



The Potential Role of Rainwater Harvesting in Irrigation in Turkey

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ABSTRACT

Turkey is one of the countries where water resources exhibit high regional and seasonal variability; it is becoming increasingly vulnerable to drought risks due to population growth, urbanization, climate change, and the impact of agricultural water demand. In this context, rainwater harvesting holds significant potential as a complementary and sustainable water management option for agricultural irrigation. In this review study, the potential role of rainwater harvesting in agricultural irrigation in Turkey was evaluated by considering the current state of water resources, agricultural water use, global and national practices, technical system components, and key opportunities and limitations. The findings indicate that rainwater harvesting can reduce pressure on surface and

groundwater resources, support supplementary irrigation practices, enhance drought resilience, and contribute to water conservation strategies, particularly in semi-arid regions and small-scale agricultural operations. However, the widespread adoption of these systems is limited by factors such as initial investment costs, the need for storage infrastructure, a lack of technical knowledge, and insufficient institutional incentives. Effective implementation requires integrated planning at the watershed and farm levels, appropriate storage design, economic support mechanisms, and farmer-focused extension activities. Overall, rainwater harvesting holds significant potential in Turkey for strengthening agricultural water security, reducing drought-related production risks, and supporting sustainable water resources management.

Keywords: Rainwater harvesting; agricultural irrigation; drought risk; water management; sustainability; Turkey

1. Introduction

Water is one of the natural resources of strategic importance for the continuity of agricultural production, food security, and rural development. Although a large portion of the Earth's surface is covered by water, the amount of directly usable freshwater is quite limited. Since a significant portion of freshwater resources is found in glaciers and groundwater reserves, the spatial and temporal distribution of water suitable for human use is unequal on a global scale. This situation makes the conservation and effective management of water resources imperative, particularly in arid and semi-arid climate regions (Özgüler, 1997; Tzanakakis et al., 2020). Agricultural production ranks among the sectors with the highest water consumption. In Turkey as well, a large portion of available water resources is utilized for agricultural irrigation. According to data from the State Hydraulic Works (DSİ), the country's annual water consumption has reached approximately 57 billion m³, and the majority of this volume has been used for irrigation activities (DSİ, 2023). While population growth, urbanization, industrialization, and changes in production patterns are increasing demand for water,

temperature rises, erratic rainfall, and drought events associated with climate change are placing even greater pressure on existing resources (IPCC, 2022; Türkeş, 2021). Although Turkey is under the influence of the Mediterranean climate system in terms of its climatic characteristics, it exhibits significant regional hydroclimatic differences due to topographic diversity and elevation variations. While Central Anatolia, Southeastern Anatolia, the Eastern Mediterranean, and parts of Eastern Anatolia have semi-arid climate characteristics, the Black Sea coast has more humid conditions. These spatial differences limit the availability of precipitation for agricultural production and increase irrigation needs, particularly during the summer months (Ministry of Development, 2014; DSI, 2020). Projections regarding climate change indicate that water resources in Turkey may decrease at the regional level, the frequency of droughts may increase, and water stress may become more critical in some basins. Under these conditions, the sustainability of irrigation practices relying solely on traditional surface and groundwater resources has become a matter of debate. For this reason, rainwater harvesting, the reuse of treated wastewater, water-saving irrigation methods, and integrated water management approaches at the watershed scale are gaining greater importance (Kahinda et al., 2010; Pandey et al., 2003).

Rainwater harvesting is a sustainable water management approach based on the collection of rainfall from roofs, agricultural land, roads, greenhouse covers, or natural surfaces, its storage in appropriate facilities, and its use during periods of need. This method is considered a supplementary water source, particularly in areas where rainfall is unevenly distributed throughout the year, dry periods limit production, and irrigation infrastructure is inadequate (Oweis et al., 2001; Mengü and Akkuzu, 2008). The objective of this study is to evaluate the potential role of rainwater harvesting in agricultural irrigation in Turkey based on the literature. In this context, the current status of water resources, the characteristics of water use in agricultural irrigation, the technical components of rainwater harvesting systems, application examples from around the world and in Turkey, potential contributions, and the key constraints limiting its widespread adoption were examined. The study aims to highlight the potential contributions that rainwater harvesting can make toward agricultural water security, drought risk reduction, and sustainable irrigation management in Turkey.

2. Literature Review and Analytical Framework

2.1. Water Resources and the State of Agricultural Irrigation in Turkey

Turkey's average annual precipitation is approximately 643 mm, which is below the global average. The country's available water potential is estimated at approximately 112 billion m³. Considering population growth, the annual per capita available water supply indicates that Turkey is not a water-rich country but, on the contrary, faces a risk of water stress (DSI, 2019; Muluk et al., 2013).

Agricultural irrigation accounts for the largest share of water consumption in Turkey. While irrigation increases crop yield and quality, the irresponsible use of water can lead to environmental problems such as salinization, drainage issues, a decline in groundwater levels, and deterioration in water quality (Kanber et al., 2005; Özkay et al., 2008). For this reason, in agricultural irrigation, the efficient and sustainable use of water is just as important as ensuring its availability. Climate change is expected to have significant effects on precipitation patterns and drought conditions in Turkey. Rising temperatures increase evaporation losses, while irregularities in the temporal distribution of precipitation reduce the availability of water during the growing season. Particularly in regions where rainfall is insufficient during the summer months, the demand for irrigation water increases, and pressure on surface and groundwater resources intensifies (Şen et al., 2013; Türkeş, 2021).

In this context, rainwater harvesting should be considered in Turkey not as the sole primary source for agricultural irrigation, but rather as a complementary and risk-mitigating water management tool (Table 1). Stored rainwater can be used for supplemental irrigation during critical growth periods; it can contribute to reducing plant water stress, particularly during dry periods.

Turkey's available water potential is approximately 112 billion cubic meters (bcm) annually, and the actual consumed volume is around 57 bcm. The largest share of this consumption is attributed to agricultural irrigation, accounting for 72% to 75% of the total (Aydogdu, 2016; Dedemen & Kocak, 2026). Considering global climate change scenarios and the country's position under water stress, the methods utilized in agricultural irrigation infrastructure and the water loss rates associated with these methods are of critical importance for sustainable water management and hydraulic efficiency.

When agricultural irrigation practices across Turkey are examined, it is observed that traditional systems remain dominant. Surface (flood or furrow) irrigation is applied in approximately 55% to 75% of the total irrigated agricultural areas (Dedemen & Kocak, 2026). Operating on the principle of delivering water to the plant root zone via gravity through open channels, this system maintains its prevalence due to low initial investment costs; however, it is the method with the highest water losses and the lowest water use efficiency. Sprinkler irrigation constitutes approximately 20% to 23% of the irrigated areas. This method, which involves pressurizing water through closed-pipe systems and spraying it over the field surface, is particularly prominent in lands with sloping topography and in cereal farming. Drip or micro-irrigation, driven by recent modernization projects and government incentives, has reached a usage rate of 21% (Dedemen & Kocak, 2026). By delivering water directly to the plant's effective root zone at low pressure, this system is rapidly becoming the standard for industrial crops, orchards, and vegetable cultivation. The hydraulic efficiency of agricultural irrigation systems is evaluated based on water application efficiency—the ratio of the water stored in

the plant root zone to the total water supplied to the system. An analysis by method reveals significant discrepancies in water loss. Water losses in surface irrigation, ranging from 40% to 60%, are primarily driven by high evaporation rates due to prolonged water retention on the field surface, field-end runoff, and deep percolation that occurs when water infiltrates below the plant root depth. Consequently, this can lead to a rise in the groundwater table and soil salinization. Losses in sprinkler irrigation, which average between 15% and 25%, occur due to wind drift and the evaporation of water droplets directly into the atmosphere before reaching the ground or while resting on the plant canopy, resulting in an average application efficiency between 75% and 85%. Because the drip irrigation system operates as a closed circuit and the wetted area is restricted strictly to the plant's immediate vicinity, both deep percolation and surface evaporation are minimized. Drip irrigation systems operate with an efficiency exceeding 90% and losses of only 5% to 10%, substantially enhancing overall water use efficiency compared to conventional methods.

In conclusion, safeguarding the total water consumption budget of 57 bcm depends directly on phasing out surface irrigation methods and accelerating the transition to high-efficiency pressurized systems, particularly drip irrigation.

Table 1. Basin-Level Rainwater Harvesting Potential and Crop Water Requirement Contributions in Major Agricultural Basins of Turkey

River Basin	Average Rainfall (mm)	Available Ag. Land (ha)	Potentially Harvestable Volume (hm ³)	Contribution to Crop Water Req. (%)
Seyhan Basin	650	800,000	780	19.5%
Büyük Menderes Basin	600	950,000	680	14.4%
Sakarya Basin	480	1,800,000	860	12.0%
Kızılırmak Basin	450	2,500,000	1125	11.2%
Gediz Basin	500	700,000	420	10.5%
Konya Closed Basin	320	3,000,000	768	6.4%

2.2. Technical Characteristics of Rainwater Harvesting Systems

Rainwater harvesting systems generally consist of a collection surface, a conveyance line, filtration/sedimentation units, a storage structure, and a point of use. In agricultural applications, the collection surface can be natural terrain, a micro-watershed, a macro-catchment, a roof, or a

greenhouse cover (Table 2). The storage structure, depending on the intended use, can be designed as a tank, cistern, small farm pond, underground reservoir, or surface retention pond (Oweis et al., 2001; Örs et al., 2011).

Table 2. Comparative assessment of rainwater harvesting systems and selected applications in Türkiye

Rainwater harvesting system	Selected location / region	Main agricultural application	Key findings / reported potential	Main advantages	Main limitations
Micro-catchment systems	Semi-arid Central and Southeastern Anatolia	Supplemental irrigation for field crops, almonds and pistachios	Concentrates runoff to the root zone and reduces water stress	Simple, low cost, easily implemented by farmers	High manual labor requirements, not suitable for steep slopes
Macro-catchment harvesting	Semi-arid regions (e.g., Konya Closed Basin)	Spate irrigation, groundwater recharge	Captures large volumes of floodwater for agricultural use	Utilizes unused floodwater, improves groundwater levels	Requires heavy machinery, risk of soil erosion and downstream impacts
Greenhouse roof harvesting	Izmir - Menderes Region / Antalya	Greenhouse irrigation	Yields high rainwater collection efficiency, meets significant water demand (250–500 mm/year)	High water quality, minimal land footprint, suitable for intensive agriculture	Requires large storage infrastructure and initial investment
Artificial catchment systems	Ankara - Haymana Region	Livestock water supply	High runoff harvesting potential (80–90%), effective in dry periods	Reliable water source for grazing animals in remote areas	High installation costs, potential water quality issues (contaminants)
Rooftop harvesting for agricultural facilities	Kırşehir - Mucur / Central Anatolia	General farm water use	Reduces reliance on groundwater, covers 30–40% of non-potable needs	Easy to integrate with existing farm buildings	Storage tanks can be expensive, limited by roof area
Surface runoff harvesting (ponds)	Aegean and Mediterranean Region	Orchard irrigation (e.g., olives, citrus)	Provides supplementary irrigation during dry summer months	Supports high-value crops, enhance local biodiversity	High evaporation losses, requires suitable topography

In micro-watershed rainwater harvesting systems, rainwater is collected over a short distance and directed directly to the plant root zone. Contour terraces, ridge terraces, semicircular terraces, negariam systems, small pits, and inter-row harvesting can be classified under this group (Figure 1). These systems are typically implemented in small-scale agricultural areas, orchards, afforestation sites, and arid-semi-arid regions to increase soil moisture (Prinz and Singh, 2000; Yıldırım, 2022).

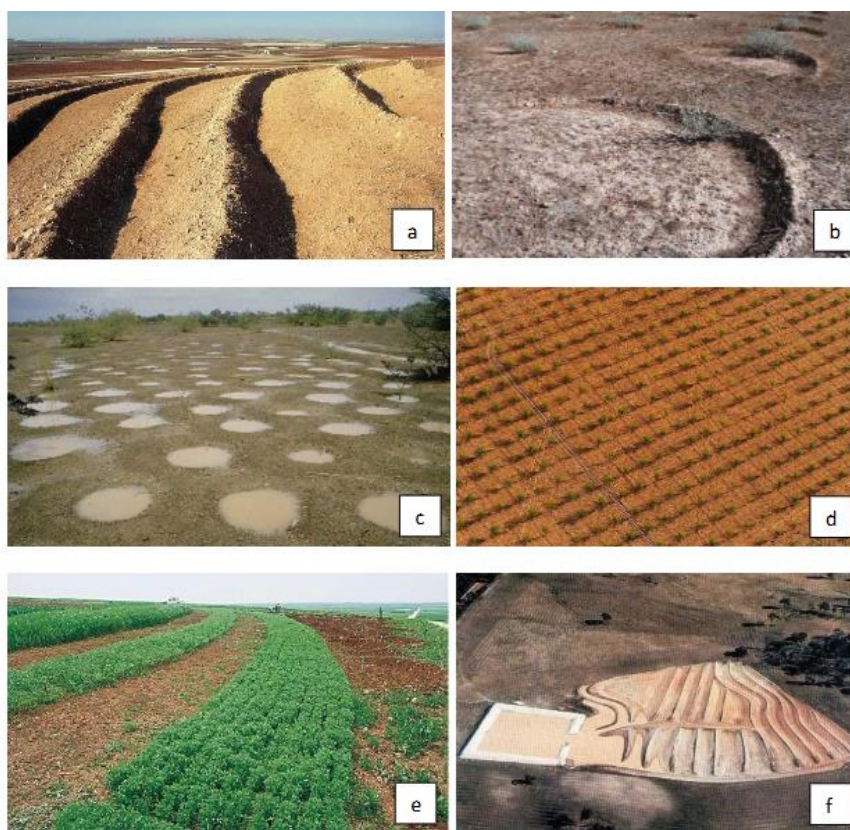


Figure 1. Examples of micro-watershed water harvesting methods.

macro-catchment systems are based on the collection of surface runoff from larger areas and its accumulation in a specific storage structure (Figure 2). Valley floor systems, small farm reservoirs, floodwater harvesting, water distribution structures, and off-valley storage systems can be considered within this scope. In macro systems, design depends on engineering criteria such as land slope, soil permeability, surface runoff potential, storage volume, and water conveyance losses (Oweis and Hachum, 2006).



Figure 2. Examples of applications related to macro-catchment water harvesting and storage systems.

Roof and greenhouse surface systems, on the other hand, enable the collection of high-quality rainwater, particularly from impermeable surfaces. Rainwater collected in greenhouses can be used for plant irrigation, cleaning, and certain production processes. In rooftop harvesting systems, while the need for treatment is more limited when the water is intended for non-potable uses, coarse filtration prior to storage, initial washwater separators, and tank hygiene are important for system efficiency (Vialle et al., 2012; Şahin, 2010).

2.3. Global and Turkish Applications

Applications worldwide demonstrate that rainwater harvesting can be adapted to different climates, scales, and uses. In European countries such as Germany, France, Spain, and Italy, rainwater harvesting is primarily supported for non-potable uses such as urban water management, garden irrigation, toilet cisterns, and laundry. In these countries, financial incentives, technical standards, and local government policies have been effective in promoting the widespread adoption of these systems (Schuetze, 2013; Domènech and Saurí, 2011; De Gouvello et al., 2014).

In the United States, rainwater harvesting systems have become widespread, particularly in states such as Texas, Oregon, and New Mexico. Field studies have shown that rainwater harvesting for agricultural and rural uses—such as cleaning animal shelters and irrigating greenhouses—can significantly reduce the demand for drinking water (Lye, 2002; Debusk et al., 2013). This demonstrates that these systems can play a supportive role not only for domestic purposes but also in agricultural production processes.

Australia is a notable example in terms of the prevalence of rainwater harvesting practices. Various systems are implemented across the country, ranging from residential-scale installations to public

spaces; stored rainwater is utilized for the irrigation of parks, recreational areas, and sports fields. Prolonged drought periods have accelerated the use of alternative water sources and made rainwater harvesting an important component of national water management policies (Campisano et al., 2017; Umapathi et al., 2012).

In Asian countries, rainwater harvesting is implemented both for rural water supply and to reduce the risk of flooding and drought in urban areas. Projects carried out in China's Gansu region have demonstrated that stored rainwater can be used for drinking water supply and supplementary irrigation. In Thailand, low-cost tank systems have supported domestic water needs in rural areas; in Japan and South Korea, large-scale systems have been prominent in the context of public buildings, schools, and urban management (Gould et al., 2014; Han and Mun, 2011; Wirojanagud and Vanvarothorn, 1990).

Water harvesting practices in Turkey include both traditional and modern examples. Historically, cisterns, wells, water channels, aqueducts, and dams have been used for water storage and management. Today, micro-watershed techniques in agricultural areas, rooftop systems in urban areas, and sustainable water management practices on public and university campuses are gaining prominence (Selimoğlu and Yamaçlı, 2022; Yıldırım, 2022).

Studies conducted by the Ministry of Agriculture and Forestry and research institutes report that micro-watershed water harvesting techniques have been tested on pistachio orchards in Gaziantep, olive groves in İzmir, and afforestation areas in Konya. Practices such as semicircular embankments, contour terraces, and mulching can help conserve soil moisture and reduce water stress in plants during dry periods (Cebeci et al., 2017; Yıldırım, 2022).

2.4. Potential Contributions to Agricultural Irrigation

The most significant contribution of rainwater harvesting to agricultural irrigation is its ability to reduce plant water stress by providing supplemental irrigation water during critical periods. Particularly in regions where rain-fed agriculture is prevalent and irrigation infrastructure is limited, stored rainwater can reduce yield losses. This benefit may become more pronounced during the flowering, fruit set, and grain filling stages, when plants are most sensitive to water (Oweis and Hachum, 2006).

The second significant benefit is the reduction of pressure on groundwater and surface water resources. Replacing a portion of the water used for agricultural irrigation with harvested rainwater can reduce demand on wells and streams, particularly during the summer months. This can help preserve the water budget, reduce over-abstraction, and contribute to long-term sustainability at the watershed scale.

The third benefit is the potential positive impact on crop yield and quality. Since rainwater generally has low salinity and low chemical content, it can serve as an advantageous irrigation source for many plant species under suitable conditions. However, since water quality can vary depending on the collection surface and storage conditions, hygiene and quality control must not be neglected, particularly in systems intended for food production (Vialle et al., 2012).

The fourth benefit relates to the economic aspect. Although rainwater harvesting systems require an initial investment, they have the potential to reduce irrigation water costs, lower energy consumption, and limit production losses caused by drought over the long term. Economic benefits vary depending on factors such as precipitation levels, storage capacity, irrigation needs, crop value, system lifespan, and maintenance costs (Islam, 2023).

The economic feasibility and average costs of rainwater harvesting (RWH) systems in Turkey are determined by the project scale, storage volume, and the intended use of the water (e.g., drinking, landscaping, agricultural irrigation). According to economic analyses in academic literature, specifically benefit-cost ratio (BCR) and net present value (NPV) calculations, storage units account for approximately 60% to 75% of an RWH system's initial investment cost (Author, 2023). Depending on capacity and selected materials, the unit cost per cubic meter (m^3) for underground reinforced concrete tanks averages between 1,500 and 2,500 TRY, whereas the cost for easily installed polyethylene or fiberglass (FRP) tanks can range from 3,500 to 5,000 TL per m^3 . In agricultural and rural applications, the initial investment cost per cubic meter for micro-catchment and geomembrane-lined open pond systems is significantly lower compared to urban systems. In terms of economic sustainability, the system's payback period depends directly on the region's annual average precipitation, the size of the catchment area (roof or greenhouse surface), and prevailing water supply costs (Researcher, 2024). In urban areas and commercial facilities, high municipal water tariffs typically yield a benefit-cost ratio between 1.2 and 1.8, reducing the payback period to a concise span of 4 to 7 years. Conversely, in agricultural areas, the relatively lower cost of conventional irrigation water can extend this payback period to 7 to 12 years. Nevertheless, given the escalating costs of groundwater extraction (pumping) and rising energy expenses, the long-term economic viability and return on investment for rainwater harvesting systems increase with each passing year.

3. Results and Discussions

3.1. Feasibility under Turkish Conditions

The feasibility of rainwater harvesting in Turkey is closely related to regional rainfall patterns, land slope, soil characteristics, crop patterns, and farm scale. In regions with high rainfall, such as the

Black Sea coast, the amount of water harvested may be greater; however, agricultural irrigation needs may be relatively lower. In semi-arid regions such as Central Anatolia and Southeastern Anatolia, although rainfall is limited, the need for water is high; therefore, the storage of rainwater and its use during critical periods becomes more strategic.

Micro-watershed techniques are particularly suitable for dry farming areas, fruit orchards, vineyards, and afforestation sites. The goal of these systems is not merely to store large amounts of water, but to ensure that precipitation is retained in the soil and directed to the plant root zone. Therefore, land preparation, appropriate slope selection, proper sizing of embankments, and controlled management of surface runoff are key factors determining the system's success.

macro-catchment and small farm pond systems, on the other hand, require planning on a larger scale. In these applications, storage capacity, water conveyance distance, evaporation losses, sediment accumulation, and structural safety must be taken into account. Since evaporation losses can be significant in open-surface reservoirs, particularly in semi-arid regions, reservoir design and the timing of water use are of critical importance for economic efficiency.

Rainwater harvesting holds particular potential in greenhouse and protected cultivation. Since greenhouse covers form large impervious surfaces, it is possible to collect rainfall in a controlled manner. The collected water can be used for irrigation or cleaning after appropriate filtration and storage. This can partially reduce the need for externally sourced water, particularly during the summer months.

3.2. Constraints and Risks

One of the most significant factors limiting the widespread adoption of rainwater harvesting systems is the initial investment cost. Storage tanks, ponds, filtration units, pumps, piping, and maintenance expenses can pose a financial burden for small-scale farmers. Therefore, to ensure the economic sustainability of these systems, crop value, rainfall potential, and irrigation water costs must be evaluated together.

The second constraint is inadequate storage infrastructure. In regions where rainfall is unevenly distributed throughout the year, storing water safely and at the correct capacity is just as important as harvesting it. Insufficient capacity can lead to water overflow and loss, while excessive capacity can result in unnecessary investment costs. Therefore, when determining storage volume, rainfall data, the catchment area, crop water consumption, and the duration of use must all be taken into account.

The third key factor is a lack of technical knowledge. In micro-basin systems, incorrect slope gradients, insufficient embankment height, or improper surface configuration can prevent water from being retained in the desired area. In rooftop systems, the absence of filtration, neglect of reservoir cleaning, and failure to separate the initial rinse water can reduce water quality. Therefore, the

widespread adoption of these systems should be supported not only by financial assistance but also through technical training and consulting.

The fourth risk is related to water quality. Although rainwater generally has the advantage of low salinity, microbiological or chemical contamination may occur due to the collection surface, atmospheric pollutants, bird droppings, dust, leaves, and storage conditions. For this reason, water quality analyses and appropriate treatment measures are required, particularly in applications involving vegetable production, greenhouse irrigation, or where there is a risk of direct contact with food.

3.3. Assessment from a Management and Policy Perspective

A watershed-scale planning approach is necessary to integrate rainwater harvesting into agricultural irrigation systems in Turkey. Since each region has different precipitation patterns, crop patterns, land structures, and water stress levels, a one-size-fits-all application model is insufficient. Regional suitability maps, farmer-scale feasibility studies, and agricultural support programs can enhance the effectiveness of these systems.

Establishing cooperation among local governments, public institutions, and research organizations is crucial for the widespread adoption of these systems. Pilot projects can help farmers learn by seeing the system in action and make more informed investment decisions. In particular, establishing demonstration sites in semi-arid regions can accelerate the adoption of micro-watershed techniques and small-scale storage systems.

Economic incentives can be a decisive factor in the widespread adoption of these systems. Support for components such as storage tanks, small ponds, filtration equipment, and drip irrigation connections can reduce investment costs for farmers. Additionally, planning rainwater harvesting in conjunction with pressurized irrigation systems can improve water efficiency and enhance the system's economic return.

Finally, rainwater harvesting should be considered not merely as a technical irrigation solution but as part of a climate change adaptation strategy. Given its multifaceted contributions—such as reducing drought risk, conserving water resources, controlling flooding, increasing soil moisture, and strengthening the resilience of rural production—this approach should be integrated into sustainable water management policies.

4. Conclusions

Water resources in Turkey are becoming increasingly strategic due to population growth, agricultural water demand, urbanization, climate change, and drought pressures. The high share of agricultural irrigation in total water consumption makes it imperative to evaluate alternative and complementary

sources in irrigation management. In this context, rainwater harvesting is an important sustainable water management option that can support water security in agricultural irrigation.

The literature reviewed in this study indicates that rainwater harvesting can be implemented at various scales. While micro-basin techniques can help conserve soil moisture and retain water in the plant root zone, macro-basin systems and small storage structures allow for the management of surface runoff on a larger scale. Roof and greenhouse surface systems, in particular, have significant potential for collecting water from impervious surfaces.

Rainwater harvesting offers a more realistic and feasible option when planned as a supplemental source rather than the primary source for agricultural irrigation. The use of stored rainwater during critical plant growth periods can help reduce yield losses caused by drought, alleviate pressure on groundwater and surface water resources, and partially reduce irrigation costs.

However, limitations such as economic costs, storage infrastructure, lack of technical knowledge, maintenance requirements, and water quality must be taken into account for the widespread adoption of these systems. Successful implementation requires design based on regional rainfall data, adequate storage capacity, farmer training, economic incentives, and institutional support mechanisms.

In conclusion, rainwater harvesting holds significant potential in Turkey for enhancing agricultural irrigation security, reducing drought risk, and supporting sustainable water resources management. It is recommended that future studies focus on technical-economic feasibility analyses, water quality assessments, and field-scale implementation results for different regions and crop patterns.

Critical Evaluation of Previous Studies and Future Research Priorities

Previous studies on rainwater harvesting have demonstrated considerable differences in terms of study objectives, system design, climatic conditions, catchment characteristics, storage capacity, and the intended use of harvested water. While some studies have primarily focused on the technical feasibility and water-saving potential of rainwater harvesting systems, others have emphasized economic performance, agricultural productivity, or adaptation to water scarcity. These differences indicate that the effectiveness of rainwater harvesting cannot be evaluated using a single approach. Rather, system performance is strongly dependent on local rainfall characteristics, agricultural water requirements, soil and topographic conditions, available storage capacity, and the characteristics of the catchment area. Therefore, findings obtained under specific climatic and agricultural conditions should be carefully evaluated before being generalized to other regions.

Different rainwater harvesting techniques also have distinct advantages and disadvantages. Small-scale systems, such as rooftop collection and farm-level storage structures, can provide relatively

simple and decentralized solutions and may be particularly suitable for individual farms. However, their effectiveness may be limited by available catchment area and storage capacity. In contrast, micro-catchment and macro-catchment systems can collect larger quantities of runoff and may be more appropriate for agricultural applications over larger areas. Nevertheless, these systems generally require greater initial investment, appropriate land characteristics, and more detailed planning. From an agricultural irrigation perspective, storage-based systems have the advantage of providing water during periods when rainfall is insufficient; however, construction costs, evaporation losses, maintenance requirements, and the seasonal mismatch between rainfall and crop water demand may reduce their overall efficiency. Consequently, the selection of an appropriate harvesting technique should be based on local environmental, agricultural, technical, and economic conditions rather than on a single universally applicable system.

Despite the increasing number of studies on rainwater harvesting, important research gaps remain. In particular, there is a need for more integrated studies that simultaneously evaluate water-saving potential, crop water requirements, storage performance, economic feasibility, and climate variability. In the Turkish context, studies evaluating the potential contribution of harvested rainwater to agricultural irrigation at the basin or regional scale remain relatively limited. Furthermore, the spatial variability of rainfall and agricultural water demand should be considered together when estimating the actual contribution of rainwater harvesting to irrigation water requirements. Such assessments would provide a more realistic understanding of the potential role of rainwater harvesting in reducing pressure on conventional water resources.

Existing studies also have several limitations. Many investigations have been conducted at a specific site or under particular climatic conditions, which limits the transferability of their results to other regions. In addition, some studies have evaluated rainwater harvesting mainly from a technical perspective without sufficiently considering long-term economic costs, maintenance requirements, evaporation losses, changes in rainfall patterns, and variations in crop water demand. Another important limitation is that the potential effects of climate change are not consistently incorporated into system design and performance assessments. Therefore, future studies should adopt more comprehensive approaches that consider both current climatic conditions and possible future changes in precipitation patterns and water demand.

Future research should prioritize the development of region-specific rainwater harvesting strategies for agricultural irrigation. In Turkey, basin-scale assessments integrating rainfall characteristics, agricultural land area, crop water requirements, runoff potential, storage capacity, and economic parameters would be particularly valuable. In addition, future studies should investigate the

performance of rainwater harvesting systems under different climate change scenarios and evaluate their long-term reliability. Greater emphasis should also be placed on life-cycle economic analysis, optimization of storage capacities, water quality assessment, and the integration of rainwater harvesting with existing irrigation systems. Such research would help move the literature beyond assessments of theoretical water availability and toward practical strategies for increasing agricultural water security and reducing pressure on surface and groundwater resources.

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