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ARAŞTIRMA MAKALESİ **RESEARCH PAPER**

Evaluation of the Potential for Roof-Scale Rainwater Harvesting in Terms of Sustainable Urban Water Management: The Case of Recep Tayyip Erdoğan University Güneysu Housing Complex

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Abstract: Climate change, rapid urbanization, the increase in impervious surfaces, and interventions in natural drainage systems are making rainwater management an increasingly important planning issue in coastal cities. Particularly in coastal cities with high precipitation regimes, sloping topography, and dense stream networks, rainwater should be considered not only as an element that creates surface runoff and flood risk, but also as a water resource that can be utilized. This study aims to determine the roof-scale rainwater harvesting potential in the case of Recep Tayyip Erdoğan University (RTEÜ) Housing Complex located in Güneysu district of Rize province and to evaluate this potential in terms of sustainable urban water management. Within the scope of the research, the roof surfaces of a total of 39 structures, consisting of housing blocks, a guesthouse, a mosque, social facilities, and auxiliary buildings, were examined. Roof areas were determined using AutoCAD base maps, Google Earth Pro data, and field observations; the rainwater harvesting potential was calculated using long-term monthly precipitation data for the period 1993-2023. According to the findings, the total roof surface area in the study area is 26,717 m², and it was determined that 49,830.6 m³ of rainwater can be harvested annually from these surfaces. It was determined that the rainwater harvesting potential is not homogeneously distributed throughout the year, that the highest values occur in the autumn months, and that 36.16% of the total annual potential is obtained during this period. The results show that roof-scale rainwater harvesting in RTEÜ Housing Complex has significant potential both in terms of creating an alternative water source and contributing to the reduction of surface runoff during periods of intense rainfall. In this respect, rainwater harvesting can be considered an applicable strategy that can be integrated with green infrastructure, sponge city, and climate-resilient urban water management approaches in high-rainfall coastal cities.

Keywords: Coastal cities, green infrastructure, hydrological risk, roof-scale rainwater harvesting, surface runoff, sustainable urban water management.

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Sürdürülebilir Kentsel Su Yönetimi Açısından Çatı Ölçekli Yağmur Suyu Hasadının Potansiyelinin Değerlendirilmesi: Recep Tayyip Erdoğan Üniversitesi Güneysu Konut Kompleksi Örneği

Öz: İklim değişikliği, hızlı kentleşme, geçirimsiz yüzeylerin artması ve doğal drenaj sistemlerine yapılan müdahaleler, kıyı kentlerinde yağmur suyu yönetimini giderek daha önemli bir planlama konusu haline getirmektedir. Özellikle yüksek yağış rejimine, eğimli topoğrafyaya ve yoğun akarsu ağlarına sahip kıyı kentlerinde, yağmur suyu sadece yüzey akışı ve sel riski oluşturan bir unsur olarak değil, aynı zamanda kullanılabilecek bir su kaynağı olarak da değerlendirilmelidir. Bu çalışma, Rize ilinin Güneysu ilçesinde bulunan Recep Tayyip Erdoğan Üniversitesi (RTEÜ) Konut Kompleksi örneğinde çatı ölçekli yağmur suyu hasadının potansiyelini belirlemeyi ve bu potansiyeli sürdürülebilir kentsel su yönetimi açısından değerlendirmeyi amaçlamaktadır. Araştırma kapsamında, konut blokları, misafirhane, cami, sosyal tesisler ve yardımcı binalardan oluşan toplam 39 yapının çatı yüzeyleri incelenmiştir. Çatı alanları, AutoCAD temel haritaları, Google Earth Pro verileri ve arazi gözlemleri kullanılarak belirlenmiştir; yağmur suyu toplama potansiyeli ise 1993-2023 dönemi için uzun vadeli aylık yağış verileri kullanılarak hesaplanmıştır. Bulgulara göre, çalışma alanındaki toplam çatı yüzey alanı 26.717 m² olup, bu yüzeylerden yıllık olarak 49.830,6 m³ yağmur suyu toplanabileceği belirlenmiştir. Yağmur suyu toplama potansiyelinin yıl boyunca homojen olarak dağılmadığı, en yüksek değerlerin sonbahar aylarında görüldüğü ve toplam yıllık potansiyelin %36,16'sının bu dönemde elde edildiği tespit edilmiştir. Sonuçlar, RTEÜ Konut Kompleksi'nde çatı ölçekli yağmur suyu toplamanın hem alternatif bir su kaynağı oluşturma hem de yoğun yağış dönemlerinde yüzey akışını azaltmaya katkıda bulunma açısından önemli bir potansiyele sahip olduğunu göstermektedir. Bu bağlamda, yağmur suyu toplama, yüksek yağışlı kıyı kentlerinde yeşil altyapı, sünger kent ve iklim değişikliğine dayanıklı kentsel su yönetimi yaklaşımlarıyla entegre edilebilecek uygulanabilir bir strateji olarak değerlendirilebilir.

Anahtar Kelimeler: Kıyı kentleri, yeşil altyapı, hidrolojik risk, çatıdan yağmur suyu toplama, yüzey akışı, sürdürülebilir kentsel su yönetimi.

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INTRODUCTION

Climate change, rapid urbanization, and structural interventions in natural hydrological systems are transforming urban water management from merely a technical drainage issue into an ecological, spatial, and climate-adaptive planning problem (Wang et al., 2024; Kordon et al., 2025; Mosso et al., 2025; Cheng et al., 2026). In particular, the more frequent occurrence of short-duration intense rainfall events increases surface runoff, triggers flood formation, increases pressure on urban infrastructure systems, and complicates the sustainable management of water resources. O'Gorman (2015) states that observational and climate model results indicate that extreme precipitation generally tends to intensify under warming climate conditions. Similarly, Maity and Maity (2022) emphasize that climate change may alter the relationships among rainfall intensity, duration, and return period characteristics, and that this change may significantly affect the design criteria of drainage systems and flood control infrastructure. In addition, the decrease in natural and permeable surfaces due to urbanization prevents rainwater from infiltrating into the soil, reduces groundwater recharge, and increases the amount of surface runoff. Çorbacı and Ekren (2022) state that the increase in impervious surfaces such as roads and buildings as a result of uncontrolled urbanization prevents rainwater from infiltrating into the soil, reduces groundwater recharge, and increases flood risk through surface drainage.

Coastal cities are among the areas where climate-related hydrological risks are intensely experienced (Burkett & Davidson, 2012; Kumar et al., 2022; Langollakpam, 2025). In these cities, high rainfall, maritime influence, coastal topography, high humidity, development pressure, and limited drainage capacity may combine to increase flood risk (Elliott et al., 2014; Dhiman et al., 2019; Shen et al., 2019). Indeed, Abiodun et al. (2017) state that extreme rainfall events occurring in coastal cities may cause floods, infrastructure damage, and pressure on water resources. Ganguli and Merz (2025) further emphasize that hydrological risks may increase in coastal cities where warm and humid climatic conditions and extreme rainfall are jointly effective. In this context, in coastal cities such as Rize, which have a high precipitation regime and marked topographical variability, rainwater management should be addressed through an integrated approach that includes on-site retention, storage, and reuse of rainwater, rather than through traditional approaches focused only on drainage and flood control.

Nguyen et al. (2019) state that rapid urbanization and the expansion of grey infrastructure lead to the loss of ecosystems with natural rainwater retention capacity, thereby increasing flood risk and negatively affecting the management of water resources. Similarly, Bayramoğlu and Oğuztürk (2020) emphasize that increasing temperatures, the disruption of precipitation regimes, and extreme rainfall events associated with climate change directly affect cities; therefore, sustainable water management approaches such as xeriscape practices, rain gardens, and rainwater harvesting are becoming increasingly important. In addition, the covering of stream beds, their confinement within channel systems, and the alteration of their natural morphologies further complicate urban hydrological problems. Disconnecting stream systems from their natural flow dynamics is not only an engineering problem that increases flood risk, but also a landscape and habitat loss problem that disrupts ecological integrity (Ward & Stanford, 1995; Jackson & Pringle, 2010; Fuller et al., 2015). Indeed, Shankman (1996) states that stream channelization significantly alters flooding and sedimentation processes, disrupts river–floodplain interactions, and consequently leads to significant changes in downstream habitats and plant communities. Likewise, Özçelik et al. (2025) state that the narrowing and covering of stream beds passing through Rize city center, as well as the alteration of stream courses with different drainage areas, disrupt water flow patterns and cause serious floods and economic losses during intense rainfall events. The same study emphasizes that urban water management is not limited only to drinking water management, but requires an integrated approach that includes wastewater, rainwater, surface water, and groundwater management together. This situation indicates that, especially in coastal cities with strong precipitation regimes, stream beds should be protected, refunctionalized, and considered together with rainwater management (Walsh et al.,2016; Geraldes et al., 2024).

Although traditional grey infrastructure solutions are functional under certain rainfall conditions, they alone are not sufficient against extreme rainfall events (Chen et al., 2021; Zhang et al., 2023). Fan et al. (2025) state that grey infrastructure plays a dominant role in flood mitigation under normal rainfall conditions; however, as rainfall intensity increases, the marginal effectiveness of grey infrastructure decreases, whereas green infrastructure and topography become more critical in urban flood mitigation. Therefore, integrated approaches in which grey infrastructure, green infrastructure, and local topographical conditions are considered together are needed in rainwater management (Tan & Kordon, 2024; Karcı et al., 2025; Ercan Oğuztürk et al., 2025a). Ecological restoration and planting practices are also an important part of this framework. Yüksek and Yüksek (2011) demonstrated that planting and restoration practices in degraded areas can improve soil properties such as soil organic matter, plant-available water, saturated hydraulic conductivity, and water-holding capacity. This finding supports the need not only to collect rainwater from roof surfaces, but also to retain it within the

city and reintegrate it into the ecological cycle through green infrastructure and restoration-based approaches. Roof-scale rainwater harvesting stands out as one of the important components of this integrated approach, as it is applicable at the building scale, decentralized, and supportive of the local water cycle. Gwenzi and Nyamadzawo (2014) state that roof rainwater harvesting can provide an alternative water source in urban areas, while also producing significant hydrological effects by influencing the timing of surface runoff, peak discharge, total runoff volume, and runoff velocity. In this respect, roof surfaces can be considered not only as part of the building envelope, but also as functional urban water management components for the on-site retention and reuse of rainwater.

Previous campus-scale studies conducted specifically in Rize also show that the high precipitation regime and topographical conditions directly affect rainwater management. Ercan Oğuztürk and Yüksek (2024) stated that Rize is one of the regions with the highest rainfall in Türkiye; its steep terrain structure and intense, sudden rainfall complicate water management, thereby increasing the risk of floods and inundation in both urban areas and infrastructure systems. Similarly, Ercan Oğuztürk et al. (2025b) emphasize that traditional drainage systems focus on rapidly removing rainwater, whereas green infrastructure solutions such as permeable surfaces, rain gardens, vegetated swales, and roof rainwater harvesting offer more sustainable alternatives in terms of retaining, filtering, infiltrating, and reusing rainwater on site. Recent research conducted in an urban park in Rize has similarly shown that integrating xeriscape principles with sponge city strategies, including permeable surfaces, rain gardens, biofiltration areas, and vegetated swales, can support more resilient and sustainable stormwater management in high-rainfall coastal cities (Ercan Oğuztürk & Butaku, 2026). These findings reveal that in high-rainfall coastal cities such as Rize, rainwater should be considered not only as a risk factor, but also as a strategic resource supporting urban resilience. Rize's urban open-green spaces also stand out due to their rich natural plant diversity. Çorbacı et al. (2020) determined that there are 305 taxa belonging to 103 families in the urban open-green spaces of Rize, of which 232 are native and 73 are exotic. This situation indicates that the water obtained through rainwater harvesting can be considered not only as a technical storage input, but also as a resource supporting local plant diversity and sustainable landscape management. However, for harvested rainwater to be used sustainably, applying water at the right time and in the right amount is as important as storage. Ercan Oğuztürk (2025) states that artificial intelligence-supported irrigation systems increase water use efficiency through sensors, machine learning, and IoT-based monitoring; according to meta-analytical findings, these systems can provide improvements of 30-50% in water savings and 20-30% in yield increase. Similarly, Ercan Oğuztürk et al. (2025c) demonstrated that artificial intelligence-supported irrigation systems continuously monitor air and soil moisture, optimize irrigation strategies, reduce water losses, and support plant growth. Therefore, when roof-scale rainwater harvesting (Boers & Ben-Asher, 1982; Helmreich & Horn, 2009) is considered together with smart irrigation systems in future applications, it can offer a stronger management model in terms of landscape irrigation and campus-scale water efficiency.

Although topics such as climate change, urban flood risk, green infrastructure, and roof-scale rainwater harvesting are widely addressed in the existing literature, studies that quantitatively reveal the monthly and seasonal rainwater harvesting potential of roof surfaces at the residential scale in high-rainfall coastal cities and evaluate this potential together with urban hydrological risks remain limited. Particularly in coastal cities such as Rize, which have a high precipitation regime, sloping topography, and a dense stream network, the question of whether rainwater is merely a drainage element that needs to be removed or a strategic water resource that can be retained and reused on site gains importance.

This study aims to quantitatively determine the roof-scale rainwater harvesting potential in the case of Recep Tayyip Erdoğan University (RTEÜ) Housing Complex located in Güneysu district of Rize province and to evaluate the obtained potential from the perspective of sustainable water management in high-rainfall coastal cities. The main research question of the study is whether rainwater that can be obtained from roof surfaces in a coastal city such as Rize, which has a high precipitation regime, offers an alternative water resource potential that can make a meaningful contribution to urban water management. In this context, the study considers rainwater not merely as surface runoff that must be removed through drainage systems, but as a strategic resource that supports urban resilience and contributes to the local water cycle. In this respect, the study aims to contribute to the literature by providing quantitative data on the rainwater harvesting potential of roof surfaces at the residential scale in high-rainfall coastal cities.

MATERIAL AND METHOD

Study Area: The study area is the Recep Tayyip Erdoğan University (RTEÜ) housing complex located in Güneysu district of Rize province. The study area is located between 40°59′33″-40°59′56″ N latitudes and 40°35′46″-40°36′23″ E longitudes, at elevations ranging from 98 to 126 m above sea level (Figure 1).

Located approximately 7 km from the Black Sea coast, the area is situated within the high-rainfall belt of the Eastern Black Sea Region and has a sloping topographical

structure that developed between the valley floor and slope areas. According to the data of the Rize Meteorological Station for the years 1964-2014, the annual average precipitation of the province is 2224 mm, and 35.76% of the total precipitation occurs in the autumn season (Yüksek, 2017; MGM, 2026). According to the Thornthwaite climate classification, Rize province is classified as A B'1 r a' climate type; it has a very humid, mesothermal climate with no or very little water deficiency and oceanic climate characteristics (Yüksek, 2017). The housing complex consists of residential buildings, transportation infrastructure, and open-green areas, and its surroundings are covered with tea cultivation areas and natural vegetation. Due to its sloping topography, high precipitation regime, and relationship with natural hydrological systems, the region represents an important case area for the evaluation of rainwater management and roof-scale rainwater harvesting practices.

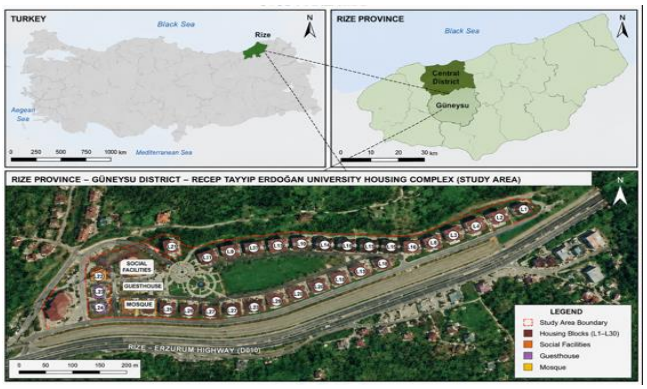

Figure 1. Location of the study area.

Material: The materials used in this study consist of AutoCAD base maps of the Recep Tayyip Erdoğan University (RTEÜ) housing area located in Güneysu district of Rize province, Google Earth Pro satellite images, long-term precipitation records, and field photographs obtained during field studies.

Method: The amount of rainwater that can be harvested from the roof surfaces of the buildings located in the RTEÜ Housing Complex was calculated by considering precipitation amount, roof collection surface area, surface runoff coefficient, and hydraulic filter coefficient. The roof surface areas of the housing blocks, guesthouse, mosque, social facilities, and auxiliary structures located in the study area were determined using AutoCAD base maps, Google Earth Pro satellite images, and field observations. In the rainwater harvesting calculations, long-term monthly precipitation data for the period 1993–2023 were obtained from Rize Meteorological Station (Station No. 17040) through the 11th Regional Directorate (Trabzon) of the Turkish State Meteorological Service (General Directorate of Meteorology), and the monthly precipitation values were converted into meters and evaluated separately for each structure. The roof-scale rainwater harvesting potential was determined based on the volumetric calculation approach widely used in the literature, and the amount of rainwater harvesting was calculated using Equation (1) (Gould & Nissen-Petersen, 1999; EPA, 2013; Kanno et al., 2021).

$$V = P \times A \times C \times h \quad (1)$$

In the formula;

V: The amount of rainwater that can be collected in a specific area and within a specific time interval (m³/year),

P: Annual Total Precipitation Amount (m),

A: Rainwater Collection Surface Area (m²),

C: Runoff Coefficient (runoff coefficients developed according to the characteristics of the roof material), (0.80 was used for concrete roofs, 0.90 was used for other types of roofs).

h: Hydraulic filter coefficient (0.90)

To provide a demand-based benchmark for evaluating the practical significance of the calculated rainwater harvesting potential, available meter-based water consumption records for three common-use facilities within the housing complex-the cafeteria, office, and swimming pool-were examined. A common observation period between 30 December 2025 and 26 June 2026 was selected to ensure temporal consistency among the three meters. Water consumption was calculated from the difference between consecutive meter readings. The total consumption recorded during the 178-day period was divided by the number of observation days to determine mean daily consumption, and this value was annualized by multiplying it by 365. The resulting annualized consumption was then compared with the calculated annual rainwater harvesting potential.

RESULTS

The roof surfaces of the buildings located in the RTEÜ Housing Complex were evaluated in terms of rainwater harvesting potential. There are a total of 39 structures in the complex, including housing blocks, a guesthouse, a mosque, social facilities, and auxiliary structures. The total roof surface area of these structures was determined as 26,717 m² (Table 1).

Table 1. Roof surface areas and usage groups of the buildings located in the RTEÜ Güneysu Housing Complex.

Building group	Number of buildings	Roof surface area (m²)
Housing blocks	30	22,994.1
Guesthouse	1	767.9
Mosque	1	278
Social facilities	5	2,463.0
Sheds	2	214.0
Total	39	26,717.0

As a result of the calculations based on the roof surfaces of the housing blocks, guesthouse, mosque, social facilities, and auxiliary structures located in the RTEÜ

Housing Complex, the total annual rainwater harvesting potential was determined as 49,830.6 m³ (Table 2).

When the monthly distribution was examined, the highest rainwater harvesting potential was calculated in October, with 6,806.8 m³. This was followed by September with 5,951.56 m³, November with 5,259.87 m³, and December with 5,224.42 m³. The lowest rainwater harvesting potential was determined in April, with 1,989.79 m³.

When the seasonal distribution was evaluated, it was determined that 36.16% of the total harvesting potential occurred in the autumn season. This situation is consistent with the precipitation regime of Rize province and results from the increased precipitation amounts in the autumn months. In contrast, only 15.07% of the annual rainwater harvesting potential occurred in the spring season, and the lowest seasonal value was determined during this period. Overall, 63.20% of the annual rainwater harvesting potential occurs in the autumn and winter seasons.

When evaluated on a building basis, the highest annual rainwater harvesting potential was determined in the Social Facility 1 building, with 1,893.09 m³. This was followed by most housing blocks (A01–A20 and A23–A30) and the guesthouse, each with an annual potential of 1,432.23 m³. The lowest annual harvesting potential was calculated for Shed 2, with 149.20 m³. It is observed that the annual harvestable rainwater amount increases depending on the size of the roof surface area. According to the results obtained, it was determined that an average of 136.52 m³ of rainwater can be harvested daily from the roof surfaces in the study area. It was calculated that an annual average of 1.87 m³ of rainwater can be harvested from each 1 m² of roof surface in the study area. During the common 178-day meter-reading period between 30 December 2025 and 26 June 2026, water consumption was 30 m³ for the cafeteria, 38 m³ for the office, and 1,094 m³ for the swimming pool, corresponding to a combined consumption of 1,162 m³. This represents an average metered water consumption of approximately 6.53 m³/day for the three monitored common-use facilities and an annualized consumption of approximately 2,382.75 m³/year. Accordingly, the calculated annual rainwater harvesting potential of 49,830.6 m³ is approximately 20.9 times the annualized metered water consumption of these three facilities. In volume terms, the estimated annual consumption of the monitored facilities corresponds to approximately 4.78% of the calculated annual rainwater harvesting potential.

Table 2. Monthly rainwater harvesting values by buildings in RTEÜ Housing Complex (m³).

Building ID.	January	February	March	April	May	June	July	August	September	October	November	December	Annual runoff (m³)
A01	135.37	101.68	99.72	57.19	58.94	89.76	101.37	120.16	171.06	195.64	151.18	150.16	1432.23
A02	135.37	101.68	99.72	57.19	58.94	89.76	101.37	120.16	171.06	195.64	151.18	150.16	1432.23
A03	135.37	101.68	99.72	57.19	58.94	89.76	101.37	120.16	171.06	195.64	151.18	150.16	1432.23
A04	135.37	101.68	99.72	57.19	58.94	89.76	101.37	120.16	171.06	195.64	151.18	150.16	1432.23
A05	135.37	101.68	99.72	57.19	58.94	89.76	101.37	120.16	171.06	195.64	151.18	150.16	1432.23
A06	135.37	101.68	99.72	57.19	58.94	89.76	101.37	120.16	171.06	195.64	151.18	150.16	1432.23
A07	135.37	101.68	99.72	57.19	58.94	89.76	101.37	120.16	171.06	195.64	151.18	150.16	1432.23
A08	135.37	101.68	99.72	57.19	58.94	89.76	101.37	120.16	171.06	195.64	151.18	150.16	1432.23
A09	135.37	101.68	99.72	57.19	58.94	89.76	101.37	120.16	171.06	195.64	151.18	150.16	1432.23
A10	135.37	101.68	99.72	57.19	58.94	89.76	101.37	120.16	171.06	195.64	151.18	150.16	1432.23
A11	135.37	101.68	99.72	57.19	58.94	89.76	101.37	120.16	171.06	195.64	151.18	150.16	1432.23
A12	135.37	101.68	99.72	57.19	58.94	89.76	101.37	120.16	171.06	195.64	151.18	150.16	1432.23
A13	135.37	101.68	99.72	57.19	58.94	89.76	101.37	120.16	171.06	195.64	151.18	150.16	1432.23
A14	135.37	101.68	99.72	57.19	58.94	89.76	101.37	120.16	171.06	195.64	151.18	150.16	1432.23
A15	135.37	101.68	99.72	57.19	58.94	89.76	101.37	120.16	171.06	195.64	151.18	150.16	1432.23
A16	135.37	101.68	99.72	57.19	58.94	89.76	101.37	120.16	171.06	195.64	151.18	150.16	1432.23
A17	135.37	101.68	99.72	57.19	58.94	89.76	101.37	120.16	171.06	195.64	151.18	150.16	1432.23
A18	135.37	101.68	99.72	57.19	58.94	89.76	101.37	120.16	171.06	195.64	151.18	150.16	1432.23
A19	135.37	101.68	99.72	57.19	58.94	89.76	101.37	120.16	171.06	195.64	151.18	150.16	1432.23
A20	135.37	101.68	99.72	57.19	58.94	89.76	101.37	120.16	171.06	195.64	151.18	150.16	1432.23
A21	131.59	98.84	96.94	55.6	57.3	87.26	98.55	116.81	166.29	190.19	146.96	145.98	1392.31
A22	131.58	98.83	96.93	55.59	57.29	87.25	98.54	116.79	166.27	190.17	146.94	145.96	1392.14
A23	135.37	101.68	99.72	57.19	58.94	89.76	101.37	120.16	171.06	195.64	151.18	150.16	1432.23
A24	135.37	101.68	99.72	57.19	58.94	89.76	101.37	120.16	171.06	195.64	151.18	150.16	1432.23
A25	135.37	101.68	99.72	57.19	58.94	89.76	101.37	120.16	171.06	195.64	151.18	150.16	1432.23
A26	135.37	101.68	99.72	57.19	58.94	89.76	101.37	120.16	171.06	195.64	151.18	150.16	1432.23
A27	135.37	101.68	99.72	57.19	58.94	89.76	101.37	120.16	171.06	195.64	151.18	150.16	1432.23
A28	135.37	101.68	99.72	57.19	58.94	89.76	101.37	120.16	171.06	195.64	151.18	150.16	1432.23
A29	135.37	101.68	99.72	57.19	58.94	89.76	101.37	120.16	171.06	195.64	151.18	150.16	1432.23
A30	135.37	101.68	99.72	57.19	58.94	89.76	101.37	120.16	171.06	195.64	151.18	150.16	1432.23
Guesthouse	135.37	101.68	99.72	57.19	58.94	89.76	101.37	120.16	171.06	195.64	151.18	150.16	1432.23
Mosque	49.01	36.81	36.1	20.71	21.34	32.5	36.7	43.5	61.93	70.83	54.73	54.36	518.52
Social facility 1	178.92	134.4	131.81	75.6	77.91	118.64	133.99	158.82	226.1	258.6	199.82	198.48	1893.09
Social facility 2	56.41	42.37	41.55	23.83	24.56	37.41	42.24	50.07	71.28	81.53	63	62.58	596.83
Social facility 3	92.55	69.52	68.18	39.1	40.3	61.37	69.31	82.15	116.95	133.76	103.36	102.66	979.21
Social facility 4	66.99	50.32	49.35	28.3	29.17	44.42	50.17	59.46	84.65	96.82	74.81	74.31	708.77
Social facility 5	39.31	29.53	28.96	16.61	17.12	26.07	29.44	34.89	49.68	56.82	43.9	43.61	415.94
Shed 1	23.62	17.74	17.4	9.98	10.29	15.66	17.69	20.97	29.85	34.14	26.38	26.2	249.92
Shed 2	14.1	10.59	10.39	5.96	6.14	9.35	10.56	12.52	17.82	20.38	15.75	15.64	149.2
Total runoff (m³)	**4709.81**	**3537.67**	**3469.49**	**1989.79**	**2050.68**	**3122.97**	**3526.92**	**4180.62**	**5951.56**	**6806.8**	**5259.87**	**5224.42**	**49830.6**

DISCUSSION

This study shows that roof surfaces in high-rainfall coastal cities can be evaluated not only as impervious areas contributing to surface runoff, but also as an important alternative water resource. The annual rainwater harvesting potential determined in the case of the RTEÜ Housing Complex supports the approach of retaining and reusing rainwater on site rather than rapidly removing it from urban areas. In this respect, the study

contributes to an important gap in the literature by providing quantitative data on the rainwater harvesting potential of roof surfaces at the residential scale in high-rainfall coastal cities.

The findings obtained from the study indicate that rainwater harvesting potential is not homogeneously distributed throughout the year and increases markedly, especially in the autumn period. This situation is directly related to the precipitation regime of Rize and reveals that rainwater harvesting systems should be designed not only according to the total annual potential, but also by considering seasonal precipitation distribution. This result is consistent with O'Gorman (2015), who states that extreme precipitation may intensify with climate change, and with Maity and Maity (2022), who emphasize that changes in precipitation regimes may create pressure on drainage infrastructure.

The results of the study also demonstrate the dual effect of urbanization and the increase in impervious surfaces on rainwater management. On the one hand, roof, asphalt, and concrete surfaces reduce the infiltration of rainfall into the soil and increase surface runoff; on the other hand, these surfaces can be transformed into water harvesting surfaces with appropriate collection and storage systems. Çorbacı and Ekren (2022) state that the increase in impervious surfaces such as roads and buildings as a result of uncontrolled urbanization prevents rainwater from infiltrating into the soil, reduces groundwater recharge, and increases flood risk. The potential of 49,830.6 m³/year calculated in this study shows that impervious roof surfaces can be transformed from a hydrological risk into a water resource through appropriate systems. The comparison with available meter-based consumption records provides a practical perspective on the magnitude of this potential. The calculated annual rainwater harvesting volume is approximately 20.9 times the annualized metered consumption of the cafeteria, office, and swimming pool combined. Although these three facilities do not represent the total water demand of the entire housing complex, the comparison demonstrates that the calculated roof-scale harvesting potential is substantial relative to the measured water demand of the monitored common-use facilities. Similarly, Kahveci and Yıldız (2023) estimated an annual rainwater harvesting potential of 95,170.30 m³ from 109 buildings selected according to a ≥2,000 m² building-area criterion in Niğde and reported that this amount could meet approximately 5.5 days of the city's total water demand, demonstrating the potential of rooftop rainwater harvesting even under relatively low-rainfall conditions.

In the context of Rize, this potential becomes even more important due to interventions in stream beds and the disruption of urban flow patterns. Özçelik et al. (2025) emphasize that the narrowing and covering of stream beds in Rize, as well as the alteration of stream courses, disrupt water flow patterns and lead to flooding and economic losses during intense rainfall events. In this context, roof-scale rainwater harvesting can be considered not only as a means of producing alternative water, but also as a complementary strategy that delays surface runoff during periods of intense rainfall and reduces sudden loads on drainage systems.

Roof-scale rainwater harvesting gains stronger significance when considered together with green infrastructure and sponge city approaches. Li et al. (2017) and Nguyen et al. (2019) emphasize that the on-site retention, storage, filtration, and reuse of rainwater are important for sustainable urban water management. The annual harvesting potential determined in RTEÜ Housing Complex shows that roof surfaces can be one of the applicable building-scale components of the sponge city approach. In addition, Ercan Oğuztürk et al. (2025a) demonstrated, through a university campus case, that green areas contribute to rainwater management and sustainable urban design. Therefore, the use of harvested rainwater in landscape irrigation can both reduce mains water consumption and support the continuity of green areas.

The utilization of harvested rainwater is important not only in terms of water saving, but also in terms of the sustainability of urban green areas, where 305 taxa belonging to 103 families have been identified (Çorbacı et al., 2020). In particular, irregularities in precipitation regimes, prolonged dry periods, and the increase in extreme rainfall events due to climate change make the more efficient use of water in cities necessary. Bayramoğlu and Oğuztürk (2020) state that sustainable water management approaches such as xeriscape practices, rain gardens, and rainwater harvesting are therefore becoming increasingly important. The rainwater harvesting potential determined in this study shows that, if harvested water is used for landscape irrigation, it can contribute to reducing mains water consumption and to the sustainable management of urban green areas.

It should be noted that the available meter records cover only three common-use facilities and therefore should not be interpreted as the total water demand of the entire housing complex. Comprehensive meter data covering residential blocks and other buildings would allow a more complete demand-supply assessment in future studies. However, for the calculated potential to be transformed into actual practice, variables such as storage capacity, filtration system, first-flush arrangement, roof material, water quality, and intended use should be evaluated together. In addition, the concentration of harvesting potential in the autumn months indicates that, if sufficient storage capacity is not provided, some of the water may turn into surface runoff again. Therefore, future

studies should address different storage volume scenarios, cost-benefit analysis, water quality assessment, and comparative use scenarios with landscape irrigation demand. The use of harvested water with smart irrigation systems is also an important area for improvement, because Oğuztürk (2025) and Ercan Oğuztürk et al. (2025c) show that sensor- and artificial intelligence-supported irrigation systems can increase water use efficiency.

Overall, this study reveals that roof-scale rainwater harvesting in the case of the RTEÜ Housing Complex has significant potential in high-rainfall coastal cities such as Rize, both in terms of hydrological risk reduction and alternative water resource production. The findings show that rainwater is not merely a flow that must be removed through drainage systems, but a strategic resource that can be collected and stored on site and integrated with green infrastructure practices. In this context, the findings support the United Nations Sustainable Development Goals, particularly SDG 6 through improved water-use efficiency and integrated water resources management (Targets 6.4 and 6.5), and SDG 11 through climate-resilient urban water management and the reduction of water-related hydrological risks (Targets 11.5 and 11.b) (United Nations, 2015).

CONCLUSIONS AND RECOMMENDATIONS

This study revealed that roof-scale rainwater harvesting can create an important alternative water resource in high-rainfall coastal cities, as demonstrated in the case of the RTEÜ Housing Complex. The results obtained indicate that rainwater should be considered not only as an element that creates surface runoff and flood risk, but also as a strategic resource that can be utilized through appropriate planning and storage systems.

The findings showed that rainwater harvesting potential is not homogeneously distributed throughout the year and increases markedly, especially in the autumn period. This situation reveals that not only the total annual precipitation amount, but also the monthly and seasonal distribution of precipitation should be taken into account in the design of rainwater harvesting systems.

The implementation of roof-scale rainwater harvesting systems in RTEÜ Housing Complex can contribute to reducing mains water consumption and managing surface runoff occurring during periods of intense rainfall. The use of harvested water for purposes such as landscape irrigation, cleaning services, and emergency water reserves offers an important opportunity to support sustainable and climate-resilient water management practices at the campus scale.

In conclusion, the case of RTEÜ Housing Complex shows that roof surfaces in high-rainfall coastal cities have significant rainwater harvesting potential. In order to evaluate this potential effectively, roof water collection systems, pre-filtration units, appropriate storage capacity, and reuse infrastructures should be planned with an integrated approach. In this respect, rainwater harvesting can be considered an applicable nature-based solution in terms of climate change adaptation, sustainable management of water resources, and increasing urban resilience.

In order to effectively evaluate the rainwater harvesting potential determined in RTEÜ Housing Complex, roof collection systems, pre-filtration units, first-flush devices, storage tanks with appropriate volumes, and reuse infrastructures should be planned with an integrated approach. Within this scope, the following recommendations have been developed:

Recommendations for Practice: The volume of storage tanks should be determined by considering the monthly and seasonal distribution of precipitation. Harvested rainwater should be used for purposes that do not require mains water, such as landscape irrigation, cleaning services, vehicle-road washing, and fire water reserves. Rainwater harvesting systems should be planned as part of sustainable water management strategies at the campus scale and integrated into the design processes of newly constructed buildings. Rainwater obtained from roof surfaces should be considered as a complementary water management tool that contributes to reducing surface runoff during periods of intense rainfall.

Recommendations for Future Research: The effects of different storage volume scenarios on system performance should be investigated. The physical, chemical, and microbiological properties of rainwater should be determined, evaluated in terms of water quality criteria, and its suitability for different intended uses should be revealed. Cost-benefit analyses should be conducted for rainwater harvesting systems, and their economic feasibility should be demonstrated.

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