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Chapter

Smart Rainwater Management: New Technologies and Innovation

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Abstract

In a smart city, the following factors are very vital such as smart grid and e-health. A smart city is one of the burning topics of research. Although there is no particular definition of a smart city, it means smart grid, e-health, e-environmental monitoring, smart home, smart water quality, smart air quality, etc. integrated into a single application. Human civilization can't be sustained and prosper with shortage of usable water. Hence, water has a vital share in human life even for those living in smart cities. This chapter describes about the smart water quality issues in a smart city and some of the research advances in handling those issues. Among them it investigates the rainwater harvesting technologies and some of their practical applications.

Keywords: rainwater harvesting, technologies, features, traditional methods, rain centers

1. Introduction

Water is one of the natural resources and comes as a free gift like air. However, it is a basic ingredient of any living beings. According to the Atharva Veda, a life is believed to be first evolved and nourished in water. The *Rig Veda* says water has the lifesaving medicinal quality, so it needs to be conserved. Humans cannot survive without water as it is one of their basic needs. In the body of a human being, around 70% is water. In addition to that, water is necessary on a daily basis lifestyle like drinking, bathing, washing, planting, etc. Water is also required in large quantities for different sectors like irrigation, industries, transportation, and hydroelectricity plants. All great civilizations started and prospered near water bodies.

The current generation wants smartness in every aspect of life. Hence, the concept of smart city has approached. In a smart city, the following factors are very vital such as smart grid, e-health, e-environmental monitoring, smart home, smart water quality, smart air quality, etc. Among them the more vital issue is the supply of clean and sufficient water. A substantial increase in population in cities is the main problem of their water stress because the cities are usually designed for a particular population, but in most cases the actual masses dwelling there are many times that of the designed value, whereas the resources remain the same. Therefore, all problems started with it including water too. With the explosion of human population, it is becoming very difficult for providing usable quality of water even with values. Therefore, many parts of the world are facing high to extreme water stresses. This stress is due to scarcity of underground water, mismanagement of existing water bodies, increase in river water pollution by allowing industrial and urban pollutants to flow into rivers, lack of water recycling, no clever usage, and wastage of water.

This is the common scene in most of the cities in the world. In addition to this, the water bodies are drying out. With this rate, many cities of India would come to day zero condition like Cape Town in South Africa. Therefore, there is a need of smart water management system.

Water is such a recurring type reserve that can be reused after proper treatment. However, water scarcity occurs due to mismanagement and overuse of the available resource. Therefore, it is often remarked that water can be better conserved by using it judiciously. In that manner, the irrigation sector needs revolution in water management as this sector needs the maximum share of water.

Most part of earth is covered by water bodies like oceans and seas. However, the water of these water bodies cannot be directly utilized in our daily needs like as drinking water and other purposes. Therefore, there is a persistent deficiency of water both for residential use and industrial use.

2. Rainwater harvesting

Rainwater harvesting is an expertise for collection and efficient storage of rainwater from different basement areas like rooftops of residential buildings, ground surface, rock catchments, etc. These techniques are very vast. They can be very artless techniques such as collection and storage using readily available, cheap utensils. They also can be some very intricate techniques such as building check dams. These methods are mostly used for water conservation. Usually, there are two basic ways of rainwater harvesting like surface runoff harvesting and rooftop rainwater harvesting. In the first method, rainwater flowing along the surface is collected in an underground tank. In the second method, rainwater is collected from roof catchment and stored in a tank. The harvested rainwater is the purest form of water source. So, it can be consumed directly. Rainwater collected from ground catchments may be poor in quality with respect to the bacteriological quality, whereas if rainwater is collected from well-maintained rooftop catchment systems and storage tanks, then that water is suitable for drinking. If water is collected from a dirty surface, then the collected water can be made utilizable by using a proper filtering system. Thereafter, it can be used for some the following purposes like drinking, culinary, bathing, laundry, toiletry purpose, watering gardens, compost making, birdbaths, recharging ponds and pools, washing vehicles, fire extinguishing, etc.

3. History

Rainwater collection technologies have a very long history. It is as early as Roman civilization. It means the period is earlier than 2000 BC. Rainwater harvesting in Asia has also been carried out since the ninth century. In rural areas of South and Southeast Asia, rainwater is collected and conserved by constructing brush dams. In Israel, rainwater is collected and used both for farming and residential use. In Istanbul of the country Turkey, the world's largest tank is created for collection of rainwater. In India also rainwater collection and utilization are practiced since long back using conventional methods. Thailand is a pioneer in applying innovation in rainwater collection since many hundred centuries back. However, recently the most recognized utilization of the innovation is done in Africa [1].

3.1 Objectives of rainwater harvesting

i. Increase volume of water bodies

Many parts of the world have two kinds of seasons like rainy season and dry season. During dry season, there is very little or no rain. Due to this, the water bodies like pond, rivers, etc. are dried. By using these techniques, the water bodies can be recharged, and their volume can be increased [2].

ii. Lessen flood and soil erosion

By storing rainwater, it reduces the surface runoff. This reduces the surface erosion. By capturing rainwater in reservoirs, the flood problem in large rainfalls is also diminished.

iii. Prevent overuse of underground water

As population of a locality increases, its demand for water increases too. To meet this, underground water is used. Due to this reason, the level of underground water is decreasing rapidly. By using rainwater, the demand on groundwater is reduced.

iv. Save money

Pumping up of underground water is very costly than that of rainwater harvest. So, the use of rainwater saves money.

3.2 Components

Rainwater harvesting systems consist of three basic components such as the catchment area, the collection device, and the conveyance system as shown in **Figure 1** [3–5].

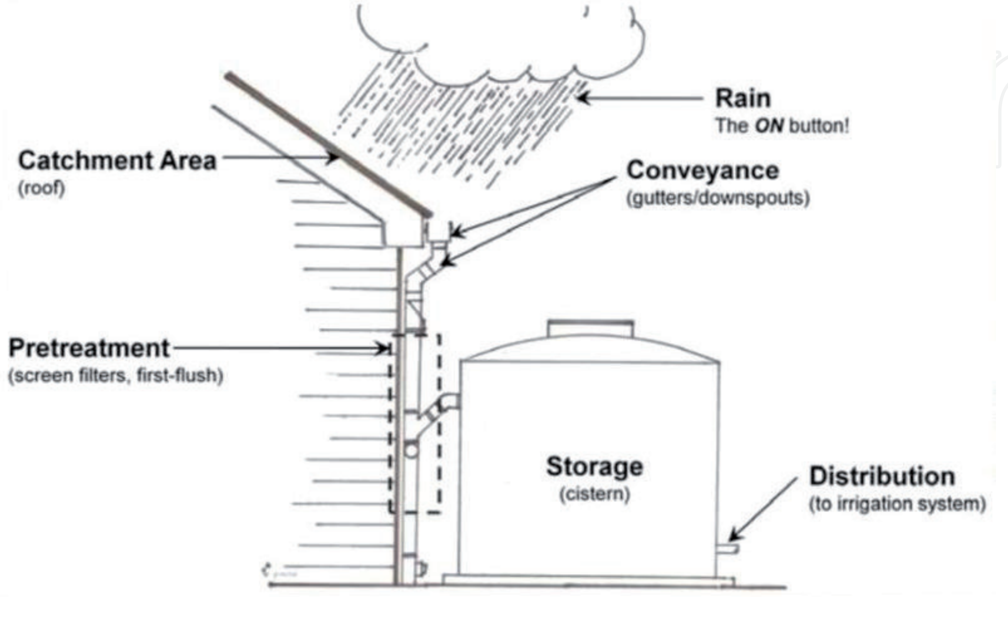

Figure 1.
Components of a rainwater harvesting system (source: https://slideplayer.com/slide/9100121/).

a. Catchment area

It is the area that gets rainwater directly. From this rainwater is collected and stored. According to the types of the catchment area, it is again of two types as follows.

3.2.1 Rooftop catchment

It is the most elementary method. Here, rooftop of any building serves as the catchment. Rainwater is accumulated using easily available and cheap pots kept at the side of the roof. The quantity and feature of this collected water are influenced by the location, size, and material of the roof. A bamboo-made roof gives the lowest quality of water. So, instead of using a bamboo-made roof, it must be made up with other materials like galvanized corrugated iron, aluminum, cement, etc. The catchments need to be cleaned frequently to wash from dirt, leaves, and birdie stools. **Figure 2** shows a rooftop-type catchment area.

3.2.2 Land surface catchment

Here, rainwater is collected from the common surface of any ground or land (**Figure 3**). This method of water collection is also very intricate. This method can be improved by improving surface runoff capacity. That is done using a number of techniques. Runoff capacity can be enhanced by using drain pipes and storing the collected runoff water. Ground catchment area is larger than that of the rooftop area. Therefore, techniques involved with this catchment have more chance for improvement. In this method, water is kept either in small storage reservoirs or in small dams. This technique is usually applied for irrigation purpose. To increase the amount of rainwater runoff within ground catchment areas, it is required to clear or alter foliage cover, increase the slope of ground by artificial means, and reduce soil permeability by proper means [6].

The steeper the slopes of catchment areas, the quicker is the runoff and hence faster collection of rainwater. But, high-speed runoff may cause soil erosion. Therefore, its rate needs to be controlled using plastic sheets, asphalt, or tiles along with slope. This method further reduces evaporative losses as well. Since more than 60 years ago, flat sheets of galvanized iron with timber frames have been used in the State of Victoria, Australia, to prevent soil corrosion of ground

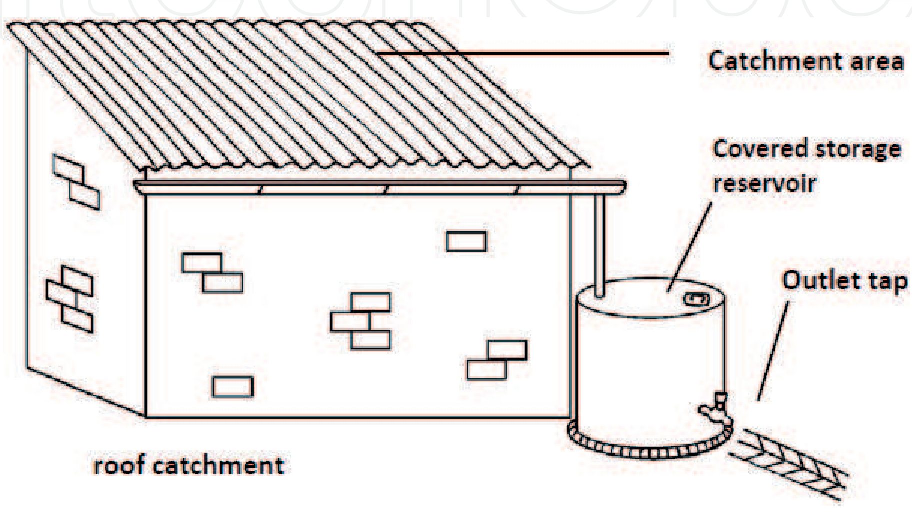

Figure 2.
Rooftop catchment system (source: CTCN site).

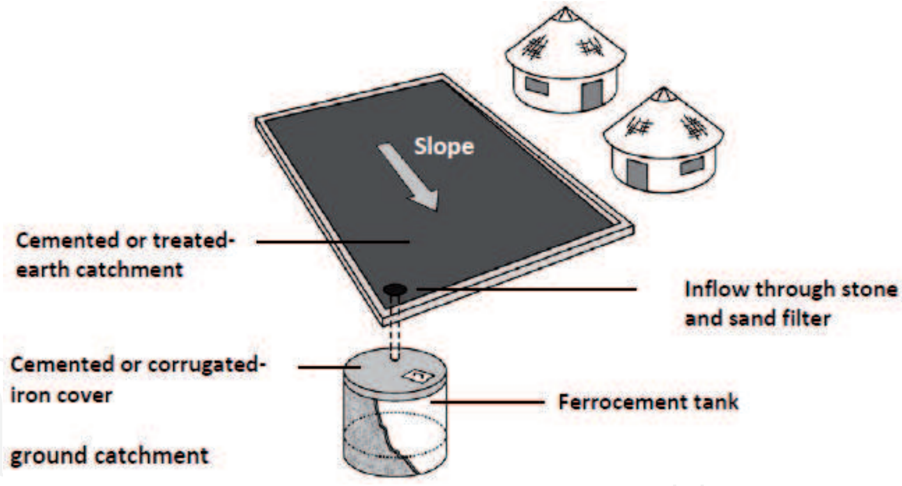

Figure 3.
Ground catchment system (source: CTCN site).

catchment area. Conservation bench terraces may also be constructed along a slope perpendicular to runoff flow for this purpose. The soil of the catchment area must be made hard and smooth. Surplus runoff water is directed to a lower collector and stored there. In addition to this, soil treatment using sodium helps in reducing soil permeability [7].

b. Collection and storage equipment

The collected rainwater from the catchment area is required to be collected and stored in proper collection equipment. It can be a storage tank or a rainfall water container. Storage tanks for this purpose may be placed either above or under the ground. The tank needs to be fitted with tight cover for preventing algal growth and the breeding of mosquitos. Measure must be taken to reduce contamination of the stored water. Storage tanks can be cylinder-shaped containers made up of ferro-cement or mortar. The former container has a slightly armor-plated concrete base. On this base the cylindrical tank is mounted. Again two layers of light wire are enfolded over this tank surface as shown in **Figure 4**. This serves as a frame for the

Figure 4.
Galvanized iron tank. (source: https://www.rainharvest.com/rainflo-3400-gallon-corrugated-steel-tank-rainwater-harvesting-package.asp).

container. The latter type container is a large vessel made up of mortar. This vessel is also wounded with light wires (**Figure 5**). In some cases, the storage tanks are concrete tanks (**Figure 6**) or plastic jars (**Figure 7**). The storing capacity of rainwater is calculated considering different factors like the dry spell span, the volume of rainfall, and the consuming demand [8, 9].

c. Conveyance structures

These structures are the means to transfer the collected water from catchment surface to the storing vessels. This structure consists of a number of downpipes attached to the rooftop gutters (**Figure 8**). Water collected from the first rain may consist of dirt and debris. The conveyance structure is required to do the primary treatment to the collected rainwater for clearing those impurities. In one of the conveyance structures, water of first rain is directed to the storage vessels after carrying

Figure 5.
Ferro-cement tanks.

Figure 6.
Concrete tank (Source: Taanka Wikipedia). (source: https://www.rainharvest.com/rainflo-3400-gallon-corrugated-steel-tank-rainwater-harvesting-package.asp).

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Figure 7.
Plastic tanks (Source: Taanka Wikipedia).

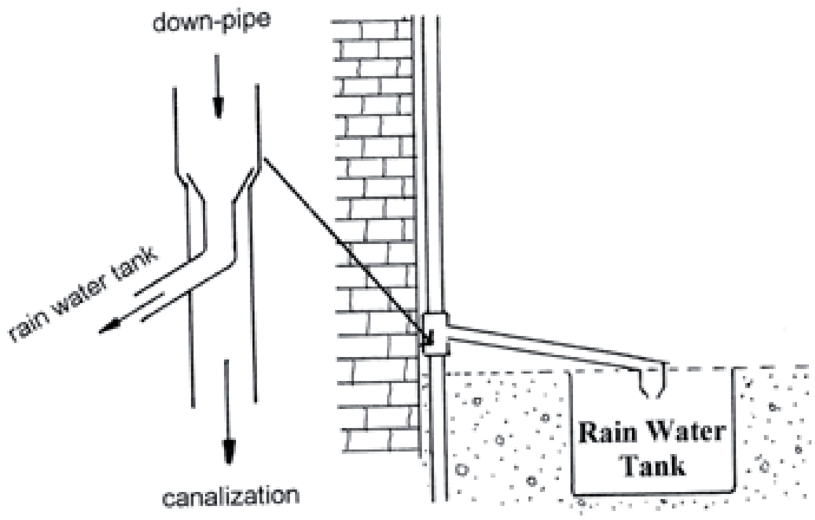

Figure 8.
Conveyance system (source: Newsletter and Technical Publications, UNEP).

out the primary treatment in these pipes. This type of structure can check the quality of the water collection. It also has a provision of manual operation of the flap. In another method, the operation of the flap is automatic. Here, a funnel-shaped device is assimilated within the downpipe structure at a place. A gap is intentionally kept between the funnel structure and inner side-wall of the downpipe. Therefore, rainwater passing through funnel gets filtered, whereas the excess of rainwater is ejected out to the ground through the gaps. At the start of rain, a small quantity of rain passes to the storage tank due to the collection of dirt. After some time, this collected dirt is flushed away to the ground through the gaps. Then, funnel can send more volume of water through pipes to storage vessels as seen in **Figure 9**. Instead of metals, this system uses plastic, PVC, or other inert substance pipes to protect from acidic water [10, 11].

d. Filtering system [12, 13]

To make the collected rainwater usable, it must be contamination free, safe, and inexpensive. For that a properly constructed water filter must be used. The following filtering system may be used such as sand gravel filter, charcoal filter, and PVC—pipe filter and sponge filter.

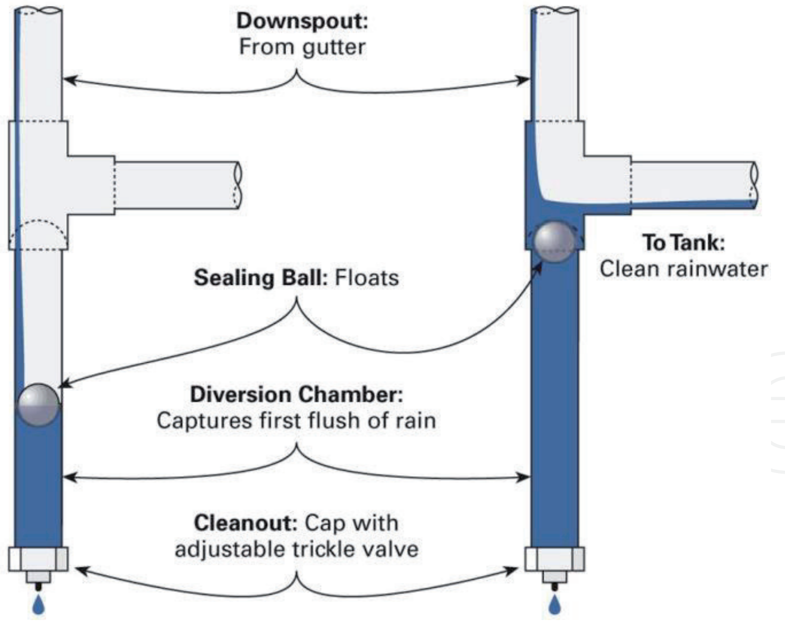

Figure 9.
First flush diversion (source: https://slideplayer.com/slide/9100121/).

Sand filters are usually the most widely used filters. These are brick masonry structure. Small stones, gravels smaller than stones, and sand are filled in this structure to serve as filtering medium. Each of these filtering media is made of one filter layer. Each one of these layers is divided using wire mesh. It is shown in **Figure 10**.

Charcoal filters are the drum- or chamber-shaped structure. These are filled up with charcoal in addition to small stones, even smaller gravels, and sand layer by layer. Here also layers are divided using wire mesh. It is shown in **Figure 11**.

PVC filters are made up of PVC pipes filled with sand and gravel separated by a layer of gravel (**Figure 12**).

Sponge filters are the most simple and inexpensive rainwater filter. It consists of a PVC drum with a sponge layer in its midway. It is appropriate for residential usage (**Figure 13**).

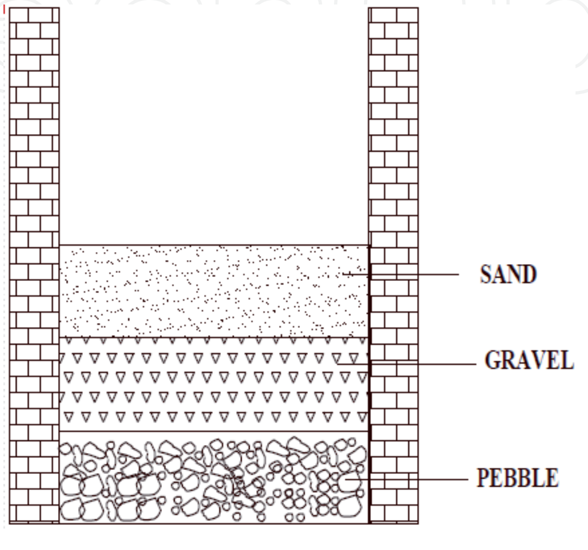

Figure 10.
Sand filter.

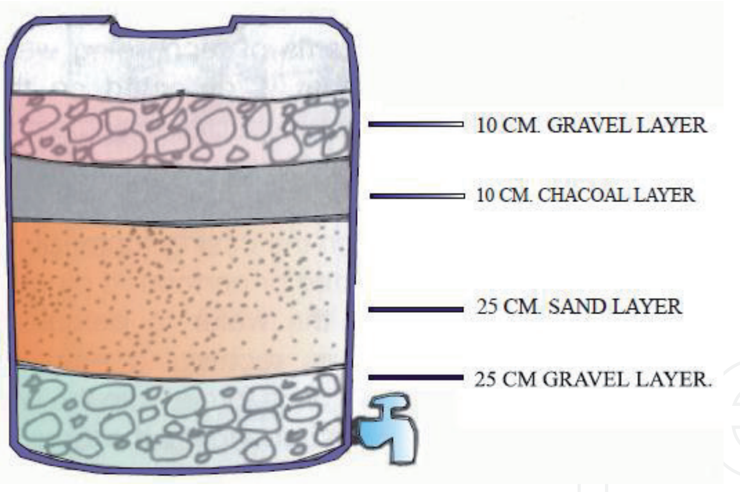

Figure 11.
Charcoal filter.

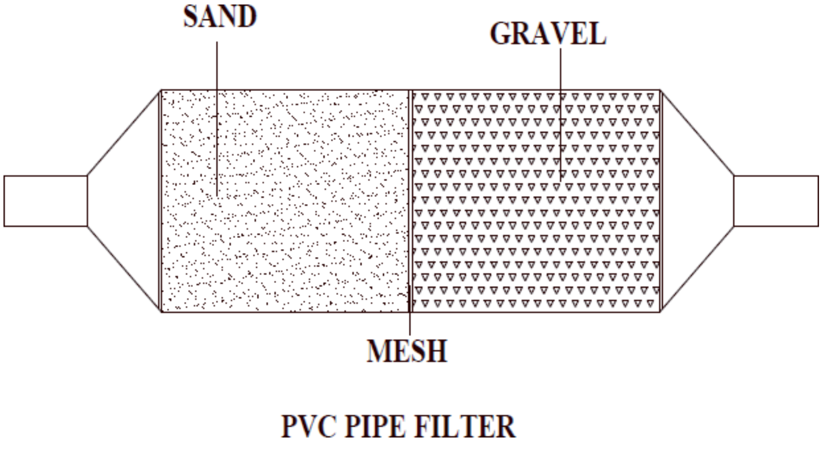

Figure 12.
PVC pipe filter.

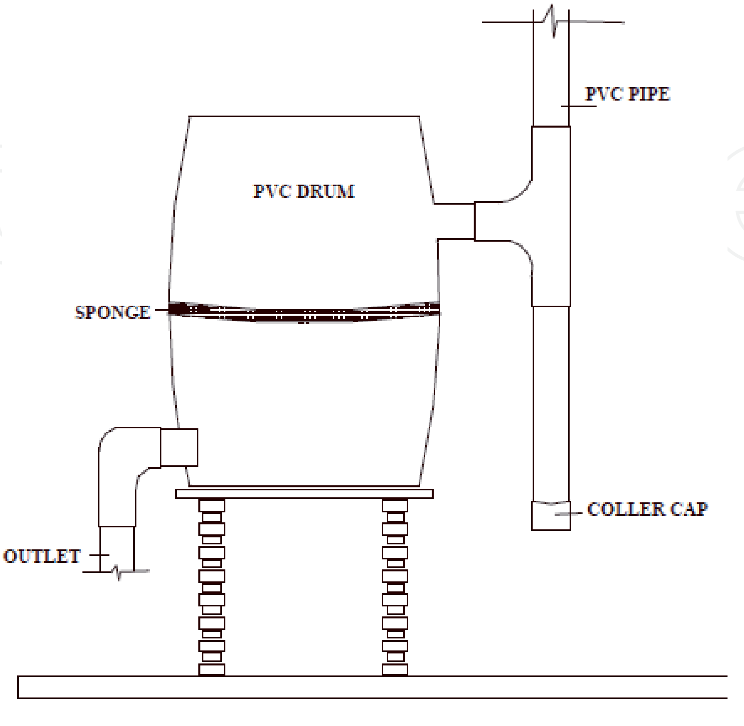

Figure 13.
Sponge filter (source: Rooftop RWH by M. Patil).

4. Methods of rainwater harvesting

1. Domestic rainwater harvesting

In this kind of harvesting, the catchment area is mainly rooftop area (**Figure 14**). Here, it is required to check two factors such as rainwater storage capacity and harvesting capacity. Harvesting capacity can be improved by using the right kind of catchment area. The storage capacity can be enhanced by considering appropriate storage vessels. Nowadays, commercial domestic rainwater harvesting systems are available. These systems are categorized according to the design and capacity of their storage vessels. The designs of these systems are very trustworthy to be used. These water systems are usually used as secondary water source in addition to the main water supply. This harvesting system is generally used for watering kitchen gardens. This water can also be used for other residential usage like bathing, cleaning, washing, etc. This system is simple to install and easy to manage [14–16].

2. Rock and other surface catchment systems

Catchment areas made up of rock are the ideal type catchment systems for rainwater. These structures are constructed at a site where users have easy access. The sites should not be a place where there is a possibility of soil erosion and negative impact to vegetation. In this case, the collected rainwater is usually stored in barrages or large open containers. These are suitable for use in school, industries, colony with a large number of residential buildings, etc. In this case water treatment is required before using it. In this case, underground tanks are also applied [17] (**Figure 15**).

3. Subsurface dam and sand dam

In sand dams, runoff rainwater is stored in various types of small-scale reservoirs [18]. The reservoir structures are like mud, stone, or concrete dams or a simple

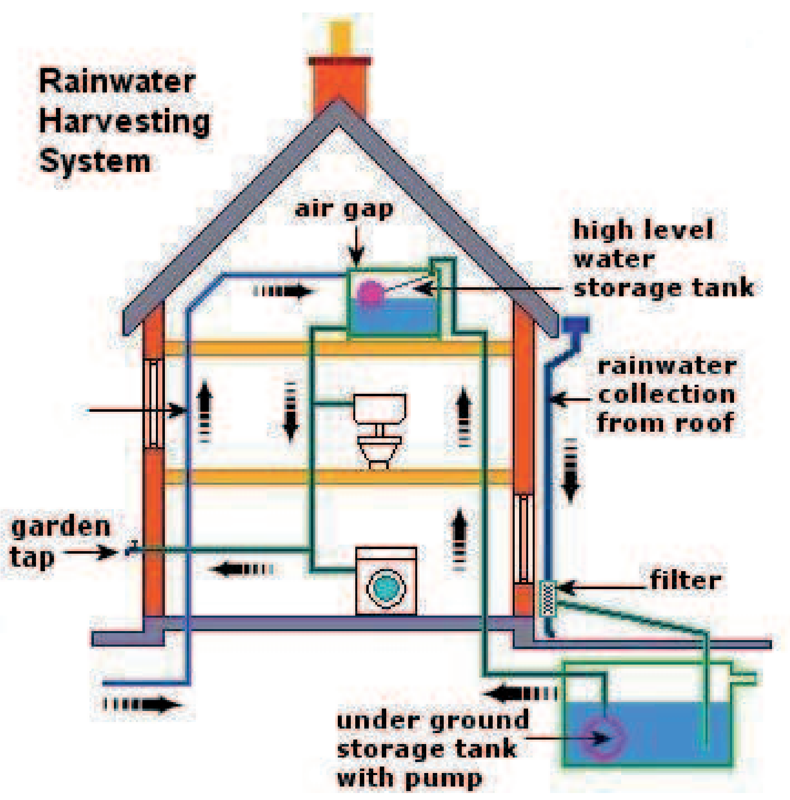

Figure 14.
Domestic rainwater harvesting (source: David English Water Pumps).

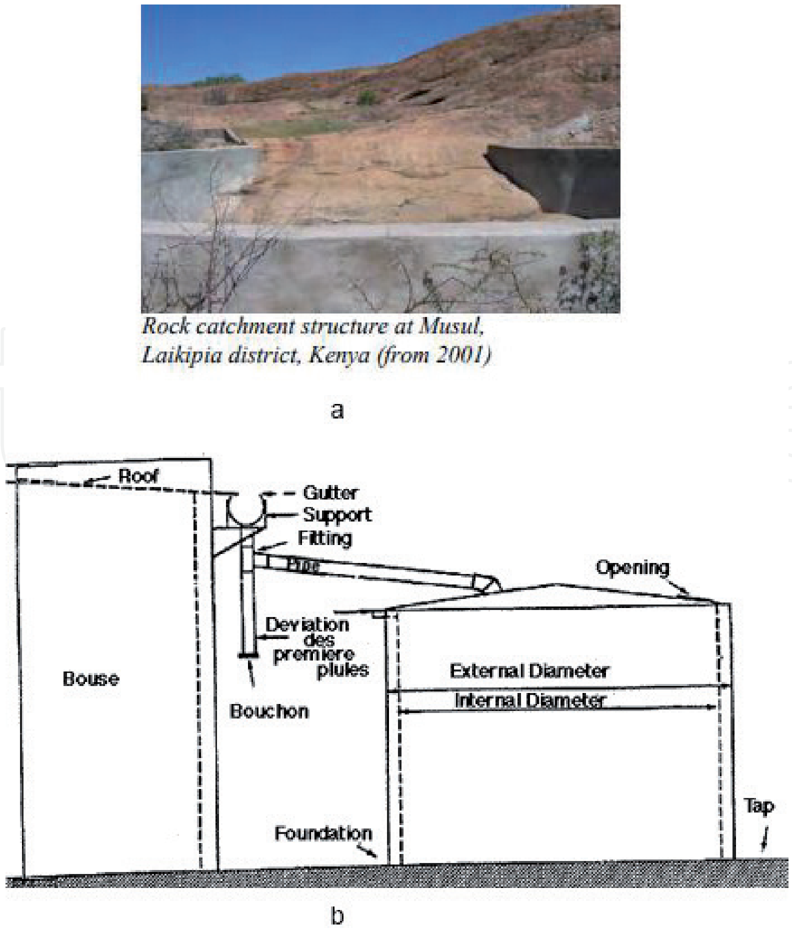

Figure 15.
(a) Picture of a rock catchment system and (b) layout of other surface catchment systems (source: UNEP and Rainwater Harvesting Handbook).

mined pond. Another form of such structure uses hand-dug wells and some horizontal inflow pipes for water mining. These are called subsurface dams (**Figure 16**). Here, water comes with its purest form and hence does not need further treatment before consuming. These types of structures are very effective functionally in arid and semiarid areas where rainfall varies from 200 to 750 mm. The harvesting water is mainly utilized for domestic, cattle, and kitchen gardening. Picture of a sand dam is shown in **Figure 17**.

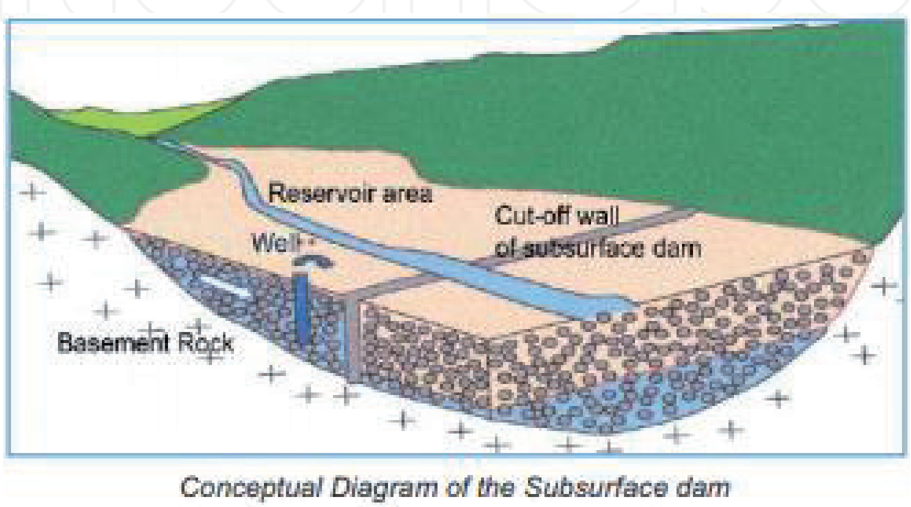

Figure 16.
Layout of a subsurface dam (source: samsamwater.com).

Figure 17.
Picture of a sand dam (source: rainfoundation.org).

4. Earth dams like ponds and pans

Earth or mud dams are capable of storing rainwater up to 10,000 m^3 [18]. The depth of these ponds is around 5 m. These are generally built using human power or using the help of domestic animals. In some cases, farm tractor, crawler, or bulldozer are also used. Such dams are categorized into three types such as Charco dams, Hillside dams, and Valley dams. Charco dams are constructed in an almost flat surface. Hillside dams are designed for sloppy hilly surface. Valley dams are constructed in a valley surface where water is available only seasonally. Ponds are the man-made-type small earth dams as seen in **Figure 18**. These are constructed by digging the earth surface and placing that mined soil on the lower side of the pond to increase the storage volume. Pans are nature-made ground dip curves where rainwater can be gathered in rainy seasons. This is the earliest form of rainwater harvesting system created by nature (**Figure 19**).

5. Recharge structures

Surface water has a natural tendency to recharge into the underground water reserve [19]. Nowadays, this recharging is done using artificial recharge structures utilizing suitable civil construction techniques. It augments cover-up of the depleted aquifer. It helps in water conservation for future usages. This recharging should not dilute the quality of the existing groundwater. The main purpose of artificial recharge of groundwater is to restore the quantity of the underground water due to excessive use.

Figure 18.
Picture of a pond.

Figure 19.
Picture of a pan (source: jkuat.ac.in).

Commonly used recharging methods are as follows:

1. Recharging bore wells
2. Recharge pits
3. Soak away or recharge shafts
4. Recharging dug well
5. Recharge trench
6. Percolation tank.

Some of these structures are shown in below figures (**Figure 20**).

6. Conservation tillage

This method is one conventional form of farming [19]. In this method, farm surface is plowed with tractor or bullock plow to loosen soil before cultivation. If certain modification is made to the conventional form of tillage as shown in the following figure, then it becomes conservation tillage. This type of modern tillage is capable of conservation of water, soil, and other energy resources by decreasing the tillage intensity and preservation of crop residue. This tillage rarely disturbs the soil surface used for harvesting of crops. A comparative view of both the tillage is shown in **Figure 21**.

7. Planting pits

Planting pits is also an innovative rainfall harvesting method (**Figures 22** and **23**) [19]. It holds rainwater in its pits and stops rainwater from runoff. This helps in

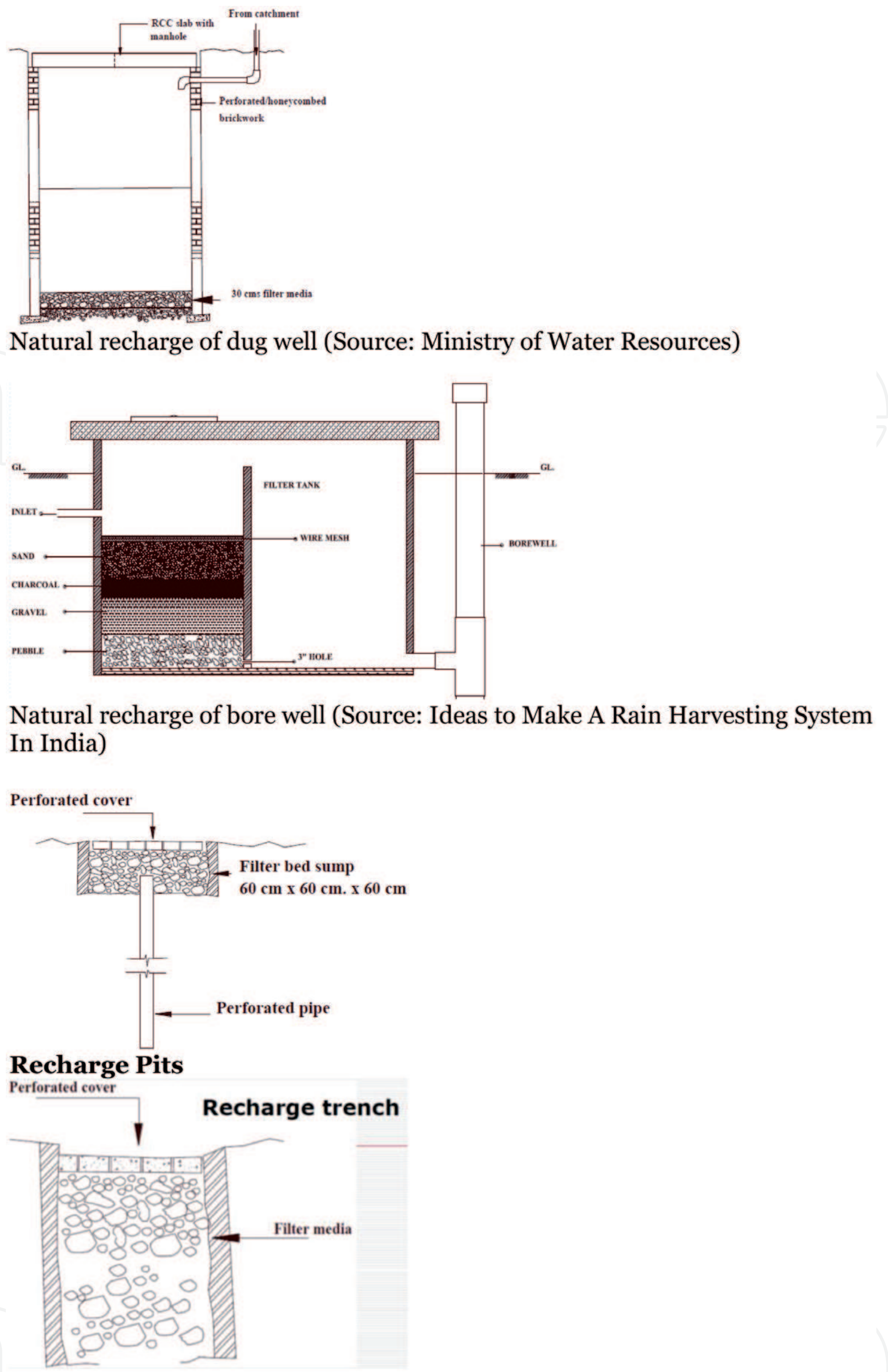

Figure 20.
Some of the recharging structures (source: Rooftop RWH by M. Patil).

enhancing infiltration of groundwater into underground. It also helps in decreasing soil erosion. Here, the distance between two nearby pits is kept at 50–100 cm. The depth of each pit is usually kept between 5 and 15 cm. This technique is suitable for soil with low permeability like clay. This method can be applied to semiarid areas for crops like sorghum, maize, sweet potato, bananas, etc. The major main benefits of this method are that it is easy to construct, use, and take care. However, large effort is required for construction of pits as they cannot be mechanized.

8. Katumani pit

Katumani pits are small crescent-shaped pits side covered by native grasses and legumes [18, 19]. Each pit is 15 cm deep and 20 cm wide with downslope ridges of about 30 cm height as shown in **Figure 24**. Pitting can be extended down the slope as per the requirement and convenience. Although it is a laborious method, it conserves soil and can meet water demand of high water demanding crops like banana and sugar canes.

9. Semicircular bunds

This is one of the micro-catchment types of rainwater harvesting system [18, 19]. These consist of semicircle-shaped stone banks. The landfills of the bunds are prepared in such stagewise orientation manner in rows (**Figure 25**). If ever rainwater overflow occurs, then it will flow from one row to the next down row. Labor cost, slope of land, availability, and size of stone are some major factors of this technique.

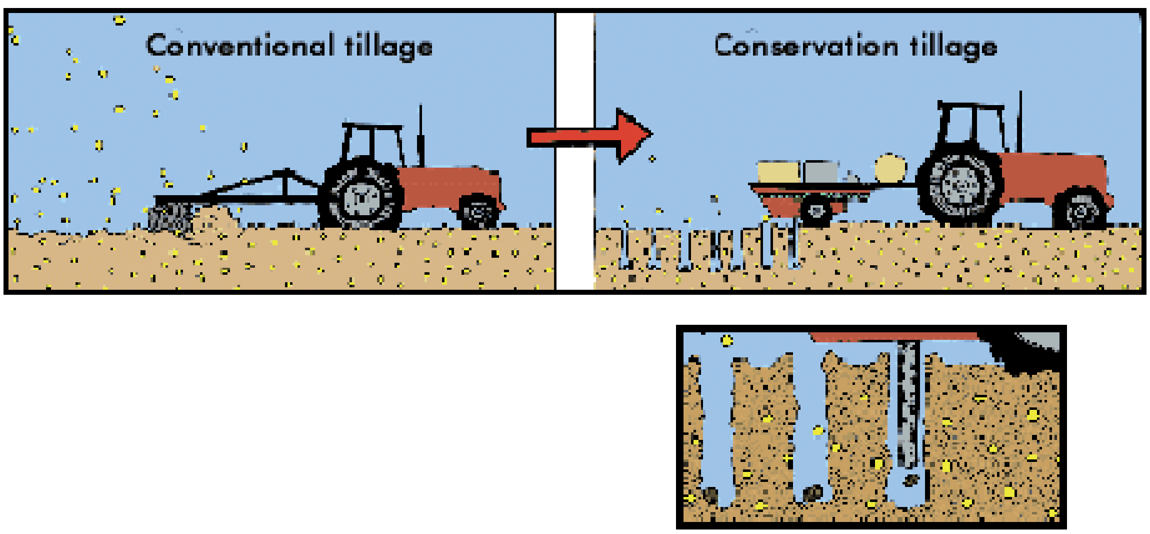

Figure 21.
Comparison of conventional tillage and conservation tillage (source: Climate Tech Wiki).

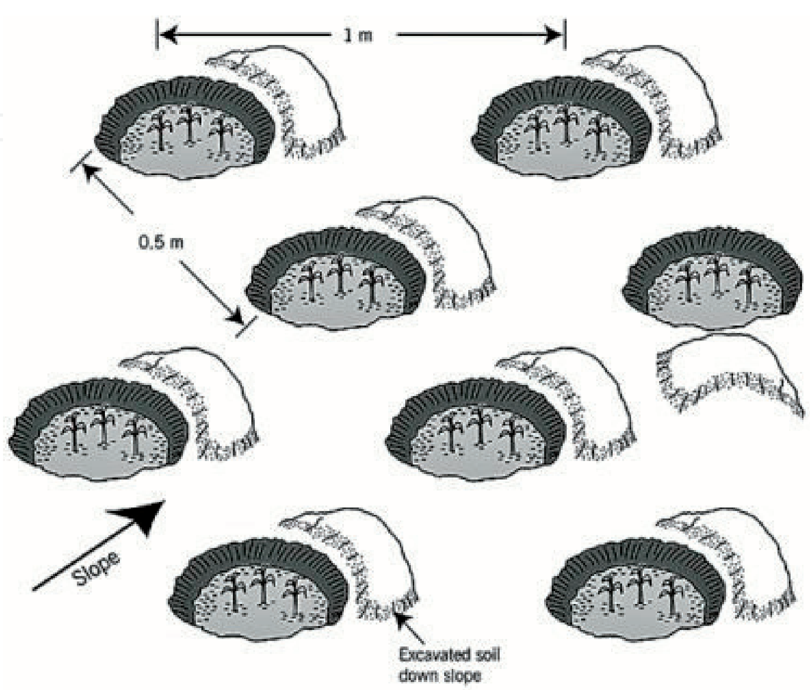

Figure 22.
Planting pits (Source: Malesu et al. [20]).

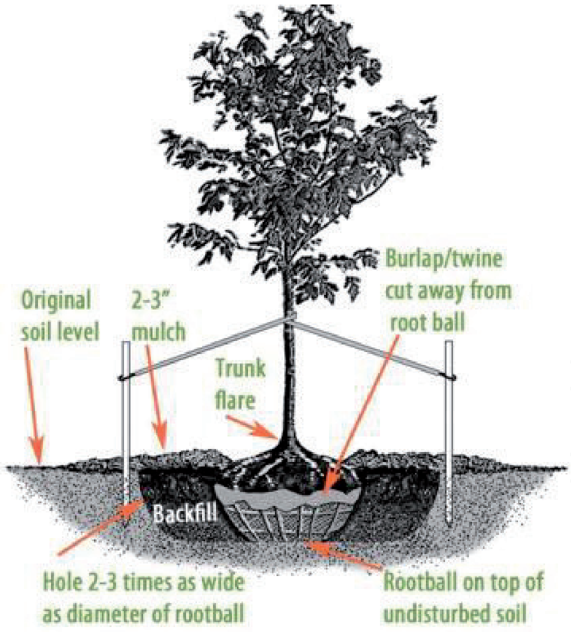

Figure 23.
Digging hole for planting pit (source: https://www.gardeners.com/how-to/tree-planting/8741.html).

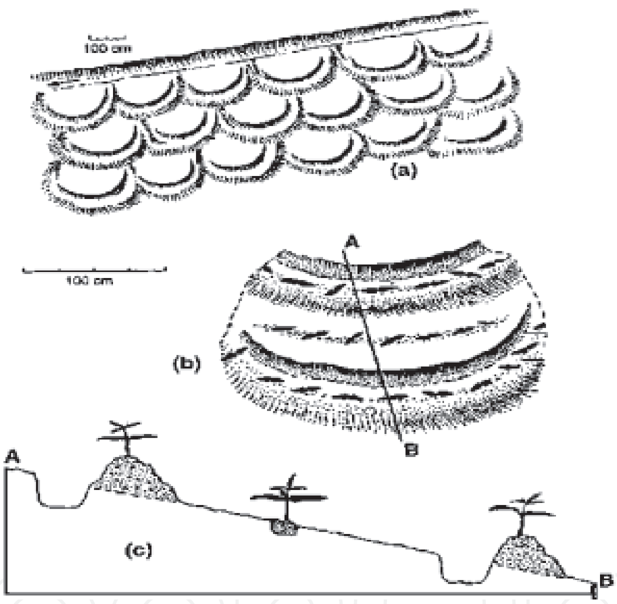

Figure 24.
Katumani pits in three plans such as a, b, and c (source: Namirembe et al. [21]).

Figure 25.
Semicircular bunds for fruit plant (source: Snobar et al. [23]).

10. Negarim micro-catchments

The word "Negarim" is derived from the Hebrew word "Neger" that means "runoff." Negarim micro-catchment is one of the most recent innovations of rainwater harvesting systems [18, 19, 22]. These look like diamond-shaped bowls (**Figure 26**). The boundary surfaces of these structures are bordered by small earth bunds. Each structure has a groundwater penetration pit in its lowermost corner. Runoff rainwater within each structure is accumulated and stored in their respective pits. These techniques are basically used for growing plants or scrubs. This technique is suitable for small-scale vegetation in dry areas. It helps in soil conservation too. These are easy to construct and structurally are well-ordered and accurate. The first ever structure of such micro-catchment is reported from southern Tunisia. However, it is widely used in the Negev desert of Israel.

11. Tied contour ridges

Contour ridges are small-sized clay ridges with height of around 20 cm [18, 19]. It has an upslope channel that helps in flowing runoff water from catchment strip between the ridges (**Figure 27**). Cultivation is not done in the catchment strip. Therefore, the purpose of this structure more satisfies controlling soil erosion rather than rainwater collection. The main purpose of this system is to collect local area runoff rainwater and then keep them in land surface near to the plant

Figure 26.
Negarim micro-catchment structure with plantation (source: Development-durable.org).

Figure 27.
Tied contour ridges (source: Muslim Science).

roots. These structures are not meant for controlling overflow. Hence, the system is needed to be designed with a cutoff drain. This technique is practiced widely in African countries like Kenya, Niger, and Zimbabwe. Its maintenance cost is less if it is well designed.

12. Contour stone bunds

These are constructed in sloppy area where rainfall varies between 200 and 750 mm [18, 19]. These structures are made of stones (**Figure 28**). So, they are suitable on stony land. These structures can slow down runoff and protect soil from filtering out. They also help in enhancing the infiltration of runoff water. These structures can be constructed both with and without spillways. Structures without spillways are simple in construction and easy to maintain. These types of structures are suitable for small-scale irrigation in farming lands.

13. Fanya juu terraces

In Kiswahili language, in Swahili, the word "juu" means "up" and the word "Fanya juu" means "throw the soil up." Fanya juu terraces are constructed by digging soil and pitching it upslope, making a mound for water collection [18]. The mound creates a runoff barrier, whereas the trench holds the runoff rainwater. The ridges are usually alleviated with fodder grasses. In these techniques crops like banana, citrus, and guava can be cultivated. This technique is suitable for areas getting low annual rainfall areas and with less than 20% slopes, hilly area, and

Figure 28.
Contour stone bunds in Kenya (source: Yazar et al. [24]).

Figure 29.
Bean being grown on Fanya juu terraces in Lanzi (source: Michael Rastall, weadapt.org).

deep soils with massive fear of soil erosion. Farmers basically use this technique to increase their crop. These terraces are perfect for cultivation of fodder grasses. In addition to it, these structures support in preventing soil erosion. Cultivation becomes easier as these terraces are made of multilevel structures. Again, yield from the crops enhanced when fertilizer is applied to it. The structure is shown in **Figure 29**.

14. Fanya chini

The structure of Fanya chini is the same as Fanya juu. However unlike Fanya juu, here soil is put on the lower side of the contour trench [19]. These are used to conserve soil as well as divert rainwater. Here, the ridges are used to grow feedstuff. These are easier in development than that of Fanya juu tarraces. But here in this case multilevel structure is not possible. The maximum limit of slope in these structures is around 35%.

15. Earth bunds with external catchment

Bunds or teras are some small barriers made to prevent runoff water from entering a catchment with crops (**Figure 30**) [18]. Bunds reduce speed of runoff rainwater on and increase recharging of the groundwater. Several different structures of bunds are found like rectangular type, contour type, and base type. In

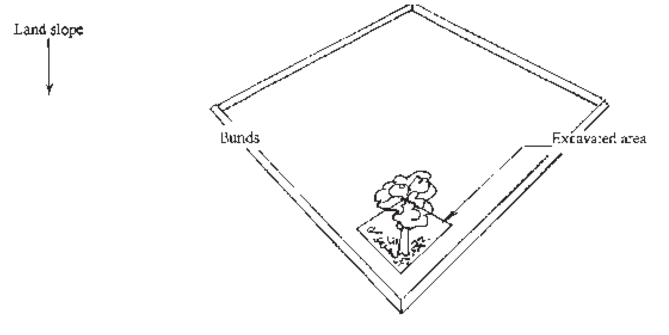

Figure 30.
Earth bunds with external catchment (source: nzdl.org).

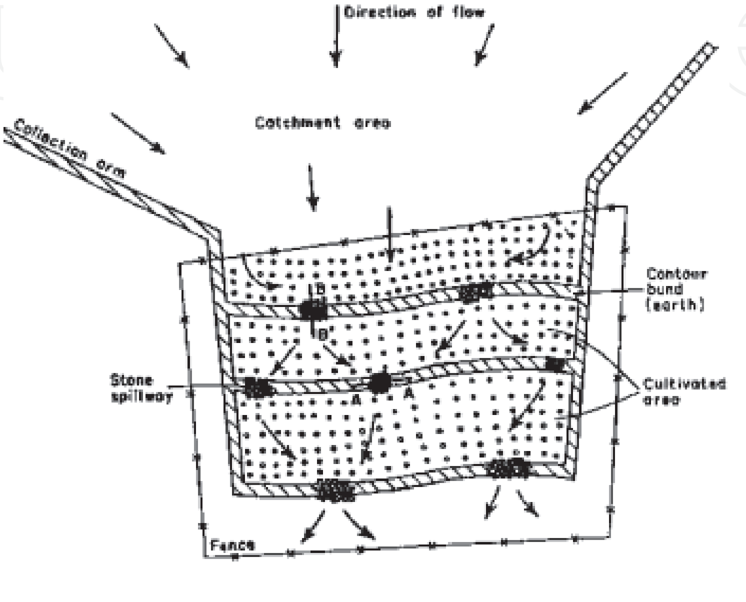

Figure 31.
Macro-catchment water harvesting system (source: Imbira [25]).

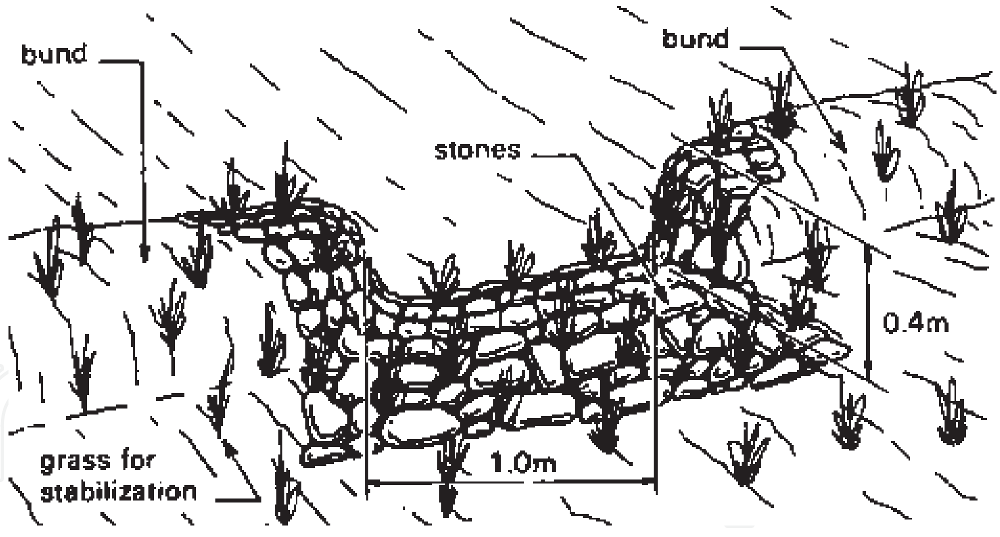

Figure 32.
Spillway construction for bunds with external catchments (Pacey and Cullis, 1991).

rectangular bund structure, three sides are bounded, and the fourth one is open to collect water. In contour-type bunds, row structure is erected along a hillside. The size of base bund structure is with length of 50–300 m and width of 20–100 m. Here, bunds are constructed not to collect water. Their main purpose is to balance the hydration of soil and also recharging under groundwater. The structure without a spillway may break the sides of the bunds. Therefore, spillways are also added to these structures. This helps in improving the efficiency and lowering the maintenance costs.

16. Contour ridges with external catchment

This technology is the same contour ridging technique but uses an external catchment (**Figure 31**) [17]. It includes an extra spillway structure that can handle the excess runoff water flow (**Figure 32**). These structures are constructed with mud or pebbles.

5. Traditional methods of rainwater harvesting in India

Indian administrations are taking many new projects to locate and to revive the age-old conventional water harvesting methods [26, 27]. These approaches are found to be very easy, reliable, and eco-friendly. The existence of many such ancient structures has been proven by archaeological findings. In past found evidences, it is verified that the Indus Valley civilization is pioneer in it. Indians have built many more such innovative and effective structures of rainwater harvesting. Although these techniques are not very popular today, some of them are still in use. Some of such structures are discussed as follows.

Jhalaras are the stepwells having stairs in its sides. Shapes of these structures are almost rectangular. These structures collect the buried discharge of a nearby water reservoir, pond, or lake.

Talabs are either pond or pans. They are utilized for meeting consumable water for drinking and domestic work purposes. These structures can be natural or man-made.

Bawaris are a type of unique structure of stepwells. These were usually used in the ancient cities of Rajasthan.

Taanka is a traditional structure of rainwater harvesting seen in the Thar Desert region of Rajasthan. This structure consists of a cylinder-shape underground well. It collects rainwater from rooftops, courtyards, or artificially prepared catchment flows and sore for future use.

Ahar pynes are found in South Bihar. These are artificial lakes in which three of their sides are ridged, whereas the fourth side is open. The open side is joined to the end of a diversion channel as in pynes.

Johads are the small-size muddy check dams that are built to store rainwater. They also help in recharging groundwater.

Kuruma tribe (a native tribe of Wayanad) uses a distinct structure of well called the **panam keni**. This structure is built using wood.

Khadins are also very inventive structures built in hilly areas. Water of these structures is used for cultivation purpose.

Kund is a structure having a plate-shaped catchment area. Its surface is gently inclined toward the center where a well is dug. The well is circular shaped. It is usually used for supplying drinking water.

Baoli was usually built for philanthropic reasons. From baoli, everyone could draw water.

Some more such structures are **Nadi, Bhandara Phad, Zing, Kuhls, Zabo, Bamboo Drip Irrigation, Jackwells, Ramtek Model, Pat System, Eri**, etc.

6. Rain centre

The Rain Centre is a chain of organization mainly to spread literacy on rainwater harvesting and utilization. Nowadays, it is becoming very popular among urban Indians. It educates the significance of rain in Indian life. It also tells about how rain influences the customs, traditions, economy, and politics of different parts of India. This center also cites the various distinct examples of harvesting rainwater and people working in this field. The rain centers are mainly built to educate people to harvest rainwater in a proper manner. For this purpose, the local NGOs and dedicated citizens of an area are selected and first educated. The first rain center in India is established in Chennai in 2002.

Now, it has a chain of 11 model rainwater harvesting projects in Delhi. The Rain Centre builds rainwater harvesting systems for individual or organization with their demands. The fourth rain center is established in Burdwan, West Bengal of India. Now, offices of rain centers are operating in West Bengal, Gujarat, Chennai, and Meerut of India [5].

7. Advantages

As per the previous all discussion, rainwater harvesting is very beneficial. Some of the remarkable advantages in implementation of this technique are marked as follows. Rainwater harvesting technologies are simple to install and operate. Highly skilled manpower is not required for implementation of this technology. Local people can be easily trained to construct and maintain rainwater harvesting plants. Construction materials are also usually locally available. It is one of the most convenient system as it provides water at the point of consumption. Also, work force in this technique are locally available. The workforces are mostly the consumer themselves only. Running costs are almost negligible [3].

8. Disadvantages

This technology usually has a very limited number of limitations as follows. Rainwater harvesting technologies are mainly depending on rainfall which is uncertain in nature. This technology uses a "bottom-up" approach instead of the conventional "top-down" approach. Therefore, awareness about this technology is less. For a particular area, the type and size of rainwater harvesting are highly reliant upon the quantity and quality of its rainfall. Catchment area and type of catchment surface are also very vital. These structures cannot be used as the primary source of water supply because rainfall is unequally distributed in different seasons in a year. Rainwater harvesting systems also depend on consumer demands and their affordable budget. The architecture of this system needs to design the structure considering every aspect from physical, environmental, to monetary point of view [26].

9. Cost

The building and maintenance cost of rainwater harvesting systems varies considering its catchment area, conveyance, and storing vessels. Place to place also, the cost varies. Like in a study, it is found that the cost of these structures in Asia varies from $0.17 to $0.37 per cubic meter of water storage. This cost is quite less than that of Africa. However, rainwater harvesting systems are less costly than the use of bore wells and tube wells if the initial investment does not include the cost of roofing materials. The lasting period of these structures is also more than 10 years. They need less maintenance and operation cost [27].

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