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Water Harvesting Techniques and Importance for Arid and Semi-Arid Areas

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ABSTRACT

It is foreseen that there may be a water crisis in the next years due to global climate change, the need for food with the increasing population and the need for fresh water. Due to the scarcity of freshwater resources and the difficulty in access to quality water, water resources should be used in the most efficient way. Water conservation is of great importance in regions where water is scarce. The water harvesting method, which allows rainwater to be collected, stored and reused could be applied in various ways. In this study, water harvesting methods and techniques aiming to develop a strategy that will provide maximum benefit from rainwater in arid and semi-arid areas are discussed.

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Introduction

Freshwater, which is necessary for the sustainability of life, constitutes only 2.5% of the world's water resources. Of this 2.5% water, 70% consists of glaciers and groundwater, and 0.007% of the remaining 30% is used sustainably (Eren et al., 2016; Yalılı Kılıç and Adalı, 2022). Green areas have been an important factor in increasing living standards in ensuring social welfare and increasing the level of development (Yazıcı and Gülgün Aslan, 2017). At the same time, green areas also have psychological effects on people (Güneş Atıl et al., 2006; Gülgün et al., 2014).

For a sustainable biological life, the continuity of green areas is needed, in this case, the need for water will increase day by day (Çakar, 2022). Collecting and storing rainwater for reuse is important for the conservation of available water resources. With this technique, it will be possible to meet the water requirements of plants and prevent surface runoff on the ground (Gülgün Aslan and Yazıcı, 2016). Rainwater harvesting method could be applied to provide optimum benefit from precipitation in arid and semi-arid areas where it is difficult to access to water, in regions where annual precipitation exceeds 150 mm and precipitation falls in winter, in regions where annual precipitation exceeds 200 mm and precipitation falls in summer (Kantaroğlu, 2009). In this method, sloping areas, streets, roofs and courtyards are used as water collection areas; pools and reservoirs and tanks on the ground surface, cisterns and sediments underground are used as water storage areas (Pamuk Mengü and Akkuzu, 2008). The increasing demand for water resources and the limited availability of water resources make it necessary to utilize water in the most efficient way. Water resources should be sustainable and maximum benefit should be obtained by using them efficiently (Meriç, 2004). The rainwater harvesting technique, which aims to provide optimum benefit, is the collection and storage of rainwater and runoff water. For this purpose, it is aimed to provide the water required for crop and animal production and to provide the water required for domestic use (Pamuk Mengü and Akkuzu, 2008).

Benefits of Rainwater Harvesting

- Reduction of urban flooding and water supply for urban green areas,
- Increased levels of groundwater and other water resources, supporting water supply and reducing costs,
- Being a viable option in regions with scarce water resources,
- Providing good quality water by reducing salinity in coastal areas,
- Increase in agricultural yields.

In addition, initial installation costs are high and require regular maintenance. It has disadvantages such as limited water supply in cases of unpredictable rainfall and the presence of harmful chemicals in some roof materials (Patel and Shah., 2015; Güzel and Benli, 2020). Effective use of water, which is a limited resource, is important. For many years, the use of rainwater has emerged for the protection of natural resources in order to ensure efficiency in optimum conditions (Atıl et al., 2005).

Rainwater Harvesting Methods

Farm Systems

Simple to plan and can be implemented at low cost.

The systems here are summarized and described below.

Co-Elevation Ridges

It is used in areas with a slope value between 1-25%. The basin area is 50-100 m^2 and the planting area is 10-20 m^2. They are embankments constructed side by side at 5-20 m intervals along the contour curves. The top of the ridges are used for crop production and the rest for the water collection area (Figure 1). They are used for fodder crops, grass and hardy trees in low-slope steppe areas, and for sorghum, rye, beans and cowpea in semi-arid climates (Örs et al., 2011).

Semi-Circular Embankments

They are semicircular earth embankments (Figure 2). They are of different sizes, especially used for pasture improvement and fodder crops. It is also used in cultivation as it is useful for some trees and shrubs (Moges, 2004).

Small Pits

A technique suitable for improving degraded soils. Pits are dug 5-15 cm deep and fertilizers and some plant wastes are mixed with some of the soil (Figure 3). Slowing surface runoff water is retained by means of pit dikes, allowing unproductive agricultural land to be brought back into use. It is used for annual crops (Örs et al., 2011).

Small Basins (Negarim)

Small diamond or rectangular-shaped grid earth embankments surrounded by low earth embankments (Figure 4). They can be constructed in any type of runoff basin (Oweis and Hachum., 2006). With the help of negarim, rainwater is diverted from surface runoff to the corner point where the plant is placed. In this way, water is collected at the lowest corner of the basin where the plant needs (Örs et al., 2011).

Surface Runoff Strips

Suitable for gently sloping land to support field crops in dry farming areas where production is low and risky. Fields are divided into strips along the escarpment curves (Figure 5). The upstream strip is used for the catchment area while the downstream strip is for crops (Oweis et al., 2001).

Figure 1. Ridges constructed at the ICARDA Research Farm in Syria (Oweis et al., 2001).

Figure 2. Semi-circular Walls in Gradual Steps in the Terrain (Incebel, 2012).

Figure 3. Small Pits (Örs et al., 2011).

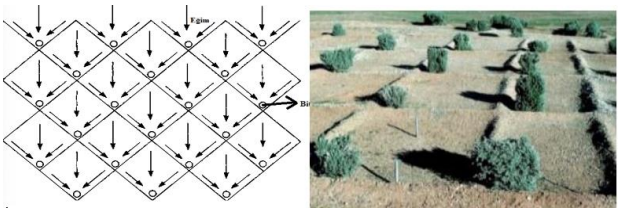

Figure 4. Negarim Technique Schematic and Field Image (Yetik and Şen, 2020).

Inter-Row Systems

It is a technique applied in areas where rainfall is sufficient but not suitable for productive plant cultivation. The planted area is shaped as furrow and ridge (Figure 6). The ridge-shaped area between the plants is either covered with mulch or the soil is compacted. Rainwater falling on the ridges is directed to the plants planted in the furrows (Örs et al., 2011).

Figure 5. Surface Flow Strips (Incebel, 2012).

Figure 6. Row spacing system collecting surface runoff in a pond in Australia (Incebel, 2012).

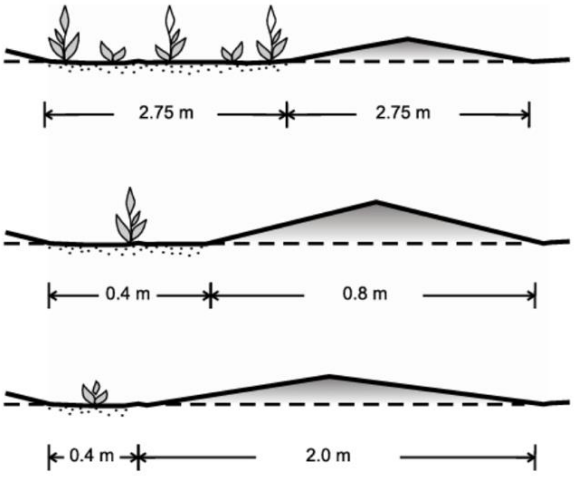

Figure 7. Inter-row System (Prinz, 1996).

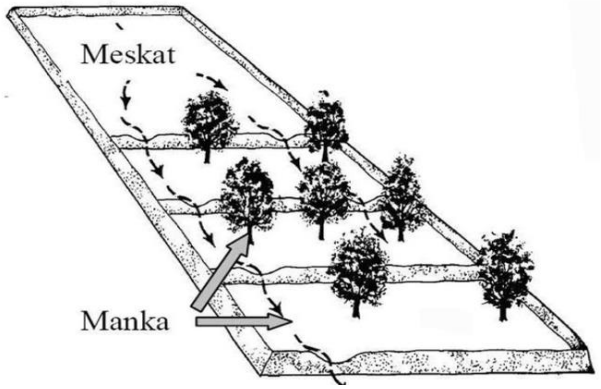

Figure 8. Meskat micro-basin water harvesting system in Tunisia (Wang et al., 2008).

Inter-row systems may be the best technique applicable on flat terrain (Figure 7). Triangular and cross-shaped swales are installed along the slope of the land. In the case of crops with high economic value, the dikes are compacted to obtain more runoff. They can be partially covered with plastic sheets or treated with waterproof materials. The dikes should be 40-100 cm high at 2-10 m intervals (Oweis et al., 2001).

Mesqat

The Mesqat system is a local term used in Tunisia and is suitable for areas with an annual rainfall of 200-400 mm and slopes between 2-15%. The system consists of a water catchment area surrounded by dikes and is about 500 m^2 in size with a cultivation area of about 250 m^2 called "manka" (Figure 8).

Co-Elevated Terraces

Co-elevated terraces are constructed in areas with 20-60% slopes with an annual rainfall of 200-600 mm. Land with natural slopes is converted into a series of stairs (Figure 9). These terraces have a flat planting area and additional water is supplied to this area from the area between the terraces where steeper vegetation is not planted. This technique is practised in many countries around the world for tree planting (Prinz, 2001).

Water Harvesting from Roof Surface

The roof surface water harvesting method has been used since ancient times to meet the drinking and utility water needs. In this method, precipitation falling on the roof surface is collected and transferred to a tank on the ground surface or to an underground tank through rain gutters (Pamuk Mengü and Akkuzu, 2008). In this method, 80-85% of the precipitation falling on the earth's surface is collected on the roof surface and transferred to a tank or an underground tank through rain gutters and stored (Figure 10). This water can be used for garden irrigation, car washing, ornamental pools, washing machines and toilet reservoirs (Şahin and Manioğlu, 2011; Yalılı Kılıç and Abuş, 2018). In addition, it is important to filter chlorinate todisinfect and so boil this water so that it can be used as0 drinking water (Pamuk Mengü and Akkuzu, 2008; Yetik and Şen, 2020).

Macro Water Collection Areas

In the macro catchment water harvesting method, runoff from the soil surface is collected. There is a large basin outside the cultivation area. The collected water is mostly stored in the soil and excess water is removed. The slope of the catchment area is between 5-50%. The cultivation area is terraced or flat land. It is applied where the annual rainfall is more than 300 mm. However, in the case of storage, this value should be 150 mm or more (Pamuk Mengü and Akkuzu, 2008).

Valley Floor Systems

Small Farm Ponds

These ponds are mostly small, but their capacity can sometimes range from 1000 m^3 to 500,000 m^3. The most important element here is a spillway with a capacity suitable for the highest flow that can pass through the valley (Figure 11). Small farm ponds are very effective for steppe areas.

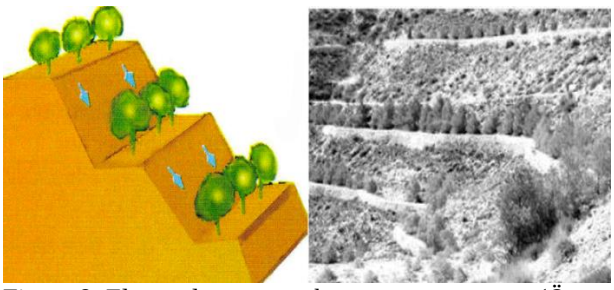

Figure 9. Elevated terraces where trees are grown (Örs et al., 2011).

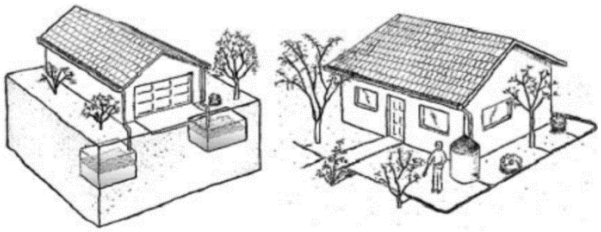

Figure 10. Water harvesting from the roof surface (Kantaroğlu, 2009)

Figure 11. Small Farming Pond in Syria (Incebel, 2012).

Figure 12. Terrace Systems in Yemen (Bruggeman and Oweis., 2005).

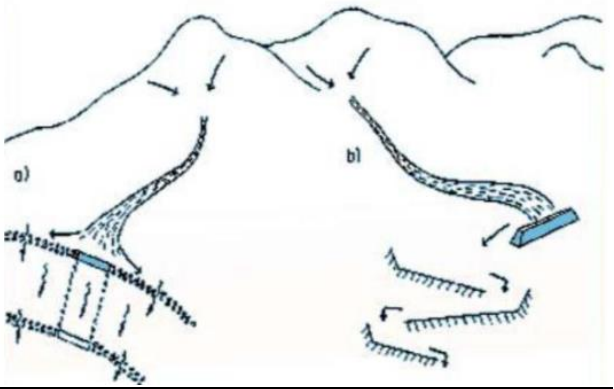

Figure 13. Simple Water Distribution System Schematic (Ekinci, 2015).

They can provide water for all agricultural crops and increase production. In order to maximize water, use and pond capacity, it is appropriate to pump the collected water as soon as possible and store it in the plant root zone. This means that, in order to obtain higher yields, the water accumulated in the pond should be used for supplementary irrigation of winter crops during the period of winter rainfall, rather than allocating all the water in the pond to meet all the water needs of summer crops (Oweis et al., 2001).

Valley Floor Agriculture

This technique is widely used on valley floors with low slopes (Figure 11). As a result of the low water velocity, the transported sediment settles on the valley floor and good agricultural areas emerge. The walls cutting the valley are usually no more than 1 m high. The distance between the walls along the valley floor is determined by the height of the wall and the slope of the valley floor. Walls increase the amount of crops that can be grown in these areas. ince the soil on the valley floor is fertile and water is sufficient, this technique is very common for fig, olive, date palm and other fruit trees of high economic value. The main problem with this water harvesting is the repair and cost of the walls (Incebel, 2012).

Terrace Systems (Jessour)

These are small earth, rock or lattice dams constructed between seasonal stream channels or at the foot of slopes (Prinz, 2001). These (Figure 12) are small dams made of earth, rock or sand baskets built either at the foot of slopes or within seasonal stream channels (Örs et al., 2011).

Out of Valley Systems

In non-valley systems, harvested rainwater is applied outside the valley floor. Structures are used to divert water from its natural flow area in the valley and allow it to flow to nearby agricultural areas (Ekinci, 2015).

Water Distribution Systems

This system, also called “flood diversion”, is applied by diverting water flow through the valley from its natural flow area and directing it to crops grown in nearby areas. Water is stored only in the root zone of plants. The diversion is accomplished by raising the water table on the valley floor and distributing the flow by gravity to one or both sides of the valley (Figure 13).

Wide Embankments

This technique is used to harvest water from large mountains and large surfaces during the rainy season (Oweis et al., 2004). The distance between slopes is expected to be about 10-100 m for each dike, and the height is expected to be at least 1 m. The distance between successive embankments along isohypses should be approximately half the length of the embankment (Quessar et al., 2004).

Water Tanks

Water reservoirs are earthen reservoirs, usually diverted from valleys or excavated in sloping areas receiving runoff from a large catchment area (Figure 14). They are also known as "Roman pools" in North Africa and are usually built with stone walls (Oweis et al., 2001).

Cisterns

It is a system used as a solution to the water shortages of settlements. They are generally built underground and water-tight. The water flowing from the roofs, courtyards or terraces of the buildings in the city is transferred to the cisterns (Şahin and Manioğlu, 2011).

Figure 14. Water Tanks (Dumanoğlu, 2020).

Slope Flow Systems

The structures created with this system are formed by diverting the water flow through the valley from its natural course and directing it to agricultural land. This system can be applied in areas where the annual rainfall is 200-600 mm and the slope exceeds 10% (Prinz, 2001).

Recently, the installation of rainwater harvesting systems has become mandatory through new regulations and efforts to protect water resources have gained importance (Yalılı Kılıç and Adalı, 2022). The most appropriate rainwater harvesting methods should be developed according to factors such as climate, soil, slope, land use purpose and land cover (Pekin Timur et al., 2012).

Conclusions

The insufficient supply of fresh water for the world's growing population is a cause for concern. One of the solutions for the sustainability of water resources is the widespread use of rainwater harvesting.

In terms of protecting existing water resources, it is important to use the roofs of shopping centers as water collection points. Appropriate planning should be made to take the harvested water to the area to be used.

In this study, water harvesting methods and techniques aimed at developing a strategy that will provide maximum benefit from precipitation waters in arid and semi-arid areas are mentioned. The main purpose here is to achieve the highest level of water harvesting for the relevant situations.

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