Determining rainwater harvesting potentials in municipalities by a semi-analytical method

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ABSTRACT

Due to increasing population, uncontrolled water consumption, and abnormal climatic conditions, the potential of usable water is running out. Water has become one of the most valuable resources for the countries; therefore, rainwater harvesting systems for water recovery gain importance to implement in buildings. Thus, authorities have begun to search for fast and accurate decision tools before taking any action. In the present study, a semi-analytical method for determining the rainwater harvesting potential of the given location is implemented in the Java programming language. Three major districts of Izmir, Turkey are chosen for the study site, namely Cigli, Bayrakli, and Karsiyaka. The result shows that implementing rainwater harvesting systems only in public buildings recovers less than 1% of the population’s water needs. On the contrary, encouraging the free zones, which has large rooftop area such as airports and malls, for implementing and using rainwater increases the water recovery to 13% of that district’s water needs. It is still a small portion of the public’s water needs; therefore, spreading rainwater harvesting in the communities is necessary. It is believed that more accurate and user-friendly rainwater harvesting simulators would encourage the communities to harvest rainwater.

Key words: feasibility, green buildings, Java simulator, rainwater, sustainable environment

HIGHLIGHTS

• Investigating rainwater harvesting potential in metropolitans.
• Determining rainwater harvesting in regions by using user-friendly simulator.
• Providing rate of return of rainwater harvesting design with simulator.
• Encouraging communities/authorities for implementing rainwater harvesting design for sustainable environment.

1. INTRODUCTION

Technological and industrial developments are milestones for guiding the world’s climate balance on uncontrolled consumption of water and growth of environmental pollution (Christian Amos et al. 2016). Climate change has the potential to tip out of balance in civilizations about the ability to access water, food, and energy systems (Angrill et al. 2012). The rapid growth of the population and industrialization cause natural resource depletion, particularly water resources. The negative impacts of climate change and environmental pollution on water resources are increasing day by day, and the strategic importance of water leads to priority cases for authorities (Campisano et al. 2017). Recently, interest and demand for sustainable sources are continuously increasing due to climate change and global warming (Oo et al. 2020). Although there are plenty of water resources on the earth’s surface, many countries face a severe lack of sufficient water, also called water scarcity (Brodie 2008; Hamel & Fletcher 2014; Burns et al. 2015).

It is obvious to state that water resources have to be used reasonably to protect ecological stability and provide the sustainable development of civilizations. Indeed, ecological regulations and research have gained momentum across the world. Due to the unplanned urbanization in metropolitan cities, municipalities start to search for alternative resources to meet their water needs. The study provided a comprehensive overview of governmental approaches to the buildings’ rainwater harvesting (RWH) system implementations (Campisano et al. 2017). Existing designs produce short-term solutions, and their adverse
effects on climate and ecological stability begin to be seen. All these concerns are combined with sustainability; therefore, the RWH system comes into prominence.

Water security has become a risk in recent years, as climate change has considerably modified the dry and wet periods, leading to an imbalance in water availability over the year (Zhang 2019; Kansoh et al. 2020). Water scarcity is a problem for many developing countries, where rainwater is the main source of drinking water. Moreover, the rainwater collection systems can supply water suitable for agriculture and domestic use (Helmreich & Horn 2009). The harvesting of rainwater from rooftops is a simple method to reduce the demands and utilization of public water resources. Obtained rainwater can also be utilized in diverse areas such as toilet flushing, toilet sinks, and irrigation systems (GhaffarianHoseini et al. 2016). Furthermore, the harvested water can be used for other purposes, such as long-term storage for firefighting and groundwater beneficiation.

Governments can lead the development of sustainable cities through the incentives and regulations of these systems. The RWH system provides the chance to achieve economic and environmental goals against rising water demands and economic benefits, which leads to becoming self-sufficient locations for their water needs and delay the need to construct new water infrastructures (Steffen et al. 2013; Morales-Pinzón et al. 2014; Devkota et al. 2015). The most important parameter to maximize the harvesting potential of water is optimizing the tank capacity concerning rainfall intensity and duration projection (Gardner & Vieritz 2010; Domènech & Saurí 2011).

It is a complex task to provide a recommendation for a well-designed RWH system since the system’s goal can vary with respect to regional necessity, economy, policy, etc. Moreover, the variability of the design has a great degree, such as cistern sizes, type of water demand, the volume of water demand, materials used, and configurations of system equipment such as downspouts and gutters. Therefore, computer simulation for a basic recommendation of RWH systems has recently taken the attention of researchers. Coombes & Barry (2007) used a probabilistic approach to develop a model to simulate RWH system performance. They stated that estimating water usage and time interval of data has a significant effect on simulation results. Guo & Baetz (2007) used an analytical approach to estimate the RWH systems. They proposed a set of analytical equations for estimating the volume of water demand. However, they assumed a variety of simplifications for overflow rates, precipitation depths, and water usage rates. Jones & Hunt (2010) also developed a simulator based on the similar approach of Coombes & Barry (2007). They conducted a case study for determining the performance of RWH systems in the southeastern United States rather than Australia.

The urban RWH system literature was reviewed by Campisano et al. (2017), and they stated that the methods of evaluating RWH performance are still in an embryonic stage and have to be dealt with by researchers. Authorities need fast and accurate information before taking any measures. This research aimed to bring a new perspective to guide authorities to take measures or provide funds for a sustainable environment in their region. Enhancing technology lets the researchers use computational simulations by implementing their proposed algorithm and providing new knowledge faster. Previous studies used either probabilistic or analytical approaches to determine the performance of RWH systems. Moreover, they conducted case studies by computer simulator for either arid or humid areas. In the present study, a semi-analytical method is used to provide the performance of RWH systems based on location, catchment area, water demand, method of rainy day calculation, and method of precipitation duration calculation. A web-based RWH simulator was developed in a Java program and applied in the previous study (Hajjar et al. 2020). As a case study, three districts of Izmir/Turkey (semi-arid region) are chosen to investigate and show that each district needs different concentration points to start fast recovery for their water resources.

The paper is organized as follows. An introduction of global water scarcity and importance of RWH systems, previous studies, and the novelty of the present study are given in Section 1. In Section 2, the present study's methodology consists of the study area, precipitation data in the location, and information about the developed computer simulator. Obtained results from the computer simulator are presented and discussed in Section 3. Finally, the findings are presented, and the future perspectives for the development of RWH systems are recommended in Section 4.

2. METHODOLOGY

RWH is an effective water management model that allows rain to be kept in the area where it is falling. The application of an appropriate RWH system is necessary, especially in areas where annual rainfall exceeds 500 mm (Syed Azizul Haq 2016). Recent RWH applications are a combination model of rain and moisture. It has been observed that the amount of water used in activities that do not require potable water, such as toilet flushing, irrigation, and domestic use, is dominant. Domestic purposes also include cleaning, fire extinguishing, laundry, toilet reservoirs, car washing, and irrigation. However, the drinking water quality is necessary for showering, cooking, and washing dishes that need some complex filtration and disinfection.
processes, increasing the design cost. Determining the volume of rainwater storage should be regulated according to the amount of water harvesting and monthly water consumption measurements of the building. The necessary coefficient can be selected according to the pollution rate of the surfaces in the region; therefore, various scenarios are needed to take into account. These scenarios vary with the design parameters of tank capacity, rainfall amount and intensity, water demand, and total surface area. The amount of water to be supplied from the network is determined monthly. So, the optimal tank size and location can be adjusted. The following sub-sections describe the study area, precipitation prediction in the location, and the developed RWH simulator.

2.1. Study area
The Gediz Delta was formed from anthropogenic old alluvium that has accumulated over a very large area due to frequent displacement of the bed where the river empties into the sea. The region consists of the formation of Neogene-aged volcanic. Precipitation is the basis of the groundwater feeding mechanism of Neogene volcanic. The lateral flows of adjacent rocks can also feed them. The formations containing groundwater are similar to each other in the Karsiyaka, Menemen, Foca, and Aliaga districts of Izmir, Turkey. There is an alluvial aquifer consisting of clay, silt, sand, gravel, and block-sized materials. The alluvial aquifer has a significant amount of groundwater reserves in the area. The alluvial aquifer is especially fed by the flow of the Gediz River and through rainfall, as seen in Figure 1. According to IZSU (Izmir Water and Drainage Organization), approximately 800 L/s drinking water in Izmir is supplied by drilled wells in the alluvial aquifer. The Gediz Delta is a young alluvial fan. The characteristic of the coastal plain is a marsh. The total agricultural land covers 26% irrigated and 74% non-irrigated land. From the portion of residential areas in the Cigli district, public institutions have large roof areas.

The buildings that might be faulty are checked by making a parcel query from the TKGM (Turkish General Directorate of Land Registry and Cadastre) website and taking into account projections. More precise results can be obtained with the help of steep projections on the TKGM website. Building locations and shapes have been verified with 3D street images. Karsiyaka, Cigli, and Bayrakli districts are shown in Figures 2, 3, and 4, respectively.

Figure 1 | Aquifers in the north and northeast of Izmir.

Figure 2 | District boundaries of Karsiyaka.
2.2. Precipitation in Izmir

The region has a Mediterranean climate that contains hot, dry summers and mild, rainy winters. More than 50% of the annual rainfall occurs during the winter season, 40–45% fall in spring and autumn, and 2–4% in summer. The average annual rainfall is 710.5 mm between 1938 and 2020. The maximum and minimum monthly average precipitation are 145.7 mm in December and 4.1 mm in July. The maximum and minimum numbers of rainy days are 14.4 days in December and 0.7 days in July (General Directorate of Meteorology Average of Monthly Precipitation 2020). The graphical representation of the rainfall amount and average monthly rainfall days versus months are presented in Figures 5 and 6, respectively.

2.3. Computer simulation

A computer simulation imitates the operation of a system over time. The intended purpose of the simulation is to present the underlying mechanisms that control the system's behavior. The program is developed to simulate the RWH system.
Figure 6 | Average monthly rainy days in Izmir.

Figure 7 | Comparison of the simulator result with Jones & Hunt (2010).

Table 1 | Monthly amounts of harvestable rainwater in IKCU (25,955 m² catchment area and 0.9 runoff coefficient)

| Months    | Average monthly rainfall (mm) | Rainwater supply (m³) |
|-----------|-------------------------------|-----------------------|
| January   | 135                           | 3,153.6               |
| February  | 101.9                         | 2,380.4               |
| March     | 75.4                          | 1,761.3               |
| April     | 46.1                          | 1,076.9               |
| May       | 31.8                          | 742.8                 |
| June      | 12                            | 280.3                 |
| July      | 4.1                           | 95.8                  |
| August    | 5.6                           | 130.8                 |
| September | 159.5                         | 362.1                 |
| October   | 44.8                          | 1,046.5               |
| November  | 92.6                          | 2,163.1               |
| December  | 145.7                         | 3,403.6               |
| Total     | 710.5                         | 16,597.3              |
and assess the RWH system’s potential. It is constructed web-based by adding the system’s input and determining the analysis results by displaying user-friendly interfaces using Java programming languages. The simulation shows how much water is utilized in different created scenarios during the different time periods by embedding the amount and intensity
of precipitation and reducing possible overflow to get the maximum tank capacity. The website’s home page consists of three parts: inputs, table of results, and graphical representation of results. The input page is a list that contains a set of variables required for the simulation, such as start date, location, catchment surface area, water demand, rainfall day calculation method, and calculation period. There are two different modes of rainfall day calculation, random mode, and continuous uniform distribution mode. The random mode is operated by dividing the amount of monthly rainfall by the number of rainy days in the same month; then, the program randomly selects the rainy days. On the contrary, the continuous uniform distribution mode is operated by dividing the monthly rainfall amount by the number of days in the month. After starting the simulation process, the volume of stored rainwater and the total savings change over the required time. The total savings value starts from a negative value that indicates the initial system cost, and by continuing the simulation process,

| Date                  | Rainfall amount | Water collected | Water used | Cash flow | Accumulated savings |
|-----------------------|-----------------|-----------------|------------|-----------|---------------------|
| 1 - 2021 January     | 150.03 mm       | 3004.06 m³      | 1101.596 m³ | 10575.31 £ | -252361.89 £        |
| 2 - 2021 February    | 123.14 mm       | 2876.46 m³      | 778.318 m³  | 7471.85 £  | -224909.84 £        |
| 3 - 2021 March       | 90.39 mm        | 2111.50 m³      | 1432.978 m³ | 13756.89 £ | -211532.25 £        |
| 4 - 2021 April       | 69.87 mm        | 1832.21 m³      | 1514.671 m³ | 14540.85 £ | -196012.40 £        |
| 5 - 2021 May         | 35.21 mm        | 822.43 m³       | 763.913 m³  | 7333.96 £  | -189278.84 £        |
| 6 - 2021 June        | 10.55 mm        | 248.34 m³       | 304.854 m³  | 2926.60 £  | -186362.24 £        |
| 7 - 2021 July        | no rain         | 0.00 m³         | 0.00 m³     | 0.00 £     | -186362.24 £        |
| 8 - 2021 August      | no rain         | 0.00 m³         | 0.00 m³     | 0.00 £     | -186362.24 £        |
| 9 - 2021 September   | 15.80 mm        | 369.08 m³       | 280.833 m³  | 2696.00 £  | -183566.24 £        |
| 10 - 2021 October    | 41.30 mm        | 964.66 m³       | 759.093 m³  | 7287.29 £  | -176368.94 £        |
| 11 - 2021 November   | 85.18 mm        | 1989.80 m³      | 1403.206 m³ | 13470.78 £ | -162898.17 £        |
| 12 - 2021 December   | 169.10 mm       | 3659.13 m³      | 1664.196 m³ | 15890.28 £ | -147017.89 £        |
| 13 - 2021 January    | 85.73 mm        | 2002.66 m³      | 1015.819 m³ | 9751.86 £  | -137266.02 £        |
| 14 - 2021 February   | 104.19 mm       | 2433.93 m³      | 744.995 m³  | 7151.36 £  | -130114.65 £        |
| 15 - 2021 March      | 65.74 mm        | 1556.83 m³      | 1529.035 m³ | 14678.73 £ | -115435.91 £        |
| 16 - 2021 April      | 17.47 mm        | 408.05 m³       | 210.960 m³  | 2052.22 £  | -113410.70 £        |
| 17 - 2021 May        | 17.60 mm        | 411.22 m³       | 476.404 m³  | 4592.68 £  | -108188.02 £        |
| 18 - 2021 June       | 5.27 mm         | 123.17 m³       | 188.998 m³  | 1813.52 £  | -107004.50 £        |
| 19 - 2022 July       | no rain         | 0.00 m³         | 0.00 m³     | 0.00 £     | -107004.50 £        |
| 20 - 2022 August     | 11.40 mm        | 266.30 m³       | 3.011 m³    | 34.67 £    | -106969.84 £        |
| 21 - 2022 September  | 15.80 mm        | 369.08 m³       | 477.562 m³  | 4585.56 £  | -102384.28 £        |
| 22 - 2022 October    | 41.30 mm        | 964.66 m³       | 877.062 m³  | 8419.99 £  | -93664.29 £         |
| 23 - 2022 November   | 117.12 mm       | 2735.98 m³      | 1481.790 m³ | 14224.60 £ | -79379.39 £         |
| 24 - 2022 December   | 189.10 mm       | 3950.13 m³      | 1571.147 m³ | 15083.01 £ | -64656.38 £         |
| 25 - 2023 January    | 150.03 mm       | 3504.66 m³      | 1127.796 m³ | 10626.46 £ | -53629.93 £         |
| 26 - 2023 February   | 194.19 mm       | 2433.03 m³      | 804.921 m³  | 8590.29 £  | -45239.64 £         |
| 27 - 2023 March      | 90.39 mm        | 2111.50 m³      | 1478.657 m³ | 14195.11 £ | -31044.54 £         |
| 28 - 2023 April      | 29.34 mm        | 680.09 m³       | 613.942 m³  | 5893.84 £  | -25560.69 £         |
| 29 - 2023 May        | 29.34 mm        | 685.06 m³       | 761.751 m³  | 7312.81 £  | -17837.89 £         |
| 30 - 2023 June       | 15.82 mm        | 369.08 m³       | 226.648 m³  | 2175.82 £  | -15662.07 £         |
| 31 - 2023 July       | no rain         | 0.00 m³         | 203.005 m³  | 1948.84 £  | -13713.22 £         |
| 32 - 2023 August     | no rain         | 0.00 m³         | 0.00 m³     | 0.00 £     | -13713.22 £         |
| 33 - 2023 September  | 15.80 mm        | 369.08 m³       | 369.080 m³  | 3543.17 £  | -10170.05 £         |
| 34 - 2023 October    | 16.54 mm        | 385.86 m³       | 335.958 m³  | 3221.72 £  | -9494.33 £          |
| 35 - 2023 November   | 74.53 mm        | 1741.08 m³      | 1256.544 m³ | 12062.83 £ | 5114.49 £           |
| 36 - 2023 December   | 124.01 mm       | 2896.76 m³      | 1428.483 m³ | 13713.44 £ | 18827.93 £          |

Figure 9 | Breakeven point at IKCU.
this value starts to increase the profit. The system also presents the consumed main water volume and the overflow water volume. The total savings value changes according to the selected scenario. The second page contains the table of simulation results, and the last page has the diagrams that include cost by scenario, rainfall days, rainfall (mm), cash flow, overflow, and payoff.

3. RESULTS AND DISCUSSION

The simulator aims to perform the RWH systems in Karsiyaka, Bayrakli, and Cigli districts. At first, the model should be validated. First, the simulator result is compared with another simulator prepared by Jones & Hunt (2010) with their field data. The comparison results show that the simulator estimates in the range of accuracy even though the details of the inputs were not given in the paper. The comparison result is shown in Figure 7. Finally, the simulator is performed for Izmir Katip Celebi University (IKCU), located in the Cigli district. To get clear data, the semester breaks, summer break, and public holidays are taken into account. The installation of the flow meters on the supply pipes is aimed to determine the consumption amount. The volume of harvested rainwater is estimated based on the rainfall data in Izmir metropolitan and the catchment area of the building, as shown in Table 1.

As rainfall is an uneven phenomenon, there are wet days and dry days. Therefore, two methods were added to the simulation to determine the rainy days. The first method is the random mode that randomly chooses the rainy days considering the number of rainy days and the average monthly precipitation. The second mode is the uniform distribution, which considers that the rainfall amount is uniform on all days. All the calculations were carried out according to the daily data, even weekly and monthly. The system’s cash flow relies on the unit price of water and used water amount. The total savings start from the system’s cost as a negative value during the simulation, increasing until the breakeven point. To determine the optimal system, three scenarios were applied in the simulation by considering the amount and intensity of rainfall. The program flowchart is shown in Figure 8. According to the optimization results, the breakeven point appears in this study after 3 years from the starting system in IKCU, as shown in Figure 9. The overflow charts show the changes in excess water and the used main water over time, and although the overflow value exceeds the used main water value, there is a need for main water because that depends on the storage volume available in the system, as shown in Figure 10. After successfully performing the developed simulation in the case study of IKCU, the study is extended to three different districts of Izmir metropolitan to analyze the recovery amount of water resources with RWH systems. The all-public buildings, such as schools, sports centers, and hospitals, are implemented in the simulator to determine the maximum RWH potential. It is investigated that implementing RWH systems in the public buildings recovers <1% of the population water needs for all three districts. However, there is an organized industrial zone in Cigli, which is indirectly regulated by the authorities. If the organized industrial zone

![Overflow charts at IKCU.](image-url)
buildings play roles in the calculation, the recovery ratio increases to 13% water need of the Cigli population. The monthly harvestable rainwater in Cigli, Karsiyaka, and Bayrakli are tabulated in Tables 2, 3 and 4, respectively.

Total RWH potentials in the Karsiyaka, Cigli, and Bayrakli districts are estimated at 279,663, 2,189,632, and 41,993 m³/year, respectively. The consumption rates of the public buildings in Karsiyaka, Cigli, and Bayrakli districts from collected rainwater are shown in Figures 11, 12, and 13, respectively.

The total RWH potential in Cigli is estimated at 2,194,856 m³/year. It corresponds to 13.1% of the total water consumption of Cigli according to the 2020 population. On the contrary, the total RWH potential in Karsiyaka is estimated at 292,714 m³/year. It corresponds to 1.02% of the total water consumption of Karsiyaka according to the 2020 population. As a result, the

Table 2 | Monthly amounts of harvestable rainwater in Cigli

| Months    | Average monthly rainfall, mm | Total rainwater harvesting, m³ |
|-----------|------------------------------|-------------------------------|
| January   | 135.0                        | 416,045.6                    |
| February  | 101.9                        | 314,037.4                    |
| March     | 75.4                         | 232,369.2                    |
| April     | 46.1                         | 142,071.9                    |
| May       | 31.8                         | 98,001.8                     |
| June      | 12.0                         | 36,981.8                     |
| July      | 4.1                          | 12,635.5                     |
| August    | 5.6                          | 17,258.2                     |
| September | 15.5                         | 47,768.2                     |
| October   | 44.8                         | 138,065.5                    |
| November  | 92.6                         | 285,376.4                    |
| December  | 145.7                        | 449,021.1                    |
| Total     | 710.5                        | 2,189,632.5                  |

The total rooftop area and the runoff coefficient of rooftop are 73,528.8 m² and 0.9, respectively. The total concrete surface area and the runoff coefficient of rooftop are 4,308,061.7 m² and 0.7, respectively.

Table 3 | Monthly amounts of harvestable rainwater in Karsiyaka

| Months   | Average monthly rainfall, mm | Total rainwater harvesting, m³ |
|----------|------------------------------|-------------------------------|
| January  | 135.0                        | 53,137.9                      |
| February | 101.9                        | 40,109.3                      |
| March    | 75.4                         | 29,678.5                      |
| April    | 46.1                         | 18,145.6                      |
| May      | 31.8                         | 12,516.9                      |
| June     | 12.0                         | 36,981.8                      |
| July     | 4.1                          | 12,635.5                      |
| August   | 5.6                          | 17,258.2                      |
| September| 15.5                         | 47,768.2                      |
| October  | 44.8                         | 138,065.5                     |
| November | 92.6                         | 285,376.4                     |
| December | 145.7                        | 449,021.1                     |
| Total    | 710.5                        | 279,663.1                     |

The total rooftop area and the runoff coefficient of rooftop are 183,696.2 m² and 0.9, respectively. The total concrete surface area and the runoff coefficient of rooftop are 326,125.5 m² and 0.7, respectively.
Table 4 | Monthly amounts of harvestable rainwater in Bayrakli

| Months   | Average monthly rainfall, mm | Total rainwater harvesting, m³ |
|----------|------------------------------|-----------------------------|
| January  | 135.0                        | 797,911                     |
| February | 101.9                        | 602,275                     |
| March    | 75.4                         | 445,648                     |
| April    | 46.1                         | 272,472                     |
| May      | 31.8                         | 187,952                     |
| June     | 12.0                         | 70,925                      |
| July     | 4.1                          | 24,233                      |
| August   | 5.6                          | 33,099                      |
| September| 15.5                         | 91,612                      |
| October  | 44.8                         | 264,788                     |
| November | 92.6                         | 547,308                     |
| December | 145.7                        | 861,153                     |
| Total    | 710.5                        | 4,199,376                   |

The total rooftop area and the runoff coefficient of rooftop are 84,435 m² and 0.7, respectively.

Figure 11 | Consumption rates of the public buildings in Karsiyaka from collected rainwater.

authorities should take priority for RWH projects in locations where it has concentrated large buildings such as industrial zones, airports, military zones, stadiums, mass housing projects, and touristic facilities. However, authorities' efforts in public buildings are not sufficient as it is seen that about 13% of the recovery rate is obtained. The main task for authorities is spreading RWH systems among the public as much as possible, particularly irrigation and agriculture. The cumbersome of this task is the economic perspective of the system. The developed RWH simulator carries out both water savings and economic analysis of any kind of building in any location in a user-friendly way. It is keenly believed that these kinds of simulators will encourage the communities to harvest rainwater by showing them how cost-effective their design could be by manipulating their inputs.
4. CONCLUSIONS

Rainwater is a natural resource that needs to be investigated regarding the potential of benefit. This natural resource needs to be evaluated both economically and in terms of creating a sustainable resource. For this reason, authorities are searching for effect. It is stated that methods of evaluating the RWH performance are still in the embryonic stage and have to be dealt with by researchers. Authorities need fast and accurate information before taking any measures. In the present study, a web-based and user-friendly RWH simulator is developed by implementing the semi-analytical method in the Java programming language program to determine the most efficient RWH design among the given design scenarios. Three districts of Izmir/Turkey were investigated by means of their RWH potential, and the analysis showed that public buildings provide less than 1% of public water needs. If the large rooftop areas, such as organized industrial zones, airports, stadiums, and military...
zones, are taken into account, the recovery ratio increases to approximately 13% of public water needs. It is still a small portion of the public's water needs; therefore, spreading RWH in the communities is necessary. It is a keen belief that accurate and user-friendly RWH simulators are going to encourage the communities to harvest rainwater.

Since evaluating RWH systems' potential is complicated due to the spatial and temporal variability, more data are necessary to grab and store. In the future, machine learning algorithms and trend analysis methods are planned for implementation in the simulator to increase its feasibility and accuracy by using the stored data.

DATA AVAILABILITY STATEMENT
All relevant data are included in the paper or its Supplementary Information.

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