

Full Length Research Paper

Grass plants crop water consumption model in urban parks located in three different climate zones of Turkey

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The most important issue is the to use of urban space to increase the number and size of green areas. As well as another important issue is to work towards maintaining these spaces. One such important effort is to meet the water needs of plants. Naturally, the amount of water needed by plants depends on the species. In order to successfully implement modern irrigation techniques in parks, gardens, rest and recreation areas, both direct calculation methods and estimation methods from climate data are used in determining evapotranspiration. In this study, climate elements based Penman-Monteith equation is used to investigate the water consumption, irrigation water need, irrigation interval and irrigation for the grass plant in park areas located in three different climate zones (Antalya, Ankara and Trabzon) in Turkey. The result of calculations, using the climate data of July, value of the province of Antalya were $ET_o=7,10464$ mm/day, for Ankara $ET_o=6,77215$ mm/day, for Trabzon $ET_o=4,03544$ mm/day. The study also reveals the importance of identifying the water consumption needs of plants while preparing irrigation projects.

Key words: Irrigation, Penmann-Monteith method, grass plants.

INTRODUCTION

Green spaces and their qualities are parallel to civilization levels of societies, they are both indispensable elements of today's well-planned cities and the indicators of socio-cultural life quality in modern cities (Demirel et al. 2005). In improving the visual qualities of our cities, grass fields which cover expansive areas in urban parks are the most vital elements of urban aesthetics (Kumbaracıbaşı, 2003), having a major role in people's lives. Therefore, the existence of green belts of various sizes, functions and distances meeting all needs of cities being well-integrated into the urban fabric have become a must more than a need (Eymirli, 1994).

Throughout the world, efforts are being made to increase the size of green spaces or reach a pre-

specified standard value for human health. In the USA, urban intensity was projected as 250 persons/ha and the size of open and green spaces per capita as 40 m². In the UK, the standard is equal to that in the USA; namely, 40 m² of green space per capita. According to the "Planning Regulation" under the Construction Law no. 3194 dated 1999, the green space per capita is 10 m² in Turkey (Yıldızci, 1982). In the developed cities of Europe, it is 45 to 50 m² in Amsterdam, and 77 m² in Stockholm (Önder, 1997). In other European cities, it is 154 m² in Frankfurt, 153 m² in Stuttgart, 112 m² in Hannover, 49 m² in Bristol and 37 m² in Budapest (Yıldızci, 1991). In Turkish cities, however, there is 2.3 m² of green space per capita in Ankara, 2.1 m² in Istanbul, and 2.8 m² in Izmir (Oruç, 1992).

In addition to increasing the number and size of green spaces, it is also important to maintain these places and undertake work to sustain the landscaping quality. For instance, meeting the water needs of plants is a critical piece of work (Sarikoç, 2007). Naturally, the amount of water needed by plants varies according to species. In

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other words, the tolerance limits that each species has for inadequate or excessive water is not the same (Anthony and Rees, 1988). At the same time, the environmental conditions in which plants absorb water also affect the level of benefiting from water significantly. The aim of today's irrigation designers is to make landscape areas stay green and produce lower cost systems (Smith, 1977). Today, the increase in water consumption and in its intensity within the total maintenance costs of energy expenditures have led many irrigation water users to reconsider water management. The aim of water management is to protect the green landscape and its aesthetics, as well as to minimize annual irrigation water use and energy consumption (Demirel, 2003).

In order to successfully implement modern irrigation techniques in parks and gardens, evapotranspiration in rest and recreation areas is calculated by direct measurement methods and estimation methods from climate data (Çakmak and Aküzüm, 1992). Even though direct measurement methods yield healthier results, they are both rather costly and time-consuming. Therefore, in practice, evapotranspiration is commonly determined using estimation equations based on climate data. Evapotranspiration is the sum of evaporation and transpiration amounts, and is given in terms of depth (mm). Many factors influence evapotranspiration. The most important ones include: 1) The climate factor (solar radiation, temperature, air humidity, wind, insolation duration, 2) Soil factors (soil humidity, soil tillage, soil type) and 3) Plant factors (plant type, development stage, growth season, plant cover).

Regarding climate factors, as the amount of solar radiation (strength of sun rays), temperature, wind speed and duration, insolation duration (daytime hours when the sky is not covered in clouds) and daytime hours until sunset increase, both evaporation and transpiration, and thus evapotranspiration amount will also increase. On the other hand, when relative humidity around plants increases, the amounts of evaporation and transpiration fall, and so does evapotranspiration (Güngör et al., 1995).

Evapotranspiration (ET) is an important variable in water and energy balances on the earth's surface (Rivas and Caselles, 2004). Estimates of reference evapotranspiration (ET_0) are used in the planning process for irrigation schemes to be developed as well as to manage distribution in existing schemes (Droogers and Allen, 2002). ET is thus the most active mechanism connecting the atmosphere with other three spheres (hydrosphere, lithosphere and biosphere) and the linkage among the climatic, hydrological and ecological systems; climatically, ET is the most active element in lands' hydrological cycle, 65% of the precipitation being evaporated and transpired (Kite, 2000). This is to say the greatest amount of water from the hydrologic system is transported and evaporated, which shows that the appropriate estimation of the ET is basic (Rivas and

Caselles, 2004). ET is of great significance in all kinds of ecosystems and the significance is much greater in semi-arid climatic conditions. The adverse human impacts on ET have degraded the already-vulnerable ecological conditions, which are further diminishing the limited environmental carrying capacity and directly threatening the economic sustainability (Wang et al., 2000). Also, understanding potential evapotranspiration is essential in planning economic uses of water resource and in assessing the potential ecological conditions for ecological restorations (Chuanyan et al., 2004).

Though there are several proposed models to predict ET_0 , but there is no universal consensus on the suitability of any given model for a given climate (Denghanisanij et al., 2004). The Penman-Monteith equation is the standard method to compute ET_0 from meteorological data (Allen et al. 1998). Although this method has been tested positively in different climates, the need for full weather data such as minimum and maximum air temperature, minimum and maximum relative humidity, solar radiation, and wind speed limits the wide spread use of The Penman-Monteith (Pereira and Pruitt, 2004).

The Penman-Monteith equation can be used to estimate evaporation from well-watered and stressed canopies, depending upon the surface resistance. The beauty of the PM is that, it is able to substitute surface temperature with air temperature and energy balance (Monteith and Unsworth, 1990). An equation based on the PM model is now largely used as the reference methodology, with adopted parameterization for surface and aerodynamic resistances for obtaining reference ET from agro-meteorological data and the Penman-Monteith method is recommended by Food and Agriculture Organisation (FAO) (Allen et al., 1998).

Penman-Monteith method is used by numerous researchers and is also appropriate for different climates (Fooladmand and Haghghat, 2007; Pereira and Pruitt, 2004; Rivas and Caselles, 2004; Irmak et al., 2003; Gávilan et al., 2006; Itensifu et al., 2005; Popova et al., 2006; Kashyap and Panda, 2001; Droogers and Allen, 2002; Temesgen et al., 1999; Samani, 2000; Xu and Singh, 2002; López-Urrea et al., 2006; Azamathulla et al., 2008). From the several existing ET_0 equations is currently widely used and can be considered as a sort of standard (Walter et al., 2000). The PM has two advantages over many other methods. First of all, it is a predominately physically based approach, indicating that the method can be used globally without any need for additional parameter estimations. Secondly, the method is well documented, implemented in a wide range of software, and has been tested using a variety of lysimeters (Droogers and Allen, 2002).

This study utilized the climate element-based method of Penman-Monteith in order to determine the water use, irrigation interval and irrigation duration of grass in parks located in three different climate zones in Turkey (Antalya, Ankara and Trabzon). In addition, it reveals the

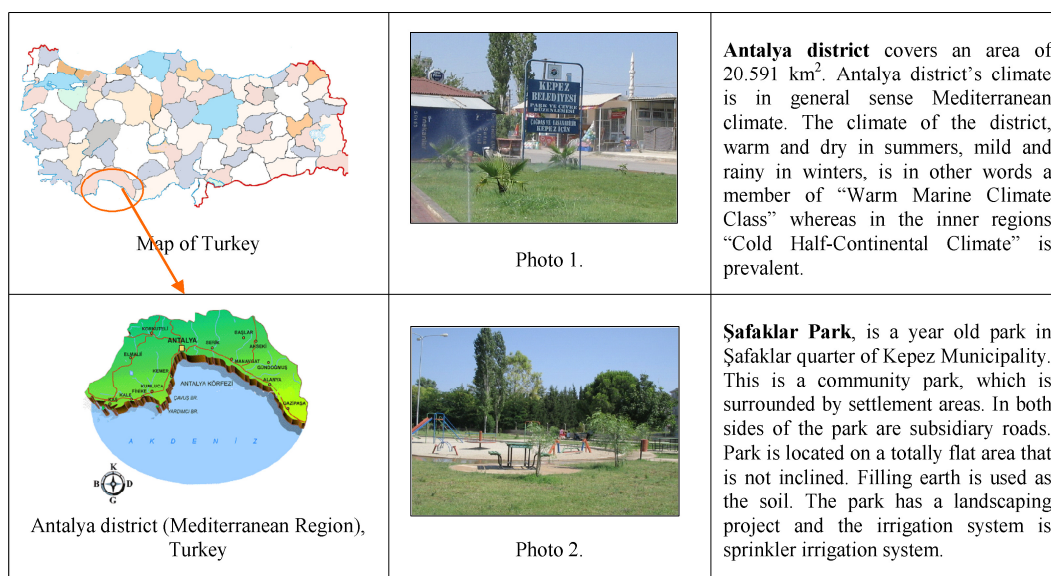


Figure 1. Şafaklar Park (Antalya/Mediterranean Region), Turkey.



Figure 2. Etimesgut Atatürk Koşu Yolu Park (Ankara/Central Anatolia Region), Turkey.

importance of determining the water needs of plants in the preparation of irrigation projects.

MATERIALS AND METHODS

Three different climate zones of Turkey representing the three different plant gene centers of the country were chosen as the study area. These zones are the Warm Climate Zone of the Mediterranean Region, the Cold Climate Zone of the Central Anatolian Region, and the Temperate Climate Zone of the

BlackSea Region. The parks selected as the study material and the 3 different locations representing the different climate zones were: Antalya and Şafaklar Park to represent the warm climate zone in the Mediterranean Region (Figure 1) (Photo 1 to 2), Ankara and Etimesgut Atatürk Koşu Yolu Park to represent the cold climate zone in the Central Anatolian Region (Figure 2) (Photo 3 to 4), and Trabzon and the İller Bankası Arboretum to represent the temperate climate zone in the Black Sea Region (Figure 3) (Photo 5 to 6). In addition, the climate values of the three regions (Table 1) which would be the basis of the Penman-Monteith method were obtained and soil analyses (Table 2) were made. Three different regions of work areas were chosen. Soil texture in the research

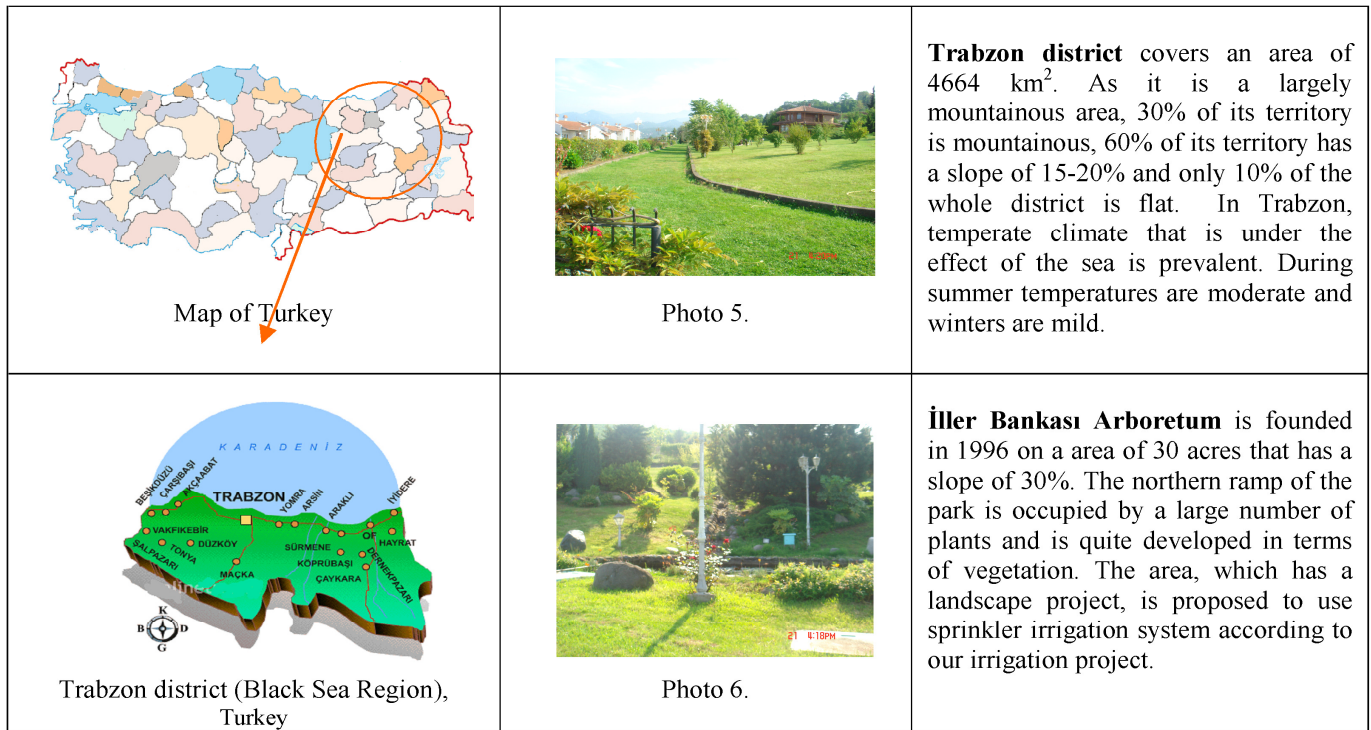


Figure 3. İller Bankası Arberotum (Trabzon/Black Sea Region), Turkey.

area were taken 30 cm depth of the soil. Soil samples collected by Special Provincial Administration Secretariat Soil and Water Analysis Laboratory. The results of the soil analyses found were in the soil texture quality, field capacity, bulk density PH and permanent wilting point.

The first study area Antalya is located in the Mediterranean Region (36°06' to 37°27'N; 32°07' to 29°04' E). The study area has a hot-climate with avarege temperature 18°C. The soil is sand with 40.64%, 37.04% silt and 22.32% clay. Avarage field capacity, 18.80%; bulk density, 1.02 g/m³; pH, 7.21 and permanent wilting point, 17.57 at 30 cm depth. The second study area Ankara is located in the Central Anatolia Region (38°43'– 40°41'N; 30°05'– 34°05' E). The study area has a cold-climate with avarege temperature 11.83°C. The soil is sand with 28.64%, 45.04% silt and 26.32% clay. Avarage field capacity, 23.61%; bulk density, 1.04 g/m³; pH, 7.84 and permanent wilting point, 21.07 at 30 cm depth. The last study area Trabzon is located in the Black Sea Region (40°33' to 41°07'N; 39°07' to 40°30' E). The study area has a temperate-climate with avarege temperature 14.57°C. The soil is sand with 21.84%, 50.72% silt and 27.44% clay. Avarage field capacity, 33.60%; bulk density, 1.44 g/m³; pH, 6.95 and permanent wilting point, 25.5 at 30 cm depth.

This study was made in all three areas in July, when plant water use is at a maximum, as the criterion. In determining the water amount, irrigation duration and interval in the experiment, grass was taken as the critical plant as it is commonly found in parks and green spaces. The grass used in the three different study areas was of different species. The species used and their proportions within mixtures were similar: 1) Şafaklar Park-Antalya: *Festuca arundinacea* (30%), *Cynodon dactylon* (40%), *Lolium perenne* (30%), 2) Etimesgut Atatürk Koşu Yolu Park-Ankara: *Poa pratensis* (25%), *Lolium perenne* (25%), *Agrostis tennisi* (10%), *Festuca rubra* (20%),

Festuca ovina (20%), 3) İller Bankası Arboretum-Trabzon: *Agrostis tennisi* (15%), *Festuca rubra var. rubra* (30%), *Lolium perenne* (30%) and *Poa pratensis* (25%).

Many methods exist for the experimental measurement of evapotranspiration and its calculation by using climate data. Jensen (1973) classified these methods as direct measurement methods (tanks and lysimeters, field experiment parcels, supervision of decreasing humidity, and measurement of incoming and outgoing flow from the basin) and estimation from climate data (micrometeorological methods, empirical methods and comparative plant water use methods). The common approach in determining evapotranspiration in our day is to first estimate water consumption for a reference plant (such as grass or clover), and then obtain evapotranspiration by correcting this value by using plant coefficient (Doorenbos and Pruitt, 1977).

The resources consulted in the identification of plant water use needs were given in the books of (Smith, 1997; Landphair and Klatt, 1979; Yıldırım, 1993; Seçkin and Çelik, 2003; Güngör et al., 1995) as well as the articles of Penman (1948), Monteith (1965), Howell et al. (2000), Sumner and Jacobs (2005), Allen (2000, 1998) and Ventura et al., (1999). In the study conducted in Istanbul, Turkey by Seçkin (1998) about water consumption of grass plants, showed that the evaporation and transpiration amounts for Bermuda grass (*Cynodon dactylon* L.Pers.) were 7.2 mm/day or 50.4 mm/week. Kneebone et al. (1992) concluded that the typical water use of grass ranged between 2.5 to 7.5 mm/day, and was 12 mm/day maximum. Aydınşakir et al. (2003) found in their study that, the actual water consumption of the popular grass species Bermuda (*C. dactylon* L.Pers.) in field conditions varied between 8.5 to 12.0 mm/day and was 10.0 mm/day on average.

The Penman-Monteith method was used in the study to determine evapotranspiration.

Table 1. The weather stations of the three cities used in this study and the annual mean values of meteorological variables at each weather station.

Station	Latitude (degrees) ^a	Longitude (degrees) ^a	Elevation (m)	Record period	Rain (mm)	T _{min} (°C)	T _{max} (°C)	T _{mean} (°C)	Wind Speed (ms ⁻¹)	E _m (mm)	RH _{mean} (%)	n(h)	Climate
Antalya ^b	36°06'N 37°27'	32°07'E 29°14'	54	1980 to 2000	1063.5	12.80	24.10	18.00	2.80	1886.4	63.0	255.63	hot-climate
Ankara ^b	38°43'N 40°41'	30°51'E 34°05'	861	1975 to 2006	386.3	6.30	17.63	11.83	2.20	107.1	61.0	210.10	cold-climate
Trabzon ^b	40°33'N 41°07'	39°07'E 40°30'	32	1975 to 2006	962.7	11.48	18.15	14.57	2.52	158.1	71.8	130.40	temperate-climate

^a, Degrees, minutes; ^b, Stationstor; T_{min}, mininum air temperature; T_{max}, maximum air temperature; T_{mean}, mean air temperature; wind speed at 2 m height; RH_{mean}, mean relative humidity; n, mean montly total of sunshine hours; E_m, evaporation (Ministry of Environment and Forestry.^{1,2} 2004; Ministry of Environment and Forestry, 2006).

Table 2. Soil analysis data of the three different regions*.

Study Area	Sand (%)	Silt (%)	Clay (%)	Soil texture quaity	Field capacity	Bulk density (gr/cm ³)	PH	Permanent wilting point
Şafaklar Park Antalya/Turkey	40.64	37.04	22.32	Clay-Sand	18.80	1.02	7.21	17.51
Etimesgut Atatürk Koşu Yolu Park Ankara/Turkey	28.64	45.04	26.32	Sand-Clay	23.61	1.04	7.84	21.07
İller Bankası Arboretum Trabzon/Turkey	21.84	50.72	27.44	Clay	33.60	1.44	6.95	25.5

*Soil analysis has been done by Special Provincial Administration Secretariat Soil and Water Analysis Laboratory. Soil texture in the research area was collected from 30 cm depth of the soil layer.

Methods description

Penman-Montaith Method

The FAO Penman-Monteith method for calculating reference (potential) evapotranspiration ET can be expressed as (Allen et al., 1998)

$$ET_0 = \frac{0.408 \Delta (RN - G) + \gamma \frac{900}{T + 273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34 u_2)}$$

ET₀ reference evapotranspiration [mm day⁻¹]
R_n net radiation at the crop surface [MJ m⁻² day⁻¹]

G soil heat flux density [MJ m⁻² day⁻¹]
T air temperature at 2 m height [°C]
u₂ wind speed at 2 m height [m s⁻¹]
e_s saturation vapour pressure [kPa]
e_a actual vapour pressure [kPa]
e_s - e_a saturation vapour pressure deficit [kPa]
Δ s lope vapour pressure curve [kPa °C⁻¹]
Δ psychrometric constant [kPa °C⁻¹] (C.-Y.Xu and V.P. Singh 2002)

Measurement of irrigation water need, irrigation interval and irrigation duration

The amount of water used by plants in irrigated areas is met by precipitation and irrigation water. The amount of

evapotranspiration to be met by irrigation water is calculated by using the equation below:

$$dn = u - r$$

dn Amount of evapotranspiration to be met by irrigation water, mm
u Evapotranspiration, mm
r Effective precipitation, mm

By using these equations, the water need of grasses in different months of the year is calculated by subtracting the multi-year mean precipitation amount for a given month, from the amount of evapotranspiration in that month. The net and total irrigation water amounts to be used in each irrigation are obtained by using the following equations:

$$d^n = \frac{(TK - SN) \times Ry}{100} \times Ha \times D$$

$$dt = \frac{d^n}{Ea}$$

d^n	Net irrigation water amount to be used in each irrigation, (mm)
TK	Field capacity, (%)
SN	Wilting point, (%)
Ry	Part of usable moisture holding capacity that can be used, (%)
Ha	Bulk density of soil, g/cm ³
D	Crop root depth, mm
d_t	Total irrigation water amount to be used in each irrigation, (mm)
E_a	Irrigation yield

The values used in the calculation of irrigation water amounts, that is, root depth of grass plants 30 cm, the part of usable moisture holding capacity at this depth that can be used is 0.50, and irrigation yield is 0.70, as describe by Korukçu and Yıldırım (1981), Güngör and Yıldırım (1987) and Çakmak (1990).

Irrigation interval is obtained by dividing the net irrigation water amount in each irrigation into the daily water use of the plant.

$$Ir = \frac{d^n}{ET_o}$$

$$t = \frac{dt}{Iy}$$

Ir	Irrigation interval, day
d^n	Net irrigation water amount used in each irrigation, (mm)
ET_o	Evapotranspiration, (mm/day)
t	Irrigation duration, h
dt	Total irrigation water amount used in each irrigation, (mm)
Iy	Sprinkling speed, (mm/h)

A monthly irrigation program for each of the study areas in the three different climate zones was made by using the equations.

RESULTS

The irrigation of grass fields is more complex than farm and garden plants. This is because grass fields may contain trees, shrubs, bushes, covering plants and flowers which have different root depth and water needs; different types of grass may be used together; soil quality may differ within one area; sloped and rolling land may be the case; and there may be parts not to be irrigated within the grass covered area.

At the present day water should be used economically and efficiently. For this reasons, water should be used economically and efficiently. In this way, it should be provided to protect the existing ecological balance. Measures are to be taken to avoid excessive water use, water contamination should be prevented, the current

situation in terms of operation and maintenance of irrigation systems should be improved.

Water demand and its interactions with water are increasing with each passing day as a result of human activities. However the quantity and quality of needed water resources are limited. Nowadays, each day the consumption of water resources is increasing and this is reflection work of irrigation. Therefore many irrigation projects intended to minimize water consumption.

Many methods have been developed to experimentally measure evapotranspiration and calculate it by using various climatic data. The evapotranspiration data to be used in the preparation of irrigation projects are ideally obtained as a result of multiple-year experiments in field conditions. However, as such studies require a lot of time, effort and cost, indirect methods (by using climatic data) are usually preferred in the measurement of evapotranspiration. The most widespread one of these methods in our times is the Penman-Monteith method which was used in this study to calculate the plant water use values from 3 different parks representing 3 different climate zones. These results are shown in Table 3.

The climate data for July obtained in Şafaklar Park in Antalya was selected to represent the warm climate zone of the Mediterranean Region, showed that $E_{to}=7,10464$ mm/day. On the other hand, $E_{to}=6,77215$ mm/day according to the calculations made in Etimesgut Atatürk Koşu Yolu Park located in Ankara was chosen to represent the cold climate zone of Central Anatolia.

Accordance with the result of soil analysis and the data obtained, amount of water consumption of the plant (mm), irrigation interval (day) and duration of irrigation(h) were calculated for 3 different study area. According to calculations, for the province of Antalya; amount of water consumption of the plant is 0,2 mm, irrigation interval is 2,8 day and duration of irrigation is 1,8 h; for the province of Ankara; amount of water consumption of the plant is 0,3 mm, irrigation interval is 5,7 day and duration of irrigation is 5,1 h; for the province of Trabzon; amount of water consumption of the plant is 0,3 mm, irrigation interval is 4,0 day and duration of irrigation is 2,3 h.

Finally, $E_{to}=4,03544$ mm/day was found from the measurements made in İller Bankası Arboretum located in Trabzon to represent the temperate climate zone of the Black Sea Region. The results showed that the highest plant water consumption value was obtained in Antalya, in the hot climate zone with 7,10464 mm/day. Considering existing climate data, the high level of evapotranspiration in Antalya, which also has a higher mean temperature and evaporation than other cities, reveals that the climate-based method of Penman-Monteith yields satisfactory results in studies focusing on the estimation of evapotranspiration.

DISCUSSION

In this study Penman-Monteith method was used to

Table 3. Result of crop water consumption (mm/day), amount of water consumption of the plant (mm), irrigation interval (day) and duration of irrigation (h) for study areas in July.

Study area	Crop water consumption (mm/day) (ET_o)	Amount of water consumption of the plant (mm)(dn)	Irrigation interval (day) (Ir)	Duration of irrigation (h) (t)
Şafaklar Parkı Antalya/Turkey	7,1	0,2	2,8	1,8
Etimesgut Atatürk Koşu Yolu Parkı Ankara/Turkey	6,7	0,3	5,7	5,1
İller Bankası Arboretumu Trabzon/Turkey	4,0	0,3	4,0	2,3

obtain more accurate results with a lot of data. This method has been used frequently in agricultural areas in recent years, especially in landscape. The protection, improvement and efficient use of land and water resources are one of the greatest concerns of today's countries. In order to derive continuous and efficient benefit from the available water irrigation programs unique to regional conditions are needed. Knowing the amount of used water of plants is a prerequisite for such programs.

The reason for conducting the study in three different climate zones was to reveal the water needs of grass, which has become popular in big cities and their surrounds in recent years, and to offer a comparative discussion with other regions.

Even though this study's use different grass mixtures that are appropriate for different climate conditions, this may seem to be an handicap for comparison, these handicaps are eliminated by the consideration of the differences in each region in the Penman-Monteith method. What really needs to be questioned here is how the mixtures are to be compared. The study used different mixtures for each climate zone owing to the durability of these mixtures in the conditions of each respective climate zone. Using mixtures will enable evaporation in a given unit of time and transpiration to obtain a mean value. In the finding of Aydınşakir et al. (2003) it was revealed that, the mean water consumption of Bermuda grass (*C. dactylon* L.Pers.) is 10.0 mm/day in the climate conditions of Antalya, this is directly and merely related to the conditions in which they held the study (mean monthly temperature in that year, soil conditions, rain, air humidity, wind speed, insolation, etc.). A future study to be held by other researchers about the water consumption of a similar grass species in similar soil conditions and during the same time of year may yield different results due to the variability of climate factors. Considering that different soil conditions in this study may pose comparison difficulties, irrigation water

need, irrigation duration and irrigation interval which were determined to reveal the differences. Two of the three study areas (Şafaklar Park-Antalya and Etimesgut Koşu Yolu Park-Ankara) were in a flat region, while the third (İller Bankası Arboretum-Trabzon) had a slope value ranging between 15 to 0%. When compared with the two flat areas, the evapotranspiration calculation in this area should not affect the results significantly.

Parks and green spaces in a country's economic development are considered as the most important indicators. Besides, the creation of parks and green areas with the implementation of policies aimed at sustainable use of water is required.

Conclusion

This study is introduces to determine grass plants crop water consumption in urban parks located in three different climate zones of Turkey. To determine the amount of crop water consumption, climate based data Penmann-Monteith equation was used. The results of the soil analyses found were in the soil texture quality, field capacity, bulk density PH and permanent wilting point. All the study showed that in Antalya, which is a hot climatic region, grass plant need more water than in the two other cities. In addition to this calculation, Trabzons, which is a temperate climate zone, grass plant need at least water. As a result of soil analysis, the grass in the province of Ankara plants must be watered more often other cities.

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