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A Comprehensive Review of Water Harvesting: Analyzing Previous Studies

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ABSTRACT

Rainwater collection has long been recognized as an efficient method for increasing agricultural output in dry and semi-arid settings. It contributes to the expansion of green spaces in such regions, the improvement of water levels in groundwater wells, the reduction of floods, and the resolution of sewage issues. The primary aim of the present study is to identify difficulties that directly impact the water harvesting process, such as soil type and surface topography, which will help us understand the value of infiltration and, as a result, the volume of water collected. The findings indicate that utilizing rainwater in buildings has a large potential for producing drinking water. Studies estimate that it is possible to supply 20% to 65% of household and agricultural drinking water. Furthermore, using technology would improve the efficiency of rainwater harvesting systems by finding appropriate surfaces for rainwater collection and limiting the consequences of floods in metropolitan areas. There is still much to learn about the benefits of water harvesting dams from a variety of viewpoints, and more study is needed on the effects of climate change on their performance over time and the best approach to managing them under present conditions, particularly in Iraq.

Keywords:

Water harvesting, water harvesting dams, surface runoff, infiltration.

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1. INTRODUCTION

Rainwater harvesting is the process of collecting rainwater from rocky or dirt surfaces or the roofs of houses and storing it, then exploiting it in agriculture and livestock raising, where it is used before it reaches groundwater. Rainwater harvesting can be defined as a set of steps followed to store as much rainwater as possible to utilize it in other purposes.

Rainwater harvesting is of great importance in contributing to providing quantities of potable water, expanding the area of green spaces in that area, and enhancing water levels in groundwater wells by supplying groundwater and enhancing its levels under what is known as the process of groundwater recharge. There is also great importance in reducing floods and eliminating sewage problems, and in the field of land reclamation by preventing the accumulation of salts in the soil. [1]

The process of diverting surface runoff from small watersheds into basins and recycling it to the same area can yield remarkable results and double net agricultural income, also help create additional job opportunities in the area [2]. Rainwater is the key to success in dryland cultivation that depends on rain-fed agriculture. Rainwater must be managed by increasing soil moisture, making optimal use of this moisture through effective cropping systems, harvesting a portion of surface runoff water, and redirecting and organizing irrigation to enhance productivity per unit of rainwater [3].

It is necessary to identify the problems that directly affect the rainwater harvesting process, including the type of soil and its surface topography. Knowing the type of soil leads us to know the value of infiltration, which is one of the important factors in the rainwater harvesting process because it affects surface runoff and thus the amount of water collected.

1.1 Date of rainwater harvesting:

The method of harvesting water is considered ancient, with its use dating back more than a thousand years in various drylands around the world. However, the technologies for these systems have undergone great development over time, especially in the field of irrigation, in addition to the development of water conservation techniques to provide irrigation water for humans and animals, providing sufficient quantities of water suitable for human use and animal production [1].

The social and economic conditions for farmers are different from those that existed in ancient times when rainwater harvesting was more common, and the advantages of rainwater harvesting are still valid and farmers must take advantage of them in dry areas if they want to have access to it in the future. They also need scientific and institutional support to start new projects. There must also be cooperation between practitioners concerned with rainwater harvesting by learning from failures and successes. It is also possible to reach a high degree of sustainability similar to that which existed in the past, which lasted a thousand years or more [4].

2. MAIN COMPONENTS OF RAINWATER HARVESTING SYSTEMS:

Watersheds must be able to supply the target area with the required amount of water and need several things, including: determining the area of the watershed according to the depth of expected rain, slope of the land, soil characteristics, vegetation, and then providing a method for transporting, storing and distributing water [1]. The components of the rainwater harvesting system can be divided into:

a. The watershed area is a part of the land that contributes its entire water share to the benefit of the target area. This area can be small, consisting of a few square meters, or large, reaching several square kilometers, or it can be a large water basin.
b. The storage site is the area where the collected water is stored until it is used. Storage is in underground or above-ground tanks or in underground reservoirs.
c. The target area is the area where we use the collected water for agricultural production or animal consumption.

3. RAINWATER HARVESTING SYSTEMS TECHNIQUES:

Rainwater harvesting systems are divided into two parts: small watershed systems and large watershed systems, in addition to groundwater catchment systems, as each main method has different sections that branch out to provide water.

3.1 Small watersheds:

In this system, water is directed directly to the planting area and is stored in the root zone within the soil. Small watersheds are usually barren land themselves and there is no need for a transportation system to the catchment area as it is close and directly connected to the target area. It is suitable for irrigation of almost all types of crops (annual crops or shrubs). Figure (1) shows a diagram of one type of rainwater harvesting for small watersheds. There are types of small rainwater harvesting catchments that are popular in arid and semi-arid areas, including:

a. Small pits: The pits are usually 20-30 cm wide, 20-30 cm deep, and spaced 1-60 cm meter apart from each other, as shown in Figure (2). Usually used for planting seeds of permanent crops. It is preferable to use it on flat or slightly sloping lands with a slope of up to 5% [5].
b. Vallerani: They are semi-circles that are dug into the soil using a specially designed tractor plow. It is preferable to use it on slopes whose slope ranges between 2 and 10% [5].
c. Semi-circular bunds: They are barriers made of soil or rocks in the shape of a semicircle or crescent, with their circumferential edges facing the top of the slope. It is preferable to use it on slight slopes of more than 5%, especially for earthen bunds. Stone bunds can be used on slopes with a slope of up to 15%, as shown in Figure (3) [5].
d. Surface runoff basins-Negarim: These are small diamond-shaped basins bounded by low-height earthen barriers, used for planting trees or shrubs. Its size can range from 10 to 100 square meters depending on the types of trees planted. It is preferable to use it on lands whose slope ranges between 1 and 5% [6].
e. Contour bunds/ridges: They are parallel, circumferential dirt ridges with a distance between them of 5 to 20 meters. This system can be used to plant annual crops and trees. It is preferable to use them on slopes whose slope ranges between 1 and 25% [6], [5].

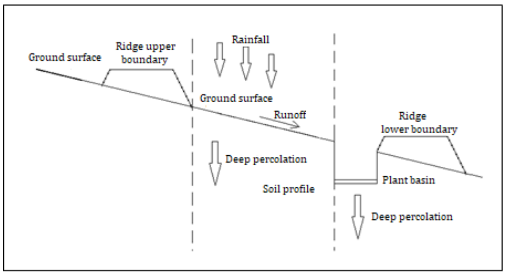

Figure (1): A diagram of rainwater harvesting for small watersheds.

Figure (2): Illustrates rainwater harvesting in a small pits.

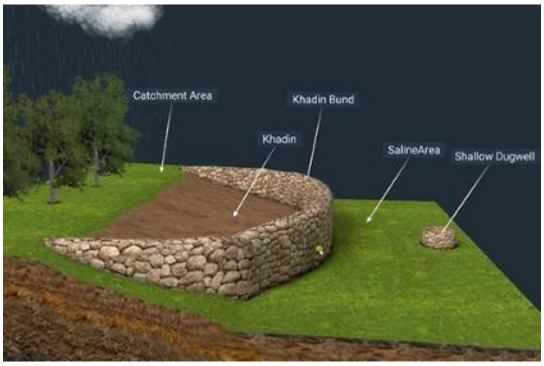

Figure (3): Illustrates rainwater harvesting in a Semi-circular bund.

3.2 Large watersheds:

Water is collected from natural watersheds such as hills, mountain slopes, etc. and transferred directly to the target area or stored in storage facilities such as ponds, small earthfill and rockfill dams, and tanks. This system is implemented to provide water for domestic use, animal consumption and irrigation. It contributes to reducing soil erosion and flood risks. Figure (4) illustrates the basic concepts of rainwater harvesting for large watersheds. Large catchment systems are large-scale systems, and the catchment area can be outside the boundaries of the target area, ranging in size from 1 to 200 hectares in some cases [7].

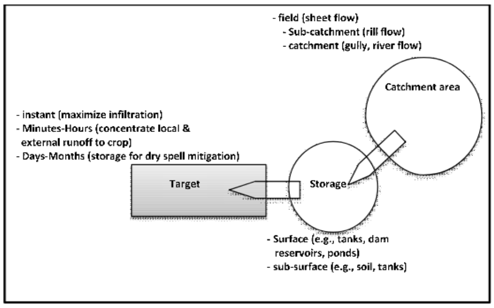

Figure (4): Basic concepts of rainwater harvesting.

There are different types of large rainwater harvesting catchments popular in arid areas, including:

a. Hillside runoff systems: Water runoff is directed through small channels to flat fields that have a slope of 1 to 10 percent at the foot of the slope. The fields are equipped with small barriers that help level the fields and define their boundaries, and contain openings that allow water to flow from one field to another. When the fields fill with water, the excess water is allowed to flow into the valley. This system is used to irrigate all crops and trees, and it is preferable to use it on slopes with slopes greater than 10 percent to avoid soil sedimentation [5].
b. Large bunds: They are large earthen barriers in a semicircular or trapezoidal shape, and are placed on curved lines. These barriers are usually built using boards and the side walls are reinforced with stones. The length of the bund ranges from 10 to 100 meters, and the height of the bund reaches one or two meters. This system is used to irrigate crops and trees, and to rehabilitate pastures [4].
c. Reservoirs and pits: These include earthen reservoirs or ponds dug into the ground in areas with small slopes, and receive surface water flows either from diversions from valleys or from large catchments. The volume of these reservoirs ranges from 200 to 500 m^2 for individual use (called *hafeer*) and 10,000 m^2 for collective use. The bottom of the reservoir may be paved or a concrete layer or plastic cover placed to limit water leakage. This system is used to supply water for domestic use, animal consumption and irrigation. Potential problems with this method include standing water, contamination risks, and drowning accidents may occur in the absence of fencing [5].

Another key component in the process of rainwater collecting and gathering, which will eventually be directed to the target location, is the shape of the valley. Some considerations include:

Valley Depth and Width: This is determined by the topography of the location, where the valley might be vast or narrow and deep. This is critical in establishing the amount of collected water and the projected dam's maximum capacity. The Valley Gradient: The higher the gradient of the valley, the more dams may be needed to efficiently direct the water flow. Soil Type: This is highly relevant in assessing the stored water, as the ground may be rocky (impermeable to water) or consist of soil (allowing water permeation).

4. RAINWATER HARVESTING PRINCIPLE:

Drylands cover about 40% of the land area, and most of the rain that falls there is in quantity and distribution that is not appropriate for crop growth, which leads to plant stress and reduced productivity. Since rain is less expensive than other sources and perhaps the only source for agriculture in these areas, we must rely on ways to benefit from it and use the latest modern technologies to harvest water. The process of rainwater harvesting increases the amount of water available per unit of cultivated area and thus reduces the rate of drought in arid areas.

Rainwater harvesting depends on the principle of adding the share of rainwater from one part of the land to other parts in order to benefit from the adjacent land area in the rainwater harvesting process. The process of harvesting water occurs naturally when rain falls and flows towards low places, creating a suitable area that can be used, or it is the result of human intervention, as it works to induce rain and flow it towards targeted areas to collect and benefit from it for the purposes of agriculture, industry, and human uses [1]. The topic of water harvesting has been the subject of many studies, including: [8] conducted a case study of three regions in northern China, North Africa, and Singapore that suffer from water scarcity, in addition to rivers being exposed to total drought, especially in rural areas where there is little surface water. A home rainwater harvesting system was used by using roofs free of gutters and paved courtyards, and collecting water in underground tanks from which water is extracted using a simple hand pump. The study showed that these systems are effective and provide a model for use in semi-arid regions in the developing world, as this system provides water supplies in residents' homes without waiting, especially for residents who suffer from deteriorating quality of groundwater reservoirs, such as China. [9] also conducted a study to evaluate the accuracy of rainwater harvesting catchment systems using a water balance simulation model (DAM CAT5), to simulate the water balance for ten sites in the arid areas of Western Australia, relying on five variables (volume, daily, weekly, monthly and annual estimates based on the period) for the accuracy of the simulation, the results show that annual estimation based on period is not appropriate for the arid and semi-arid regions of Western Australia, due to the risk of underestimating the period of agricultural activity and water demand, while estimation based on volume and daily and weekly estimates entails the risk of overestimation. Therefore, it is recommended to use monthly estimation to design water collection systems from catchments, as it provides the best results for arid and semi-arid areas.

[10] focused in their study on the importance of rainwater harvesting in addressing the problem of drought and water scarcity. The study conducted an economic and environmental analysis of two different rain harvesting systems, which are a typical water pond and a water storage system. They found that the performance of the rainwater storage system was better in all environmental and economic aspects, which led to a suitable and sustainable solution for rainwater harvesting, and they reached very useful results for farmers and the workers in water management.

[11] showed that using rainwater in buildings has great potential to provide drinking water. Most of the studies reviewed also found safe water savings of 20 to 65%. He also showed that rainwater harvesting systems may reduce the volume of surface runoff from 13 to 91%.

5. EVALUATION OF RAINWATER HARVESTING PERFORMANCE:

There are many studies that dealt with evaluating the performance of rainwater harvesting and determining the appropriate method, [12] studied the evaluation of the performance of rainwater harvesting catchments of the Najarim type in Jordan through three small water catchments (25, 50, 75) m^2, based on three treatment methods, the efficiency of surface runoff was evaluated for sixteen storms, and the efficiency of storage was evaluated for eight periods by monitoring the water balance in the root zone. The results showed that the overall efficiency of the system varied from 85% to 7% depending on the size of the catchment and the root area. The efficiency of runoff from the natural soil surface can reach 60% in small catchment areas, but it will decrease in large areas.

[13] also conducted a study in Africa because of the problem of food security and the fact that these areas suffer from droughts and thus

low productivity, and this requires rainwater harvesting at the field level. In this study, the water balance was calculated at different levels of the watershed, the surface runoff and rainfall generated from the satellite were estimated, the annual surface runoff volume that could be stored in a pond during storms was estimated, and evaporation losses were calculated. This study provided an index of rainwater harvesting across Africa that can be used in feasibility studies on a regional scale in assessing the relative differences between regions for the potential of using rainwater harvesting systems as a water management tool. [14] conducted a study whose aim was to evaluate the quality of rain-harvested water using a small tank for irrigation. Measurements were made at different depths of water at a distance of 2.5 m, 5 m, and 7.5 m from entering the water and at depths of 25 cm and 175 cm from the water surface. Samples were taken at each point three times, and quality parameters included dissolved oxygen (DO), turbidity (TSS), pH, and nitrate. The results showed that the water tested was usable and suitable for irrigation according to the standards used. [15] conducted a study that identified challenges, knowledge gaps, and research needs for rainwater harvesting irrigation on urban farms. Home harvesting, development of rainwater harvesters designed for crop irrigation, water quality monitoring, and water-crop-soil interactions were highlighted. This study also provided information and perspectives to explore technical strategies for rainwater harvesting irrigation to support sustainability and urban agriculture, as shown in Figure (5).

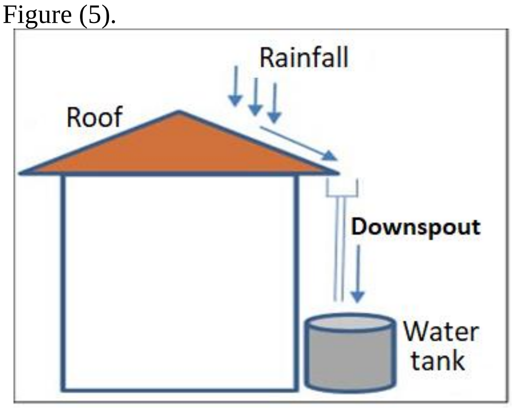

Figure (5) Shows rainwater harvesting from rooftops.

[16] conducted a study on the possibility of using rainwater collected on the roofs of houses and buildings to solve the problem of water scarcity. The study was conducted to determine the quality of rainwater collected during three consecutive months and measure its quality before and after treatment. The results showed that the quality of rainwater before and after treatment was second-class according to the Water Quality Index. This water is used for external and domestic purposes and can be treated for drinking purposes. Several recommendations were made, including ensuring the cleanliness of the roofs of homes and buildings to ensure the cleanliness of collected rainwater.

[17] studied rainwater harvesting solutions in West Bengal, where the region suffers from water scarcity and low agricultural production. The study used techniques such as checking dams and ponds and recharging wells. Grass has been used to control riverbank erosion and earth tiles are used as an environmentally friendly and inexpensive alternative. The study showed that rainwater harvesting is an economical and feasible option for water storage in the region, and its application was tested with a solar battery-powered drip irrigation system. Implementing these programs can have a significant positive impact on drought management, agricultural development and environmental conservation.

5.1 Improving the crop productivity:

Agriculture in many countries of the world faces major problems related to water resources and soil erosion, and the solution to these problems depends on developing more effective water management practices. Studies have indicated that the rainwater harvesting system has the potential to improve the performance of agricultural systems and address environmental problems. The small cost also makes implementing the system simple, and for the harvesting system to be successful, the system must be integrated with water management, including modern agricultural techniques and choosing the type of crops that tolerate drought [18].

[19] presented an economic solution to low maize crop productivity in Uganda as a result of drought during the rainy season. The study used the AquaCrop model to evaluate the benefit of supplemental irrigation at critical stages of maize growth. The results showed that using supplemental irrigation in case of soil moisture deficiency can increase crop productivity, and the system can be improved by using part of the land to create a lined runoff storage pond. PVC plastic tubs covered with natural grass can be used to grow Azolla on the surface of the water to increase the productivity of the land.

The study published by [20] evaluated crop water needs and irrigation requirements in upland areas of Ethiopia. The study used the Cropwat model and the rainfall index and the results showed the importance of rainwater harvesting and integrated and sustainable management of water resources, especially for crops that grow during the limited periods of rainfall. The study recommends effectively collecting rainwater and using it for supplementary irrigation to ensure the sustainability of agriculture and serve the population. In another study by [21], the focus was on treating wastewater in villages with limited resources and using it for irrigation. The treated water was stored in irrigation ponds and additional crops such as chickpeas and maize were grown. The vegetative part of the crops was also used as fodder for livestock, which increased productivity and generated additional income for farmers.

5.2 Choosing the appropriate location for the dam:

In the absence of complete information about the relationship between the watershed, storage and the target area, it is difficult to draw any conclusions about these relationships so these systems have been classified on the basis of their physical status and functioning. There is great variation in the relationships between watersheds and storage in the study area and from one region to another [22].

There are many studies that deal with determining the appropriate location for the dam in terms of the size of the tank, the required uses and its purpose. [23] conducted a study in one of the states of India, through which an evaluation of the characteristics of the water storage system in terms of its location and size was carried out, and the impact of water harvesting activities on direct and indirect feeding techniques was analyzed. The study showed that about 24 million hectares of rainwater can be collected within the water storage system. Preliminary results in one of the watersheds in Gujarat state also showed that about 6.5% of annual rainfall is effective in recharging the aquifer. [24] studied determining the appropriate location for a dam in the Wadi Al-Ajeej basin, which is located within the Sinjar Plain, to analyze hydrological and topographical data and to determine the extent of the possibility of harvesting surface water resulting from rain, relying on the WMS system (Watershed Modeling System). It was proposed to construct a small water dam located on Wadi Al-Ajeej, which has an annual surface runoff volume of about (53.144) million cubic meters. The study showed that constructing small dams in those locations that are characterized by water scarcity throughout the year will support sustainable development by increasing the areas of agricultural land and its production and eliminating the problem of desertification.

There are studies focused on evaluating the performance of rainwater harvesting, and these studies include: [25] which evaluated the possibility of collecting and harvesting surface water in A’aq Imam region of Golestan Governorate in Iran and identified suitable areas for water harvesting, as the region is located within the arid areas and is characterized by low rainfall. Due to population growth, urban expansion, and increased demand for water, in addition to the low groundwater level and its high salinity, it is necessary to exploit rainwater. The results showed that it is possible to benefit from rainwater during the months of May and June in particular. [26] also showed that rainwater management has a major role in overcoming drought problems on small islands where rain falls and infiltrates the sea quickly due to the short distance with no opportunity for water to enter the soil and recharge groundwater. Through rainwater management, it is possible to give a greater opportunity for water to seep into the soil by creating a series of water storage ponds and collecting and storing rainwater in them, it can also be used for domestic and agricultural purposes. [27] also confirmed that the depth of cumulative infiltration increases as the time of soil ponding in water increases, but in the case of intermittent ponding of the soil, the depth of cumulative infiltration is greater than in the case of continuous ponding.

Both [28] and [29] mentioned that it is important to use engineering methods in rainstorm management to determine the amount of floods that occur in the study area through meteorological study, soil classification, and flood hydrograph modeling. Surface runoff varies depending on the land and soil type, and the flood return period of 100 years can reach sensitive areas such as urban, agricultural and residential areas. Therefore, suitable sites can be identified in the watershed area to create small dams and ponds to harvest water.

Dams are built based on the amount of water gathered as well as the sort of region from which rainfall may be collected. As a result, there are several types of dams, including: 1. Earth dams: These are the most common types of rainwater harvesting dams. This dam consists of soil, rocks, and other structural materials. 2. Concrete dams: These are the most durable types of rainwater harvesting dams. 3. Storage dams: used to collect rainwater in valleys, which depend on the shape of the valley. 3. Rock dams: which are used in areas with mountainous terrain.

6. REASONS FOR FAILURE OF RAINWATER HARVESTING SYSTEMS:

There are many reasons that lead to failure in rainwater harvesting, including: 1- Lack of rainfall: If the area suffers from a lack of rainfall, there may be a lack of water available for harvesting. 2- Climate changes: Changes that occur in the pattern of rainfall and rain distribution due to climate changes can negatively affect rainwater harvesting. 3- Soil: Some areas may face challenges in water collection due to the type of the soil. Sandy soil or heavy clay soil may be difficult to work with and affect rainwater harvesting. 4- Poor planning and design: If the rainwater harvesting system is not planned and designed properly, water leakage or insufficient water collection may occur, leading to failure of the process. 5- Lack of resources and funding: There may be a lack of resources and funding necessary to effectively implement and maintain the rainwater harvesting system, which affects its effectiveness and sustainability. 6- Pollution and desertification: If the area suffers from water pollution or desertification problems, it may be difficult to achieve effective rainwater harvesting. Therefore, there are some studies that focus on studying the above points, as bellow:

A study [30] was conducted with the aim of overcoming the problem of water scarcity in Iraq as a result of climate change. A comprehensive rainwater harvesting technique was used to analyze future forecast rainfall data, in a period extending from 2020 to 2099, in Sulaymaniyah Governorate, two different scenarios were compared. The volume of water that could be harvested under different rainfall seasons, namely maximum, average and minimum seasons, was calculated for both scenarios. The results showed that as a result of expected climate change, the volume of harvested surface water in the future will decrease by up to 10.82% and 43% for the first and second scenarios, respectively. The study highlights the importance of directing attention to rainwater harvesting and effective use in the face of increasing climate challenges, and enhances our understanding of the expected impacts of climate change on water availability in selected regions. The researchers [31] presented a study in Iran in which rain and runoff measurements were conducted during four consecutive years in order to evaluate the hydrological data obtained through regional analysis within the Mediterranean climate, which is considered one of the main obstacles to the direct use of seasonal runoff resulting from small watersheds, the results showed that the regional analysis overestimated the surface runoff and monthly distribution, and the recorded data also showed that rainfall (in the case of once a year) is the only way to collect flood water, so water storage is very important to regulate surface runoff in order to support crop requirements throughout the year. A scheme has also been developed to be used to improve storage capacity in relation to cultivated area and water transport problems. In a laboratory study on soil type, [32] confirmed that the advance of the wetting front in a sandy loam soil is greater than that in a loamy soil. The study focused on the characteristics of infiltration before and after the time of pond formation. All experiments under sprinkler irrigation are characterized by two stages of infiltration rate. The first begins from the beginning of irrigation until the time of pond formation (tp), at this stage, all irrigation water seeps through the surface of the soil, while the second begins after the time of pond formation, where the surface runoff process begins. At that time, the rate of infiltration is less than the rate of water addition.

6.1 Cost compared to the amount of water collected:

The cost of harvesting collected water is a very important issue that must be taken into consideration when implementing rainwater harvesting projects. This topic concerns estimating the financial cost of establishing and maintaining rainwater harvesting systems and comparing it with the amount of water collected. Rainwater harvesting projects could be an effective method in the future, as the collected water can be used to meet various needs, including agricultural irrigation and providing water for domestic and industrial use. However, the costs associated with designing and implementing a rainwater harvesting system must also be considered. The cost of rainwater harvesting can be affected by several factors, including:

a. The cost of materials and equipment: These costs include the cost of purchasing and installing rainwater harvesting, storage, and distribution devices and equipment.
b. Engineering and design cost: Designing a rainwater harvesting system may require consultation with engineers and experts to ensure that the system is implemented in an efficient and sustainable manner.
c. Labor cost: Installing and maintaining a rainwater harvesting system requires trained and qualified labor, whose costs must be taken into account.
d. Maintenance and repair costs: Maintaining good rainwater harvesting system performance requires regular maintenance and repairs when needed, which causes additional costs.
e. Project management costs: Project management costs must also be taken into

consideration, including planning, supervision, and reporting costs.

In general, evaluating the benefits and costs of rainwater harvesting requires a comprehensive study that takes into account local factors and the specific circumstances of the project. These studies should be carried out by qualified experts to obtain accurate and reliable results, which can help in making informed decisions regarding the implementation of rainwater harvesting projects. Among these studies related to this topic is [33] where he conducted a study in Ireland, the aim of which was the possibility of using rainwater collection systems. In this research, water collected from rainwater was replaced instead of main water in the livestock supply with drinking water. The study showed the possibility of expanding rainwater harvesting systems to include homes, in addition to conducting a financial evaluation of projects and discovering additional benefits for storing rainwater by installing special tanks to harvest rainwater. [34] also conducted a study, the most important of which was to evaluate the level of adoption of rainwater harvesting in drought-prone areas and the extent of its impact on farm income (in Ntarama, which is the southern province of Rwanda) and its performance in water storage, as 15 basins were monitored and the level at which the residents of these areas adopted rainwater basins was evaluated, in addition to calculating the storage capacity to ensure that it meets the demand for irrigation water. The results showed that 42.5% of the region’s population relied on rainwater harvesting basins, and it was also revealed that the use of rainwater harvesting basins positively affects agricultural income per 1/4 hectare annually by approximately (3100 USD). [35] also studied the provision of an alternative and sustainable source to meet irrigation needs in arid and semi-arid areas. Covered and open tanks were used to meet the needs of plants in covered houses planted with tomatoes and ornamental plants (begonia) for a time series of 12 years. The results showed that, in general, these two types can be used as alternative sources of available water to meet irrigation needs, as these tanks are low-cost and their use can reduce local pressures on water resources.

7. BEST TECHNIQUES FOR RAINWATER HARVESTING:

In order to ensure an increase in the amount of surface runoff in the catchment area, the depth of surface infiltration of soil must be reduced either by mechanical methods, as this method requires the necessity of preparing the land by cleaning, smoothing and compacting it, as [36] confirmed that the rate of infiltration decreases with the increase in the bulk density of the soil, and its effect is much greater than the effect of the initial soil moisture on the rate of infiltration. Or by covering it with a set of metal or plastic sheets and ensuring that water does not penetrate through them. Or by chemical methods, the chemicals in this method are considered an urgent need to reduce water permeability to the soil, including sodium salts and paraffin wax. Therefore, there are many studies related to preserving the largest amount of water with minimal losses of the collected water. Among these studies are: [37] conducted a study in which he demonstrated that the availability of water is a necessity for the irrigation system and is the main requirement for achieving stability in arid areas, and that efforts must be made to benefit to the maximum extent of rainwater through the use of rainwater harvesting technology, as water harvesting is an important means of obtaining water when common sources such as streams, ponds, and wells fail to provide it. [38] also conducted a study in which he showed the role of vegetation cover in the rate of surface runoff and erosion. The results showed that 85% of rainwater reaches the ground, and that surface runoff is dominant as the main component of the reservoir water flow. [39] conducted a study whose goal was to analyze the advantages and disadvantages of each type of rainwater harvesting system. He used a new rainwater harvesting system called rainwater harvesting for greenhouse agriculture. The study showed that with the new system, the efficiency of rainwater harvesting can reach 66% of the total rainfall, and this method is considered better than the rest of the methods used. The researchers also explained that the features of this new system are optimally designed to reduce the cost and increase the volume of harvested water. [40] showed that rainwater harvesting contributes to sustainable development by providing water to arid and remote areas, and helps improve the quantity, quality and economics of water. The research also indicated that the use of modern technology and techniques makes rainwater harvesting systems more effective.

As for studies related to groundwater harvesting: A study of [41] presented methods for storing groundwater in underground dams in arid countries such as Jordan in Wadi Aish, with the aim of reducing water shortages and evaporation losses. The results showed the possibility of applying groundwater dam technology in different regions of the world, using a new technology that combines the effects of harvesting and artificial recharge. Adequate rainwater harvesting can be achieved even when annual rainfall rates fall to 150 mm, and water stored in underground reservoirs can be used for irrigation and grazing purposes. [42] also showed the importance of rainwater harvesting in arid areas such as the Arab Gulf countries that suffer from a shortage of rain and water. He explained that the groundwater aquifers are geologically interconnected, meaning that pumping in one country may affect the groundwater potential in another country. The Arab Gulf countries use seven methods to harvest water, such as dam technology, the process of storing and recovering groundwater, ponds, treating groundwater soil, and storing rainwater on roofs. The most common method is recharging through ponds and dams, and the method of storing and recovering groundwater contributes to the recovery of approximately 80 to 95% of the recharged water, as it requires a suitable geological medium to store groundwater.

8. CONCLUSION

There are many challenges associated with the use of rainwater harvesting dams that must be addressed to be more effective. We can conclude from previous studies that there is much to be studied about the effectiveness of rainwater harvesting dams. The studies showed that using rainwater in buildings has great potential to provide drinking water. Most of the studies reviewed also found that drinking water could be saved by 20 to 65%, a home rainwater harvesting system was used by using roofs free of gutters and paved courtyards, and collecting water in underground tanks from which water is extracted using a pump, after ensuring the cleanliness of the roofs of homes and buildings to ensure the cleanliness of collected rainwater. For a rainwater harvesting system to be successful, the system must be integrated with management, Including the use of modern water technologies. Finally, with regard to watershed management, there is an urgent need for research on developing plans to manage them well in order to maximize their effectiveness.

Stimulating surface runoff, collecting and storing water in special tanks in turn reduces leakage and evaporation losses and uses the stored water more efficiently. Also, the use of technology will make modeling rainwater harvesting systems more effective in determining suitable surfaces for harvesting and mitigating floods in urban areas.

As for the small watershed system, water is available in the rainy season, when the moisture content of the soil is the highest possible, and the water requirement is very low. On the contrary, in the next stage, the lack of rain and increased evaporation lead to a decrease in the moisture content of the soil. Therefore, it is necessary to find ways of treatment by selecting crops with a suitable age for this region to ensure an appropriate economic return.

9. RECOMMENDATION

Here are some important points and recommendations from the current study:

- More studies are needed on how climate change and drought affect the performance of rainwater harvesting dams over time and what are the best ways to manage them under climate change.
- There is also a need for more research on the best ways to design and operate these systems to reduce environmental impacts.
- There is also a need for more studies to estimate the evaporation rate from rainwater harvesting specifically for the region of Iraq and to investigate its impact.
- Proper design and implementation are of paramount importance to improve the performance and adoption of rainwater harvesting systems, ensuring that rainwater harvesting systems are reliable, technically and economically feasible as well as having water saving efficiency.

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الملخص

ان اساليب جمع مياه الأمطار معروفه قديما، كأسلوب فعّال لزيادة إنتاجية الزراعة في المناطق الجافة وشبه الجافة، وتوسيع رقعة المساحات الخضراء في تلك المنطقة وتعزيز مستويات المياه في الآبار الجوفية، وأيضا للحد من الفيضانات والتخلص من مشاكل الصرف الصحي. لذا فان الهدف الرئيسي من الدراسة الحالية هو الوقوف على المشاكل التي تؤثر بشكل مباشر على عملية حصاد المياه، ومنها نوع التربة والتضاريس السطحية لها، وهذا يقودنا ذلك الى معرفة فواقد المياه وكمية المياه المجمعة من الامطار. وبينت النتائج ان لاستخدام مياه الامطار في المباني إمكانية كبيرة لتوفير مياه الشرب، كما انه وجدت بعض الدراسات التي تمت مراجعتها إمكانية توفير المياه الصالحة للشرب من 20 إلى 65%، للاستخدام المنزلي وللزراعة. بالإضافة الى ان استخدام التكنولوجيا سيجعل نمذجة أنظمة تجميع مياه الأمطار أكثر فعالية في تحديد الأسطح المناسبة لتجميع مياه الأمطار والتخفيف من آثار الفيضانات في المناطق الحضرية.

واخيرا، بينت الدراسة انه لا يزال هناك الكثير حول حصاد المياه يجب تعلمه حول فعالية سدود الحصاد من نواحي مختلفة، فهناك حاجة إلى مزيد من البحوث حول تأثير التغيرات المناخية على أدائهم بمرور الوقت وأفضل طريقة لإدارتها في ظل الظروف الحالية وخاصة في منطقة العراق.

الكلمات الدالة:

حصاد المياه، سدود حصاد المياه، السيح السطحي، الارتشاح.