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Technical and Economic Analysis of Rainwater Harvesting in University Buildings

Üniversite Binalarında Yağmur Suyu Hasadının Teknik ve Ekonomik Analizi

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Abstract: Water is becoming more valuable every day in today's world, where the effects of the growing global population and global warming are increasing, and existing water resources continue to deplete. The inadequacies in water resources are causing problems for the environment and all living beings. Therefore, protecting existing water resources or creating alternative sources has become necessary. Rainwater harvesting is effective method for generating an alternative water source. In this study, the monthly and annual water storage potentials of the buildings in Bursa Uludağ University Faculty of Agriculture were determined by using the rainwater harvesting method, and the rates of meeting the need were calculated in two different scenarios, namely irrigation of the lawn area in the faculty and meeting the amount of water needed in the buildings, and the aim was to determine the amount of economic gain to be obtained. As a result of the study, it was determined that the rainwater harvesting method has an annual water collection potential of 2045.16 m^3. With the installation of the system, it was concluded that an annual economic gain of 76858 TL was achieved in the faculty and that the initial investment costs of the system were amortized over 15.4 years.

Keywords: Rainwater, Rainwater Harvesting, Water, Water management, Sustainability, Water Scarcity

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Öz: Su, dünya nüfusunun ve küresel ısınmanın etkilerinin giderek arttığı ve mevcut su kaynaklarının yok olmaya devam ettiği günümüzde kıymetini her geçen gün arttırmaktadır. Su kaynaklarında yaşanan yetersizlikler çevre ve tüm canlılar için sorunlar ortaya çıkarmaktadır. Bu nedenle mevcut su kaynaklarının korunması veya alternatif kaynaklar yaratılması zorunlu hale gelmiştir. Yağmur suyu hasadı, alternatif bir su kaynağı oluşturmak için etkili bir yöntemdir. Bu çalışmada yağmur suyu hasadı yöntemi ile Bursa Uludağ Üniversitesi Ziraat Fakültesinde bulunan binaların aylık ve yıllık olarak su depolama potansiyelleri belirlenerek, fakültede bulunan çim alanın sulanması ve binalarda ihtiyaç duyulan su miktarının karşılanması olmak üzere iki farklı senaryoda ihtiyacın karşılanma oranları hesaplanmış ve elde edilecek ekonomik kazanç miktarının belirlenmesi amaçlanmıştır. Çalışma sonucunda, yağmur suyu hasadı yöntemi ile 2045.16 m^3'lük yıllık su toplama potansiyeline sahip olduğu belirlenmiştir. Sistemin kurulumu ile birlikte fakültede yıllık olarak 76858 Türk Lirası(TL) ekonomik kazanç elde edildiği ve sistemin ilk yatırım maliyetlerinin 15.4 yıllık bir sürede amorti edildiği sonucuna varılmıştır.

Anahtar Kelimeler: Yağmur Suyu Hasadı, Su, Su Yönetimi, Sürdürülebilirlik, Su Kıtlığı

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INTRODUCTION

Water is one of the basic needs necessary for living beings to sustain their lives. In order to maintain the balance of nature, prevent health problems in living beings, and avoid disruption of the economic order, the efficient use of water has become imperative (Firidin, 2014; Kayaer and Çiftçi, 2018). As the world's population grows each year, the water demand is also increasing accordingly. Due to factors such as global warming, the industrial revolution, and similar causes of environmental pollution and damage, despite the increasing need for water, existing water resources worldwide are being depleted (Doğan and Sever, 2023). In addition to only 3.5% of the total water available worldwide being usable, the losses occurring in existing water resources are causing water problems to increase daily (Aksungur and Firidin, 2008).

Due to the losses in the world's water resources, significant administrative and economic difficulties are being experienced. In countries, if the annual per capita water amount is between 1700 m^3 and 1000 m^3, limited water scarcity occurs, and if it falls below 1000 m^3, water poverty emerges (Evsahibioğlu et al., 2010; Uçar, 2022). Türkiye is losing its water resources day by day and facing increasing water problems due to various reasons such as environmental pollution, inefficient irrigation in agriculture, unsustainable water projects, and climate change. Türkiye while the annual amount of water per capita was 1519 m^3 in 2014, it is expected to decrease to 1120 m^3 in 2030 (Uyduranoğlu Öktem and Aksoy, 2014). While Türkiye is a water-scarce country today, it will become a water-poor country in the coming years. Therefore, some steps must be taken to conserve and create new resources. Rainwater harvesting is an alternative solution to create a new water source and save water.

Rainwater harvesting can be defined as the collection of rainwater, which is then filtered and reused for various purposes. The use of water harvesting, which was first utilized in China 6000 years ago, has continued for thousands of years. This method, which was primarily used in areas where access to water was either non-existent or limited in the past, is now becoming more common in cities due to the increasing pollution and depletion of water resources (Alpaslan, 1992; Örs et al., 2011; Stahn and Tomini, 2016; Börü and Toprak, 2022). The rainwater harvesting system was made mandatory for new buildings on plots of 2,000 square meters and more significant by the Ministry of Environment and Urbanization in 2021 (T.C Resmi Gazete; 2021). As the use of the system becomes increasingly widespread, significant amounts of water and economic gains can be achieved.

This study determined the rainwater harvesting potential of the buildings at the Faculty of Agriculture, Bursa Uludağ University. The rate of meeting the monthly and annual total water requirements for the students, academic, and administrative staff at the faculty, as well as the economic analysis and system designs, were aimed to be established.

MATERIAL AND METHOD

Study Area

This study determined the rainwater storage potential and economic analysis of 6 buildings, namely the Dean's office, lecture hall, and blocks A, B, C, and D, located in the Faculty of Agriculture at Bursa Uludağ University. The buildings where the study was conducted are shown in Figure 1 (Anonymous, 2015). In the study, Equations 1 and 2 were used to determine the rainwater storage potential (m^3) of buildings and the tank volume (m^3) to be used in system designs (DIN, 1989; Yalılı Kılıç et al., 2023; Dağ and Ay, 2024).

Figure 1. Buildings where the study was conducted at the faculty of agriculture, Bursa Uludağ University.
Şekil 1. Bursa Uludağ Üniversitesi Ziraat Fakültesinde çalışmanın yürütüldüğü binalar.

Data Collection and Rainwater Calculation

In the study, Equations 1 and 2 were used to determine the rainwater storage potential (m^3) of buildings and the tank volume (m^3) to be used in system designs (DIN, 1989; Yalılı Kılıç et al., 2023; Dağ and Ay, 2024).

$$\text{Rainwater Storage Potential} = RA \times AOR \times RC \times FAC \quad (1)$$

$$\text{Tank Volume} = HMP \times AOR \times RC \times FAC \quad (2)$$

RA: The roof area (m^2) of the building

AOR: The average rainfall amount (mm) in the region

HMP: The highest rainfall amount (mm) of the year.

RK: The coefficient indicates the amount of precipitation that cannot be collected on the roof. It is expressed as 0.8 in DIN 1989.

FAC: The coefficient expressing the loss of collected rainwater during the first filtration stage. It is expressed as 0.9 in DIN 1989.

Within the scope of the study, the roof areas of all buildings at the Faculty of Agriculture, Bursa Uludağ University, were calculated using a laser meter (Extech DT300, Extech Instruments, USA) to determine their rainwater storage potential. The roof areas of the buildings where the study was conducted are provided in Table 1.

Table 1. Roof areas of the buildings where the study was conducted.
Çizelge 1. Çalışmanın yapıldığı binaların çatı alanları.

Work on completed buildings	Roof areas (m²)
A and B Blocks	2109.33
C block and Lecture Hall	1630.92
D block	1079.12
Dean's Office	819.04

The average monthly precipitation amount for the Bursa region, where the study was conducted, between 1928-2023 was obtained from the official website of the General Directorate of Meteorology. The monthly average precipitation amount is provided in Table 2 (MGM, 2025).

Table 2. Monthly average rainfall in the Bursa region.
Çizelge 2. Bursa bölgesinde aylık ortalama yağış miktarları.

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Avg. of rained day number (day)	14.77	13.43	12.63	11.3	9.02	6.16	3.06	2.91	5.09	8.95	11.11	14.15
Amount of rainfall (mm)	88.5	76	70.3	62.2	50.5	35.5	21.9	18.2	43.2	65.8	77.8	98.9

Calculations were made in two different scenarios regarding the amount of water to be obtained through rainwater harvesting: one for meeting the water needs of the people using the buildings in the faculty and the other for irrigating the 5677 m² grass area in the Faculty of Agriculture.

In the first scenario, the potential to meet the needs of the people using the buildings with the amount of water obtained has been determined. While calculating the average water consumption in the buildings, the number of students studying in the Faculty of Agriculture and the number of academic and administrative staff were considered. The average water consumption per student is considered while calculating the water consumption amount for students. In contrast, parameters such as sink usage, general cleaning tasks, and dishwashers are considered for academic and administrative staff. Table 3 shows the average water used for calculating water consumption (Anonymous, 2024).

Table 3. Average water quantities required for calculating water consumption.
Çizelge 3. Su tüketimini hesaplamak için gereken ortalama su miktarları.

Average water consumption areas	Amount of water (liters)	Unit
Student	5	L/day/student
Dishwasher	20	L/day/personnel
Use of the Sink	22,5	L/day/personnel
Cleaning	10	L/day/personnel

Based on the numbers of all administrative and academic staff and students using the buildings in the faculty, as well as the daily average water consumption amounts, the necessary total water consumption amounts have been calculated. Since the buildings are not used on weekends, calculations have been made based on an average of 23 days per month.

In the second scenario, while calculating the annual water requirement for the grass area, the necessary water consumption amounts were calculated by considering the rainfall amounts in May, June, July, August, and September when irrigation will be carried out. When looking at the long-term average in the Bursa region, the total rainfall amount during the months when irrigation will be carried out is 169.3 mm, while a total of 650.07 mm of irrigation should be applied per square meter. Using the obtained data, the annual irrigation water requirement for the grass area has been calculated (Emekli et al. 2007; Yönter et al. 2023).

RESULTS AND DISCUSSION

Rainwater Harvesting Calculations

The amount of water to be collected from the buildings has been calculated using the rainwater harvesting potential formula. Based on the number of students, academic, and administrative staff using the buildings where the study was conducted, and the average per capita water consumption amounts, the total water consumption amounts and the coverage rates of the needs for all buildings have also been determined. The study achieved the highest annual water collection amount in the A and B block buildings with 1076.47 m^3, and 65.93% of the total annual water requirement can be met. The Dean's office, with an annual water volume of 417.99 m^3, is at the lowest level of water harvesting, but due to its low water consumption, it has the highest coverage rate at 72.11%. The average annual water requirement for all the buildings in the faculty is 5248.83 m^3. With the established system, 2045.16 m^3 of water is collected from all buildings, meeting 38.96% of the need. Figure 2 provides the annual water collection and consumption amounts of all the buildings where the study was conducted.

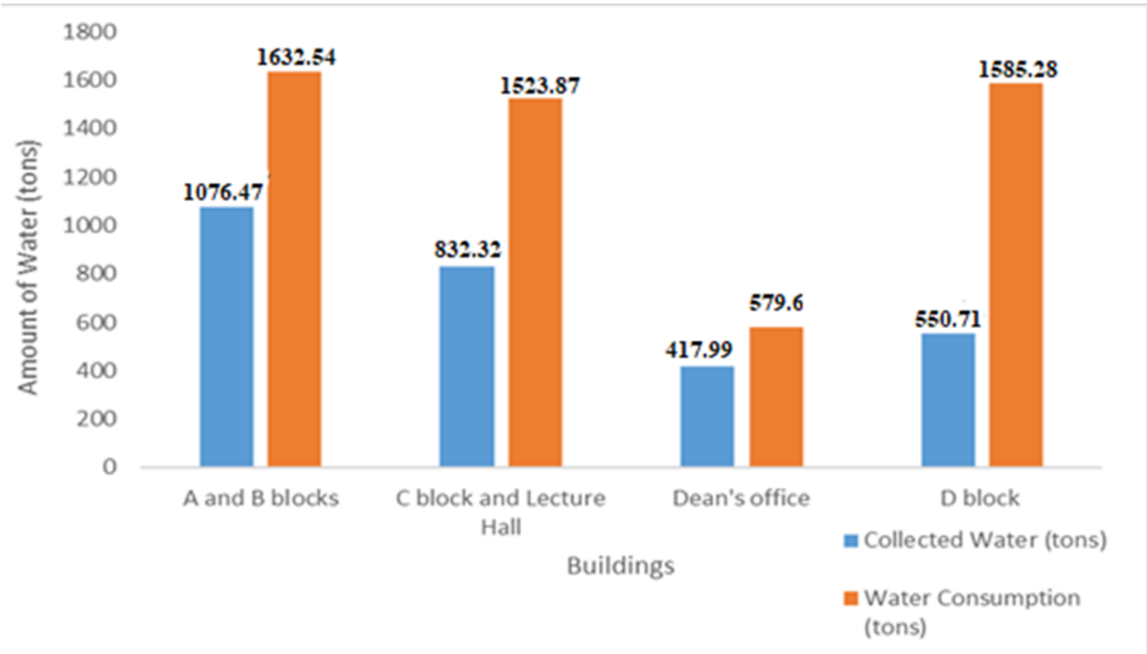

Figure 2. Annual collected and consumed water amount for all buildings.

Şekil 2. Tüm binalar için yıllık toplanan ve tüketilen su miktarı.

In order to prevent declines in the performance of the rainwater harvesting method, various precautions and maintenance should be carried out, taking seasonal realities into account. Excessive snow load, frost, and wind during the winter months can cause the gutters and pipes where water collects from the roofs to break. The leaves that fall from the trees in the spring months clog the gutters, causing a decrease in the amount of water collected and leading to problems in the system. Due to these effects, there may be a decrease in the amount of water collected, and the existing system components may be damaged, resulting in economic losses. Therefore, the gutters, roofs, and system components need to be regularly inspected and maintained.

Due to the large roof areas of the A and B block buildings, the amount of water collected is high; however, the water consumption is also high because of the large number of students, administrative staff, and academic personnel using the buildings. In the A and B block buildings, 150.20 m^3 of water was collected in December, fully meeting the water demand water needs, while in the other months of the winter season, more than 80% of the total need can be met. In the summer months, due to the decrease in the number of students, the amount of water consumption decreases, and the collected water amount also drops to around 40 m^3, leading to a decrease in the rate of meeting the demand. In August, 25% of the water needed in blocks A and B was supplied, reaching the lowest fulfillment rate of the year.

Academic and administrative staff use the C block building in the faculty, while students use the Amphitheater building. The average water consumption in the C block and lecture hall is high at 132.02 m^3, but the water collected is low due to the smaller roof areas. In the winter months, more than 70% of the total water needs for the C block and lecture hall can be met, while in the summer months, the fulfillment of these needs drops to around 20%. Table 4 provides the monthly collected water, consumption, and the rate of meeting the total need for the A, B, and C blocks and the lecture hall buildings using the rainwater harvesting method.

Table 4. Monthly collected and consumed water amount and saving rate for A, B, C Blocks and Lecture hall buildings.
Çizelge 4. A, B, C Blok ve Derslik binaları için aylık toplanan ve tüketilen su miktarı ve tasarruf oranları.

Months	A and B blocks			C block and Lecture Hall		
	Collected water (m^3)	Monthly water consumption (m^3)	Saving rate (%)	Collected water (m^3)	Monthly water consumption (m^3)	Saving rate (%)
January	134.41	145.475	92.39	103.92	132.02	78.72
February	115.42	145.475	79.34	89.24	132.02	67.60
March	106.77	145.475	73.39	82.55	132.02	62.53
April	94.46	145.475	64.94	73.04	132.02	55.32
May	76.70	145.475	52.72	59.30	132.02	44.92
June	53.91	107.755	50.03	41.69	111.895	37.25
July	33.26	107.755	30.87	25.72	111.895	22.98
August	27.64	107.755	25.65	21.37	111.895	19.10
September	65.61	145.475	45.10	50.73	132.02	38.42
October	99.93	145.475	68.69	77.27	132.02	58.53
November	118.16	145.475	81.22	91.36	132.02	69.20
December	150.20	145.475	100.00	116.13	132.02	87.97
Total	1076.47	1632.54	65.9	832.31	1523.86	54.6

Students at the faculty use the D block building. There are 23 classrooms in that building. Due to the large number of classrooms in Block D, the monthly water consumption amount is 150.995 m^3, making it the highest of all the buildings. Although the water consumption in Block D is higher than in all other buildings, the roof area is smaller than in the other buildings, resulting in the lowest level of need fulfillment. In the D block building, 50.89% of the water needs were met with 76.84 m^3 of water in December, while in August, 18.74% of the water needs were met with 14.14 m^3 of water. Due to the decrease in the number of students during the summer months, the buildings that are more frequently used by students experience a reduction in water consumption during these months.

In the Dean's office, the amount of water collected is low due to the small roof area; however, since the building is used by administrative staff, the need is met at a high level because the monthly water consumption is low. In the Dean's office, while the total need can be fully met in December and January, only 92.79% is met in February. Table 5 provides the monthly collected water amount, consumption amount, and the rate of meeting the total need for the D block and Dean's Office buildings using the rainwater harvesting method.

Table 5. Monthly collected and consumed water amount and savings rate for D block and Dean's office.
Çizelge 5. D blok ve dekanlık binası için aylık toplanan ve tüketilen su miktarı ve tasarruf oranları.

Months	D blocks			Dean's Office		
	Collected water (m^3)	Monthly water consumption (m^3)	Saving rate (%)	Collected water (m^3)	Monthly water consumption (m^3)	Saving rate (%)
January	68.76	150.995	45.54	52.19	48.3	100.00
February	59.05	150.995	39.11	44.82	48.3	92.79
March	54.62	150.995	36.17	41.46	48.3	85.83
April	48.33	150.995	32.01	36.68	48.3	75.94
May	39.24	150.995	25.99	29.78	48.3	61.66
June	27.58	75.44	36.56	20.93	48.3	43.34
July	17.02	75.44	22.56	12.91	48.3	26.74
August	14.14	75.44	18.74	10.73	48.3	22.22
September	33.56	150.995	22.23	25.48	48.3	52.74
October	51.12	150.995	33.86	38.80	48.3	80.34
November	60.45	150.995	40.03	45.88	48.3	94.99
December	76.84	150.995	50.89	58.32	48.3	100.00
Total	550.71	1585.27	34.74	417.98	579.6	72.12

The rate at which the irrigation water needs of the grass area in the faculty between May and September have been met has been calculated. The amount of water obtained from all buildings during the irrigation periods meets 18.6% of the required water amount. The amounts of water collected during the months when irrigation is not carried out are planned to be used for the people in the building, as in the other scenario. The potential for meeting the irrigation needs of the grass area using the rainwater method is provided in Table 6.

Table 6. The rate of meeting the need through rainwater harvesting during the irrigation period of grass area
Çizelge 6. Sulama döneminde yağmur suyu hasadı yöntemi ile çim alanın su ihtiyacının karşılanma oranı

Irrigation Season	Collected water (m^3)	Annual required water amount (m^3)	Saving rate (%)
MAY - SEPTEMBER	687.30	3690.472	18.6

In a study conducted similarly to this one, the rainwater harvesting method was used in university buildings, and work was carried out in 24 buildings on the central campus of Ege University in Izmir. Authors aimed to determine the potential amount of water that could be collected from these buildings using rainwater harvesting methods to meet the water needs for irrigating the green areas on the campus. As a result of the study, it was concluded that by installing a rainwater harvesting system in 24 buildings, an annual water harvest of 16.570.30 m^3 could be achieved. The rate of meeting the water requirement for the irrigation of green areas was found to be 11%, similar to this study (Özeren Alkan and Hepcan, 2022).

Yalılı Kılıç et al. (2023) in their study conducted at the Faculty of Theology of Bursa Uludağ University, aimed to determine the potential of the amount of water obtained through the rainwater harvesting method to meet the water needs for irrigating the green areas within the faculty. While determining the amount of water needed for irrigating the green areas on campus as 12.376 m^3 annually, they have also noted that 3.918 m^3 of water can be stored annually through rainwater harvesting methods. As a result of the study, they concluded that 31.7% of the annual water requirement for irrigating green areas could be met.

Design of Rainwater Harvesting System

While designing the rainwater harvesting system to be installed in the A and B block buildings, the slope of the land and the availability of suitable vacant land for the reservoirs were considered, and it was decided to install the system on the north facade of the buildings. In the system to be established, considering the amount of water collected from the A and B block buildings during the year with the highest rainfall, three galvanized modular water tanks with a storage capacity of 50 m^3 each will be used, totaling 150 m^3. Due to the large total roof area of the A and B block buildings, a filter system with a high water filtration rate has been added. Due to the low rainfall, the amount of water collected in the system has decreased, and three-way valves have been added separately for each tank to facilitate tasks such as cleaning. Figure 3 shows the design of the rainwater harvesting system to be installed in the A and B block buildings.

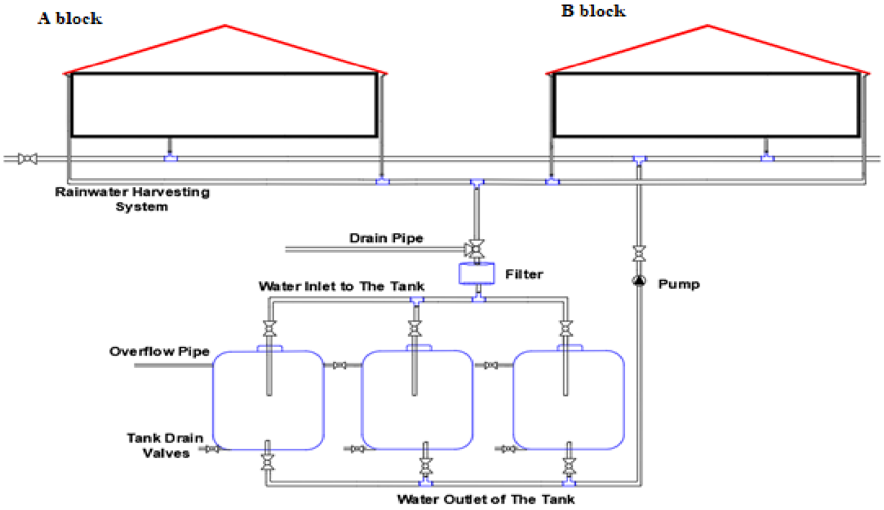

Figure 3. Rainwater harvesting system design for blocks A and B.
Şekil 3. A ve B blokları için yağmur suyu hasadı sistemi tasarımı.

While designing the system for the C block and Dean's office buildings, it was decided to use two 50 m^3 and one 20 m^3 galvanized modular water tank, totaling 120 m^3, considering that December has the highest rainfall, collecting 116.13 m^3. The system is planned to be installed on the eastern facade of the buildings. To facilitate the easy emptying of the tanks in case of malfunction or cleaning, tank drainage valves, and an overflow pipe have been added to the system design. Figure 4 provides the design of the rainwater harvesting system to be installed in the C block and Lecture hall buildings.

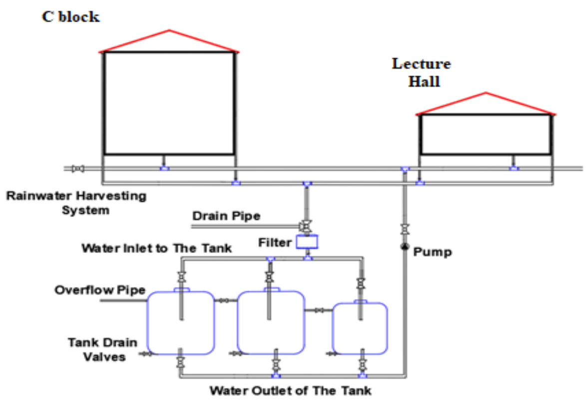

Figure 4. Rainwater harvesting system design for block C and Lecture hall buildings.
Şekil 4. C bloğu ve Derslik binaları için yağmur suyu hasadı sistemi tasarımı.

It is planned to use two tanks with a total water capacity of 60 m³, one with 50 m³ and the other with 10 m³, for the design of the rainwater system of the Dean's office building. Due to the smaller roof area of the Dean's Office building compared to other buildings, a filter with a lower filtration rate was preferred in this design, considering the cost. Figure 5 shows the design of the rainwater harvesting system to be installed in the Dean's office building.

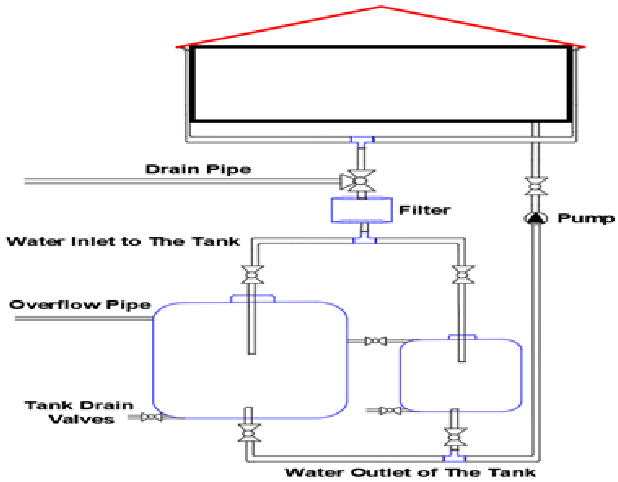

Figure 5. Rainwater harvesting system design for the Dean's building.
Şekil 5. Dekanlık binası için yağmur suyu hasadı sistemi tasarımı.

In the D block building located in the faculty, despite the high usage due to the low amount of water collected, it is planned to use two tanks with a total capacity of 80 m³, one with a capacity of 50 m³ and the other with a capacity of 30 m³. The western facade was preferred for installing the system because the parking lot is the most suitable area around the building. Figure 6 provides the design of the rainwater harvesting system to be installed in Block D.

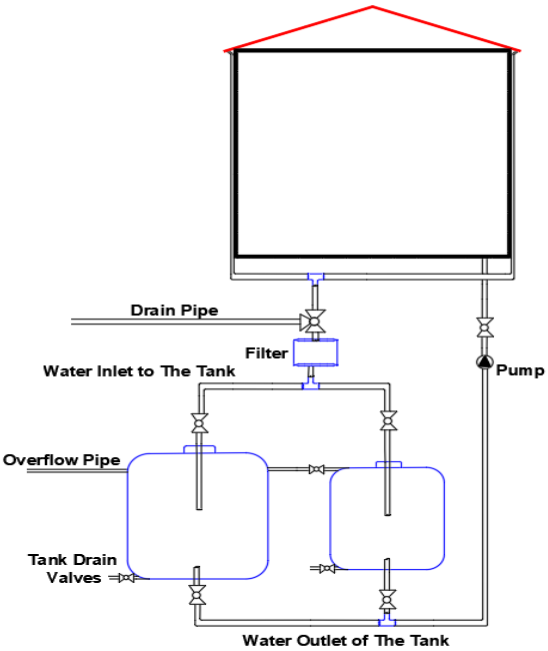

Figure 6. Rainwater harvesting system design for block D building.
Şekil 6. D blok binası için yağmur suyu hasadı sistemi tasarımı.

One of the effects of climate change is excessive rainfall. Especially due to the increase in urbanization, these heavy rains cause floods, high economic damages, and loss of life. (Sılaydın Aydın ve Kahraman, 2022). The rainwater harvesting method also provides benefits as a measure against floods in cases of excessive rainfall.

Economic Analysis of Rainwater Harvesting Method

An economic analysis evaluation was conducted for all buildings where the rainwater harvesting method was applied. Water fee calculations have been carried out considering the pricing implemented by the General Directorate of Bursa Water and Sewerage Administration (BUSKI). As a result of the evaluation, the highest profit from the water fee is achieved from the A and B block buildings, amounting to 28811 TL annually. The study obtained the lowest profit amount in the Dean's building, with an annual profit of 10885 TL. Figure 7 provides the water fees before and after implementing the rainwater harvesting method for all buildings where the study was conducted.

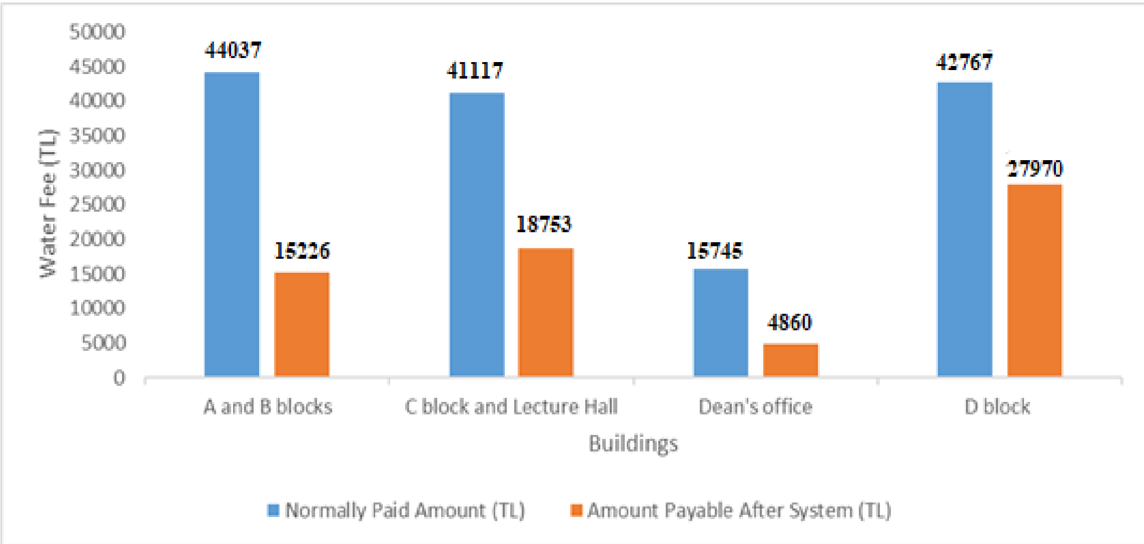

Figure 7. Water costs before and after rainwater harvesting method for all buildings.
Şekil 7. Tüm binalar için yağmur suyu hasadı yöntemi öncesi ve sonrası su maliyetleri.

With the establishment of the rainwater harvesting method in all the buildings where the study is conducted, water conservation is achieved, and significant economic benefits are obtained. The average monthly water fee before the rainwater system was 3669.76 TL in the A and B block buildings. In contrast, after installing the rainwater system in the buildings, the average monthly water fee decreased to 1268.83 TL. In December, when the highest amount of rainfall is collected from these buildings, the entire water need is met, so no water fee is charged.

In the C block and Lecture hall buildings, the water fee to be paid during the Spring, Autumn, and Winter seasons is 3561.61 TL, while due to the decrease in the number of students during the summer months, the water fee is at the level of 3020.87 TL. After installing the system, the average monthly water fee will be 1562.78 TL. Table 7 provides the monthly profit amount to be obtained after installing the rainwater harvesting system in Blocks A, B, C, and the Lecture hall building.

In the D block building, the average water fee paid over the 9 months of the year is 4071.45 TL, while it drops to 2041.35 TL during the summer months. The average monthly water fee paid for Block D is 3563.92 TL. The average water fee to be paid after the system is 2330.83 TL. A monthly average economic gain of 34.6% is achieved from the water bill of the Block D building.

Table 7. Amount of profit obtained from the rainwater system of blocks A, B, C, and the Lecture hall building.
Çizelge 7. A, B, C blokları ve Anfi binasından yağmur suyu sistemi ile elde edilen kar miktarı.

Months	A and B blocks			C block and Lecture Hall		
	The standart water fee (TL)	Post-system water fee (TL)	Profit amount (TL)	The standart water fee (TL)	Post-system water fee (TL)	Profit amount (TL)
January	3923.14	311.74	3611.40	3561.61	769.30	2792.31
February	3923.14	821.83	3101.31	3561.61	1163.70	2397.91
March	3923.14	1054.42	2868.71	3561.61	1343.54	2218.07
April	3923.14	1384.96	2538.18	3561.61	1599.11	1962.50
May	3923.14	1862.40	2060.74	3561.61	1968.26	1593.35
June	2909.63	1460.99	1448.64	3020.87	1900.79	1120.08
July	2909.63	2015.96	893.67	3020.87	2329.89	690.98
August	2909.63	2166.95	742.68	3020.87	2446.63	574.24
September	3923.14	2160.29	1762.85	3561.61	2198.59	1363.02
October	3923.14	1238.05	2685.08	3561.61	1485.52	2076.09
November	3923.14	748.37	3174.76	3561.61	1106.91	2454.71
December	3923.14	0.00	3923.14	3561.61	441.17	3120.44
Total	44037.12	15225.96	28811.16	41117.11	18753.41	22363.69

Due to the low water consumption in the Dean's office building, the water fee is the lowest among all buildings, averaging 1312.12 TL per month. With the rainwater harvesting system, the Dean's Office building achieves an average monthly economic gain of 907.15 TL, resulting in a 69.1% saving. Table 8 shows the monthly profit obtained after installing the rainwater harvesting system in the D Block and Dean's Office buildings.

Table 8. Amount of snow obtained from the rainwater system of block D and the Dean's office buildings.
Çizelge 8. D Blok ve Dekanlık binasından yağmur suyu sistemi ile elde edilen kar miktarı.

Months	Dean's Office			D block		
	The standart water fee (TL)	Post-system water fee (TL)	Profit amount (TL)	The standart water fee (TL)	Post-system water fee (TL)	Profit amount (TL)
January	1312.12	0	1312.12	4071.45	2223.89	1847.57
February	1312.12	107.90	1204.22	4071.45	2484.84	1586.61
March	1312.12	198.22	1113.90	4071.45	2603.84	1467.62
April	1312.12	326.56	985.56	4071.45	2772.94	1298.52
May	1312.12	511.95	800.17	4071.45	3017.19	1054.26
June	1312.12	749.62	562.50	2041.35	1300.24	741.11
July	1312.12	965.12	347.01	2041.35	1584.16	457.19
August	1312.12	1023.74	288.38	2041.35	1661.40	379.95
September	1312.12	627.62	684.50	4071.45	3169.59	901.86
October	1312.12	269.52	1042.60	4071.45	2697.78	1373.67
November	1312.12	79.38	1232.74	4071.45	2447.27	1624.19
December	1312.12	0	1312.12	4071.45	2006.77	2064.68
Total	15745.44	4859.63	10885.82	42767.1	27969.91	14797.23

It has been decided to use galvanized modular water tanks to install rainwater harvesting systems in all buildings of the Faculty of Agriculture. Galvanized modular water tanks have been preferred due to their durability, long lifespan, ease of installation, use, maintenance, and cost-effectiveness (Anonymous, 2025a). Two different rainwater filters have been used in the system, considering the roof sizes of the buildings. Table 9 provides the materials and price list for the rainwater harvesting system to be installed.

Table 9. List of materials and prices used in the rainwater system.
Çizelge 9. Yağmur suyu sisteminde kullanılan malzemelerin listesi ve fiyatları.

Material	Number	Price	References
50-ton galvanized modular water tank	7	868000	Anonymous (2025a)
30-ton galvanized modular water tank	1	84000	
20-ton galvanized modular water tank	1	58500	
10-ton galvanized modular water tank	1	34000	
YFVR-0200 Polyethylene (HDPE) Rainwater Filter	2	36200	Anonymous (2025b)
YFVR-3000 Polyethylene (HDPE) Rainwater Filter	2	77173	
Clean Water Submersible Pump	4	22812	Anonymous (2025c)

The initial investment costs required for installing the rainwater harvesting system in all the buildings where it will be implemented amount to 1180685 TL. With the system installed in all buildings, the annual savings from the water fee amount to 76858 TL. The payback period for the initial cost of the system is 15.4 years. Galvanized modular water tanks have been preferred despite being more durable than polyethylene water tanks because there is not a significant price difference between them. So the galvanized steel modular water tanks used in the study are long-lasting, therefore, in addition to the annual gain of 2877 m^3 of water from the system, economic benefits can also be obtained for many years after the payback period. In both scenarios, there is no change in the amount of economic profitability obtained and the initial costs due to the complete utilization of the annually collected water.

Şimşek and Demir (2023) in their study conducted at On Dokuz Mayıs University, aimed to determine the ratio of the amount of water obtained from the roof of the library on campus through rainwater harvesting to the amount of water needed for irrigation purposes on campus. With the implementation of the rainwater harvesting method on the campus, it has been determined that 33.8% of the annual water requirement for irrigation can be met, and an annual economic gain of 41359.32 TL can be achieved from water fees. As a result of the study, they concluded that the initial investment costs of the system to be installed on the campus could be paid back in 8.7 years.

Dündar et al. (2015) in their study conducted at the Health Campus of Bülent Ecevit University, aimed to determine the potential of the amount of water obtained through rainwater harvesting from the buildings on the campus to meet the water needs for toilets, cleaning, and irrigation of green areas on the campus. In the study, the most economical result with the rainwater harvesting method was found using a reservoir with a capacity of 1200 m^3 to meet 70% of the total water requirement. As a result of the study, it has been determined that 22% of the targeted amount of water to be collected from the buildings on the campus through rainwater harvesting can be met, and a total economic gain of 2933780 TL will be achieved over 50 years. When comparing the cost of the system and the economic benefits obtained, they concluded that the system's payback period is 3 years.

Due to climate change, in addition to losses in existing water resources, there are also reductions in precipitation amounts. This situation is one of the risky aspects of the rainwater harvesting method. Because in the coming years, the significant decrease in rainfall will lead to a decrease in the water level collected, which will cause economic losses to the buildings where the system will be installed.

CONCLUSION

This study was conducted to perform a technical and economic analysis under two different scenarios: one where the amount of water obtained from the installation of a rainwater harvesting system in the buildings of the Faculty of Agriculture at Bursa Uludağ University meets the annual water requirement of the grass area in the faculty, and the other where it meets the water needs of the students, academic, and administrative staff in the faculty. The rainwater harvesting method has determined the average monthly and annual water supply rates for all buildings in the Faculty of Agriculture. The buildings were grouped according to location, and calculations and system designs were carried out.

In the first scenario, calculations were carried out to compare the amount of water obtained through the rainwater method with the consumption amounts of the people using the buildings and to determine the amount of savings.The highest amount of water harvested in the study was 1076.47 m^3 from the A and B block buildings. The amount of water harvested from the A and B block buildings meets 65.93% of the water requirement for these buildings. Among the buildings in the faculty, the building with the lowest water storage was the Dean's Office, with a water volume of 417.99 m^3. When calculating the total water consumption based on the daily average water consumption of students, academic, and administrative staff using all the buildings in the Faculty of Agriculture where the study was conducted, it is determined that an annual amount of 5248.83 m^3 of water is needed. With the installation of the rainwater harvesting method in buildings, an average annual water amount of 2045.16 m^3 can meet 38.96% of the total need.

In the second scenario, calculations were made to determine the amount of irrigation water needed for the 5677 m^2 grass area in the faculty between May and September, which would be met through rainwater harvesting. A total of 687.30 m^3 of water is collected from all the buildings in the faculty between May and September. During this period, 18.6% of the 3690.4 m^3 of water needed for irrigation can be met. In the second scenario, the amounts of water obtained during the periods outside the irrigation season are planned to be used for the consumption water needs of the buildings, just as in the first scenario.

In both scenarios, the economic gain is similar due to the full utilization of the water obtained and the lack of changes in the initial costs. With the established system, an economic gain of 76858 TL is achieved from the annual water fee paid by the faculty. The initial investment cost required for installing the system in all buildings is 1180685 TL. The initial investment cost paid for installing the system is payback over 15.4 years, along with the economic gain from the water fee.

While designing the rainwater harvesting system, it was decided to use galvanized modular steel tanks due to their durability, long lifespan, and low cost. In the designs, two different filters were used, considering the roof sizes of the buildings. Considering the cleaning, maintenance, malfunction, and excess capacity rainfall situations of the tanks, tank drainage valves, overflow, and discharge pipes have been added to the system designs.

As a result of implementing the rainwater harvesting method in the buildings of the Faculty of Agriculture at Bursa Uludağ University, significant water and economic savings are being achieved. Due to the large number of buildings and extensive roof areas on university campuses, rainwater harvesting is a highly profitable method. Due to the high water and economic savings achieved, it has been concluded that this method could be an alternative for use in university buildings for the conservation of existing water resources and the creation of new water resources.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this article.

DECLARATION OF AUTHOR CONTRIBUTION

The authors' contributions to the article are equal.

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