0900	28.8300	2.4025	0.4823	1.6709	2.7917
2012	12	4.6600	0.5500	5.2100	30.4300	2.5358	0.5065	1.7545	3.0782
2013	12	4.5900	0.4700	5.0600	30.2900	2.5242	0.4935	1.7096	2.9228
2014	12	2.3700	0.5100	2.8800	21.5300	1.7942	0.2557	0.8857	0.7844
2015	12	4.3800	0.5100	4.8900	29.7200	2.4767	0.4701	1.6285	2.6520
2016	12	4.6700	0.4700	5.1400	31.5000	2.6250	0.4899	1.6971	2.8803
2017	12	4.7700	0.4400	5.2100	30.1800	2.5150	0.4862	1.6844	2.8372
2018	12	5.1400	0.0000	5.1400	30.2600	2.5217	0.5406	1.8729	3.5076

İ. Descriptive statistics of Akşehir Meteorological station using Radiation method

	N	Range	Minimum	Maximum	Sum	Mean	Mean Std. error	Std. Deviation	Variance
2009	12	6.5100	0.9700	7.4800	47.0700	3.9225	0.7100	2.4597	6.0499
2010	12	7.0800	1.0800	8.1600	50.9600	4.2467	0.7383	2.5576	6.5412
2011	12	7.3600	0.9100	8.2700	45.3900	3.7825	0.7247	2.5103	6.3016
2012	12	7.5600	0.7200	8.2800	49.8500	4.1542	0.8025	2.7800	7.7283
2013	12	6.8000	0.9000	7.7000	51.3400	4.2783	0.7433	2.5749	6.6300
2014	12	7.4100	0.6800	8.0900	47.6000	3.9667	0.7270	2.5184	6.3424
2015	12	7.0800	0.6100	7.6900	45.3000	3.7750	0.6900	2.3904	5.7140
2016	12	7.2200	0.7700	7.9900	51.3500	4.2792	0.7104	2.4610	6.0567
2017	12	7.0700	0.8000	7.8700	44.6700	3.7225	0.6465	2.2397	5.0160
2018	12	7.2900	0.0000	7.2900	41.8900	3.4908	0.6893	2.3879	5.7020

J. Descriptive statistics of Beyşehir Meteorological station using Radiation method

	N	Range	Minimum	Maximum	Sum	Mean	Mean Std. error	Std. Deviation	Variance
2009	12	7.0500	1.0600	8.1100	50.4900	4.2075	0.7806	2.7042	7.3129
2010	12	7.5200	1.0300	8.5500	52.7400	4.3950	0.7572	2.6230	6.8802
2011	12	7.8100	1.1500	8.9600	49.0100	4.0842	0.7748	2.6838	7.2030
2012	12	8.1900	0.8600	9.0500	53.1000	4.4250	0.8570	2.9687	8.8130
2013	12	7.5300	1.0100	8.5400	54.4000	4.5333	0.8146	2.8219	7.9631
2014	12	8.0200	0.6700	8.6900	50.4600	4.2050	0.7805	2.7036	7.3096
2015	12	7.5700	0.6100	8.1800	48.8300	4.0692	0.7361	2.5500	6.5024
2016	12	7.8000	0.8600	8.6600	54.0100	4.5008	0.7648	2.6493	7.0189
2017	12	7.7200	0.7800	8.5000	46.8800	3.9067	0.7126	2.4686	6.0938
2018	10	6.6700	1.1400	7.8100	43.6100	4.3610	0.6533	2.0659	4.2680

K. Descriptive statistics of Cihanbeyli Meteorological station using Radiation method

	N	Range	Minimum	Maximum	Sum	Mean	Mean Std. error	Std. Deviation	Variance
2009	12	7.0600	0.8000	7.8600	48.0200	4.0017	0.7821	2.7092	7.3399
2010	12	7.6300	0.9400	8.5700	51.2700	4.2725	0.7996	2.7699	7.6723
2011	12	7.7200	0.8800	8.6000	46.9100	3.9092	0.7759	2.6878	7.2242
2012	12	8.1600	0.7900	8.9500	51.2300	4.2692	0.8705	3.0156	9.0938
2013	12	7.5800	0.8500	8.4300	52.0800	4.3400	0.8309	2.8784	8.2852
2014	12	7.7900	0.9200	8.7100	50.9500	4.2458	0.7914	2.7415	7.5159
2015	12	7.8000	0.8100	8.6100	49.0800	4.0900	0.7757	2.6872	7.2211
2016	12	8.0600	0.7400	8.8000	53.5600	4.4633	0.8073	2.7964	7.8200
2017	12	7.9700	0.7400	8.7100	50.2300	4.1858	0.7880	2.7298	7.4519
2018	12	8.6000	0.0000	8.6000	51.6100	4.3008	0.9010	3.1213	9.7424

L. Descriptive statistics of Ereğli Meteorological station using Radiation method

	N	Range	Minimum	Maximum	Sum	Mean	Mean Std. error	Std. Deviation	Variance
2009	12	7.6100	1.1100	8.7200	54.1200	4.5100	0.8453	2.9282	8.5744
2010	12	7.8400	1.2300	9.0700	55.5700	4.6308	0.8397	2.9089	8.4619
2011	12	7.7800	1.0600	8.8400	50.5600	4.2133	0.8213	2.8452	8.0949
2012	12	8.1700	0.9300	9.1000	53.7800	4.4817	0.8976	3.1093	9.6677
2013	12	8.3000	0.7500	9.0500	54.1600	4.5133	0.8797	3.0475	9.2875
2014	12	3.9500	1.1500	5.1000	29.8800	2.4900	0.3351	1.1609	1.3477
2015	12	7.8000	0.8600	8.6600	51.8700	4.3225	0.8076	2.7975	7.8260
2016	12	8.4200	0.8200	9.2400	57.5200	4.7933	0.8484	2.9389	8.6372
2017	12	8.4700	0.9500	9.4200	54.5600	4.5467	0.8335	2.8874	8.3369
2018	12	9.0700	0.0000	9.0700	53.2900	4.4408	0.9432	3.2674	10.6760

M. Descriptive statistics of Akşehir Meteorological station using Hargreaves-Samani method

	N	Range	Minimum	Maximum	Sum	Mean	Mean Std. error	Std. Deviation	Variance
2009	12	4.8200	0.9000	5.7200	36.3300	3.0275	0.5326	1.8448	3.4034
2010	12	5.4400	0.9400	6.3800	40.1800	3.3483	0.5688	1.9703	3.8822
2011	12	5.3300	0.8000	6.1300	35.9900	2.9992	0.5528	1.9151	3.6675
2012	12	5.7000	0.6600	6.3600	38.1300	3.1775	0.5974	2.0696	4.2833
2013	12	5.1200	0.6500	5.7700	38.1000	3.1750	0.5535	1.9175	3.6769
2014	12	5.3600	0.8800	6.2400	37.9100	3.1592	0.5562	1.9269	3.7128
2015	12	5.1300	0.7500	5.8800	36.7600	3.0633	0.5350	1.8533	3.4349
2016	12	5.6300	0.6400	6.2700	39.8500	3.3208	0.5673	1.9650	3.8613
2017	12	5.6300	0.6600	6.2900	38.2200	3.1850	0.5602	1.9406	3.7659
2018	12	6.1700	0.0000	6.1700	38.5400	3.2117	0.6429	2.2270	4.9597

N. Descriptive statistics of Beyşehir Meteorological station using Hargreaves-Samani method

	N	Range	Minimum	Maximum	Sum	Mean	Mean Std. error	Std. Deviation	Variance
2009	12	4.8900	0.9200	5.8100	37.2800	3.1067	0.5481	1.8988	3.6055
2010	12	5.2000	0.9700	6.1700	40.0100	3.3342	0.5546	1.9213	3.6914
2011	12	5.2600	0.8600	6.1200	36.1800	3.0150	0.5507	1.9077	3.6393
2012	12	5.4500	0.6800	6.1300	37.7300	3.1442	0.5779	2.0019	4.0078
2013	12	5.0600	0.7100	5.7700	38.2500	3.1875	0.5524	1.9135	3.6614
2014	12	5.1200	0.8600	5.9800	37.8600	3.1550	0.5359	1.8562	3.4456
2015	12	5.1400	0.8400	5.9800	37.4800	3.1233	0.5433	1.8821	3.5422

2016	12	5.3900	0.6600	6.0500	39.4300	3.2858	0.5545	1.9209	3.6898
2017	12	5.5700	0.6300	6.2000	37.7100	3.1425	0.5631	1.9506	3.8049
2018	12	5.9100	0.0000	5.9100	37.6000	3.1333	0.6241	2.1620	4.6741

O. Descriptive statistics of Cihanbeyli Meteorological station using Hargreaves-Samani method

	N	Range	Minimum	Maximum	Sum	Mean	Mean Std. error	Std. Deviation	Variance
2009	12	5.3500	0.8600	6.2100	39.0700	3.2558	0.5863	2.0310	4.1250
2010	12	5.8500	0.9100	6.7600	42.8000	3.5667	0.6330	2.1929	4.8087
2011	12	5.8500	0.8100	6.6600	38.4300	3.2025	0.6019	2.0851	4.3477
2012	12	6.1500	0.6900	6.8400	40.6400	3.3867	0.6540	2.2656	5.1328
2013	12	5.6400	0.6300	6.2700	40.5800	3.3817	0.6111	2.1169	4.4813
2014	12	5.7400	0.9000	6.6400	40.3400	3.3617	0.5947	2.0603	4.2447
2015	12	5.7200	0.6600	6.3800	38.8300	3.2358	0.5951	2.0613	4.2491
2016	12	6.0400	0.6100	6.6500	42.5100	3.5425	0.6224	2.1562	4.6492
2017	12	6.1500	0.6000	6.7500	40.4600	3.3717	0.6252	2.1658	4.6905
2018	12	6.4800	0.0000	6.4800	39.7800	3.3150	0.6754	2.3398	5.4748

P. Descriptive statistics of Ereğli Meteorological station using Hargreaves-Samani method

	N	Range	Minimum	Maximum	Sum	Mean	Mean Std. error	Std. Deviation	Variance
2009	12	5.2300	1.0300	6.2600	40.6000	3.3833	0.5722	1.9820	3.9284
2010	12	5.5800	1.1400	6.7200	43.8700	3.6558	0.5969	2.0677	4.2753
2011	12	5.6100	0.9100	6.5200	38.9600	3.2467	0.5828	2.0187	4.0752
2012	12	5.8100	0.8700	6.6800	41.2200	3.4350	0.6334	2.1942	4.8144
2013	12	5.6000	0.6700	6.2700	40.9800	3.4150	0.5875	2.0351	4.1417
2014	12	5.5200	1.0800	6.6000	41.9400	3.4950	0.5840	2.0232	4.0932
2015	12	5.7200	0.7500	6.4700	40.5500	3.3792	0.5896	2.0423	4.1709
2016	12	5.7600	0.7000	6.4600	42.4700	3.5392	0.5899	2.0433	4.1752
2017	12	5.9700	0.7600	6.7300	41.4300	3.4525	0.6010	2.0818	4.3340
2018	12	6.4200	0.0000	6.4200	40.5400	3.3783	0.6742	2.3355	5.4546

Q. Descriptive statistics of Akşehir Meteorological station using Blaney-Cıddle method

	N	Range	Minimum	Maximum	Sum	Mean	Mean Std. error	Std. Deviation	Variance
2012	12	8.2200	-0.2000	8.0200	41.6300	3.4692	0.8506	2.9466	8.6823
2013	12	7.1800	-0.0700	7.1100	42.8600	3.5717	0.7603	2.6339	6.9373
2014	12	7.4400	0.3800	7.8200	40.6300	3.3858	0.7457	2.5831	6.6722
2015	12	7.0900	0.0900	7.1800	37.9600	3.1633	0.7184	2.4886	6.1931
2016	12	7.7400	-0.0600	7.6800	44.2000	3.6833	0.7468	2.5868	6.6918
2017	12	7.8400	-0.1700	7.6700	37.8400	3.1533	0.6961	2.4113	5.8142
2018	12	6.7000	0.0000	6.7000	37.5800	3.1317	0.6375	2.2085	4.8775

R. Descriptive statistics of Beyşehir Meteorological station using Blaney-Cıddle method

	N	Range	Minimum	Maximum	Sum	Mean	Mean Std. error	Std. Deviation	Variance
2012	12	8.4700	-0.0900	8.3800	42.2400	3.5200	0.8740	3.0277	9.1670
2013	12	7.6900	-0.0600	7.6300	43.4700	3.6225	0.8083	2.8002	7.8409
2014	12	7.8300	0.2000	8.0300	41.1500	3.4292	0.7769	2.6913	7.2431
2015	12	7.3700	0.0300	7.4000	39.8500	3.3208	0.7513	2.6025	6.7729
2016	12	8.0400	-0.0700	7.9700	44.2900	3.6908	0.7832	2.7132	7.3616
2017	12	8.1800	-0.3500	7.8300	37.9100	3.1592	0.7490	2.5946	6.7317

2018	12	7.1700	0.0000	7.1700	37.8200	3.1517	0.6698	2.3204	5.3841

S. Descriptive statistics of Cihanbeyli Meteorological station using Blaney-Crıddle method

	N	Range	Minimum	Maximum	Sum	Mean	Mean Std. error	Std. Deviation	Variance
2012	12	8.9700	-0.1300	8.8400	44.0300	3.6692	0.9369	3.2455	10.5336
2013	12	8.0800	-0.1400	7.9400	44.3600	3.6967	0.8645	2.9949	8.9693
2014	12	8.2300	0.2500	8.4800	44.5400	3.7117	0.8308	2.8781	8.2833
2015	12	8.3900	-0.0700	8.3200	42.3900	3.5325	0.8383	2.9038	8.4321
2016	12	8.7200	-0.1300	8.5900	47.7300	3.9775	0.8688	3.0095	9.0573
2017	12	8.8200	-0.3000	8.5200	43.0700	3.5892	0.8397	2.9088	8.4608
2018	12	8.3900	0.0000	8.3900	46.7300	3.8942	0.8614	2.9838	8.9031

T. Descriptive statistics of Ereğli Meteorological station using Blaney-Crıddle method

	N	Range	Minimum	Maximum	Sum	Mean	Mean Std. error	Std. Deviation	Variance
2012	12	8.4800	0.1500	8.6300	45.0000	3.7500	0.9219	3.1936	10.1990
2013	12	8.5000	-0.2300	8.2700	45.0300	3.7525	0.8763	3.0355	9.2143
2014	12	3.5800	0.5900	4.1700	28.1400	2.3450	0.3892	1.3482	1.8178
2015	12	8.1000	-0.0200	8.0800	43.8700	3.6558	0.8429	2.9200	8.5263
2016	12	8.7200	-0.0900	8.6300	49.2000	4.1000	0.8692	3.0109	9.0653
2017	12	9.1000	-0.1000	9.0000	46.2600	3.8550	0.8650	2.9966	8.9796
2018	12	8.5900	0.0000	8.5900	47.7900	3.9825	0.8941	3.0971	9.5922

U. Paired T-Test results of Akşehir Meteorological station

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
Year	Methods	Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
2009	ASCE P-M	0.6075	0.2924	0.0844	0.4217	0.7933	7.1970	11	0.0000
	RAD.	-1.0008	0.7100	0.2050	-1.4519	-0.5497	-4.8830	11	0.0000
	HA-SA	-0.1058	0.1525	0.0440	-0.2027	-0.0090	-2.4050	11	0.0350
2010	ASCE P-M	0.3417	0.2285	0.0660	0.1965	0.4869	5.1800	11	0.0000
	RAD.	-1.4883	0.7737	0.2233	-1.9799	-0.9968	-6.6640	11	0.0000
	HA-SA	-0.5900	0.2675	0.0772	-0.7600	-0.4201	-7.6410	11	0.0000
2011	ASCE P-M	0.4625	0.3057	0.0883	0.2682	0.6568	5.2400	11	0.0000
	RAD.	-1.1092	0.7190	0.2076	-1.5660	-0.6524	-5.3440	11	0.0000
	HA-SA	-0.3258	0.2538	0.0733	-0.4871	-0.1646	-4.4470	11	0.0010
2012	ASCE P-M	0.5825	0.3837	0.1108	0.3387	0.8263	5.2590	11	0.0000
	RAD.	-1.2017	0.8358	0.2413	-1.7327	-0.6706	-4.9800	11	0.0000
	HA-SA	-0.2250	0.2334	0.0674	-0.3733	-0.0767	-3.3390	11	0.0070
	BL-CR	-0.5167	1.0171	0.2936	-1.1629	0.1295	-1.7600	11	0.1060**
2013	ASCE P-M	0.6608	0.3438	0.0992	0.4424	0.8793	6.6590	11	0.000
	RAD.	-1.2267	0.7313	0.2111	-1.6913	-0.7620	-5.8100	11	0.000
	HA-SA	-0.1233	0.1680	0.0485	-0.2300	-0.0166	-2.5440	11	0.027
	BL-CR	-0.5200	0.8119	0.2344	-1.0359	-0.0041	-2.2190	11	0.048
2014	ASCE P-M	0.5758	0.3285	0.0948	0.3671	0.7845	6.0730	11	0.000
	RAD.	-1.0842	0.7508	0.2167	-1.5612	-0.6072	-5.0020	11	0.000
	HA-SA	-0.2767	0.1718	0.0496	-0.3858	-0.1675	-5.5800	11	0.000
	BL-CR	-0.5033	0.8173	0.2359	-1.0226	0.0159	-2.1330	11	0.056**
2015	ASCE P-M	0.5025	0.2638	0.0762	0.3349	0.6701	6.5980	11	0.000
	RAD.	-1.0167	0.7343	0.2120	-1.4832	-0.5501	-4.7960	11	0.001
	HA-SA	-0.3050	0.2749	0.0794	-0.4797	-0.1303	-3.8430	11	0.003
	BL-CR	-0.4050	0.8450	0.2439	-0.9419	0.1319	-1.6600	11	0.125**
2016	ASCE P-M	0.6825	0.2981	0.0861	0.4931	0.8719	7.9310	11	0.0000
	RAD.	-1.1533	0.6767	0.1953	-1.5833	-0.7234	-5.9040	11	0.0000
	HA-SA	-0.1950	0.1969	0.0568	-0.3201	-0.0699	-3.4310	11	0.0060
	BL-CR	-0.5575	0.8275	0.2389	-1.0833	-0.0317	-2.3340	11	0.0400

2017	ASCE P-M	0.6000	0.2577	0.0744	0.4363	0.7637	8.0660	11	0.0000
	RAD.	-0.8942	0.6102	0.1762	-1.2819	-0.5065	-5.0760	11	0.0000
	HA-SA	-0.3567	0.3264	0.0942	-0.5641	-0.1493	-3.7850	11	0.0030
	BL-CR	-0.3250	0.7750	0.2237	-0.8174	0.1674	-1.4530	11	0.1740**
2018	ASCE P-M	0.5492	0.3341	0.0964	0.3369	0.7614	5.6950	11	0.0000
	RAD.	-0.7992	0.7124	0.2056	-1.2518	-0.3466	-3.8860	11	0.0030
	HA-SA	-0.5200	0.6162	0.1779	-0.9115	-0.1285	-2.9240	11	0.0140
	BL-CR	-0.4400	0.4958	0.1431	-0.7550	-0.1250	-3.0740	11	0.0110

V. Paired T-Test results of Beyşehir Meteorological station

		Paired Differences							
				95% Confidence Interval of the Difference					
Year	Methods	Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	Df	Sig. (2-tailed)
2009	ASCE P-M	0.7592	0.4898	0.1414	0.4480	1.0703	5.3700	11	0.000
	RAD.	-1.0958	0.6998	0.2020	-1.5405	-0.6512	-5.4250	11	0.000
	HA-SA	**0.0050**	**0.2229**	**0.0643**	**-0.1366**	**0.1466**	**0.0780**	**11**	**0.939****
2010	ASCE P-M	0.7675	0.3907	0.1128	0.5192	1.0158	6.8040	11	0.000
	RAD.	-1.1208	0.7141	0.2061	-1.5745	-0.6672	-5.4380	11	0.000
	HA-SA	**-0.0600**	**0.2320**	**0.0670**	**-0.2074**	**0.0874**	**-0.8960**	**11**	**0.390****
2011	ASCE P-M	0.6742	0.4722	0.1363	0.3741	0.9742	4.9450	11	0.000
	RAD.	-1.1250	0.6670	0.1925	-1.5488	-0.7012	-5.8430	11	0.000
	HA-SA	**-0.0558**	**0.3581**	**0.1034**	**-0.2834**	**0.1717**	**-0.5400**	**11**	**0.600****
2012	ASCE P-M	0.7567	0.5634	0.1627	0.3987	1.1147	4.6520	11	0.001
	RAD.	-1.2233	0.7620	0.2200	-1.7075	-0.7392	-5.5620	11	0.000
	HA-SA	**0.0575**	**0.3755**	**0.1084**	**-0.1811**	**0.2961**	**0.5300**	**11**	**0.606****
	BL-CR	**-0.3183**	**0.8080**	**0.2332**	**-0.8317**	**0.1950**	**-1.3650**	**11**	**0.200****
2013	ASCE P-M	0.8342	0.5239	0.1512	0.5013	1.1670	5.5160	11	0.0000
	RAD.	-1.2275	0.6952	0.2007	-1.6692	-0.7858	-6.1160	11	0.0000
	HA-SA	**0.1183**	**0.3906**	**0.1128**	**-0.1299**	**0.3665**	**1.0490**	**11**	**0.3170****
	BL-CR	**-0.3167**	**0.6712**	**0.1938**	**-0.7431**	**0.1098**	**-1.6340**	**11**	**0.1300****
2014	ASCE P-M	0.6942	0.4494	0.1297	0.4086	0.9797	5.3510	11	0.0000
	RAD.	-1.1183	0.7408	0.2139	-1.5890	-0.6477	-5.2300	11	0.0000

	HA-SA	**-0.0683**	**0.2592**	**0.0748**	**-0.2330**	**0.0964**	**-0.9130**	**11**	**0.3810****
	BL-CR	**-0.3425**	**0.6896**	**0.1991**	**-0.7806**	**0.0956**	**-1.7210**	**11**	**0.1130****
2015	ASCE P-M	0.6817	0.3729	0.1077	0.4447	0.9186	6.3320	11	0.0000
	RAD.	-1.0525	0.7186	0.2074	-1.5091	-0.5959	-5.0740	11	0.0000
	HA-SA	**-0.1067**	**0.2478**	**0.0715**	**-0.2641**	**0.0508**	**-1.4910**	**11**	**0.1640****
	BL-CR	**-0.3042**	**0.7478**	**0.2159**	**-0.7793**	**0.1710**	**-1.4090**	**11**	**0.1860****
2016	ASCE P-M	0.7958	0.4037	0.1165	0.5393	1.0523	6.8290	11	0.0000
	RAD.	-1.2033	0.6937	0.2003	-1.6441	-0.7626	-6.0090	11	0.0000
	HA-SA	**0.0117**	**0.2510**	**0.0725**	**-0.1478**	**0.1712**	**0.1610**	**11**	**0.8750****
	BL-CR	**-0.3933**	**0.7434**	**0.2146**	**-0.8656**	**0.0790**	**-1.8330**	**11**	**0.0940****
2017	ASCE P-M	0.6950	0.4609	0.1330	0.4022	0.9878	5.2240	11	0.0000
	RAD.	-0.9483	0.5625	0.1624	-1.3057	-0.5910	-5.8400	11	0.0000
	HA-SA	-0.1842	0.2500	0.0722	-0.3430	-0.0254	-2.5520	11	0.0270
	BL-CR	**-0.2008**	**0.6736**	**0.1945**	**-0.6288**	**0.2272**	**-1.0330**	**11**	**0.3240****
2018	ASCE P-M	0.8150	0.3864	0.1222	0.5386	1.0914	6.6700	9	0.0000
	RAD.	-0.9320	0.7366	0.2329	-1.4589	-0.4051	-4.0010	9	0.0030
	HA-SA	**-0.0500**	**0.8073**	**0.2330**	**-0.5629**	**0.4629**	**-0.2150**	**11**	**0.8340****
	BL-CR	**-0.0683**	**0.8481**	**0.2448**	**-0.6072**	**0.4705**	**-0.2790**	**11**	**0.7850****

W. Paired T-Test results of Cihanbeyli Meteorological station

		Paired Differences							
					95% Confidence Interval of the Difference				
Years	Methods	Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	Df	Sig. (2-tailed)
2009	ASCE P-M	0.9767	0.6680	0.1928	0.5522	1.4011	5.0650	11	0.0000
	RAD.	-0.7108	0.9206	0.2658	-1.2958	-0.126	-2.6750	11	0.0220
	HA-SA	**0.0350**	**0.6323**	**0.1825**	**-0.3668**	**0.4368**	**0.1920**	**11**	**0.8510****
2010	ASCE P-M	1.1750	0.7348	0.2121	0.7081	1.6419	5.5390	11	0.0000
	RAD.	-0.5725	0.9044	0.2611	-1.1471	0.0021	-2.1930	11	0.0510
	HA-SA	**0.1333**	**0.7665**	**0.2213**	**-0.3536**	**0.6203**	**0.6030**	**11**	**0.5590****
2011	ASCE P-M	0.9308	0.6476	0.1869	0.5194	1.3423	4.9790	11	0.0000

	RAD.	-0.7058	0.7142	0.2062	-1.1596	-0.252	-3.4230	11	0.0060
	HA-SA	**0.0008**	**0.6606**	**0.1907**	**-0.4189**	**0.4206**	**0.0040**	**11**	**0.9970****
2012	ASCE P-M	1.1325	0.7863	0.2270	0.6329	1.6321	4.9890	11	0.0000
	RAD.	-0.6708	0.8292	0.2394	-1.1977	-0.144	-2.8030	11	0.0170
	HA-SA	**0.2117**	**0.6500**	**0.1876**	**-0.2013**	**0.6246**	**1.1280**	**11**	**0.2830****
	BL-CR	**-0.0708**	**0.9619**	**0.2777**	**-0.6820**	**0.5403**	**-0.2550**	**11**	**0.8030****
2013	ASCE P-M	1.0908	0.6616	0.1910	0.6705	1.5112	5.7120	11	0.0000
	RAD.	-0.7725	0.7039	0.2032	-1.2197	-0.325	-3.8020	11	0.0030
	HA-SA	**0.1858**	**0.5840**	**0.1686**	**-0.1852**	**0.5569**	**1.1020**	**11**	**0.2940****
	BL-CR	**-0.1292**	**0.8195**	**0.2366**	**-0.6498**	**0.3915**	**-0.5460**	**11**	**0.5960****
2014	ASCE P-M	1.0800	0.6721	0.1940	0.6530	1.5070	5.5670	11	0.0000
	RAD.	-0.7100	0.8622	0.2489	-1.2578	-0.162	-2.8530	11	0.0160
	HA-SA	**0.1742**	**0.6133**	**0.1770**	**-0.2155**	**0.5638**	**0.9840**	**11**	**0.3460****
	BL-CR	**-0.1758**	**0.9004**	**0.2599**	**-0.7479**	**0.3963**	**-0.6760**	**11**	**0.5130****
2015	ASCE P-M	1.0042	0.6151	0.1776	0.6134	1.3950	5.6560	11	0.0000
	RAD.	-0.7083	0.7458	0.2153	-1.1822	-0.234	-3.2900	11	0.0070
	HA-SA	**0.1458**	**0.5839**	**0.1686**	**-0.2252**	**0.5169**	**0.8650**	**11**	**0.4050****
	BL-CR	**-0.1508**	**0.8767**	**0.2531**	**-0.7079**	**0.4062**	**-0.5960**	**11**	**0.5630****
2016	ASCE P-M	1.2758	0.6528	0.1884	0.8611	1.6906	6.7710	11	0.0000
	RAD.	-0.5800	0.7203	0.2079	-1.0377	-0.122	-2.7890	11	0.0180
	HA-SA	**0.3408**	**0.6419**	**0.1853**	**-0.0670**	**0.7487**	**1.8390**	**11**	**0.0930****
	BL-CR	**-0.0942**	**0.8873**	**0.2561**	**-0.6579**	**0.4696**	**-0.3680**	**11**	**0.7200****
2017	ASCE P-M	1.0033	0.7337	0.2118	0.5372	1.4695	4.7370	11	0.0010
	RAD.	-0.7450	0.8740	0.2523	-1.3003	-0.189	-2.9530	11	0.0130
	HA-SA	**0.0692**	**0.8004**	**0.2311**	**-0.4394**	**0.5777**	**0.2990**	**11**	**0.7700****
	BL-CR	**-0.1483**	**0.8172**	**0.2359**	**-0.6675**	**0.3709**	**-0.6290**	**11**	**0.5420****
2018	ASCE P-M	1.2020	0.6886	0.2178	0.7094	1.6946	5.5200	9	0.0000
	RAD.	-0.9690	0.5334	0.1687	-1.3506	-0.587	-5.7450	9	0.0000
	HA-SA	**0.2140**	**0.5742**	**0.1816**	**-0.1968**	**0.6248**	**1.1790**	**9**	**0.2690****
	BL-CR	-0.4810	0.4405	0.1393	-0.7961	-0.165	-3.4530	9	0.0070

X. Paired T-Test results of Ereğli Meteorological station

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
2009	ASCE P-M	0.8475	0.5135	0.1482	0.5213	1.1737	5.7180	11	0.0000
	RAD.	-1.1350	0.7740	0.2234	-1.6268	-0.6432	-5.0800	11	0.0000
	HA-SA	**-0.0083**	**0.2564**	**0.0740**	**-0.1712**	**0.1546**	**-0.1130**	**11**	**0.9120****
2010	ASCE P-M	0.6900	0.3792	0.1095	0.4491	0.9309	6.3040	11	0.0000
	RAD.	-1.3025	0.8701	0.2512	-1.8553	-0.7497	-5.1860	11	0.0000
	HA-SA	-0.3275	0.1811	0.0523	-0.4425	-0.2125	-6.2660	11	0.0000
2011	ASCE P-M	0.5492	0.3722	0.1075	0.3127	0.7857	5.1110	11	0.0000
	RAD.	-1.2617	0.8151	0.2353	-1.7796	-0.7438	-5.3620	11	0.0000
	HA-SA	-0.2950	0.2137	0.0617	-0.4308	-0.1593	-4.7830	11	0.0010
2012	ASCE P-M	0.6492	0.4839	0.1397	0.3417	0.9566	4.6470	11	0.0010
	RAD.	-1.2967	0.8958	0.2586	-1.8658	-0.7275	-5.0140	11	0.0000
	HA-SA	-0.2500	0.1969	0.0568	-0.3751	-0.1249	-4.3990	11	0.0010
	BL-CR	**-0.5650**	**0.9950**	**0.2872**	**-1.1972**	**0.0672**	**-1.9670**	**11**	**0.0750****
2013	ASCE P-M	0.6800	0.4716	0.1362	0.3803	0.9797	4.9950	11	0.0000
	RAD.	-1.3092	0.8788	0.2537	-1.8675	-0.7508	-5.1610	11	0.0000
	HA-SA	-0.2108	0.3035	0.0876	-0.4036	-0.0180	-2.4070	11	0.0350
	BL-CR	**-0.5483**	**0.8773**	**0.2533**	**-1.1058**	**0.0091**	**-2.1650**	**11**	**0.0530***
2014	ASCE P-M	0.7283	0.4649	0.1342	0.4330	1.0237	5.4270	11	0.0000
	RAD.	0.0325	0.8113	0.2342	-0.4830	0.5480	0.1390	11	0.8920
	HA-SA	-0.9725	0.8069	0.2329	-1.4852	-0.4598	-4.1750	11	0.0020
	BL-CR	**0.1775**	**0.2424**	**0.0700**	**0.0235**	**0.3315**	**2.5370**	**11**	**0.0280****
2015	ASCE P-M	0.5692	0.3618	0.1044	0.3393	0.7990	5.4500	11	0.0000
	RAD.	-1.2767	0.8296	0.2395	-1.8038	-0.7496	-5.3310	11	0.0000
	HA-SA	-0.3333	0.1663	0.0480	-0.4390	-0.2277	-6.9450	11	0.0000
	BL-CR	**-0.6100**	**0.9791**	**0.2827**	**-1.2321**	**0.0121**	**-2.1580**	**11**	**0.0540****
2016	ASCE P-M	0.7350	0.4124	0.1191	0.4730	0.9970	6.1740	11	0.0000
	RAD.	-1.4333	0.8439	0.2436	-1.9695	-0.8972	-5.8840	11	0.0000
	HA-SA	-0.1792	0.1464	0.0423	-0.2722	-0.0862	-4.2400	11	0.0010

	BL-CR	-0.7400	0.9419	0.2719	-1.3384	-0.1416	-2.7220	11	0.0200
2017	ASCE P-M	0.6933	0.4382	0.1265	0.4149	0.9718	5.4810	11	0.0000
	RAD.	-1.3383	0.7861	0.2269	-1.8378	-0.8389	-5.8980	11	0.0000
	HA-SA	-0.2442	0.1702	0.0491	-0.3523	-0.1360	-4.9690	11	0.0000
	BL-CR	-0.6467	0.9236	0.2666	-1.2335	-0.0598	-2.4250	11	0.0340
2018	ASCE P-M	0.8020	0.3980	0.1259	0.5173	1.0867	6.3720	9	0.0000
	RAD.	-1.5010	0.8219	0.2599	-2.0889	-0.9131	-5.7750	9	0.0000
	HA-SA	-0.2260	0.2471	0.0782	-0.4028	-0.0492	-2.8920	9	0.0180
	BL-CR	-0.9510	0.7764	0.2455	-1.5064	-0.3956	-3.8730	9	0.0040

**statistically not significant

CURRICULUM VITAE

KİŞİSEL BİLGİLER

Adı Soyadı	:	Peter Addo Amarkai
Uyruğu	:	Gana
Doğum Yeri ve Tarihi	:	Accra, 11/11/1985
Telefon	:	+905398919418
Faks	:	
e-mail	:	Paddokkojoaddo@gmail.com

EĞİTİM

Derece		**Adı, İlçe, İl**	**Bitirme Yılı**
Lise	:	St. Martins High School	2005
Üniversite	:	University of Ghana, Legon	2010
Yüksek Lisans	:	Selçuk Üniversitesi	2019
Doktora	:		

İŞ DENEYİMLERİ

Yıl	**Kurum**	**Görevi**
2018	Boro Makıne Metal, Konya, Turkey	Foreign Trade Personnel
2014	SNV Netherlands Development Organization, Ghana	Field Research Assistant
2013	Ghana International School, Cantoment, Accra, Biology Department, Ghana	Teaching/Administrative Assistant
2011	University of Ghana, Legon, Department of Agric. Extension	Teachıng Assistant
2010	Superbrand Solutions Consult, Mmai-Djorn, Accra, Ghana	Evaluator
2008	Gye Nyame Fishing Company, Sekondi-Ghana	Internship
2007	Alomal Farms Ltd., Nsawam, Ghana	Internshıp

UZMANLIK ALANI

Ziraat Mühendisliği

YABANCI DİLLER

Inglizce
Turkçe

BELİRTMEK İSTEĞİNİZ DİĞER ÖZELLİKLER

YAYINLAR