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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Evaluation of the Relationship Between Rainwater Harvesting and Landscape Plant Water Consumption*

Yağmur Suyu Hasadı ile Peyzaj Bitkilerinin Su Tüketimi Arasındaki İlişkinin Değerlendirilmesi

Nilay MISIRLI[1*], Elif Ebru ŞİŞMAN[2]

Abstract

If rainwater is not used, it is considered waste and ends up as surface water in underground resources or flows into oceans. In view of dwindling water resources, rainwater should not only flow as surface water but should be reused to conserve groundwater and mains water. To achieve this, rainwater must be collected and solutions produced on site. When we look at water consumption rates, we realize that a large amount of water is significantly used for the irrigation of landscaped areas. In addition, the water requirements of plants are often not known and water is wasted through unconscious irrigation. This study aims to provide the right amount of irrigation by showing the water requirements of plants according to their species. At the same time, it aims to provide the right amount of irrigation by showing the water requirements of plants according to their species. These two main objectives are aimed at learn the needs of plants and at the same time ensuring efficient water use. In this study, it is aimed to contribute to the water cycle by reusing rainwater. Various roofing and paving materials were identified in the study area. The amount of rainwater to be collected from the different materials within the study area was calculated using the Rational Method and the water consumption of each plant was calculated using the CropWat 8.0 program. In conclusion, the amount of rainwater collected on the entire campus was calculated as 494.000 m^3per year and the amount of irrigation water required by the plants was 54.530 m^3per year. This data shows that the amount of rainwater collected corresponds to the water consumption of the landscape plants. The rainwater harvested on campus is fed into tanks. The rainwater collected on the campus is channelled into tanks. The volume of the tanks was calculated. In addition to the stored rainwater, solutions were developed on-site using sustainable methods for the remaining rainwater. Plants with low or medium water requirements are recommended for use in new landscape areas.

Keywords: Rainwater harvesting, Rainwater reuse, Landscape plant water consumption, Irrigation, Sustainability, Urban stormwater management

[1]***Sorumlu Yazar/Corresponding Author:** Nilay Mısırlı, Trakya University, Faculty of Architecture, Department of Landscape Architecture, Edirne, Türkiye. E-mail: nilaymisirli@trakya.edu.tr OrcID: 0000-0003-2250-6216
[2]Elif Ebru Şişman, Tekirdağ Namık Kemal University, Faculty of Fine Arts, Design and Architecture, Department of Landscape Architecture, Tekirdağ, Türkiye. E-mail: esisman@nku.edu.tr OrcID: 0000-0002-5114-7980
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Öz

Yağmur suyu değerlendirilmediği sürece atık olarak görülmekte ve yüzey suyu olarak yeraltı kaynaklarına veya denizlere ulaşmaktadır. Azalan su kaynakları düşünüldüğünde, yağmur suyu sadece yüzey akış suyu olmamalıdır. Yağmur suyunun yeniden kullanımı ile yeraltı ve şebeke sularından tasarruf sağlanmalıdır. Bunun gerçekleştirilmesi için yapılması gereken yağmur suyunun toplanarak yerinde çözüm önerileri üretilmesidir. Su tüketim oranlarına bakıldığında, peyzaj alanlarının sulanması için büyük miktarda suyun kullanıldığı açıkça görülmektedir. Ayrıca bitkilerin türler özelinde su ihtiyacı genellikle bilinmemekte olup ve bilinçsiz sulama ile hem su israf edilmekte hem de bitki için gereğinden az veya fazla sulama yapılmaktadır. Bu çalışmada yağmur suyunun yeniden kullanımı ile doğal su döngüsüne katkı sağlanması amaçlanmıştır. Aynı zamanda bitkilerin türlerine göre su isteklerini ortaya koyarak, doğru miktarda sulama yapılmasını hedeflemektedir. Bu iki temel hedef suyun etkin kullanımını sağlarken, bitkilerin doğru su ihtiyaçlarını öğrenmeyi amaç edinmiştir. Çalışma alanı içerisinde yer alan farklı çatı ve yer döşeme malzemeleri tespit edilmiştir. Her bir farklı yüzeyden toplanacak yağmur suyu miktarı Rasyonel Metot ile hesaplanmıştır. Çalışma alanı içerisinde bitki tür tespiti yapılmıştır. Her bir bitkiye ait su tüketim hesabı ise CropWat 8.0 programı ile hesaplanmıştır. Sonuç olarak, toplanacak yağmur suyu miktarı 494.000 m^3yıl, bitkilerin sulama suyu ihtiyacı 54.530 m^3yıl olarak hesaplanmıştır. Bu veriler karşılaştırıldığında, toplanan yağmur suyu miktarının bitkilerin sulama suyu ihtiyacını karşıladığını göstermektedir. Yerleşke içerisinde toplanacak yağmur suları tanklara yönlendirilecektir. Bu nedenle tanklar için uygun hacim hesaplan yapılmıştır. Depolanan yağmur suları dışında arta kalan yağmur suları için sürdürülebilir yöntemlerle yerinde çözüm önerileri üretilmiştir. Su isteği az veya orta olan bitkiler, yeni yapılacak peyzaj düzenlemelerinde kullanılmak üzere öneri olarak sunulmuştur.

Anahtar Kelimeler: Yağmur suyu hasadı, Yağmur suyunun yeniden kullanımı, Peyzaj bitkisi su tüketimi, Sulama, Sürdürülebilirlik, Kentsel yağmur suyu yönetimi

1. Introduction

Today, 55% of the world's population lives in cities, andthis figure is expected to rise to 68% by 2050 (United Nations Human Settlements, 2020). The proportion of the urban population in Europe is expected to rise from 74% in 2015 to 84% in 2050. While this increase is expected to correspond to 77 million new urban dwellers, Turkey is cited as one of the most affected countries (IPCC Sixth Assessment Report, 2022). As the urban population grows, the demand for water will also proportionally increase. However globally, sufficient, and clean water is vital for the health of humans and other living beings, for industry, agriculture and energy production. By 2025, an estimated 3.5 billion people will be affected by water scarcity. This figure is expected to rise by up to 30 % by 2050 (World Resources Institute, 2022). The United Nations is conducting numerous studies on this topic. The United Nations programmes “2005-2014: UN Decade of Education for Sustainable Development” and “International Decade for Action “Water for Life”, 2005-2015” underscore the current need to address water management on campus. Both programmes were launched to give special attention to sustainability and water in higher education, which are considered important for achieving environmental sustainability (Anonymous, 2023; UNESCO, 2005). As a result, the United Nations declared the period from 2018 to 2028 to be the international decade of action “Water Action Decade 2018-2028”. The program focuses on the sustainable development and integrated management of water resources to achieve social, economic and environmental goals, the implementation and promotion of relevant programs and projects, and the promotion of cooperation and partnerships at all levels to achieve internationally agreed water-related goals and targets, including those of the 2030 Agenda for Sustainable Development (Water Action Decade, 2016). As part of the United Nations “Sustainable Development Goals”; at least 1.8 billion people worldwide use a completely contaminated drinking water source, 663 million people still have no improved drinking water sources between 1990 and 2015, more than 80% of wastewater from human activities is discharged untreated into rivers or oceans, it is clearly stated that more than 40 of the world's population is affected by water scarcity and this number is expected to rise, that floods and other water-related disasters are responsible for 70 of deaths caused by natural disasters and that every day nearly 1.000 children die every day from preventable waterborne and diarrheal diseases. To prevent all this, the United Nations aims to halve the rate of untreated wastewater by 2030, increase water efficiency, including rainwater harvesting, wastewater treatment, recycling and reuse technologies, integrated water resources management, improve water quality by reducing pollution, significantly increase recycling and ensure global security, universal and equitable access to safe and affordable drinking water for all (The United Nations, 2022; The United Nations Sustainable Development Goals, 2022).

Turkey’s population is expected to reach 100 million by 2030. In this case, it is said that the amount of water available per capita in 2030 will be about 1100 m^3 per year. In addition, it is estimated that the demand for drinking and industrial water, which was 5 billion m^3 per year in 2000, will reach 18 billion m^3 by 2030 (Ministry of Development, 2018). The world's water systems are severely threatened by unsustainable management and climate change. The problem of climate change is exacerbated by the consequences of increasing floods and droughts, changing rainfall patterns, and rising sea levels (World Resources Institute, 2022). As most of the water used in cities cannot safely return to nature, groundwater and surface water resources are diminishing. As the economic value of clean water resources increases in urban and industrial use, wastewater is increasingly becoming a cost-effective and reliable alternative (Çakmakçı and Şahin, 2020).Water reuse in urban areas is now the first and most sought-after strategy for wastewater resource sustainability. The sustainability of water use in landscapes mainly depends on the reduction of consumption, collection and reuse of water (Amr et al., 2016). One way to increase water use efficiency in urban landscapes is to provide plants with the amount of water they need to maintain their healthy and aesthetic appearance (Nouri et al., 2013). Depending on the morphological and physiological structure of the plant, the amount of water to be consumed and the amount of irrigation water to be supplied to the plant differ. Since the amount of water consumed by each plant is different, the water consumption of the plants should be determined (Jensen, 1968). Proper pre-planning of factors such as the amount of water used by the plant, the amount of irrigation water to be applied, the duration of irrigation and the timing of irrigation are also indispensable prerequisites for the success of irrigation applications (İşbilir and Erdem, 2012). It is common practice to estimate the water consumption of crops. However, suitable methods for estimating the water requirements of urban landscapes are lacking in many respects (Nouri et al., 2012).

2. Materials and Methods

The Balkan campus of Trakya University, located at 41°38'19.3 "N and 26°36'58.1'Ein the central district of Edirne province, Turkey, was selected as the study area (*Figure 1*).

Figure 1. The study area location and out of scope areas (Source(s): Created by authors)

It covers an area of about 2.260 ha. There is currently no campus-wide application for water harvesting and recycling. The municipal water supply provides the water used in the buildings. Water for irrigation of the green areas is obtained from wells and from the municipal water supply. There are 15 wells on campus, of which 9 are active, 3 have collapsed and 3 are being rebuilt.

The irrigation, maintenance and water costs of the plants located within the boundaries of the dormitories were excluded from the study as they do not belong to Trakya University. In some areas within the campus, the necessary access for species identification was not possible due to dense shrub and tree cover. The areas outside the scope of application make up around 4% of the campus. The identification of plant species and the number of plants were determined as part of the landscaping.

The study was conducted in two phases. The amount of rainwater use on campus and the water consumption of landscape plants were calculated (*Figure 2*).

The "Rational Method" was used as a method to calculate the amount of rainwater on campus using Equation 1 (Awawdeh et al., 2012). The rational method provides good results up to 1-1.5 km^2 and can be applied in catchments up to 5 km^2 (İstanbulluoğlu, 2015; Official Gazette, 2017). This method was applied because the study area covers an area of 2.3 km^2.The calculations were performed specifically for the materials (surface types) used on campus.

$$V = Sum\ (R * A * RC)/1000 \qquad \text{(Eq.1)}$$

V: The rainwater yield in m^3 per year, R: The quantity of precipitation in liters per square millimeters (mm), A: The collecting area in square meters (m^2), RC: The efficiency coefficient in %, 1000 represents the conversion factor from mm to m. A hydraulic filter efficiency of 0.9 is achieved as a rule with filter systems that are maintained on a regular basis. Therefore, the total amount of water is multiplied by the coefficient of 0.9 (DeutschesInstitutfürNormunge.V., 2001).

The area calculations by material type are brick, 25.286; metal, 80.009; shingles, 23.061; glass, 528; concrete, 199.100; asphalt, 70.164; green areas, 884.328; and wooded areas, 196.526 m^2. The accepted yield coefficients are brick (0.8), metal (0.75), shingle (0.75), glass (0.9), concrete (0.7), asphalt (0.8), landscape (0.05), intensive woodland (0.1) and cultivated land (0.72) (DeutschesInstitutfürNormunge.V., 2001; Doğangönül and Doğangönül, 2009; Pande and Telang, 2014; Ramachandra et al., 2014; Bektaş et al., 2017).

Methods for estimating climate data are used to calculate the water requirements of crops. Among them, there are various equations such as the Blaney-Criddle Method, Radiation Method, the Penmann-Monteith Method, the Hargreaves-Samani Equation, Pan Evaporation Method (Smith et al., 1996; Kaya, 2011; Taş and Kırnak, 2011; Orta, 2017). These methods make the calculations dependent on many parameters, such as temperature, humidity, wind, precipitation, solar radiation, sunshine duration, length of daylight hours, soil type, soil moisture, plant type, plant growth stage, etc. Many studies have shown that the Penman-Monteith equation is the best method for determining plant water use based on climatic data (Smith et al., 1996; Allen et al., 1998; Kaya, 2011; Bayramoğlu, 2013). The CropWat 8.0 software was developed by the Food and Agriculture Organization of the United Nations (FAO) based on the Penman-Monteith method to perform these calculations in a computer environment.

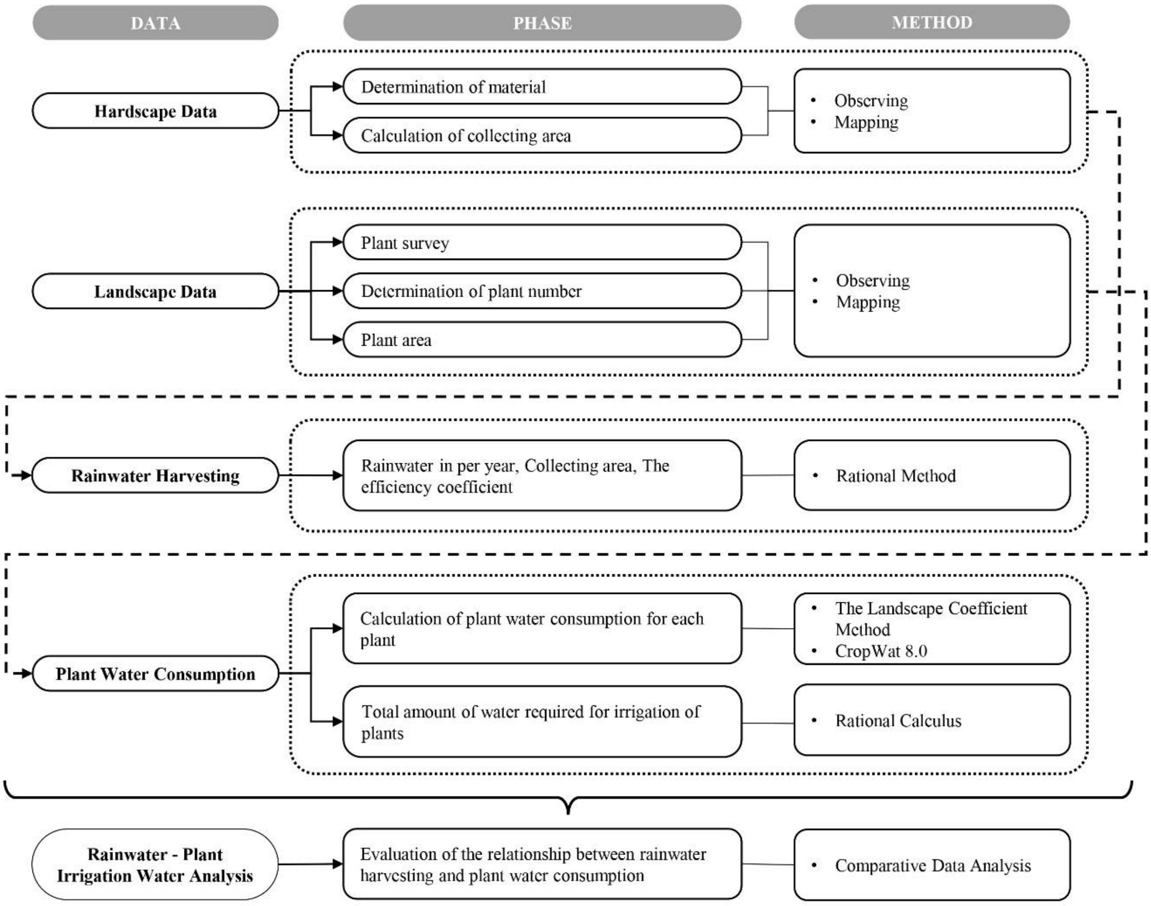

Figure 2. Research framework

In this study, the programme CropWat 8.0 is used to calculate the water consumption of plants. Within the programme, various data under 4 main headings are used: Climate, Precipitation, Plant and Soil. Summer temperatures are above 22 °C (Turkey State Meteorological Service, 2016). According to measurements taken between 1930-2021, the average annual temperature in Edirne province is 13.7 °C and the average annual precipitation is 604.4 mm (Turkey State Meteorological Service, 2022). The plant-related part of the programme includes values for kc (crop coefficient), plant growth stages and root depth. The kc value is specific to each plant and is defined as the ratio of the plant's water consumption to the water consumption of the reference plant. In other words, it is expressed as the plant's tolerance to drought. However, kc values have not been determined for plants used in the landscape (except for some grass species) (Orta, 2017). It is based on “The Landscape Coefficient Method” of the “University of California Cooperative Extension California Department of Water Resources” in California, USA (Costello et al., 2000). The use of the same method in many publications was found in the literature search (Hilaire, et al, 2008; Dayani et al., 2017; Li et al., 2017; Strbac et al., 2017; Pérez-Urrestarazu et al., 2018; Rana et al., 2019). In this study, the kc value is expressed by KL (The Landscape Coefficient). The KL value was associated with three factors. These are: Plant species (k_S), density (k_D) and microclimate (k_{MC}) (*Table 1*).

The calculation is made from the Equation 2;

$$KL = k_s * k_D * k_{MC} \quad \text{(Eq2).}$$

Table 1. Value ranges for plant species, density and microclimate (Costello et al., 2000)

	High	Medium	Low	Very Low
Plant species (k_S)	0.7-0.9	0.4-0.6	0.1-0.3	<0.1
Density (k_D)	1.1-1.3	1.0	0.5-0.9	
Microclimate (k_{MC})	1.1-1.4	1.0	0.5-0.9	

The value ranges for plant species, density and microclimate are based on another study. In this study, plant climate zones were defined. The climate zones are categorised according to the average temperatures (winter minimum, summer maximum, daily above, daily below) and average precipitation in the provinces within the California region (Perry, 2010). The closest plant zone for Edirne was determined based on the closest winter minimum, summer maximum and average rainfall in the list.

The KL values of the plants "*Aesculus hippocastanum, Cydonia oblonga, Laurocerasus officinalis*", which are not included in "The Landscape Coefficient Method", were determined as 0.6 based on Pittinger (Pittenger, 2014).

The values of the effective root depth are used for the root depth in the plant area of the programme. The effective rooting depth is defined as the depth at which the plants receive 80 % of the water required for their normal development. In general, plants take up a large part of the water they need from the upper parts of the root zone. For this reason, moistening the effective root zone instead of moistening the entire root depth can save considerable water during irrigation. The effective root depth can be 30 cm for grass plants, 45 cm for shrub plants and 60-90 cm for tree plants (Orta, 2017).

It was determined that the Balkan settlement is in the non-calcareous brown earth and the deep group within the large soil groups and depth maps of Edirne. For the soil part of the programme, the soil data developed by the FAO was used for the most important soil groups. For the total area covered by the plants on the campus, the spread of each plant was first listed. Based on the spread, the area (m^2) covered by a plant was calculated for each plant. The area covered by a plant was multiplied by the number of plants on the campus and the total area covered by the plants was calculated based on the species.

3. Results and Discussion

It is assumed that a total of 548.776 m^3year of rainwater can be harvested on the campus. Considering that not all water can be captured on the site and that 90 % of the flowing water is retained, the total amount of rainwater on the Balkan campus of Trakya University was calculated to be 494.000 m^3year.

After calculating the area each plant occupies on the campus, the water consumption of the plants was calculated based on the length of the four growing seasons of the plant. It indicates the total length of the growing period between the last frost and the first frost date for perennial plants. The total duration is divided into four development periods. If we calculate this period between March 1 and November 1 under Edirne conditions, it is determined as 8*30 = 240 days. The water consumption of the plants was calculated over 240 days. The water consumption amounts calculated in 1m^2 were determined with CropWat 8.0. The total water quantities were calculated by comparing the water consumption quantities calculated per 1m^2 with the total areas they cover on the campus. The total amount of water used by all plants was determined to be 54.530 m^3.

4. Conclusions

Structural surfacing materials such as tile, metal, shingles, glass, concrete, and asphalt, along with landscape features like trees, shrubs, and soil have been found to build up on the campus. The amount of rainwater that needs to be harvested for each of these materials totals 494.000 m^3year. 16 species of conifers, 43 species of deciduous broadleaf trees, 16 species of evergreen broadleaf shrubs, 16 species of deciduous broadleaf shrubs, 3 species of coniferous shrubs were identified. The values of the landscape coefficient (KL) of these plants were 0.098, 0.5 and 1.2. Based on these coefficients, the water consumption of the plants was classified as low (0.098), moderate (0.5) and high (1.2). Water consumption for plants with low water requirements was 70.3 mm per square meter, while moderate water-use plants require 351.3-421.6 mm, and the high water – use plants require approximately 843.2 mm per square meter (*Table 2*).

Table 2. Water consumption of the plant

Latin Name	Number	K_L	WaterNeeds	Plant Spread (m)	Spread withinthecampus (m^2)	Waterconsumption of oneplantper m^2 (mm)	Total waterrequirement on campus (m^3)
Conifers (Trees)							
Cedrusatlantica(Endl.) ManettiexCarr.	162	0.5	Moderate	6	4374	351.3	1536.6
Cedrusdeodora(Roxb. exLamb.) G.Don.	1	0.5	Moderate	8	48	351.3	16.9
*Cedruslibani*A.Rich.	46	0.5	Moderate	8	2208	351.3	775.7
*Cupressusarizonica*Greene	133	0.098	Low	4	1596	70.3	112.2
*Cupressusmacrocarpa*Harw. ex Gordoncv. “Goldcrest”	46	0.5	Moderate	5	863	351.3	303.0
*Cupressussempervirens*L.	245	0.5	Moderate	6	6615	351.3	2323.8
Cupressussempervirens(O. Tarz.Tozz.) Nymancv.“Pyramidalis”	46	0.5	Moderate	2	138	351.3	48.5
*Cupressocyparis x leylandii*A.B.Jacks. &Dallim.	62	0.5	Moderate	4	744	351.3	261.4
Piceaorientalis(L.) Peterm.	5	0.5	Moderate	6	135	351.3	47.4
*Piceapungens*Engelm.cv. “Glauca”	15	0.5	Moderate	3	101	351.3	35.6
*Pinusbrutia*Ten.	10	0.098	Low	10	750	70.3	52.7
*Pinusnigra*Arnold. subsp. pallasiana (Lamb.) Holmboe.	204	0.5	Moderate	10	15300	351.3	5374.9
*Pinuspinea*L.	75	0.098	Low	15	12656	70.3	889.7
Platycladusorientalis(L.) Franco. cv.“Aurea”	125	0.5	Moderate	2	375	351.3	131.7
Platycladusorientalis(L.) Franco.	1	0.5	Moderate	4	12	351.3	4.2
*Taxusbaccata*L.	2	0.5	Moderate	12	216	351.3	75.9
DeciduousBroad-leavedTrees							
Latin Name	**Number**	**K_L**	**WaterNeeds**	**Plant Spread**	**Spread withinthecampus**	**Waterconsumption of oneplantper m^2 (mm)**	**Total waterrequirement on campus (m^3)**
*Acer negundo*L.	174	0.5	Moderate	6	4698	351.3	1650.4
*Acer palmatum*Thunb.cv. “Atropurpureum”	2	0.5	Moderate	2	6	351.3	2.1
*Acer platanoides*L.	116	0.5	Moderate	10	8700	351.3	3056.3
*Acer pseudoplatanus*L.	2	0.5	Moderate	8	96	351.3	33.7
*Aesculushippocastanum*L.	49	0.6	Moderate	15	8269	421.6	3486.1
*Catalpabignonioides*Walter	29	0,5	Moderate	6	783	351.3	275.1
*Cercissiliquastrum*L.	27	0.5	Moderate	4	324	351.3	113.8
*Cercissiliquastrum*L.cv. “Album”	1	0.5	Moderate	4	12	351.3	4.2
*Cydoniaoblonga*Mill.	33	0.6	Moderate	3	223	421.6	93.9
*Elaeagnusangustifolia*L.	8	0.098	Low	6	216	70.3	15.2
*Ficuscarica*L.	6	0.5	Moderate	6	162	351.3	56.9
*Fraxinusangustifolia*Vahl.	15	0.5	Moderate	10	1125	351.3	395.2
*Fraxinusexcelsior*L.	131	0.5	Moderate	15	22106	351.3	7765.9

Table 2. Water consumption of the plant (continued)

*Gleditsiatriacanthos*L.	14	0.098	Low	6	378	70.3	26.6
*Juglansregia*L.	99	0.5	Moderate	15	16706	351.3	5868.9
*Lagerstromiaindica*L.	24	0.098	Low	3	162	70.3	11.4
*Magnoliavirginiana*L.	1	0.5	Moderate	3	7	351.3	2.4
Malus x domestica Borkh.	99	0.5	Moderate	4	1188	351.3	417.3
*Malusfloribunda*Siebold. ex Van Houtte.	2	0.5	Moderate	3	14	351.3	4.7
*Meliaazedarach*L.	3	0.098	Low	4	36	70.3	2.5
*Morusalba*L.	33	0.5	Moderate	6	891	351.3	313.0
*Morusalba*L. cv. “Pendula”	7	0.5	Moderate	2	21	351.3	7.4
Paulowniatomentosa(Thunb .) Britton.	3	1.2	High	8	144	843.2	121.4
*Platanusorientalis*L.	127	0.5	Moderate	15	21431	351.3	7528.8
*Populusalba*L.	4	0.5	Moderate	10	300	351.3	105.4
Populustremula L.	13	0.5	Moderate	10	975	351.3	342.5
*Prunus armeniaca*L.	30	0.5	Moderate	4	360	351.3	126.5
*Prunus avium*L.	27	0.5	Moderate	4	324	351.3	113.8
*Prunus cerasifera*Ehrh.	29	0.5	Moderate	3	196	351.3	68.8
*Prunus cerasus*L.	1	0.5	Moderate	3	7	351.3	2.4
Prunus x domestica L.	10	0.5	Moderate	4	120	351.3	42.2
*Prunus amygdalus*Batsch	332	0.5	Moderate	4	24	351.3	8.4
Prunus persica(L.) Batsch	2	0.5	Moderate	4	396	351.3	139.1
*Pyruscommunis*L.	33	0.5	Moderate	8	1392	70.3	97.9
Robiniapseudoacacia L.	29	0.098	Low	8	48	843.2	40.5
*Salixalba*L.	1	1.2	High	8	1200	843.2	1011.8
Salixbabylonica L.	25	1.2	High	2	3	843.2	2.5
*Salixcaprea*L.	1	1.2	High	8	864	70.3	60.7
*Sophorajaponica*L.	18	0.098	Low	3	7	351.3	2.4
Sorbus domestica L.	1	0.5	Moderate	8	288	351.3	101.2
*Ulmuscampestris*L.	6	0.5	Moderate	10	20175	351.3	7087.5
*Tiliatomentosa*Moench	269	0.5	Moderate	10	150	351.3	52.7
*Quercus alba*L.	2	0.5	Moderate	10	2775	351.3	974.9
EvergreenBroad-leavedShrubs							
Latin Name	**Number**	**K_L**	**WaterNeeds**	**Plant Spread**	**Spread withint hecampus**	**Waterconsumption of oneplantper m^2 (mm)**	**Total waterrequirement on campus (m^3)**
Abelia x grandiflora(RovelliexAndré) Rehder	3	0.5	Moderate	1	2	351.3	0.8
*Buxussempervirens*L.	44	0.5	Moderate	3	297	351.3	104.3
*Cotoneasterhorizontalis*Decne.	60	0.098	Low	1	45	70.3	3.2
*Euonymusjaponica*L.cv. “Aurea”	79	0.098	Low	1	59	70.3	4.2
*Euonymusjaponicus*H. Jaegercv. “Microphyllus”	15	0.098	Low	0.5	3	70.3	0.2
*Laurusnobilis*L.	2	0.098	Low	3	14	70.3	0.9
*Lavandulaangustifolia*Mill.	46	0.098	Low	0.5	9	70.3	0.6

Table 2. Water consumption of the plant (continued)

*Lupustumvulgare*L.	103	0.098	Low	3	695	70.3	48.9
*Mahoniaaquifolium*Nutt.	14	0.5	Moderate	1	11	351.3	3.7
*Photinia x fraseri*Dresscv. "RedRobin"	91	0.5	Moderate	3	614	351.3	215.8
Pittosporumtobira(Thunb.) Ait.	1	0.5	Moderate	2	3	351.3	1.1
*Pyracanthacoccinea*M. J. Roemer	72	0.098	Low	2	216	70.3	15.2
Spirea x vanhouetti(Briot) Zab.	182	0.5	Moderate	2	546	351.3	191.8
*Viburnumtinus*L.	45	0.5	Moderate	2	135	351.3	47.4
*Yuccafilamentosa*L.	12	0.098	Low	0.5	2	70.3	0.2
DeciduousBroad-leavedShrubs							
Latin Name	**Number**	**K_L**	**WaterNeeds**	**Plant Spread**	**Spread withinthecampus**	**Waterconsumption of oneplantper m^2 (mm)**	**Total waterrequirement on campus (m^3)**
*Berberisthunbergii*DC. cv. "Atropurpurea"	54	0.098	Low	1	41	70.3	2.8
Chaenomelesjaponica(Thunb.) Lindl. &Spach	1	0.098	Low	1.5	2	70.3	0.1
*Cornusalba*L.	12	0.5	Moderate	1	10	351.3	3.4
Cornus mas L.	1	0.5	Moderate	1	35	70.3	2.5
*Forsythia x intermedia*Zabel	47	0.098	Low	1	15	351.3	5.3
*Hibiscussyriacus*L.	20	0.5	Moderate	3	95	70.3	6.6
Hydrangeamacrophylla(Thunb.) Ser.	14	0.098	Low	1	16	351.3	5.5
Kerriajaponica(L.) DC.	21	0.5	Moderate	1	2	351.3	0.8
*Loniceraetrusca*Santi	3	0.5	Moderate	1	411	351.3	144.4
*Rosa*sp. L.	548	0.5	Moderate	2	39	351.3	13.7
*Philadelphuscoronarius*L.	13	0.5	Moderate	1.5	19	70.3	1.3
Symphoricarposorbiculatus Moench	11	0.098	Low	2	9	70.3	0.6
*Syringavulgaris*L.	3	0.098	Low	2.5	56	70.3	4.0
*Tamarixtetrandra*PallasexBieb.	12	0.098	Low	2	132	351.3	46.4
*Viburnumopulus*L.	44	0.5	Moderate	1	1	351.3	0.3
Conifers (Shrubs)							
Latin Name	**Number**	**K_L**	**WaterNeeds**	**Plant Spread**	**Spread withinthecampus**	**Waterconsumption of oneplantper m^2 (mm)**	**Total waterrequirement on campus (m^3)**
*Juniperuscommunis*L.	24	0.098	Low	2	72	70.3	5.1
*Junıperushorizontalis*Moench.	113	0.098	Low	2	342	70.3	24.0
*Juniperussabina*L.	2	0.098	Low	1	2	70.3	0.1

To use the rainwater collected throughout the campus for watering the plants, storage areas are required. The design of storage areas can be accomplished by installing tanks of appropriate size and materials. Methods for determining tank volume based on different variables can include applications such as 5% of average annual rainfall, 14 to 30-day rainwater demand for toilet flushing, water consumption for garden irrigation in a 3-month period, and 1 m^3 tank per 25 m^2 of roof area (Madzia, 2019). To determine the size of the rainwater storage tank, calculations should be made based on different variables such as collection area, number of users, rainfall data, amount of rainwater collected, amount of water required, calculation of daily water consumption, budget, etc. (ESCAP, 2013; Okoye et al., 2015). Depending on these variables, storage areas of between 25.000 and 30.000 m^3 can be created.

Apart from this, rain garden proposals can be made to reintroduce the remaining rainwater back into the natural cycle with on-site solutions after it has been stored on campus. In this way, the need for tap water and groundwater for irrigation is reduced or eliminated. Rainwater is also incorporated into the natural cycle by using it efficiently instead of generating surface runoff. At the same time, flooding and encroachment that can occur in impermeable urban areas is prevented. By revealing the water requirements of plants, one can also contribute to effective water use by creating designs with plants that require less water in the vegetative design phase. Plants such as *Acer campestre* L., *Artemisia vulgaris* L., *Cercis siliquastrum* L., *Chrysanthemum segetum* L., *Festuca glauca* Lam., *Forsythia x intermedia* Zabel, *Gaura lindheimeri*Engelm. & Gray, *Iris pseudacorus* L., *Lagerstroemia indica* L., *Lavandula angustifolia* Mill., *Melia azedarach* L., *Ophiopogon japonicus* Thunb., *Ophiopogon japonicus* Thunb., *Populus nigra* L., *Rosmarinus officinalis* L. have low, medium, low-medium water requirements and can be used in landscape areas and rain gardens.Although the water requirements of plants vary depending on data such as climate and location, it is important to determine them on a plant-specific basis. In Turkey, there is no comprehensive study dealing with the water requirements of plants except for grass species. This study provides a basis for other studies as it shows the plant-specific plant coefficients (KL) and water consumption.

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Ethical Statement

There is no need to obtain permission from the ethics committee for this study.

Conflicts of Interest

We declare that there is no conflict of interest between us as the article authors.

Authorship Contribution Statement

Concept: Mısırlı, N., Şişman, E. E.; Data Collection or Processing: Mısırlı, N., Şişman, E. E.; Statistical Analyses: Mısırlı, N., Şişman, E. E.; Literature Search: Mısırlı, N.; Writing, Review and Editing: Mısırlı, N., Şişman, E. E.

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