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Research Rainwater Harvesting Potential of Erciyes University Campus Based on The UI GreenMetric Ranking

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Abstract: A green campus is one of the important aspects of an ecological city. Setting and infrastructure, energy and climate change, waste, water, transportation, and education are major elements of a green campus. This study focuses on water consumption and savings, which generally involves a rainwater harvesting system. Erciyes University became the third environmentally sensitive university in Turkey according to the UI GreenMetric 2020–2021 ranking. While Erciyes University was ranked 142nd in the world in 2020, with a total score of 7175, it rose to 99th place in 2021, with 7775 points. According to UI GreenMetric Erciyes University was ranked 85nd in the world in 2023. This paper investigates and describes a rainwater harvesting method for Erciyes University. The total harvestable water was calculated as the roof surface area × the average annual rainfall × the loss coefficient. The loss coefficient was set as 0.75 considering the differences in roof forms. The rainwater harvesting calculations were computed based on the building floor areas because of the differences in roof forms. The total harvestable water was calculated to be 64,635.432 m^3 from the roofs (floor area) in the campus area of Erciyes University. Accordingly, it is possible to save approximately 7.55% of the annual water consumption, saving 1,066,477 TL and supplying water to 7,181 people per year by harvesting rainwater from the roofs at Erciyes University. It is concluded that the proposed rainwater harvesting method help Erciyes University rank higher in the UI GreenMetric ranking, contribute to the eco-city approach, and enhance campus sustainability.

Erciyes Üniversitesi Yağmur Suyu Potansiyelinin UI GreenMetric Sıralaması Bağlamında Araştırılması

Anahtar Kelimeler
Anahtar Kelime 1, Yağmur Suyu Hasadı, Anahtar Kelime 2, Universite Kampüsü, Anahtar Kelime 3, UI GreenMetric

Öz: Yeşil kampüs, ekolojik şehrin önemli unsurlarından biridir. Yerleşim ve altyapı, enerji ve iklim değişikliği, atık, su, ulaşım ve eğitim yeşil bir kampüsün başlıca ögeleridir. Bu çalışma, yağmur suyu toplama sistemini içeren su tüketimi ve tasarrufuna odaklanmaktadır. Erciyes Üniversitesi, UI GreenMetric 2020-2021 sıralamasına göre Türkiye'de çevreye duyarlı üçüncü üniversite olmuştur. Erciyes Üniversitesi 2020 yılında toplam 7175 puanla dünyada 142. sırada yer alırken, 2021 yılında 7775 puanla 99. sıraya yükselmiştir. UI GreenMetric sıralamasına göre Erciyes Üniversitesi 2023 yılında dünyada 85. sırada yer almıştır. Bu makalede, Erciyes Üniversitesi için yağmur suyu hasadı yöntemi kullanılmıştır. Toplam hasat edilebilir su miktarı, çatı yüzey alanı × yıllık ortalama yağış miktarı × kayıp katsayısı hesabı esas alınarak hesaplanmıştır. Kayıp katsayısı, çatı formlarındaki farklılıklar göz önünde bulundurularak 0,75 olarak belirlenmiştir. Hesaplamada çatı farklılıkları nedeniyle bina taban alanları esas alınmıştır. Erciyes Üniversitesi kampüs alanındaki çatılardan toplam hasat edilebilir su miktarı 64.635,432 m^3 olarak hesaplanmıştır. Buna göre, Erciyes Üniversitesi'nde çatılardan yağmur suyu hasadı yapılarak yıllık su tüketiminin yaklaşık %7,55'inden tasarruf edilmesi, 1.066.477 TL tasarruf sağlanması ve yılda 7.181 kişiye su temin edilmesi mümkündür. Önerilen yağmur suyu hasadı yönteminin, Erciyes Üniversitesi'ni UI GreenMetric sıralamasında daha üst sıralara taşıyacağı, eko-kent yaklaşımına katkıda bulunacağı ve kampüs sürdürülebilirliğini geliştirmesine yardımcı olacağı sonucuna varılmıştır.

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1. Introduction

Considering various criteria, ranking tables have been created for universities since 1983 when the annual America's Best Colleges Review was first published [1, 2]. Within the scope of this issue, many universities have been conducting studies worldwide on sustainability and green university rankings [3, 4, 5]. With the Talloires Declaration published in 1990, 40 different countries and nearly 300 universities have prioritized sustainable development in education, research, information exchange, policy-making, and practices, and accordingly, the concept of the sustainable campus has started to gain prominence [4, 6, 7]. Consequently, sustainable campuses have become a global area of interest for planners and university administrations [6]. Starting in the 2000s, and especially after 2010, the concepts of green universities and green campuses have gained attention as a part of environmental sustainability, not only in scientific research but also in campus infrastructure and environmentally friendly practices [3]. Created in 2010 at Universitas Indonesia, UI GreenMetric is one of the university rankings used to measure green campus practices on a global scale and evaluate the efforts of universities for sustainability [3, 4, 5, 8]. UI GreenMetric helps clarify multiple definitions of green campuses and is used to evaluate the sustainability efforts of university campuses [1, 9]. Specifically, the UI GreenMetric rating addresses universities' practices and performances in six categories: infrastructure, energy and climate change, waste, water, transport, and education and research [10].

This study examined the rainwater harvesting potential at Erciyes University, categorized under the water heading of the UI GreenMetric sustainable campus performance.

1. 1. Erciyes University: UI GreenMetric

Erciyes University is located in the city of Kayseri. Figure 1 depicts the location of Kayseri province in Turkey, as well as the city and Erciyes University. Erciyes University is one of the 10 research universities established in Turkey in 2017 [11]. Today, there are 20 research universities in Turkey, and Erciyes University ranks 8th among them [12]. Erciyes University has a total of 49,721 students, and among them, 2,377 are associate degree students, 38,011 are undergraduates, 6,935 are graduates, and 2,398 are doctoral students in 2021-2022 academic year. In addition, 2,218 academics work at the university [13].

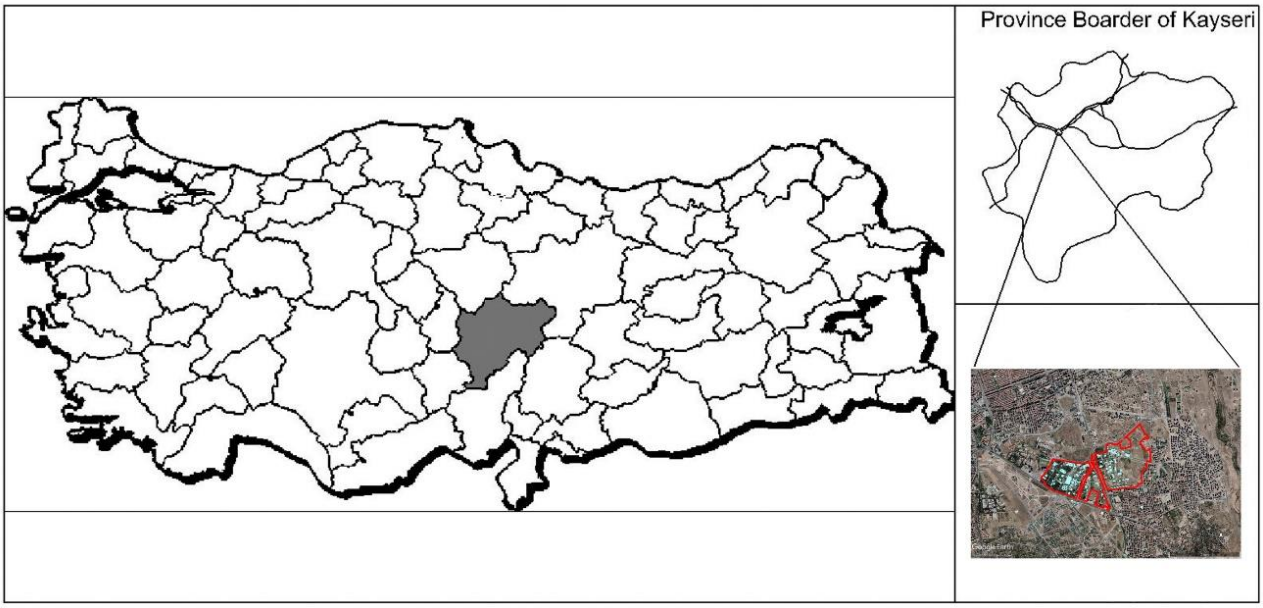

Figure 1. Location of Kayseri in Türkiye

Figure 2 shows the central campus of Erciyes University, where the buildings shown in blue are used in the rainwater harvesting calculation. In this study, the buildings under construction were not considered. The total floor area of the buildings used in the study is 219,289 m^2. The implementation-zoning plan was based on determining the campus area boundary. According to the implementation-zoning plan, the total area of the university is 3,092,585.274 m^2 (309.26 hectares). Erciyes University's 2019 sustainability report states that 39% of the total area is covered with vegetation [14]. Erciyes University's 2021 Sustainability report states that the proportion of cultivated areas in the total area is 24.38% [14]. The university not only provides green space for students with its campus area but also for the city of Kayseri.

Figure 2. Erciyes University campus boundary and the buildings considered in this study

Figure 3 shows implementation-zoning plan around Erciyes University campus. When the implementation-zoning plan is examined to understand the urban development around the Erciyes University campus, it is seen that the city of Kayseri and the Erciyes University campus are integrated with linear green spaces. In this case, the Erciyes University campus area contributes to the urban ecosystem and offers green spaces that integrate with other green spaces in the city, contributing significantly to the overall urban sustainability. According to the implementation-zoning plan, the built environment around the Erciyes University campus area will intensify in the future. The Erciyes University campus has a high green space potential within the city because of its low building density and valuable open space where water can be collected through rain harvesting.

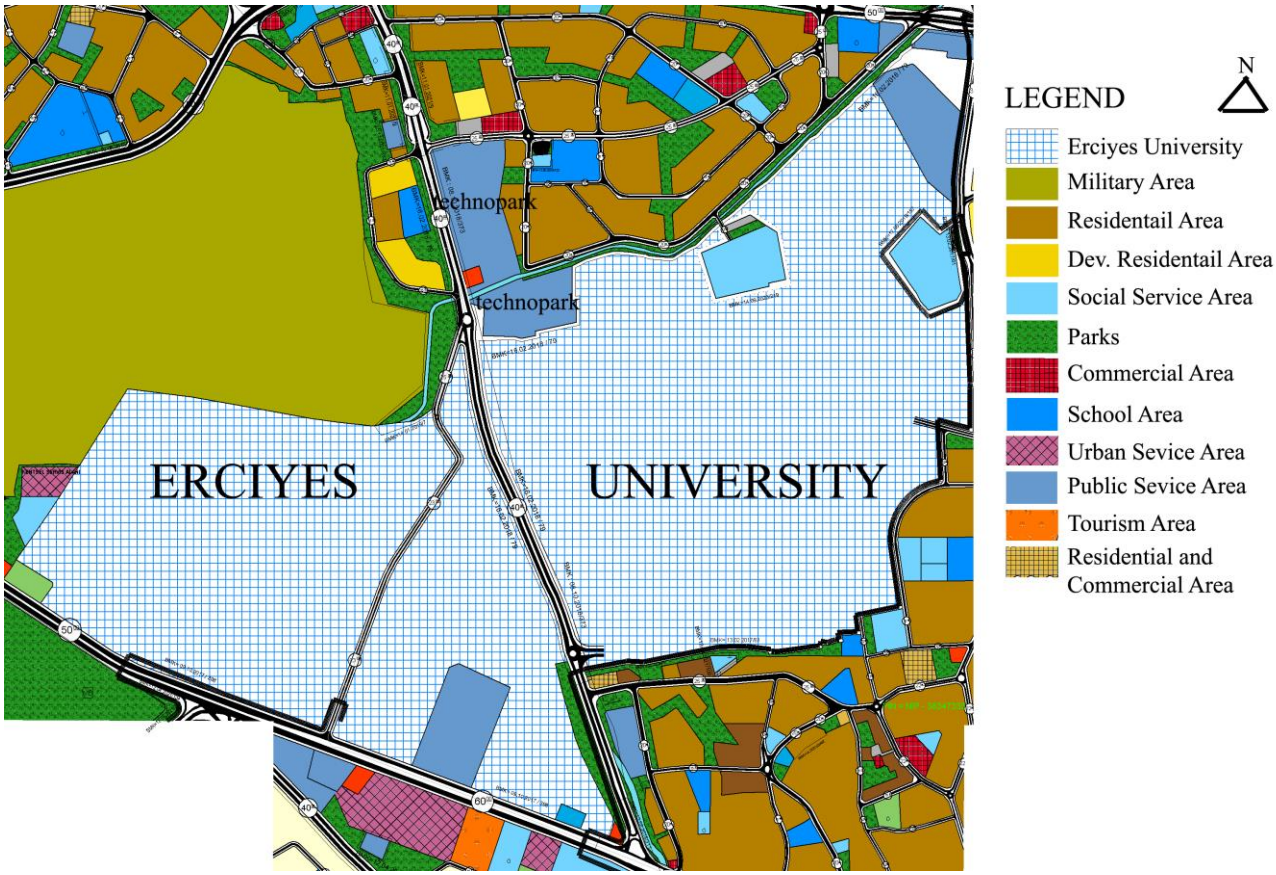

Figure 3. Implementation-zoning plan around Erciyes University campus

Water is stored in an artificial pond at Erciyes University, and the needs of plants are met using water from this pond during dry periods. In addition, rainwater harvesting is conducted over an area of 71,000 m^2 at the Erciyes University Technopark [15]. Examining the UI GreenMetric studies of Erciyes University, important steps have been taken to attain the goal of campus sustainability. Table 1 shows the performance of Erciyes University in the 2017–2023 annual rankings of UI GreenMetric. There was a decrease in the water score in 2018; however, a 3-fold increase occurred in 2019 compared with 2018. In 2020, the same performance was observed as that in 2019. Although there was an increase of 50 points in 2021, the same score was received in 2022 as that in 2021. In 2023, the total score increased; however, the impact of water remained stable over the last three years. Notably, the water criterion has the lowest score among the sustainability criteria in the performance table of Erciyes University.

Table 1 Erciyes University UI GreenMetric Performance (2017–2023)

Year	Setting and Infrastructure	Energy and Climate Change	Waste	Water	Transportation	Education	Total Score
2023	13.50	16.10	14.25	8.00	16.00	16.75	84.60
2022	13.25	15.35	14.25	8.00	16.00	15.75	82.60
2021	12.25	14.00	13.50	8.00	14.25	15.75	77.75
2020	11.00	12.50	12.00	7.50	13.75	15.00	71.75
2019	11.00	12.00	9.00	7.50	11.75	14.25	65.50
2018	12.50	10.75	6.00	2.50	9.50	12.50	53.75
2017	9.50	877	5.73	4.41	9.13	7.56	45.10

Source: [16]

Table 2 shows Erciyes University's performance based on the proportions of their scores in Setting and Infrastructure, Energy and Climate Change, Waste, Water, Transportation, and Education from the UI GreenMetric criteria between 2017 and 2023. Considering the change in the percentage ratios of the performance data over the years, there has been a gradual increase in the waste heading, and the largest decrease was experienced in the

performance of Setting and Infrastructure. When the change is analyzed in terms of percentages, there is a 0.23% decrease in the water in 2023 compared with the previous year. There has been a decrease in the water topic in terms of percentage change over the last four years.

Table 2 Percentage Changes of UI GreenMetric Criteria (2017–2023)

Year	Setting and Infrastructure	Energy and Climate Change	Waste	Water	Transportation	Education	Total Score
2023	15.96	19,03	16.84	9.46	18,91	19,8	100.00
2022	16.04	18.58	17.25	9.69	19.37	19.07	100.00
2021	15.76	18.01	17.36	10.29	18.33	20.26	100.00
2020	15.33	17.42	16.72	10.45	19.16	20.91	100.00
2019	16.79	18.32	13.74	11.45	17.94	21.76	100.00
2018	23.26	20.00	11.16	4.65	17.67	23.26	100.00
2017	21.06	19.45	12.71	9.78	20.24	16.76	100.00

Source: [17]

As seen in Table 2, Erciyes University received the lowest score for the water criterion. For this reason, the water score requires attention and should be strengthened.

Table 3 shows the annual water consumption of Erciyes University. Accordingly, 975,320 m^3 of water was consumed in 2018, 963,500 m^3 in 2019, and 790,329 m^3 in 2020. The decrease in the amount of water used in 2020 was due to the COVID-19 measures that included first stopping education for three weeks, then completing that semester by switching to distance education and providing 40% of education through distance education in September in2020. Looking at the amount of water consumed in 2021 and 2022, there was a positive change in water savings after 2020. Approximately 855,282 m^3 of average water is consumed annually at Erciyes University.

Table 3 Amount of water used at Erciyes University (2018–2021)

Years	Amount of water (m^3)
2018	975,320
2019	963,500
2020	790,329
2021	754,900
2022	792,362

Sources: [18, 19]

Overall, it is clear that the annual water consumption of Erciyes University is considerably high. In this context, water harvesting is necessary to support the efficient use of water resources and contribute to the campus's sustainability.

1. 2. Kayseri and Precipitation

According to the climate data obtained from the Turkey General Directorate of Meteorological Affairs for the years 1970–2013, the average precipitation in Kayseri city center was 393 mm, and the average number of rainy days was 109.6 (Kayseri Province Clean Air Action Plan Report). Table 4 shows the monthly average rainfall and number of rainy days. Precipitation is typically the highest in April and May. In addition, the driest month is August, although July, August, and September are also relatively dry.

Table 4 Monthly Distribution of Precipitation and Average Number of Rainy Days in Kayseri City Center (1970-2013)

	Average amount of precipitation (mm)	Average number of rain days
January	33.1	12
February	33.1	11
March	42.2	12

April	55.9	138
May	54.3	135
June	38.6	8
July	11.4	2
August	5.8	18
September	11.3	37
October	33.3	8
November	35.5	9
December	38.5	118

Source: [20]

Thornthwaite developed a method to calculate the evapotranspiration potential based on the relationship between temperature, average precipitation, and humidity [21, 22, 23]. Figure 4 shows the climate characteristics in Turkey according to Thornwaite's climate classification. According to this classification, Kayseri has a semi-arid to less humid climate where high levels of evaporation may occur, implying that water resources are generally insufficient, increasing the importance of supplemental methods such as rainwater harvesting.

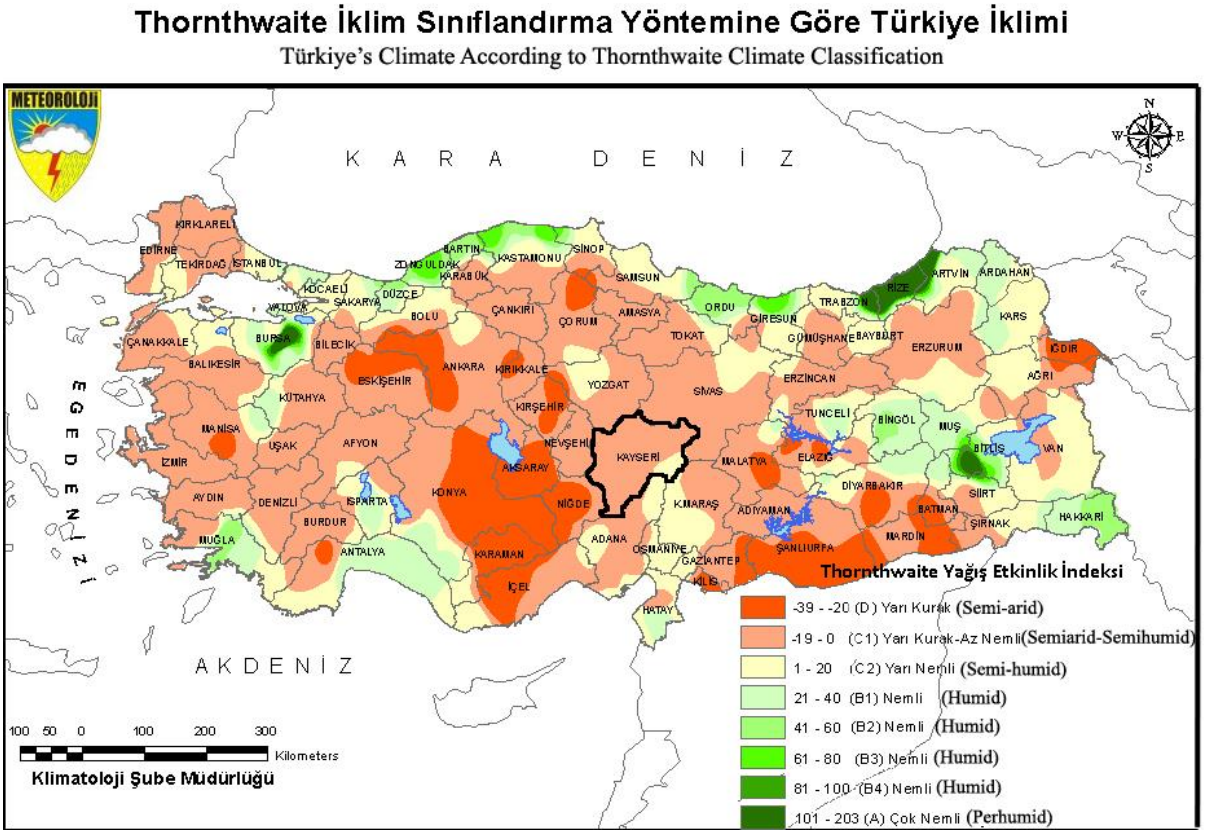

Figure 4. The climate in Kayseri according to Thornthwaite's climate classification, Source: [24]

In an analysis using the Mann–Kendall method and considering annual average precipitation, the average annual precipitation increased slightly between 1960 and 2005, but the change was not significant [25]. Ünlükara et al. investigated drought considering annual precipitation changes between 1975 and 2010 and reported that mostly mild droughts occurred in Kayseri, although severe and moderate droughts also occurred between these years [26]. The limits of water resources were taxed during periods of sudden precipitation changes and drought in Kayseri [25]. Figure 5 displays a map depicting the average annual precipitation in Turkey, showing that Kayseri city center receives less than 400 mm of precipitation.

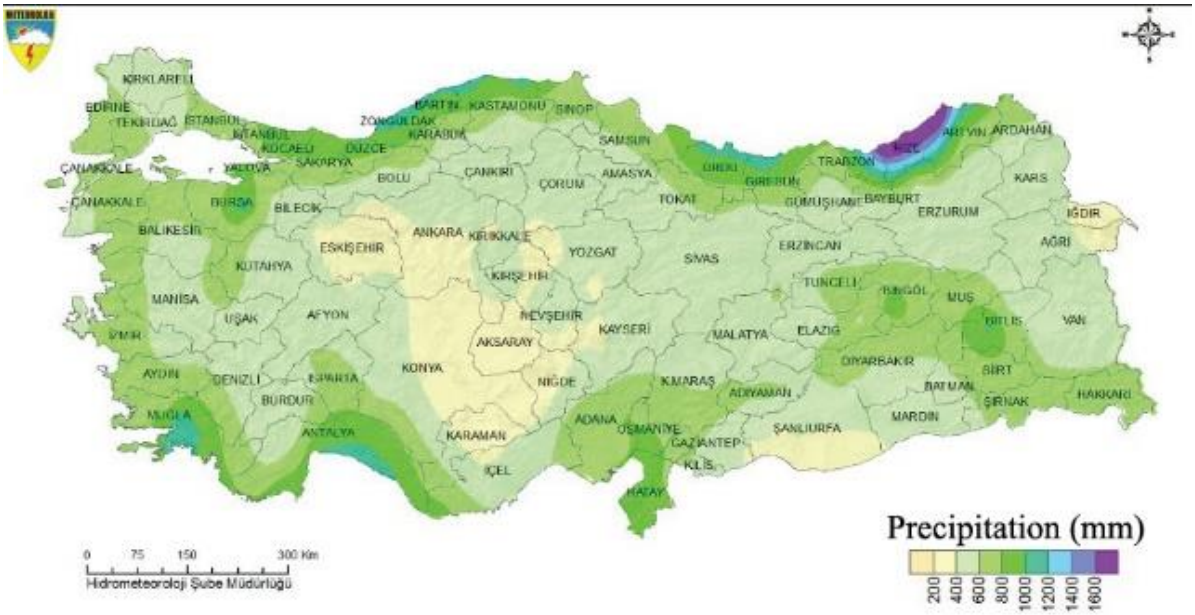

Figure 5. Average annual precipitation in Turkey (1981-2010), Source: [27]

Owing to the semi-arid climate and precipitation of less than 400 mm, it is important to use rainwater efficiently in Kayseri. Regardless, water should be prioritized in sustainable practices and green campus design.

2. Material and Method

Rainwater harvesting is the process of collecting and storing rainwater for later use [28, 29]. Rainwater collected by rainwater harvesting can be recharged to the groundwater [30] or collected in man-made tanks [31]. Rainwater harvesting is predominantly and most commonly harvested from roofs but can also be collected from impermeable surfaces where rainwater often accumulates, such as roads and rock surfaces. Rainwater harvesting is a simple and inexpensive but effective method for obtaining usable water considering diminishing water resources [29, 32, 33]. Rainwater harvesting involves the collection of rainwater from the catchment surface through pipes, which is stored in natural ponds or artificial tanks, and typically filtered [29, 32, 33, 34]. Rainwater harvesting is effective in reducing the use of municipal water, reducing water costs for users, protecting the soil from erosion by reducing the risk of flooding. Additionally, recharging/replenishing the water collected using this method to groundwater and aquifers helps to protect existing water sources [33, 34].

In recent years, rainwater harvesting has become increasingly important in sustainable campus practices and has been discussed in scientific research [35, 36, 37, 38].
Rainwater harvesting is recognized as one of the most effective methods for creating water resources [31] and promises to make a significant contribution to addressing water scarcity in the future [28]. It is not possible to use the water obtained from rainwater harvesting directly as drinking water because it contains microbial pathogens, waste from urban dwellers, traffic emissions, and industrial pollutants. Thus, chemical or biological treatment is needed before using it as drinking water [39].

Collecting water through rainwater harvesting is theoretically directly proportional to the amount of rainfall and the water collection surface area. However, the storage tank capacity is also very important because it is not possible to store the precipitation that continues to fall after the water tank is full. In addition, the intensity of the rainfall and wind during precipitation, the rate of evaporation, and the structure of the collection surface are among the factors affecting storage [29, 39]. In this study, it was assumed that rainwater was harvested from all buildings on the Erciyes University campus and that rainwater can be collected effectively from all surfaces and all rainwater can be stored.

Rainwater harvesting potential (Pw), catchment area (total roof area) (A), runoff coefficient (C), and rainfall (R) values were used in the calculation.

Pw = Potential of rainwater harvesting (m^3)
A = Area of catchment (total roof area) (m^2)
C = Runoff coefficient
R = Amount of Rainfall (mm)

The runoff coefficient can be defined as the ratio of rainwater drained during rainfall to the total surface runoff [40, 41]. The occurrence and volume of the runoff are affected by rainfall characteristics such as intensity, duration [42, 43], catchment material [44], distribution, and some physical characteristics of watersheds [40]. The runoff coefficient for rain collection from roofs varies depending on factors such as the roof form, materials, rainfall intensity, and wind speed; however, it is generally accepted to be in the range of 0.75–0.95 [45, 46]. A minimum value (0.75) was used herein because of the differences in roof forms among the campus buildings.

The water collection area is defined as the area where rain falls and water is collected. In this study, the water collection area was determined by the roof surfaces. Roof form, surface material, and slope are important factors in rain harvesting. Owing to the variation in roof forms and the difficulties in calculating roof surface area, the rainwater harvesting calculations were computed based on the building floor areas.

Rainfall is based on the average annual rainfall amount. Monthly rainfall data are necessary to calculate how much water can be collected during the wet and dry seasons, which helps to determine the appropriate storage volume. In this study, these values were considered, and the following formula was applied [28, 29, 30, 47].

$$Pw = A \times C \times R$$

The total floor area of all buildings in Erciyes University is 219,289 m^2. According to the meteorological station data in Kayseri city center where Erciyes University is located, the average annual rainfall is 393 mm. Considering the differences in roof surface material and roof form, the runoff coefficient was assumed to be 0.75, as shown below.

$$219{,}289 \times 393 \times 0.75 = 64{,}635.432\ m^3$$

As a result, the amount of water savings that can be obtained only using all the roof surfaces is 64,635.432 m^3 if all the rainwater is harvested.

The months of July, August, and September coincide with the academic holiday period. For this reason, it is important to calculate the rainwater harvesting potential on a monthly basis in terms of water collected by rainwater harvesting and water consumption. An examination of Table 5 indicates that there is not enough rainfall in July, August and September, and the average precipitation is low, so it is necessary to use water economically.

Table 5 The average monthly roof water harvesting potential of Erciyes University

	Average amount of precipitation (mm)	Roof surface (m^2)	Runoff coefficient	Monthly rainwater harvesting potential (m^3)
January	33.1	219,289	0.75	544,385
February	33.1	219,289	0.75	544,385
March	42.2	219,289	0.75	694,050
April	55.9	219,289	0.75	919,369
May	54.3	219,289	0.75	893,054
June	38.6	219,289	0.75	634,842
July	11.4	219,289	0.75	187,492
August	5.8	219,289	0.75	95,391
September	11.3	219,289	0.75	185,847
October	33.3	219,289	0.75	547,674
November	35.5	219,289	0.75	583,857
December	38.5	219,289	0.75	633,197

3. Results

Under the heading of water, UI GreenMetric gives scores based on the water savings program and implementation (WR 1), implementation of water recycling program (WR 2), water-saving device usage (WR 3), consumption of treated water (WR 4), and water pollution control in the campus area (WR 5). If rainwater is harvested from the roof surfaces of all buildings on the campus and the harvested rainwater is treated and recycled as domestic water, full scores can be obtained for WR1, WR 2, WR 4, and WR 5. In addition, the water obtained by rainwater harvesting can be used for irrigation of the existing cultivated vegetation in the campus area, and the use of rainwater harvested in afforested areas can help increase the total area covered with forest vegetation on the campus. The use of harvested water for irrigation in cultivated and vegetation areas can also help Erciyes University rank higher in the UI GreenMetric ranking.

The average monthly water consumption of a student in vocational schools and higher education institutions on the Warsaw University campus is 0.8 m^3 per month in departments with laboratories and 0.45 m^3 per month in departments without laboratories [48]. Assuming that there is an equal number of students in the departments with and without laboratories, the average monthly water consumption of a person in the campus area can be considered as 0.625 m^3. According to this calculation, the average annual water consumption of a student is 7.5 m^3. Another study reports that the daily water consumption per person at Al-Quds University is 25 liters [49]. Considering this study, the total annual water consumption of a person is approximately 9.125 m^3. Thus, the water consumption of a person on campus varies between 7.5 and 9 m^3. When the amount of water consumption per person in campus areas is considered as 9 m^3, which is the highest value in the literature, it is possible to meet the annual water needs of approximately 7,181 people using the rainwater harvested from the roof surfaces at Erciyes University. There are 49,721 students studying at Erciyes University, as well as 2,218 academics and approximately 4,000 administrative staff. It is possible to meet the annual water use needs of 7,181 of the 56,000 people, meeting the water consumption of approximately 13% of the total university population. In terms of economic evaluation, the unit price per m^3 of water in Kayseri was 16.5 TRY as of July 2023. If rainwater is harvested from all roof surfaces at Erciyes University and the water obtained by harvesting is used as domestic water on the campus, it is possible to save approximately 1,066,477 ₺ (US $ 39,527 according to dollar exchange rate in July 2023) per year.

4. Discussion

University campuses resemble small cities owing to their large size, the substantial number of students and teaching staff, and the accommodation of different activities [6, 50, 51, 52]. As an important element of cities, the sustainability of campus areas significantly contributes to urban sustainability. Furthermore, campuses are important elements of the urban ecosystem. They add positive value to the urban ecosystem with their environment, particularly their open areas and green spaces. Similarly, Erciyes University has the potential to significantly contribute to the urban ecosystem with its open areas, vegetation, and green spaces suitable for various environmental interactions.

Nature-friendly, ecological designs and studies to be carried out in universities will be role models for ecological and nature-friendly designs and applications that will be conducted in other areas of the city and thus contribute to the protection of the environment.

The importance of water management is increasing, especially today when the effects of global climate change are felt. At Erciyes University, it is possible to collect approximately 64,635.432 m^3 of water annually through rainwater harvesting. The average annual water consumption of Erciyes University is approximately 855,282 m^3. Considering that a large amount of the water is used for irrigation of the green area in the dry period, along with the gray water system, it is possible to save a significant amount of water by simply catching rainwater. Considering that Erciyes University achieved its score from water criterion in the IU GreenMetric ranking due to its water saving in 2019, rainwater harvesting will make a significant contribution to the university's goal of becoming a sustainable campus.

5. Conclusion

The sustainability of campus areas is gaining more importance day by day in the world. The IU GreenMetric ranking is a valuable approach in the assessment of a sustainable campus. Erciyes University has taken major steps, such as installing a gray water treatment facility, adding water sensors in restrooms, and using drip irrigation systems for plants, to achieve a sustainable campus area. Moreover, water management is becoming increasingly important considering the changing climate conditions, and Kayseri has a semi-arid and less humid climate, which may suffer from droughts more in the coming years. From the potential 64,635.432 m^3 of rainwater harvested annually, the university can reduce 7.55% of its annual water consumption. This can considerably enhance the campus and urban sustainability, ultimately increasing their IU GreenMetric score. The effects of global warming have been felt more and more in years. One of the most important problems that can emerge in provinces in semi-arid climates like Kayseri is water scarcity. Considering this issue, it is clear that every step toward rainwater harvesting can actually contribute to the sustainability of the Kayseri University campus and thus to urban sustainability.

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