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Aydın, Türkiye'deki Müstakil Evler için Beton ve Kiremit Çatıların Yağmur Suyu Toplama Potansiyelinin Değerlendirilmesi

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ÖZ

Bu çalışma, farklı çatı malzemeleri konusunda yağmur suyu hasadı (YSH) verimliliğinin kapsamlı bir analizini gerçekleştirmekte olup özellikle beton ve kiremit kaplı çatıları karşılaştırmaktadır. YSH stratejileri, Aydın, Türkiye'deki iki ayrı müstakil konut üzerinde uygulanmış olup farklı çatı senaryolarını temsil etmektedir. Uyarlanabilir prototip YSH sistemleri, hassas performans değerlendirmesini mümkün kılmıştır. Hidrolojik veriler ve belediye su kullanım istatistikleri, YSH etkinliğini ölçmek amacıyla analiz edilmiştir. Sistem bileşenlerini yönlendiren hidrolik prensipler açıklanmıştır. Sonuçlar, uygulanan YSH sisteminin suyun yeniden kullanımını önemli ölçüde artırdığını ve sürdürülebilir hedeflerle uyumlu olduğunu göstermektedir. Döngüsellik ve maliyetle ilgili düşünceler bütüncül bir görünüm sunmaktadır. Bu çalışma, YSH sistemlerine olan farkındalığı ilerletmekte olup malzeme etkisinin sistem performansına olan etkisini vurgulayarak su yönetimi gelişimine katkı sağlamaktadır.

Evaluating Rainwater Harvesting Potential of Concrete and Tile Roofings for Detached Houses in Aydın, Türkiye

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ABSTRACT

This study comprehensively analyzes of rainwater harvesting (RWH) efficiency concerning distinct roofing materials, specifically comparing concrete and tile-covered roofs. RWH strategies were applied to two separate detached residences in Aydın, Turkey, representing varied roof scenarios. Tailored prototype RWH systems enabled precise performance evaluation. Hydrological data and municipal water usage statistics were analyzed to measure RWH effectiveness. Hydraulic principles governing system components are outlined. Results indicate the implemented RWH system significantly enhances water reuse, aligning with sustainable goals. Circular and cost considerations provide a holistic view. This study advances RWH understanding, highlighting material influences on system performance and contributing to water management progress.

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1. Introduction

1.1. Rainwater Harvesting (RWH)

Rainwater Harvesting (RWH) is a sustainable method for collecting and storing rainwater, promoting water conservation, reducing reliance on municipal supplies, and mitigating runoff by channeling precipitation into storage tanks for diverse uses. It is adaptable to both urban and rural settings, customizable to individual needs, and fosters an eco-friendly lifestyle.

In the realm of environmental consciousness, RWH emerges as a forward-thinking and eco-aware approach to water management. This method involves the collection and storage of rainwater, turning precipitation into a valuable resource. RWH addresses significant water-related challenges by actively promoting conservation and reducing reliance on traditional water supplies. Its adaptability to different settings, combined with the capacity for customization according to specific needs, positions RWH as a practical solution for various communities. Moreover, the environmentally conscious lifestyle associated with RWH extends beyond immediate water-related benefits. Through the redirection of rainwater into storage tanks, RWH actively contributes to conservation efforts, preventing erosion and supporting ecosystem health. The forthcoming exploration of RWH will delve into its historical origins, current applications, and the potential it holds for shaping a more sustainable water future.

The purpose of this study is to comprehensively analyze the efficiency of rainwater harvesting (RWH) by specifically examining its relationship with distinct roofing materials, particularly comparing concrete and tile-covered roofs. The study centers on two separate detached residences located in Aydın, Turkey, each representing different roof scenarios. The primary aim is to design and develop customized prototype RWH systems tailored to each residence for a meticulous evaluation of their performance. This evaluation encompasses the consideration of hydrological data and municipal water usage statistics to measure the effectiveness of the RWH systems. Additionally, the study seeks to enhance understanding by outlining the hydraulic principles governing the components of the implemented RWH system. In doing so, it aspires to contribute valuable insights that advance the knowledge of rainwater harvesting efficiency, particularly with a focus on the influence of roofing materials, thereby informing future developments in sustainable water management practices.

Extensive research focuses on RWH systems, emphasizing their potential and practical applications, particularly in preserving potable water through rooftop collection, e.g., for toilet flushing in a British residence (Fewkes, 1999). Another study investigates the water conservation benefits of rainwater tanks in Greater Sydney, Australia, using a daily temporal simulation model (Rahman et al., 2012). An optimization-based methodology aims to create resource-efficient and cost-effective RWH systems for residential areas, demonstrating their potential to fulfill significant household water needs while reducing expenses (Bocanegra-Martínez et al., 2014). Climate change's impact on residential RWH systems, considering aspects like water conservation, dependability, and safety, is studied, highlighting potential challenges due to shifting climatic conditions (Haque et al., 2016). Innovative approaches to RWH system creation are introduced, utilizing existing scarce data, such as monthly rainfall records, to minimize errors and ensure accurate forecasts (Nguyen and Han, 2017). Shorter duration rainfall data (10 years of daily data) can produce results similar to a 30-year dataset (Geraldi and Ghisi, 2017). A recent study evaluates RWH viability in Central Europe, with a focus on Poland, and assesses potential long-term climate effects over 50 years in 19 Polish cities. It underscores the importance of integrating historical data for RWH system planning, considering evolving rainfall patterns (Gwoździej-Mazur et al., 2022). A recent study explored the quality of rainwater from private rooftops (roof-harvested rainwater or RHRW), aiming to uncover its unique physicochemical and microbiological traits. The research not only identified these characteristics but also explored potential connections among them. Additionally, the study assessed health risks for children interacting with this water during recreational activities. The findings significantly contribute to our understanding of RHRW quality and safety, serving as a valuable resource for examining potential hazards associated with this water source (Carpio-Vallejo et al., 2024). In another recent study, static rainwater storage experiments were conducted over approximately 60 days. The outcomes revealed a crucial finding: nutrients present in rainwater tended to accumulate in sediment during the storage process. This insight into nutrient behavior during the storage phase significantly contributes to a broader understanding of water quality dynamics within Rainwater Harvesting (RWH) systems, informing comprehension of the factors influencing the effectiveness and sustainability of such systems over time (Gao et al., 2024). In one of the recent studies, an assessment of the impact associated with the implementation of rainwater harvesting systems in urban buildings throughout their entire lifespan, spanning from manufacturing to disposal, was conducted. To achieve this goal, the researchers divided urban systems into components, encompassing the water treatment plant, potable water distribution, consumer water use, wastewater collection, and wastewater treatment plant. This comprehensive approach sought to yield insights into the effectiveness and environmental implications of rainwater harvesting systems at different stages within the urban environment (Teston et al., 2024).

1.2. Case Study City

Aydın, located on Turkey's western coast, is a province bordered by İzmir, Denizli, and Muğla, covering 8116 sq km (Republic of Turkey, Ministry of National Defence, General Directorate of Mapping, 2023) with over a million inhabitants (TurkStat, 2023). It boasts a rich history seen in its ancient cities, ruins, and archaeological sites, attracting tourists. The Mediterranean climate with hot summers, mild winters, and beautiful Aegean beaches is appealing. Agriculture is vital to Aydın's economy, producing olives, cotton, and high-quality figs. Table 1 presents Aydın’s meteorological data from 1941 to 2022, essential for assessing rainwater harvesting potential. Understanding the city's water consumption patterns is vital for assessing system efficiency. Table 2 compares Aydın's per capita daily water use with 17 other Turkish cities, including densely and sparsely populated ones. Aydın's per capita water usage even surpasses Istanbul's, a city 16 times its size, as shown in Figure 1. Geographically, Figure 2 maps these cities with red four-point stars.

Table 1. Meteorological Data between 1941 and 2022 (Republic of Turkey, Ministry of Environment, Urbanization and Climate Change, General Directorate of Meteorology, 2023)

Data Collection (1941 - 2022)													
AYDIN	January	February	March	April	May	June	July	August	September	October	November	December	Yearly
Average Temperature (°C)	8.1	9.4	11.7	16.0	20.9	25.6	28.3	27.7	23.7	18.6	13.5	9.5	17.7
Average of Maximum Temperatures (°C)	13.0	14.8	17.9	22.7	28.3	33.4	36.2	35.8	32.1	26.3	19.9	14.5	24.6
Average of Minimum Temperatures (°C)	4.3	5.1	6.7	10.1	14.3	18.2	20.6	20.4	16.8	12.8	8.9	5.8	12.0
Average Sun Hours	3.7	4.2	5.4	6.4	7.8	9.3	9.9	9.3	8.2	6.2	4.3	3.4	6.5
Average Number of Rainy Days	12.93	10.41	9.76	8.28	6.17	2.55	0.72	0.60	1.96	5.56	8.22	12.82	80.0
Average Monthly Total Rainfall (mm)	118.9	92.3	70.6	47.5	35.9	16.4	7.5	5.7	17.3	43.5	81.7	122.6	659.9
Maximum Temperature (°C)	23.2	27.4	32.4	35.4	42.6	44.4	44.8	45.1	43.3	39.5	31.1	25.9	45.1
Minimum Temperature (°C)	-11.0	-5.4	-5.0	-0.8	4.6	8.4	13.4	11.8	7.6	1.6	-4.7	-5.3	-11.0

Table 2. Daily Abstracted Water Amount per Capita in 18 Cities of Turkey (TurkStat, 2023)

Selected Years	Aydın	Ankara	Antalya	Bayburt	Bursa	Denizli	Diyarbakır	Hakkari	Karabük	Manisa	Muğla	Samsun	Sinop	Uşak	İstanbul	İzmir	Şanlurfa	Şırnak
2010	188	202	293	281	157	207	235	163	180	156	364	247	215	183	195	192	257	128
2012	211	217	282	281	143	239	220	156	146	164	335	265	206	177	186	223	260	138
2014	257	211	280	219	125	180	125	119	294	154	347	229	324	177	181	180	172	139
2016	233	227	293	104	163	232	135	119	316	176	239	220	368	181	189	173	172	93
2018	196	239	329	231	171	245	147	117	287	153	403	246	240	178	189	208	171	234
2020	193	246	283	211	199	216	162	128	276	216	383	261	281	172	190	221	171	235

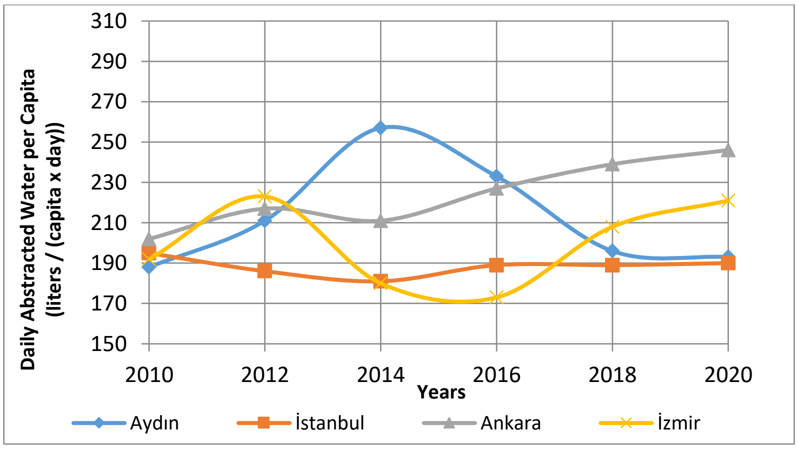

Figure 1. Comparison of Daily Abstracted Water per Capita in Aydın and the Most Crowded Three Cities of Turkey

Figure 2. Selected City Locations (D-Maps.com)

From Figure 1 and Table 2, it can be concluded that Aydın, despite being significantly smaller in population compared to densely populated cities in Turkey, exhibits a per capita daily water usage that surpasses even Istanbul, a city 16 times its size. Table 2 provides a comparative analysis of Aydın's per capita daily water use with 17 other Turkish cities, both densely and sparsely populated. The data in Figure 1 visually reinforces this observation, highlighting Aydın's higher water consumption in comparison to the more densely populated cities.

This stark contrast underscores the significance of the application of rainwater harvesting in Aydın. Despite its smaller population, the city's high water consumption emphasizes the importance of adopting sustainable water management practices. The comparison with other cities in Table 2 and the visual representation in Figure 1 accentuate the need for effective water conservation measures, making a compelling case for the implementation of rainwater harvesting to alleviate the strain on municipal water supplies and promote a more sustainable approach to water consumption in Aydın.

Aydın's high per capita water usage results from several factors, including its arid climate, water-intensive agriculture, coastal tourism, population growth, urbanization, and inadequate water management and infrastructure. Aydın relies primarily on wells for water abstraction, followed by springs and dams, with no abstraction from lakes, seas, or rivers. Table 3 presents the water abstraction volume for Aydın from 2018 to 2020.

Table 3. The Amount of Abstracted Water by Aydın Municipality from 2018 to 2022 (thousand m^3) (TurkStat, 2023)

Years	Total	Spring	Lake / artificial lake / sea	River	Dam	Well
2022	81655	575	0	8122	24773	48185
2020	78951	21460	0	6843	11867	38781
2018	78499	57081	0	6682	11708	3028

It is observed that municipalities basically withdraw water from 5 different media (spring, artificial or natural lake/sea, river, dam, well). While the amount of water withdrawn from year to year increases in parallel with the need, it is obvious that the construction and maintenance costs of the facilities used for this purpose will also increase. With the widespread use of RWH systems, the water demand pressure on these facilities, and thus on municipalities, will decrease and the financial resources transferred to these facilities will be used for other infrastructure works.

2. Methodology

2.1. Determination of RWH Potential

RWH begins on rooftops, emphasizing the importance of efficient design, including dimensions, slope, morphology, and maintenance. Diverse roof layouts can increase the collection surface area, while proper slope and maintenance are vital for system effectiveness. Accurate measurement of roof area and coefficients is essential for assessing RWH potential in existing structures and precise runoff calculations, as shown in Equation 1 (Gould and Nissen-Petersen, 1999).

$$S = R \times A \times Cr \quad (1)$$

S is the RWH potential (m^3), R is monthly rainfall (m), A is roof area (m^2), and Cr is runoff coefficient. Roof area calculation can be accomplished through on-site measurements or the use of satellite imagery for expedited analysis. Table 4 provides the runoff coefficients associated with various roofing materials.

Table 4. Runoff Coefficient for Different Roof Types (AFPRO, 2006)

Roof Type	Runoff Coefficient
Galvanized Iron Sheet	0.90
Asbestos Sheet	0.80
Tiled Roof	0.75
Concrete	0.70

Table 1 data reveals December as the wettest month with 122.6 mm of precipitation, while August is the driest with only 5.7 mm. This motivates an examination of rainwater harvesting (RWH) potential during these months.

This study assesses RWH potential in two separate detached houses within the same district, accounting for variations in geometric attributes and roofing materials. In Scenario 1, we assume flat concrete roofs due to logistical constraints, providing a conservative estimate of RWH capacity. Scenarios 2 and 3 consider roof inclines and different materials for potentially enhanced harvesting. Figures 3 and 4 display satellite images of the two houses (House 1 and House 2), with roof areas assessed visually in Figures 5 and 6.

Figure 3. Satellite Image of House Number 1 (Google Earth Pro)

Figure 4. Satellite Image of House Number 2 (Google Earth Pro)

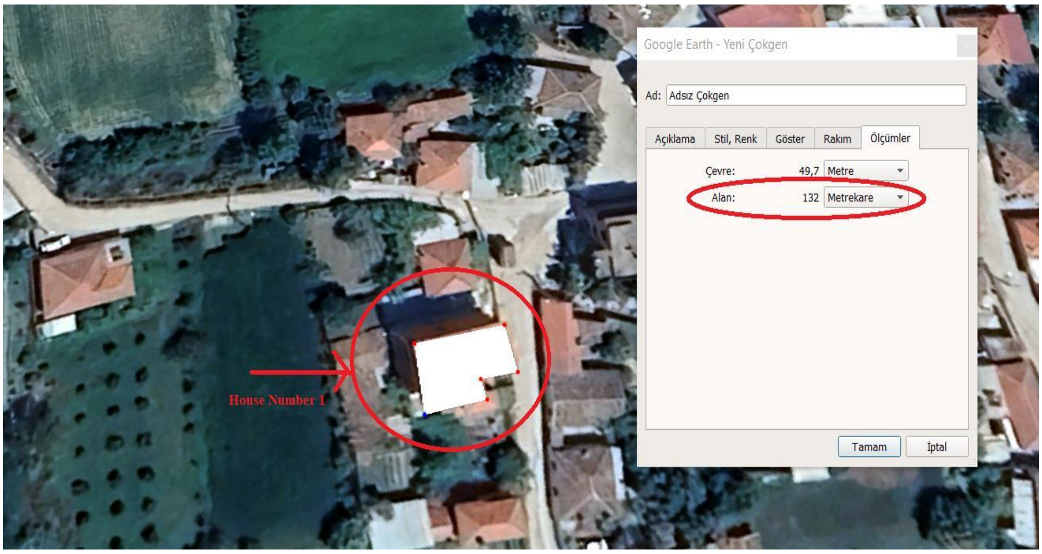

Figure 5. Roof Area of House Number 1 using the Polygon Function of Satellite Image Provider (Google Earth Pro)

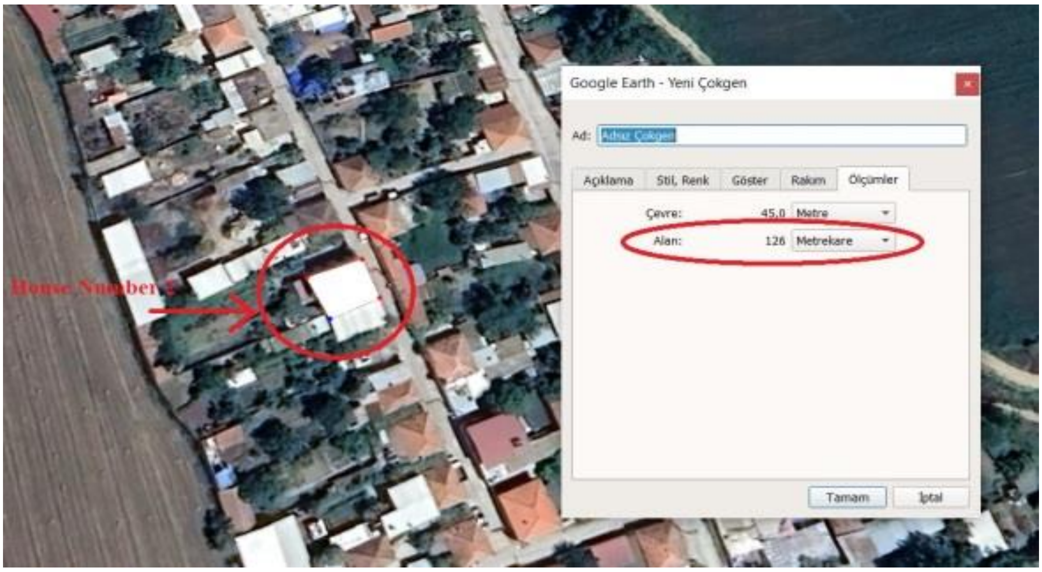

Figure 6. Roof Area of House Number 2 using the Polygon Function of Satellite Image Provider (Google Earth Pro)

2.2. RWH System Components

Figure 7 shows a standard standalone house, and Figure 8 illustrates the operational principles of a compact household water harvesting system designed for household appliances, drinking water, and garden irrigation.

Figure 7. A Detached House

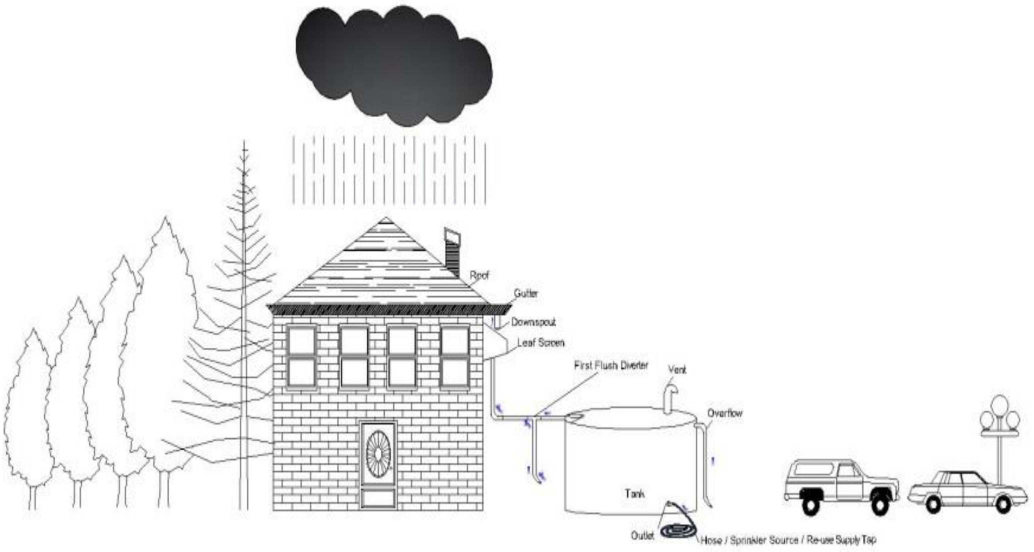

Figure 8. A Detached House with Fundamental RWH Components

As mentioned earlier, RWH starts at the rooftop, highlighting the importance of suitable roofing materials. Metal roofs are preferred due to reduced debris accumulation compared to wood or tile. Painted metal surfaces also minimize rust. Asphalt shingles can introduce chemicals into the water supply.

Roof runoff passes through gutters, which can get blocked by debris. To address this, a mesh leaf screen, as shown in Figure 9, filters particles, though some contaminants may remain.

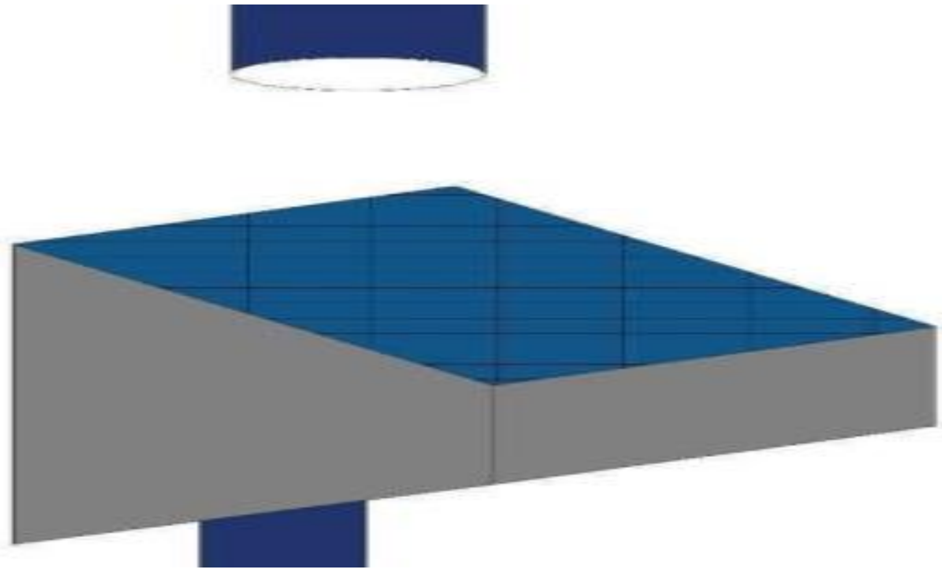

Figure 9. The Leaf Screen

Before entering storage, water undergoes a preliminary/first flush diverter process, as shown in Figure 10, to remove heavier pollutants not captured by the leaf screen.

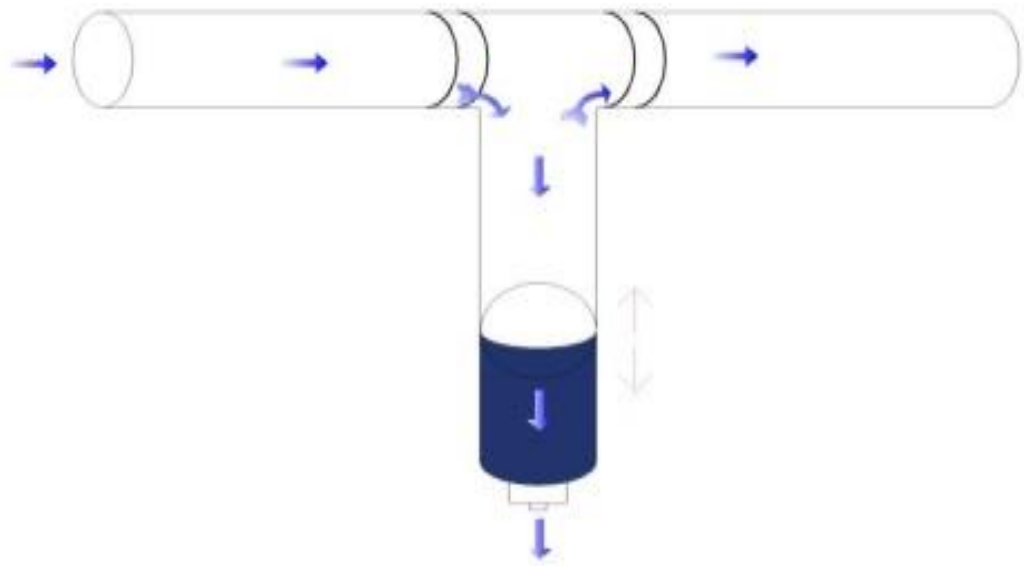

Figure 10. The First Flush Diverter

Using a vertical pipe with a ball valve, the initial flush diverter prevents contaminated water from mixing with the clean flow destined for the tank. The high-quality collected water is used for irrigation through a slow-release valve or tap. Additional water quality enhancement is achieved through filtration, desalination, and purification. Water storage tanks, made of various materials, share common components, as shown in Figure 11.

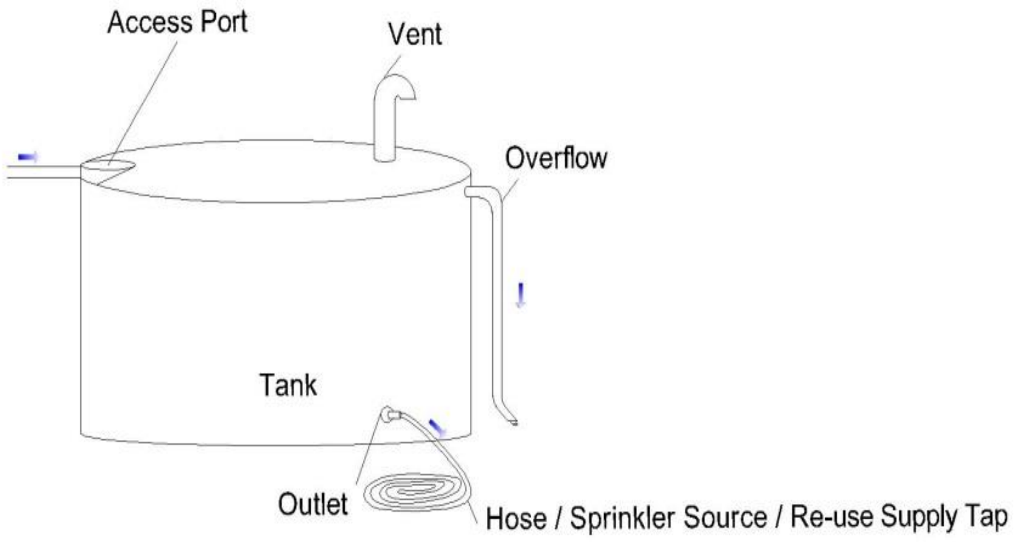

Figure 11. The Tank and Related Components

The maintenance access port is essential for cleaning and repairs, and the ventilation opening prevents vacuum formation during water flow. The overflow opening prevents pressure buildup and allows connections to neighboring tanks. The outlet serves various distribution needs. Tank material must resist environmental factors, and strategic outlet placement prevents clogging. Extending the inlet pipe minimizes sludge impact.

For household water pump selection, precise operational pressure determination is crucial. The chosen pump should exceed this pressure, considering factors like pipe attributes, length, diameter, fittings, and elevation, calculated using hydraulic power (Equations 2 and 3), shaft power (Equation 4), and motor power (Equation 5).

$$Power_{hydraulic}(kW) = \frac{Q\left(\frac{m^3}{hr}\right) x\ \rho\left(\frac{\text{kg}}{m^3}\right) x\ g(\frac{\text{m}}{\text{s}^2})\text{x}\ \ h(m)}{3.6\ x\ 10^6} \quad (2)$$

$$Power_{hydraulic}(kW) = \frac{Q\left(\frac{m^3}{hr}\right)\ x\ dP(kPa)}{3600} \quad (3)$$

$$Power_{shaft}(kW) = \frac{Power_{hydraulic}(kW)}{\eta_{pump}} \quad (4)$$

$$Power_{motor}(kW) = \frac{Power_{shaft}(kW)}{\eta_{motor}} \quad (5)$$

$\text{Power}_{\text{hydraulic}}$ is hydraulic power, Q is flow rate, ρ is fluid density, g is gravitational acceleration, h is pressure head, dP is the pressure difference. $\text{Power}_{\text{shaft}}$ is shaft power, η_{pump} is pump efficiency. $\text{Power}_{\text{motor}}$ is motor power, η_{motor} is motor efficiency.

3. Results and Discussion

As previously mentioned, the study analyzed rainwater harvesting potential under different scenarios, considering roof material and slope variations. It compared results to assess potential water consumption reductions and cost savings. The research also suggests measures to improve compensation and highlights key factors for homeowners when choosing a pump.

3.1. Compensation Amounts of Water Adopting RWH in Different Scenarios

3.1.1. Scenario 1 (house number 1 and house number 2, flat roof surface made of concrete)

As shown in Figures 6 and 7, House Number 1 and House Number 2 have roof dimensions of 132 m² and 126 m², respectively. Although they have sloped tile roofs, for calculations, they are assumed to have flat concrete roofs (Cr=0.70). Therefore, the RWH potentials for these houses in December, August, and annually can be obtained using Eq. 1 as shown in Table 5.

Table 5. The RWH Potentials (December, August, annual) of House Numbers 1 and 2 in Scenario 1

	December (liters)	August (liters)	Annual (liters)
House 1	11320	520	60970
House 2	10810	500	58200

Referring to Table 2, the daily per capita water usage in the studied city for 2020 was 193 liters. Assuming an average household size of four individuals, daily household water consumption is 772 liters. This translates to 23,160 liters per month and 277,920 liters per year. Thus, the compensation percentage (Comp) of a fully functional rainwater harvesting system indicates how much it can offset household water consumption as shown in Table 6. The compensation percentage can be obtained by Equation 6;

$$\text{Comp}(\%) = \frac{Consumption}{RWH\ Potential} \tag{6}$$

Table 6. The Compensation Percentages (December, August, annual) of House Numbers 1 and 2 in Scenario 1

	December (%)	August (%)	Annual (%)
House 1	48.87	2.24	21.93
House 2	46.67	2.15	20.94

House Number 1, with a 132 m² flat concrete roof, can offset 48.8% of December water consumption and 2.2% in August. House Number 2, with a slightly smaller roof area, performs slightly lower due to reduced rainwater harvesting potential. While these calculations assume flat concrete roofs from satellite imagery, adjusting the roof slope and material can greatly improve harvesting. Further exploration of alternative scenarios is needed.

3.1.2. Scenario 2 (house number 1 and house number 2, sloped roof surface made of concrete)

As mentioned earlier, the roof areas for House Number 1 and House Number 2 were determined using a satellite image provider's polygon tool, resulting in measurements of 132 m² and 126 m², respectively. For House Number 1, the roof is rectangular with dimensions of 6 m (shorter edge) and 22 m (longer edge). The introduction of a slope increases the area, yielding a ridge height of 3.38 m, as shown in Figure 12. The ridge height is determined by the maximum slope in accordance with Turkish zoning regulations (Ministry of Environment, Urbanization and Climate Change of Turkey, Planned Areas Zoning Regulation, 2023). The cumulative hip roof area is 168.44 m².

For House Number 2, the roof is rectangular with dimensions of 6 m (shorter edge) and 21 m (longer edge). Adhering to a slope compliant with Turkish zoning regulations results in an expanded area, with the maximum slope leading to a ridge height of 3.07 m, as seen in Figure 13. The cumulative hip roof area is 155.82 m². In both scenarios, the roof surface is assumed to be concrete, as in Scenario 1, introducing the impact of the roof slope for the first time in the scenarios, similar to Scenario 2.

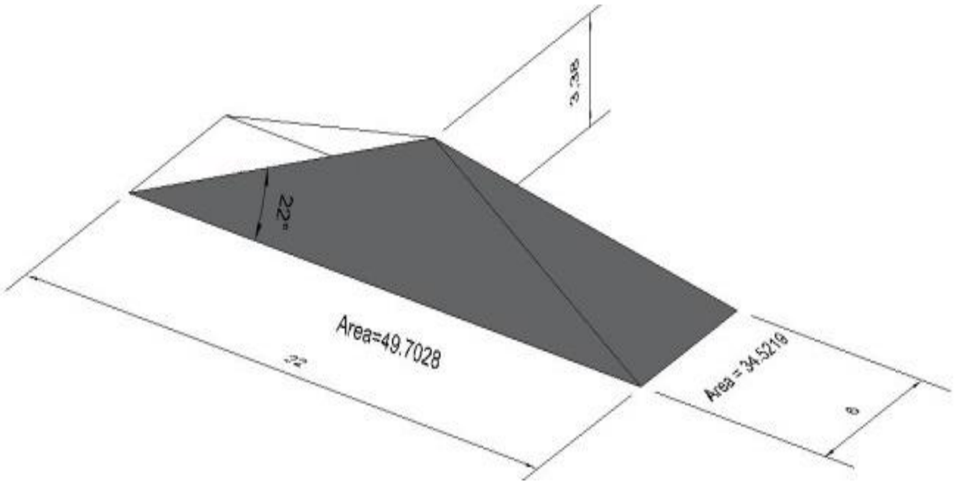

Figure 12. Sloped Roof and Concrete Surface for House Number 1

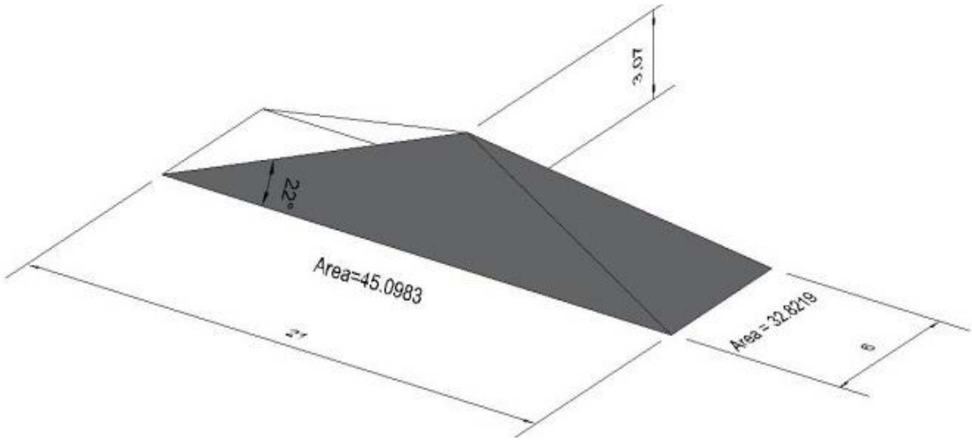

Figure 13. Sloped Roof and Concrete Surface for House Number 2

The RWH potentials for House Number 1 and House Number 2 in Scenario 2 are presented in Table 7. Scenario 2 differs from Scenario 1 by incorporating a sloped concrete roof instead of a flat concrete roof. The compensation percentages for Scenario 2 are presented in Table 8.

Table 7. The RWH Potentials (December, August, annual) of House Numbers 1 and 2 in Scenario 2

	December (liters)	**August (liters)**	**Annual (liters)**
House 1	14410	670	77600
House 2	13380	620	72060

Table 8. The Compensation Percentages (December, August, annual) of House Numbers 1 and 2 in Scenario 2

	December (%)	**August (%)**	**Annual (%)**
House 1	62.21	2.89	27.92
House 2	57.77	2.67	25.92

3.1.3 Scenario 3 (house number 1 and house number 2, sloped roof surface made of tiles)

As mentioned earlier, the roof areas for House Number 1 and House Number 2 were determined using a satellite image provider's polygon. The roof surfaces with tiles are presented in Figure 14-15.

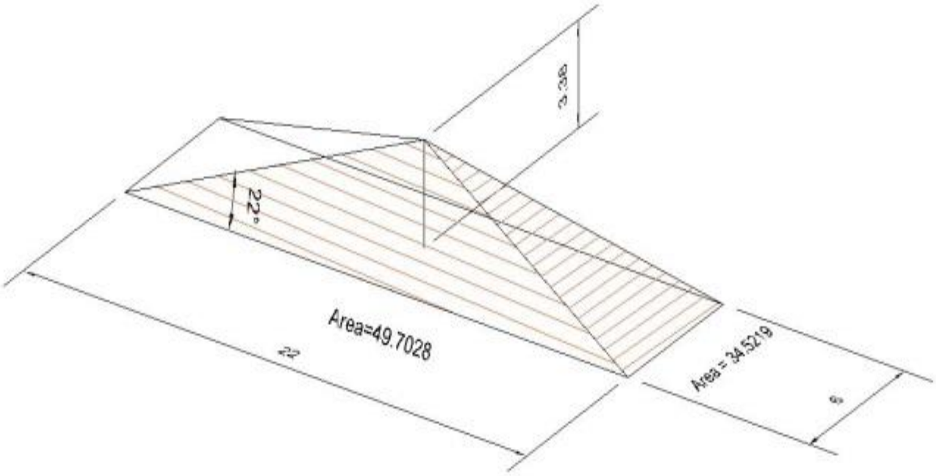

Figure 14. Sloped Roof and Tile Covered Surface for House Number 1

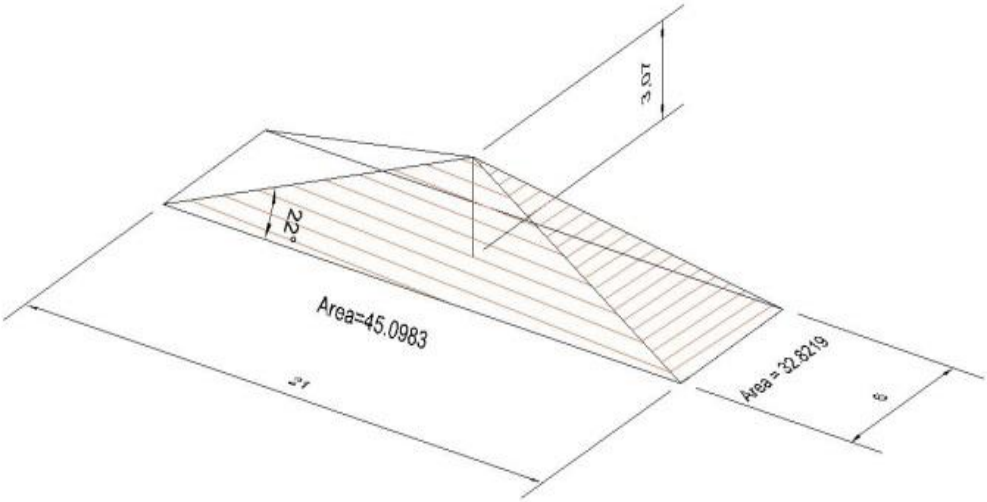

Figure 15. Sloped Roof and Tile Covered Surface for House Number 2

The rainwater harvesting potentials for House Number 1 and House Number 2 in Scenario 3 are presented in Table 9. Scenario 3 differs from Scenario 2 in that it includes a sloped tile-covered roof surface instead of a sloped concrete roof surface. The compensation percentages for Scenario 3 are presented in Table 10.

Table 9. The RWH Potentials (December, August, annual) of House Numbers 1 and 2 in Scenario 3

	December (liters)	August (liters)	Annual (liters)
House 1	15440	720	83140
House 2	14340	670	77200

Table 10. The Compensation Percentages (December, August, annual) of House Numbers 1 and 2 in Scenario 3

	December (%)	August (%)	Annual (%)
House 1	66.7	3.10	29.92
House 2	61.91	2.89	27.77

3.1.4. Comparison of compensation for all scenarios

The comparision of compensation for all scenarios, considering the houses and monthly cases is presented by histograms in Figure 16-18.

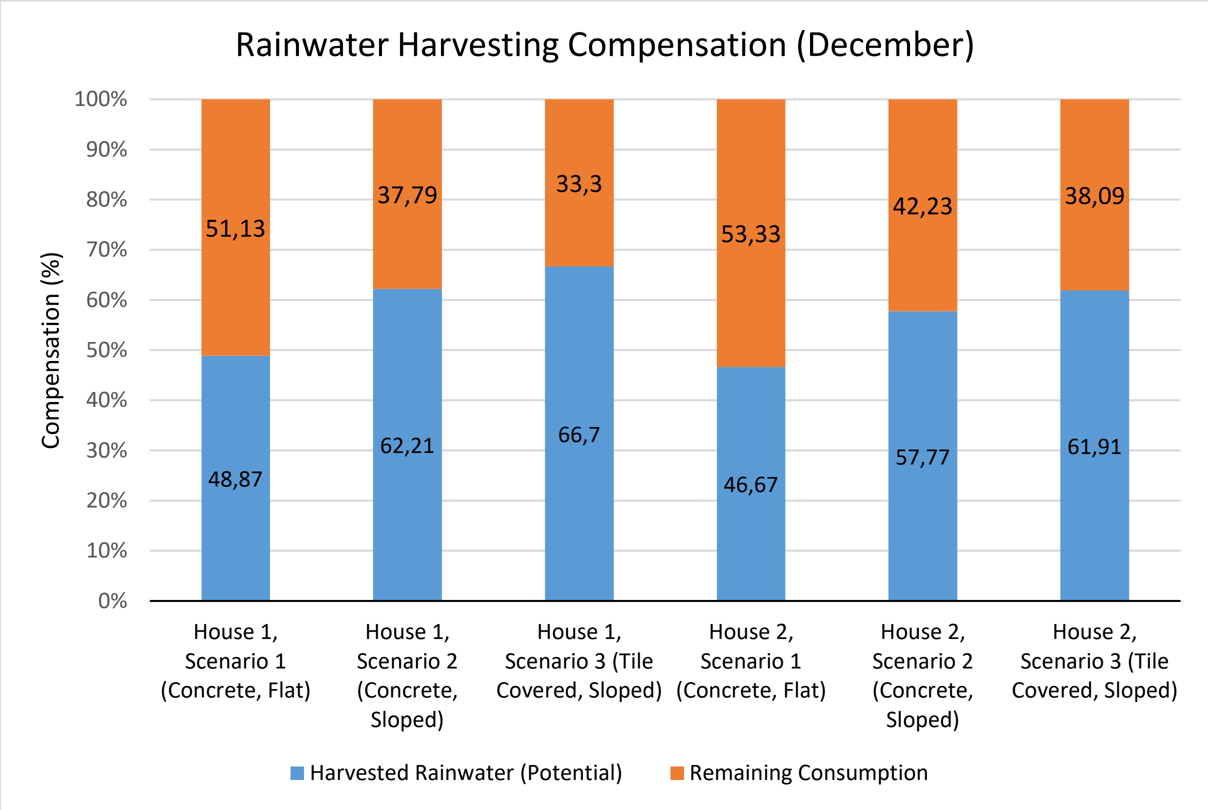

Figure 16. Comparison of Compensation in all Scenarios for December

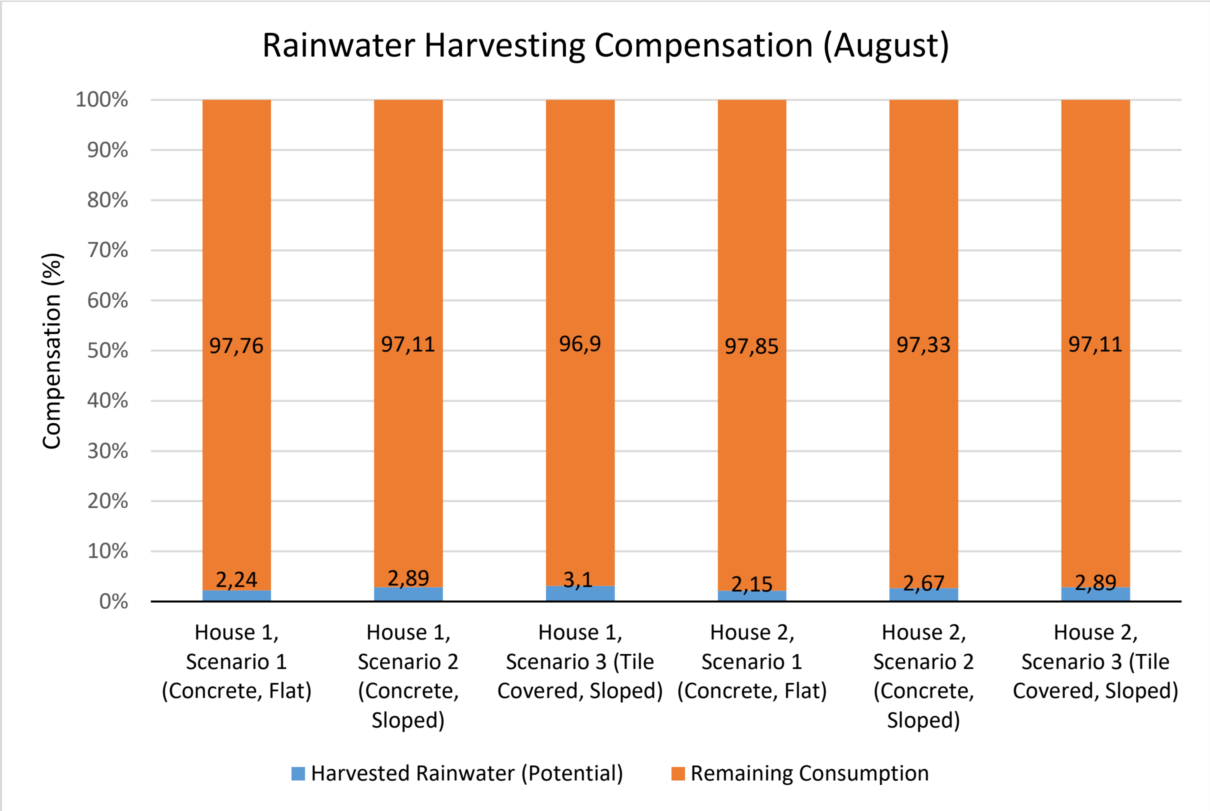

Figure 17. Comparison of Compensation in all Scenarios for August

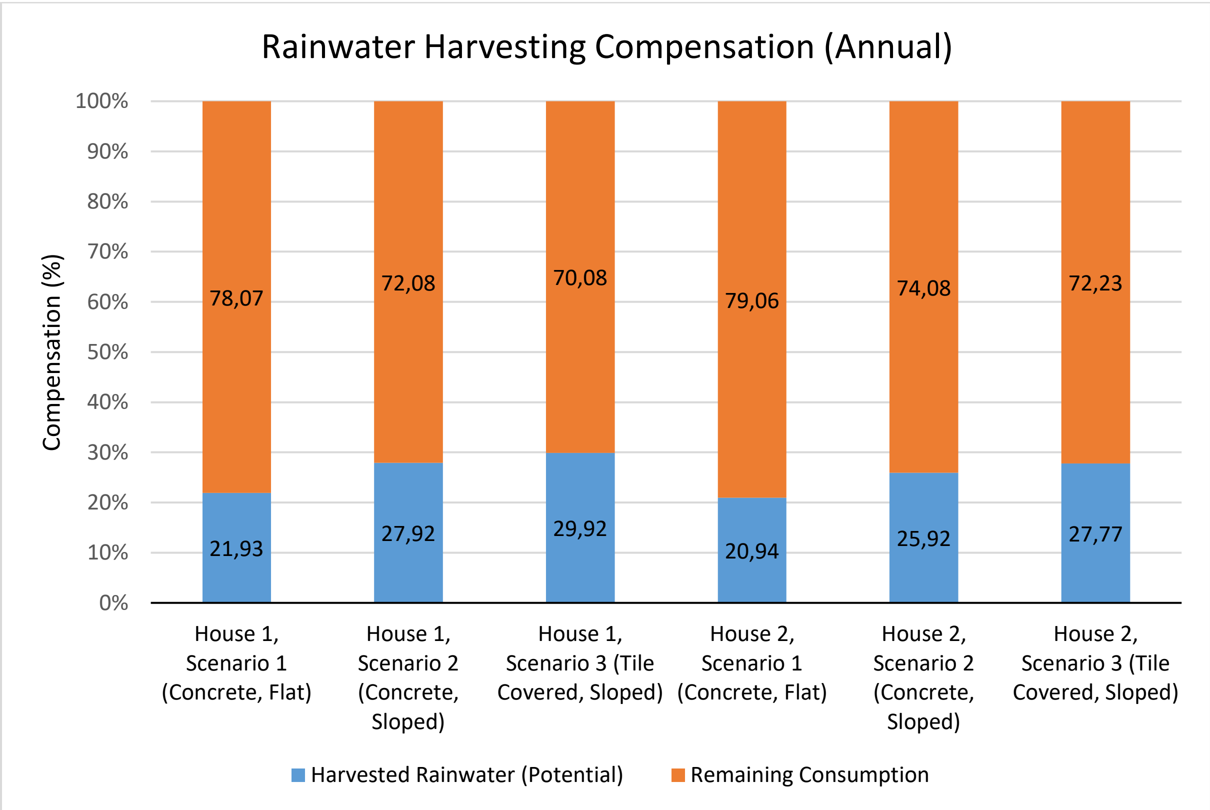

Figure 18. Comparison of Compensation in all Scenarios Anually

3.2. Reduction in Water Bills based on RWH Scenarios

Calculating water bills is complex due to varying infrastructure distribution among district municipalities, impacting water unit prices. Additional charges, like taxes and solid waste collection fees, are included in the bills. Despite the absence of current unit prices and excluding taxes and fees, rainwater harvesting savings percentages remain consistent. This study calculates potential savings based on a 1000 TL invoice for both households in all three scenarios. The financial impact can be determined using the compensation values (Comp) from the scenario sections. For each dwelling, the calculation involves finding the percentage decrease in water costs for the best and worst rainwater harvesting months (December and August) and annually (1000 TL and 12000 TL, respectively). The calculation of the reduction in water bills relies on a quite simple formula, as shown in Equation 7, and the reductions in water bills (out of 1000 TL) for each scenario are presented in Tables 11-13.

$$\text{Reduction(TL)} = \text{Comp(\%)} \text{ x } 1000 \text{ TL} \tag{7}$$

3.2.1. Reduction in water bills for scenario 1

Table 11. The reductions in water bills out of 1000 TL (December, August, annual) for House Numbers 1 and 2 in Scenario 1.

	December (TL)	August (TL)	Annual (TL)
House 1	489	24.15	2632
House 2	467	21.5	2513

3.2.2. Reduction in water bills for scenario 2

Table 12. The reductions in water bills out of 1000 TL (December, August, annual) for House Numbers 1 and 2 in Scenario 2.

	December (TL)	August (TL)	Annual (TL)
House 1	622	30	3350
House 2	578	27	3110

3.2.3. Reduction in water bills for scenario 3

Table 13. The reductions in water bills out of 1000 TL (December, August, annual) for House Numbers 1 and 2 in Scenario 3.

	December (TL)	August (TL)	Annual (TL)
House 1	667	31	3590
House 2	619	29	3332

3.3. Appropriate Pump Selection

Various factors affect pump selection, with frictional pressure drop being a key consideration. It determines the pump power needed to maintain flow in a pipe (Sorgun et al., 2022). The Darcy-Weisbach equation, widely used for assessing frictional pressure drop, considers pipe diameter, flow rate, length, and inner surface roughness to estimate pressure loss due to friction as fluid moves through the conduit. The equation is as follows:

$$\Delta P = f \; x \; (L/D) \; x \; (\rho \; x \; V^2)/2 \tag{8}$$

Where ΔP represents pressure drop due to friction, f represents Darcy friction factor, L represents the length of the pipe, D represents the diameter of the pipe, ρ represents the density of the fluid, and V represents the velocity of the fluid.

Selecting a pump requires detailed calculations, but fundamental attributes and guidelines assist homeowners in making the right choice. For multi-story buildings, a pump with a head pressure of 30 m to 50 m is generally suitable. Water pressure is crucial for appliance performance. Calculating flow rates helps in choosing the right pump, preventing unnecessary resource usage. Noise levels can be managed with enclosures or covers.

4. Conclusion

This study investigates rainwater harvesting potential in two detached houses in the same city, considering variations in roof size, design, and materials. It collected data on monthly precipitation from 1941 to 2022 and daily per capita water consumption from 2010 to 2021. Seventeen other cities were chosen for comparison, including densely populated (Istanbul, Ankara, and Izmir), sparsely populated (Bayburt), and cities similar in size and location to the study area. After analyzing the data, the study assessed rainwater harvesting potential in three scenarios with different roof designs and materials. It found that, in some cases, rainwater could meet household water needs by a great percentage, particularly in winter. However, the Mediterranean climate reduces effectiveness in the summer. Nevertheless, the capacity to cover nearly 30% of annual water consumption through rainwater harvesting is noteworthy.

The research also examined potential cost savings on water bills from rainwater harvesting and provided insights into selecting pump systems for water distribution within houses, emphasizing key features for efficiency.

Conflict of Interest Declaration

The author of the article declares that there is no conflict of interest.

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