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Study of Rainfall Harvesting System on a Local Perspective & Design of System for Valsad

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ABSTRACT

Rainwater harvesting (RWH) is one of the best practices to overcome the scarcity of water. Rainwater harvesting involves collection and storage of rainwater locally through different technologies, for future use. It is also useful for livestock, groundwater recharge and for irrigation practices. Potential of rainwater harvesting refers to the capacity of an individual catchment that harnesses the water falling on the catchment during a particular year considering all rainy days. study analyzes the potential benefits of implementing rainwater harvesting in a specific area, considering factors like annual rainfall, runoff, and aquifer recharge capacity. It aims to optimize the system design for maximum water storage and utilization, potentially reducing reliance on conventional water sources and promoting water conservation. This article shows the Rainwater Harvesting system components, its design criterion, and their suitability using a one common example of the design. It gives the actual consideration of the design the system and it fulfill the sustainability criteria of the Nation. This article is useful to the policymakers and the government officials.

KEYWORDS: *Rainwater harvesting (RWH), Sustainable water management, Indian technique, water collection*

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INTRODUCTION

Rainwater harvesting is the accumulating and storing of rain water for reuse before it reaches the acuifer. It has been used to provide drinking water , water for livestock, water for irrigation, as well as other typical uses. Rainwater collected from the roofs of houses and local institution can make an important contribution to the available drinking water. It can supplement the subsoil water level and increase urban greenery.

It is imperative to take adequate measures to meet the drinking water needs of the people in the country besides irrigation and domestic needs. Today, rainwater harvesting has gained much on significance as a modern, water-saving and simple technology. The practice of collecting rainwater from rainfall events can be classified into two broad categories: land-based and roof-based. Land-based rainwater harvesting occurs when runoff from land surfaces is collected in furrow dikes, ponds, tanks and reservoirs. Roof-based rainwater harvesting refers to collecting rainwater runoff from roof surfaces which usually provides a much cleaner source of water that can be also used for drinking.

OBJECTIVES OF RAINWATER HARVESTING

- **Reduce Runoff** – Minimize surface runoff and erosion by capturing and storing rainwater.
- **Conserve Water Resources** – Increase the availability of water by using harvested rainwater for various needs.
- **Recharge Groundwater** – Enhance groundwater levels by directing rainwater to recharge aquifers.
- **Manage Stormwater** – Control and manage stormwater runoff to prevent flooding and reduce soil erosion.
- **Support Agriculture** – Provide additional water resources for irrigation, especially in drought-prone areas.
- **Decrease Dependency** – Reduce reliance on traditional water supply systems, which can be overburdened or unreliable.
- **Promote Sustainable Practices** – Encourage sustainable water management practices and reduce environmental impact.

TECHNIQUES USED IN RAIN WATER HARVESTING

Various techniques have been used in **rainwater harvesting in rural and urban areas,** which are as follows:

In Urban Areas
Roof Top Rainwater/Storm Runoff Harvesting through urban areas:

Recharge Pit – A **recharge pit** are constructed for recharging the shallow aquifer. These are constructed generally 1 to 2m wide and 2 to 3 m deep. After excavation , the pits are refilled with pebbles.

Recharge Trench – It is a trench of shallow depth filled with pebbles and boulders. These are constructed across the land slopes. It may be 0.5 to 1 m wide, 1 to 1.5 m deep and 10 to 20 m long.

Tube well – The well can also be used for pumping. This technique is suitable where land availability is limited. Recharge water should be silt free as far as possible.

In Rural Areas
Roof Top Rainwater/Storm Runoff Harvesting through in rural areas:

- **Gully Plug** – **Gully plugs** are built using local stones, clay, and bushes across small gullies and streams running downhill slopes. They help capture drainage and create tiny catchments during the rainy season.
- **Contour Bund** – **Contour bunds** are effective for conserving soil moisture in a watershed. They are constructed on sloping ground along the contour lines to impound monsoon runoff, intercepting water before it gains erosive velocity. They are suitable for low rainfall areas.
- **Dug well Recharge** – A dug well can be used as a recharge structure. The recharge water is guided through a pipe to the bottom of well or below the water level to avoid scouring of bottom and entrapment of air bubbles in the aquifer.
- **Percolation Tank –** A percolation tank is an artificially created surface water body that submerges highly permeable land, allowing surface runoff to percolate and recharge groundwater storage. It is best constructed on second—to third-order streams with highly fractured and weathered rocks.
- **Check Dam/Cement Plug/Nala Bund – Check dams** are built across small streams with gentle slopes. They store water mostly within the stream course and are usually less than 2 meters high, allowing excess water to flow over the wall.
- **Recharge Shaft** – This technique is dug manually. Diameter of recharge shaft varies from 0.5 to 3 m. It is constructed where the shallow aquifer is located below clayey surface.

SYSTEM COMPONENTS

1. **Collection system:** Roof surface and gutters to capture the rainwater and send it to the storage system
2. **Inlet filter:** Screen filter to catch large debris
3. **First flush diverter:** Diverter that removes debris not captured by the inlet filter from the initial stream of rainwater
4. **Storage tank:** Storage water tank store water from filter unit is storage tank. Mainly three types of storage tanks are constructed for roof water harvesting. They are under ground, on the ground and above ground tanks. The overhead tanks are made of PVC or masonary.
5. **Overflow:** Drainage spout that allows for overflow if the storage tank gets full
6. **Controls:** Control system that monitors water level and filtration system
7. **Treatment system:** Filtration and disinfection system that treats the water to non-potable or potable standards
8. **Pump:** Pump to move water through the system to where it will be used
9. **Backflow prevention:** Backflow preventer to ensure that under negative pressure water cannot flow backwards through the system into the make-up water system
10. **Flow meter:** Flow meter (with data logger) to measure water production
11. **Power supply:** Systems may use either conventional power sources or, to improve off-grid capabilities, alternative sources such as stand-alone or grid-tied solar systems
12. **Water level indicator:** Monitors the water level in the storage tank

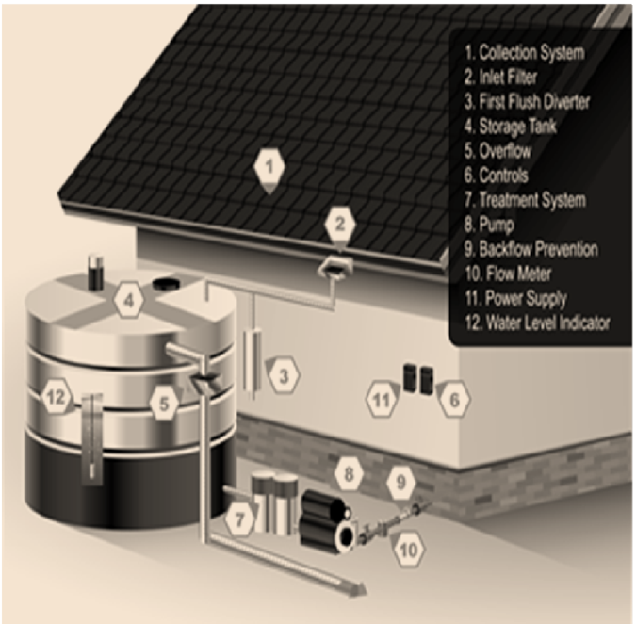

Figure 1. Components of a typical rainwater harvesting

https://www.energy.gov/femp/rainwater-harvesting-systems-technology-reviewtechnology-review

DESIGNING OF RAIN WATER TANK

Suppose the system has to be designed for meeting drinking water requirement of a five member family living in a building with a rooftop area of 100 sq.m.

The average annual rainfall in the region is 600mm

Daily drinking water requirement per person (drinking and cooking) is 10 litres.

Following details are available:
Area of the catchment (A) = 100 sq.m.

Average annual rainfall (R) = 600 mm (0.60 m)

Runoff coefficient (C) = 0.85

Calculate the maximum amount of rainfall that can be harvested potential

= 100 x 0.6 x 0.85

= 51 cu.m.(51,000 litres)

We know that 1 cube meter = 1000 litres

Now,

We are determining the water tank capacity

This is based on the dry period, i.e., the period between the two consecutive rainy seasons.

For example, with a monsoon extending over four months, the dry season is of 245 days.

Calculate drinking water requirement for the family for the dry season

= 245 x 5 x 10

= 12,250 litres

As a safety factor,

The tank should be built 20 percent larger than required, i.e (12,250 x 1.2) = 14,700 litres.

This tank can meet the basic drinking water requirement of a 5 member family for the dry period.

A typical size of a rectangular tank constructed in the basement will be about 4.0 m x 4.0 m x 1.0 m

For circular tank,

Suppose height of tank = 1.5m

Volume of tank = area x height

$14700 - \pi r^2$ X height X 1000

r = 3.119 m

Diameter of base tank = 2 X r = 6.238 m

= 6.25m

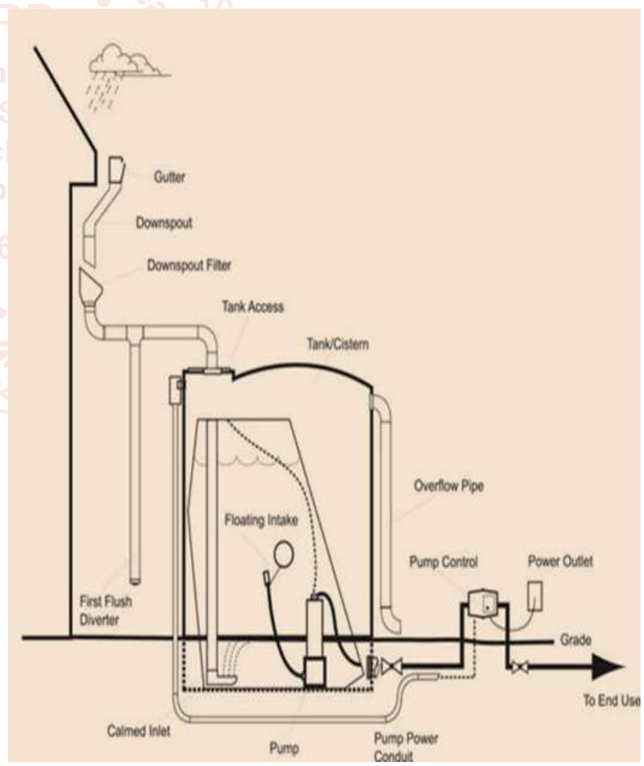

Figure 2: Schematic representation of above ground rainwater harvesting system

(Source : Debusk and Hunt, 2014)

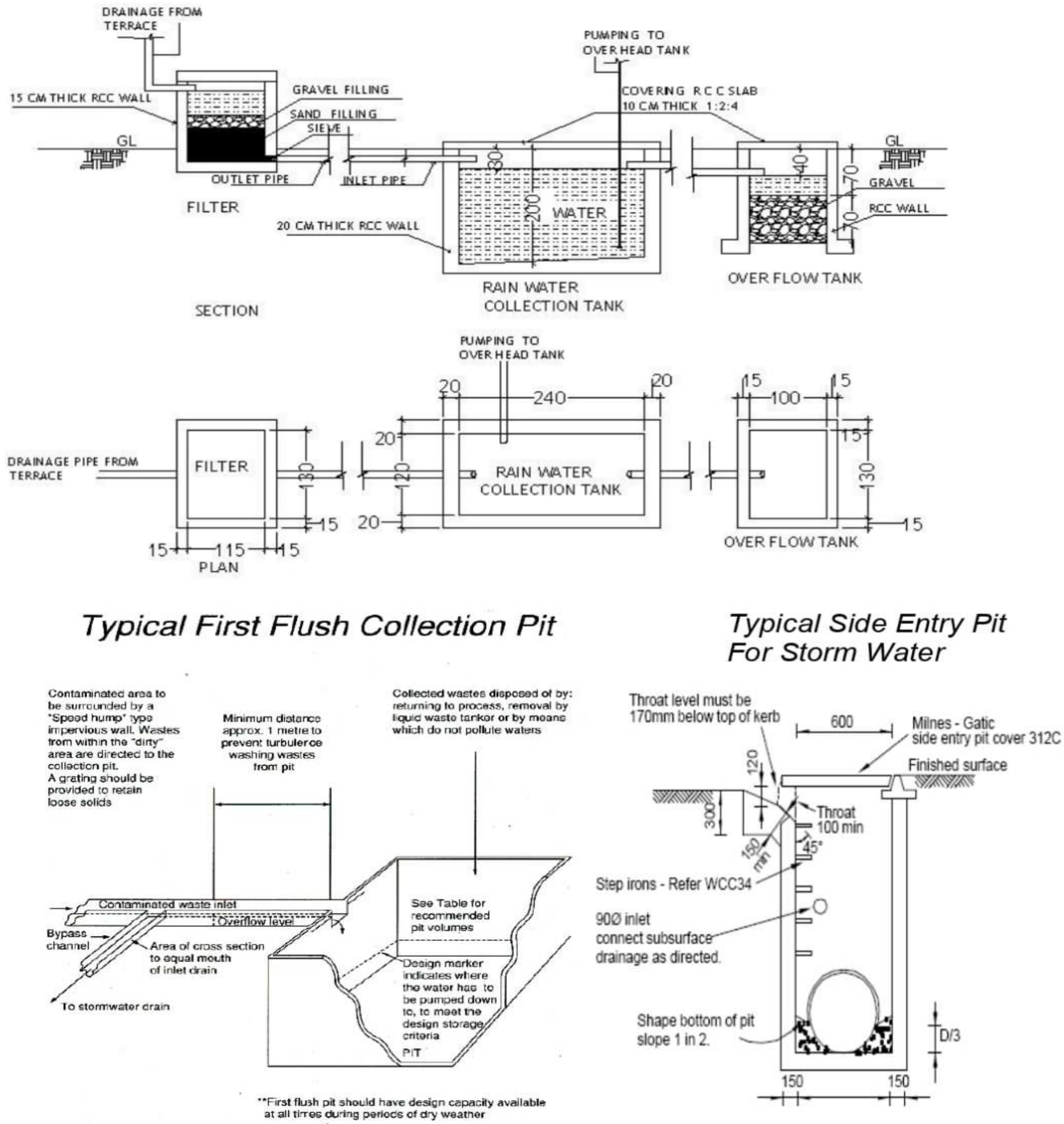

Figure 3 (Narula Institute of Technology / Civil Enginering Dept / Agrpara)

TYPICAL FIRST FLUSH COLLECTION PIT

A typical first flush collection pit is a pit or chamber designed to divert the initial, dirtier portion of rainwater runoff away from a larger storage tank.

This helps to improve the quality of collected rainwater by preventing the introduction of contaminants like dust, leaves and other debris that are typically carried in the first flush runoff.

Design and Function:

Pit or Chamber: The first flush pit or chamber is typically a simple container, often made of a concrete or plastic, located at the point where the runoff enters the system.

Diversion: A device, such as a floating ball, tipping bucket, or simple pipe section, diverts the first portion of the runoff into the pit.

Overflow: Once the pit is full, the remaining runoff is diverted into the main collection system or storage tank.

Maintenance: Regular inspection and maintenance of the pit are important to ensure that it's functioning properly and to remove accumulated sediment and debris.

Sizing:

Volume: The size of the first flush pit is typically determined by the size of the catchment area and the desired amount of runoff to be diverted. A general rule of thumb is to divert 10 gallons (37.8 liters) of water per 1,000 square feet (92.9 square meters) of roof area.

Considerations: In areas with high pollution levels or larger roof areas, a larger first flush pit may be necessary.

Benefits:
Improved water quality: As mentioned, this is the primary benefit, as it helps to ensure that the collected rainwater is cleaner.

Reduced maintenance: By diverting contaminants, first flush systems can help to reduce the amount of maintenance required on the overall rainwater harvesting system.

Extended tank life: By preventing the introduction of large amounts of sediment and debris, first flush systems can help to extend the life of the storage tank.

TYPICAL SIDE ENTRY PIT FOR STORMWATER

A typical side entry pit for stormwater is a drainage structure that collects surface runoff from roads and directs it into underground pipes. It's characterized by an opening on the side, allowing water to enter the pit, which is then connected to the drainage system.

Key Features and Components:

- **Side Inlet:**

The most defining feature is the sid opening, allowing water to enter directly into the pit.

- **Lintel or Kerb Entry:**

A lintel or kerb entry unit is usually required to guide the water flow effectively into the pit.

- **Concrete Construction:**

Pits are typically made of concrete and can be modular or custom-designed.

- **Cover:**

A cover (grated or solid) is placed over the pit opening to prevent accidental entry and to allow for maintenance access.

Reinforcement: Pits deeper than 1 meter may require step irons for safe access, and pits deeper than 2 meters need reinforcing fabric in the walls.

Dimensions: Pits are designed to accommodate various pipe sizes and can be customized to suit specific requirements, including depth and shape.

Typical Applications:
Roadside Drainage: Used to collect stormwater runoff from roads, sidewalks, and other paved areas.

Junction Pits: Connects pipes at junctions and allows for maintenance access.

Various Locations: Found in both roads and nature strips, with variations in lintel types and cover styles.

Construction Considerations:
Concrete Strength: Concrete used for pit construction typically has a minimum strength of 25 MPa.

Reinforcement: Reinforcement is crucial for deeper pits to ensure structural integrity.

Step Irons: Step irons are essential for safe access in deeper pits, especially for maintenance purposes.

Kerb and Channel: The pit is often designed to integrate with the kerb and channel system, ensuring smooth water flow.

ESTIMATING THE RAINWATER HARVESTED QUANTITY

In a rainwater harvesting system, the received rainfall over a surface catchment is collected and directed to the storage tank and consumed as non-potable water. The surplus water is allowed to flow through surface drainage system or by wastewater network.

The size of a catchment area and the storage tank should be enough to fulfill the water requirements of users during the dry period. The capacity of the storage system can be decided by the available roof area and the rainfall. The total amount of rainwater received over an area is called the rainwater endowment of that area and the amount of rainwater that can effectively be harvested is called as the rainwater harvesting potential (CPWD, 2002). The rainwater harvesting potential can be calculated as:

Rainwater Harvesting Potential = Rainfall (mm) × Area of the catchment × Runoff Coefficient
Rainwater endowment of an area = Area plot (sq.m) × Rainfall height (m)

All the calculations related to determine the rainwater harvesting potential of a catchment involve the use of runoff coefficient. As runoff coefficient is important to count the runoff losses due to spillage, leakage, infiltration, catchment surface wetting and evaporation. Runoff is the water that flows away from the catchment after rainfall and depends upon the surface features, area and type of the catchment over which it falls. Therefore, runoff coefficient for any catchment is the value that represents the ratio of runoff to rainfall. Hence, depend on certain parameters such as material use in roof or catchment construction, slope, soil type, land use, degree of imperviousness, surface roughness and duration and intensity of rainfall. Runoff coefficient of various surfaces is given in Table 1.

Table 1: Runoff coefficient of various surfaces

Catchment variety	Surface types	Runoff co-efficient
Roof catchment	Tiles	0.8 - 0.9
	Corrugated metal sheets	0.7 – 0.9
	concrete	0.70 – 0.95
Ground surface covered with	Soil slope (<10%)	0.0 – 0.3
	Rocky material catchment	0.2 – 0.5
	Brick pavement	0.70 – 0.85
	playgrounds	0.2 - 0.35

(Source: CPWD, 2002)

DESIGN CONSIDERATIONS FOR EXAMPLE: RAINWATER HARVESTING SYSTEM DESIGN – VALSAD, GUJARAT

📍 **Location: Valsad, Gujarat**

- **Average Annual Rainfall:** ~1900 mm (source: IMD data)
- **Roof Catchment Area:** 100 m² (assumed residential RCC roof)
- **Runoff Coefficient (RCC roof):** 0.85
- **Number of People in House:** 6
- **Non-potable water use per person/day:** ~50 liters (toilet flushing, gardening, cleaning)

✅ **Step 1: Calculate Annual Rainwater Potential**

Volume=Rainfall (m)×Catchment Area (m²)×Runoff Coefficient

$=1.9\times100\times0.85=161.5\ m^3/year=161{,}500$ liters/ year

✅ **Step 2: Estimate Water Demand**

Daily demand=6 persons×50=300 liters/day Annual demand=300×365=109,500 liters/year

So, the harvested water (161,500 L/year) exceeds the estimated annual non-potable demand.

✅ **Step 3: Determine Optimal Tank Size**

Tank size depends on:

- Distribution of rainfall (monsoon-heavy)
- Storage for 2–3 months to bridge dry periods

📌 **Assume: 90 days of dry period storage**

Tank Volume=300 L/day×90 days=27,000 liters

▯ **Tank Design Specifications**

- **Volume:** 27,000 liters = 27 m³
- **Shape:** Cylindrical underground or overground tank
- **Formula for cylindrical volume:**

$$V=\pi r^2 h$$

📐 **Assume height h = 2.0 meters**

$27=3.1416\times r^2\times2\Rightarrow r^2=27/6.2832=4.295\Rightarrow r\approx2.07m$

Tank Dimensions:

- Radius = 2.1 m
- Height = 2.0 m
- Diameter = 4.2 m
- 🔧 System Components

Component	Specification
Catchment	100 m² RCC flat roof
Conveyance	PVC gutter (150 mm dia)
First flush	Manually operated valve (20-30 liters)
Filtration	3-layer filter: sand, charcoal, gravel
Storage tank	27,000-liter RCC or HDPE tank
Overflow	Connected to recharge pit or drain

CONCLUSION

Rainwater harvesting seems to be a beneficial method for minimizing water scarcity in developing countries. It is essential that local materials and man power is to be used to spot catchment areas and build up harvesting systems. For agricultural use most of the harvested water can be stored underground in natural systems protecting it from evaporation. On the other hand, bacteria and hazardous substances requiring a vigilant choice of the catchment area may pollute rainwater harvested for domestic use. For disinfection purposes there are many techniques available, some of these utilizing natural sources such as solar energy. GIS technology might enhance locating potential areas for RWH.

With Valsad's high annual rainfall (~1900 mm), a household with a 100 m² roof can harvest enough rainwater to meet its non-potable needs. A **27,000-liter tank** is sufficient to cover about 3 months of dry season storage. This system not only conserves water but also reduces municipal load and encourages sustainability.

A well-designed rainwater harvesting system can play a crucial role in sustainable water management. This study demonstrates that with accurate data and cost-effective materials, RWH can be widely adopted in urban residential areas. Future work should include real-time monitoring and integration with smart water systems. Rainwater harvesting is a viable, eco-friendly solution for water sustainability. Proper design tailored to local conditions ensures maximum efficiency and cost-effectiveness. Integration with other water management strategies can further enhance resilience to climate-induced water stress.

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