Precision-Driven Rooftop Rainwater Harvesting Framework for Enhancing the Resilience of Himachal Pradesh Jal Shakti Vibhag Water Supply Schemes to Seasonal Water Deficits

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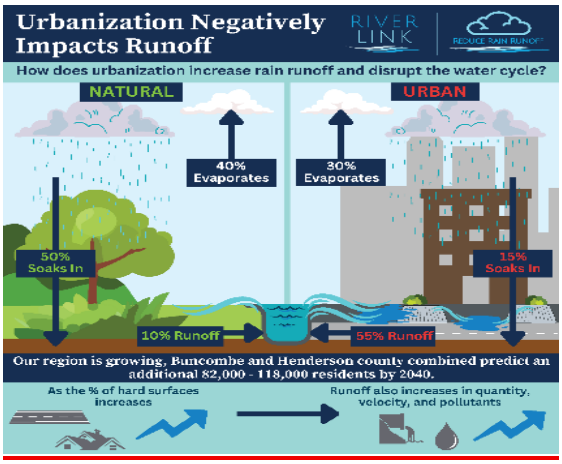
***Abstract*—Water security has emerged as a critical challenge in hilly regions where domestic water availability is increasingly affected by population growth, urbanization, climate variability, and growing dependence on centralized water supply systems. In Himachal Pradesh, households frequently experience water shortages during lean and non-monsoon periods despite receiving considerable annual rainfall. The seasonal nature of rainfall, combined with limited household-level planning, has resulted in inefficient utilization of available water resources, thereby increasing pressure on conventional supply systems.**

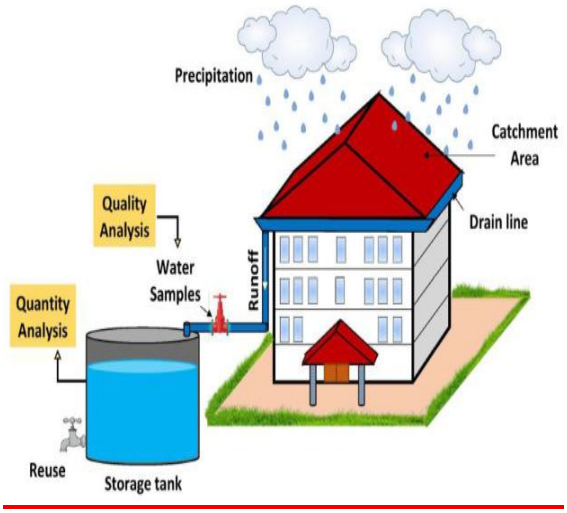
A substantial portion of rainwater received in residential areas of Himachal Pradesh remains unutilized at the household level. Rainwater falling on rooftops, open courtyards, and paved surfaces generally flows directly into nearby khads, streams, and rivers due to steep slopes and hilly terrain. In the absence of systematic capture and storage practices, this naturally available resource is lost as surface runoff. Consequently, residents continue to rely heavily on the public water supply and regularly demand increased water provision from the Jal Shakti Vibhag for daily domestic needs, even during years of normal or above-average rainfall.

This study presents an integrated domestic rainwater utilization framework aimed at enhancing sustainable water security at the household level. The proposed framework emphasizes planned capture, storage, and utilization of rainwater within residential premises, with a focus on non-potable daily applications such as kitchen gardening, cleaning, washing, toilet flushing, and other household chores. By storing rainwater received during monsoon months and utilizing it throughout the year, households can significantly reduce their dependence on conventional water sources. The study further highlights that effective domestic rainwater utilization does not necessarily require complex or high-cost infrastructure. Instead, improved awareness, simple planning strategies, and decentralized household-level adoption can transform rainwater from an unused runoff into a reliable supplementary resource. The proposed framework offers a practical, region-specific, and sustainable approach for strengthening domestic water resilience in hilly areas. It also contributes to reducing long-term stress on public water supply agencies and supports the broader goal of sustainable water management in Himachal Pradesh.

***Index Terms*—Rainwater Utilization, Domestic Water Management, Sustainable Water Security, Household Water Systems, Rainwater Runoff, Decentralized Water Resources, Hilly Regions, Himachal Pradesh.**

I. INTRODUCTION





Water security has become an increasing concern in hilly regions due to rising population, changing consumption patterns, climate variability, and growing dependence on centralized water supply systems. In Himachal Pradesh, domestic water availability is highly seasonal and largely dependent on monsoon rainfall. Despite receiving considerable annual rainfall, many households experience water shortages during non-monsoon periods, indicating inefficiencies in household-level water utilization and storage practices.

Himachal Pradesh receives an average annual rainfall of approximately 1,200–1,300 mm, with the majority occurring during the southwest monsoon season. Due to steep slopes and hilly terrain, a large proportion of this rainfall is lost as surface runoff. Rainwater falling on rooftops, courtyards, and paved residential areas is rapidly conveyed into local khads, streams, and rivers without serving any productive domestic purpose. This runoff-dominated hydrological response results in significant loss of a naturally available water resource at the household level.

To illustrate the magnitude of this loss, a typical residential house with a roof catchment area of about 150 m² can receive nearly 1.25 m of rainfall annually. This corresponds to approximately 187,500 litres of rainwater per year. Considering a conservative runoff coefficient of 0.8 for sloped rooftops, nearly 150,000 litres of rainwater per household per year can be made available for domestic use. However, in the absence of planned storage and utilization systems, most of this water is lost as runoff and remains unused.

Despite the availability of this substantial quantity of rainwater, households continue to depend heavily on public water supply systems and frequently demand increased water provision from the Jal Shakti Vibhag for daily domestic needs. This situation reflects a clear mismatch between locally available rainfall and its effective utilization at the household scale. If systematically stored, the available rainwater could meet a significant portion of non-potable daily requirements such as kitchen gardening, cleaning, washing, and other household chores throughout the year.

This study proposes an integrated domestic rainwater utilization framework tailored to the geographical and climatic conditions of Himachal Pradesh. The framework emphasizes reducing rainwater losses due to runoff and promoting household-level utilization to enhance sustainable water security. By integrating rainwater into everyday domestic water management practices, the proposed approach aims to reduce dependency on conventional water supply systems and strengthen long-term household water resilience in hilly regions.

II. MEANING

2.1. Integrated

Elaborated Meaning: The term integrated refers to a holistic and interconnected approach in which rainwater is not treated as an isolated or temporary resource, but as a planned and coordinated component of the overall household water system. Instead of viewing rainwater only during the rainy season or as excess water to be drained away, integration means linking rainfall with collection, storage, and utilization in a systematic manner.

In the context of this paper: Integration implies that rainwater is considered alongside existing water sources such as piped supply and springs. The approach combines physical components (roof catchment, storage structures, distribution within the house) with planning aspects (seasonal rainfall, household demand, annual usage pattern). This ensures that rainwater contributes meaningfully to domestic water needs throughout the year rather than being wasted as runoff during monsoon months.

2.2 Domestic

Elaborated Meaning:The term domestic specifically relates to water use at the household level. It excludes industrial, large-scale agricultural, or commercial applications and focuses entirely on everyday water requirements within residential premises.

In the context of this paper: Domestic use includes water required for household chores such as cleaning, washing clothes, mopping floors, toilet flushing, and kitchen gardening. The emphasis is on typical homes in villages and towns of Himachal Pradesh, where water demand is modest but continuous. By limiting the scope to domestic use, the study remains practical, realistic, and easily adoptable by common households.

2.3. Rainwater

Elaborated Meaning: Rainwater refers to precipitation received during different seasons, especially during the monsoon. It is a naturally occurring freshwater resource that is renewed every year and does not require extraction from underground or diversion from rivers.

In the context of this paper: Rainwater mainly refers to rainfall received on rooftops, courtyards, and residential open spaces. In Himachal Pradesh, this rainwater currently flows rapidly into local streams and rivers due to steep slopes and lack of storage. The paper treats rainwater as a valuable but underutilized resource that can supplement household water needs if managed properly.

2.4. Utilization

Elaborated Meaning: Utilization means purposeful, planned, and efficient use of a resource. It is not limited to availability but emphasizes actual consumption in a meaningful manner.

In the context of this paper: Rainwater utilization implies that rainwater is captured, stored, and used to meet daily household requirements instead of being allowed to flow away unused. It highlights a shift from passive drainage of rainwater to active use, ensuring that the water contributes to reducing demand on conventional sources.

2.5. Framework

Elaborated Meaning: A framework is a structured conceptual model that provides guidance on how different components work together. It does not necessarily involve complex technology but offers a logical arrangement of processes.

In the context of this paper: The framework outlines how rainfall, household catchment area, storage capacity, and domestic water demand are interconnected. It serves as a guiding model for households, planners, and policymakers to understand how rainwater can be systematically incorporated into domestic water management in hilly regions.

2.6. Sustainable

Elaborated Meaning: Sustainability refers to practices that meet present needs without compromising the ability of future generations to meet their own needs. In water management, it means using water resources responsibly, efficiently, and in an environmentally friendly manner.

In the context of this paper: Sustainable rainwater utilization reduces excessive dependence on groundwater and centralized supply systems, minimizes environmental stress, and ensures long-term water availability. It also promotes self-reliance at the household level and reduces recurring water scarcity problems.

2.7. Water Security

Elaborated Meaning: Water security refers to the reliable availability of adequate quantities of water of acceptable quality for health, livelihoods, and daily activities.

In the context of this paper: Domestic water security means households having sufficient water throughout the year, including dry seasons, without frequent shortages or dependence on emergency supply. Rainwater utilization enhances water security by acting as a supplementary and dependable source.

2.8. Rainwater Runoff Loss
Elaborated Meaning: Runoff loss refers to rainwater that flows over surfaces and leaves the residential area without being stored or used.
In the context of this paper: In Himachal Pradesh, steep slopes cause rainwater to quickly drain into rivers. This runoff represents a major loss of usable water at the household level, even though the same households face shortages later.

2.9. Household-Level Non-Utilization
Elaborated Meaning: Non-utilization means the absence of mechanisms or practices to use available rainwater at the household scale.
In the context of this paper: Despite receiving enough rainfall annually, households lack storage structures and planning, leading to complete dependence on external water supply agencies.

2.10. Dependence on Centralized Water Supply
Elaborated Meaning: Centralized water supply refers to water provided by government agencies through pipelines and distribution networks.
In the context of this paper: Households in Himachal Pradesh heavily depend on the Jal Shakti Vibhag, repeatedly demanding more water even though rainwater potential exists locally.

2.11. Annual Rainwater Potential
Elaborated Meaning: Annual rainwater potential is the total quantity of rainwater that can be received over one year.
In the context of this paper: For a typical 150 m² roof, this potential is about 1.5 lakh litres per year, which is sufficient to support many domestic needs if stored and used efficiently.

2.12. Non-Potable Domestic Applications
Elaborated Meaning: Non-potable uses are applications that do not require drinking-quality water.
In the context of this paper: Using rainwater for cleaning, washing, and gardening is safe, practical, and significantly reduces pressure on treated water supplies.

2.13. Hilly Terrain Influence
Elaborated Meaning: Hilly terrain affects rainfall behavior, runoff speed, and storage possibilities.
In the context of this paper: The steep slopes of Himachal Pradesh accelerate runoff and increase water loss, making household-level rainwater utilization especially important.

III. HISTORICAL CONTEXT OF RAINWATER UTILIZATION IN HIMACHAL PRADESH

Historically, communities in Himachal Pradesh developed localized and sustainable practices to manage rainwater and natural water sources in response to the region's hilly terrain and seasonal rainfall. Before the expansion of centralized water supply systems, households and villages relied on a combination of rainwater, springs, small streams, and traditional storage structures to meet their daily domestic needs. These practices evolved over generations and were well adapted to the local geography and climatic conditions.
Traditional water management systems in Himachal Pradesh included the use of stone-lined tanks, ponds, step structures, and spring protection methods that helped retain rainwater and recharge local sources. In many villages, rainwater falling on rooftops and open areas was guided into storage tanks or allowed to percolate slowly into the ground, ensuring water availability during dry periods. These systems emphasized conservation, reuse, and shared responsibility, making communities relatively self-reliant in terms of domestic water supply.
With the introduction of modern piped water supply schemes during the late twentieth century, reliance on traditional rainwater-based practices gradually declined. The expansion of centralized water distribution networks, managed by government agencies such as the Jal Shakti Vibhag, led to a perception that water scarcity could be addressed solely through external supply. As a result, household-level rainwater storage systems were neglected or abandoned, and rainwater began to be viewed as excess runoff rather than a usable resource.
Urbanization, changing housing patterns, and the construction of paved surfaces further accelerated rainwater runoff in both rural and urban settlements. Rooftop rainwater that was earlier stored or slowly absorbed into the ground now flows directly into drains, streams, and rivers. Over time, this shift reduced household resilience to seasonal water

shortages and increased dependence on centralized water supply systems.

In recent years, increasing water demand, declining spring discharge, and climate variability have exposed the limitations of exclusive dependence on centralized water supply. The recurring demand for additional water supply during dry seasons reflects a disconnect between historical water wisdom and present-day practices. Revisiting traditional rainwater utilization principles and integrating them with modern household systems provides an opportunity to restore balance between rainfall availability and domestic water demand.

Thus, the historical context highlights that rainwater utilization is not a new concept in Himachal Pradesh but a rediscovery of traditional knowledge adapted to contemporary needs. Building upon this historical understanding forms a strong foundation for developing an integrated domestic rainwater utilization framework aimed at achieving sustainable water security.

IV. FACTORS AFFECTING DOMESTIC RAINWATER UTILIZATION IN HIMACHAL PRADESH

4.1. Hilly Terrain and Steep Slopes:

The mountainous topography of Himachal Pradesh is one of the most significant factors affecting rainwater utilization. Steep slopes cause rainwater to flow rapidly over rooftops, courtyards, and roads, leaving little opportunity for natural retention. Unlike plain areas where water can stagnate or percolate slowly, hilly terrain accelerates runoff, resulting in immediate loss of rainwater to khads and rivers. This natural condition makes household-level planning for rainwater storage more critical, yet also more challenging.

4.2. Monsoon-Dominated Rainfall Pattern:

Rainfall in Himachal Pradesh is highly seasonal, with a large proportion occurring during a short monsoon period. Intense rainfall events over limited durations generate excess runoff, while extended dry periods follow during winter and pre-monsoon months. Due to this uneven temporal distribution, rainwater is often perceived as abundant only for a short time and scarce for the rest of the year. Without proper storage planning, households fail to utilize monsoon rainwater for year-round domestic needs.

4.3. Absence of Household-Level Storage Infrastructure:

A major factor contributing to rainwater loss is the lack of dedicated storage structures at the household level. Many residential buildings do not include rainwater storage tanks or provisions for collecting rooftop runoff. Existing houses, especially in older settlements, were not designed with integrated rainwater utilization in mind. As a result, even though significant quantities of rainwater fall on rooftops annually, it is immediately discharged into drainage systems.

4.4 Increasing Dependence on Centralized Water Supply:

The expansion of piped water supply systems managed by the Jal Shakti Vibhag has reduced household motivation to adopt rainwater utilization practices. Easy access to piped water has created a perception that domestic water needs can always be met through external supply. This dependence discourages households from investing in rainwater storage, even when supply systems face shortages during dry seasons.

4.5. Lack of Awareness and Technical Knowledge:

Many households are unaware of the quantity of rainwater that can be collected from their rooftops or its potential contribution to daily domestic needs. Limited technical knowledge regarding simple storage methods, space requirements, and usage planning further restricts adoption. As a result, rainwater is often viewed as insignificant or unsuitable for domestic use, despite its substantial availability.

4.6. Urbanization and Changing Housing Patterns:

Rapid urbanization in hill towns has led to increased construction of paved surfaces, multi-storey buildings, and concrete roads. These developments reduce natural infiltration and increase surface runoff. Traditional open spaces that once allowed water retention have been replaced by impermeable surfaces, further limiting opportunities for rainwater utilization at the household level.

4.7. Policy and Institutional Gaps:
Although rainwater harvesting is promoted at policy levels, implementation at the household scale remains limited. Lack of mandatory provisions in building by-laws, insufficient incentives, and weak monitoring mechanisms reduce the effectiveness of rainwater utilization initiatives. The absence of integrated planning between household practices and public water supply systems further contributes to underutilization.

4.8. Perception of Rainwater as a Secondary Resource:
Culturally and behaviourally, rainwater is often considered an emergency or secondary source rather than a planned domestic resource. This perception leads households to prioritize conventional supply systems and ignore rainwater potential, even when annual rainfall is sufficient to meet a significant portion of domestic demand.

Summary of Factors:
In summary, domestic rainwater utilization in Himachal Pradesh is constrained by natural terrain conditions, seasonal rainfall patterns, inadequate storage infrastructure, behavioural factors, and institutional limitations. Addressing these factors through integrated household-level planning and awareness is essential for transforming rainwater from an unused runoff into a reliable component of sustainable domestic water security.

V. RESEARCH OBJECTIVES

The present study aims to examine the potential and practical application of rainwater utilization at the household level in hilly regions. Increasing population pressure, irregular water supply, and climate variability have created significant challenges for domestic water availability in mountainous regions. In this context, rainwater harvesting and utilization can serve as an important supplementary source of water for households.
The specific objectives of this study are:

1. To assess the rainwater harvesting potential at the household level in selected hilly regions of Himachal Pradesh.
2. To analyze the relationship between annual rainfall availability and domestic water demand in rural and semi-urban households.
3. To identify the key factors influencing the adoption of rainwater utilization systems in residential areas.
4. To develop an integrated framework for domestic rainwater utilization that can enhance household water security.
5. To examine the role of rainwater harvesting in **reducing dependence on centralized water supply systems operated by the Jal Shakti Vibhag.

These objectives collectively aim to contribute to sustainable water management practices in hilly regions.

VI. RESEARCH METHODOLOGY

This study adopts a mixed-method research approach, combining quantitative analysis with qualitative observations to understand the potential and practicality of rainwater utilization in domestic settings.

6.1 Study Area
The study focuses on selected settlements located in the mountainous terrain of Himachal Pradesh. The region is characterized by steep slopes, dispersed settlements, and significant seasonal rainfall. Despite receiving considerable precipitation during the monsoon season, many households face water shortages due to inadequate storage infrastructure and dependence on centralized supply systems.
The primary domestic water supply in these areas is generally managed by the Jal Shakti Vibhag, which distributes water through gravity-based or pumped supply systems. However, irregular supply, increasing demand, and infrastructural limitations often result in water scarcity.

6.2 Data Collection
The research relies on both primary and secondary data sources.
Primary Data
Primary data were collected through:

- Household surveys to understand water consumption patterns.
- Field observations of roof structures and water storage facilities.
- Informal interviews with local residents regarding water availability and coping strategies.
- Discussions with technical staff associated with

the Jal Shakti Vibhag regarding supply conditions.

These methods helped in assessing the feasibility of rainwater harvesting systems at the household level.

Secondary Data

Secondary data were obtained from:

- Meteorological rainfall records
- Government reports
- Water supply statistics
- Academic research publications on rainwater harvesting

These sources helped estimate rainfall potential and evaluate water demand trends.

6.3 Estimation of Rainwater Harvesting Potential

The potential volume of rainwater that can be collected from rooftops was estimated using the standard rainwater harvesting formula:

$$R = A \times R_f \times C$$

Where:

- R = Annual rainwater harvesting potential (litres)
- A = Roof catchment area (square meters)
- Rf = Annual rainfall (meters)
- C = Runoff coefficient (generally between 0.75 and 0.85 for rooftops)

For example, a house with a roof area of 150 m² receiving 1.25 meters of annual rainfall with a runoff coefficient of 0.8 could potentially collect approximately 150,000 litres of rainwater annually.

This estimation provides a basic understanding of the quantity of rainwater that can be captured and utilized for domestic purposes.

Based on the estimated annual rooftop rainwater potential of approximately 150,000 litres per household, it is necessary to determine an appropriate storage capacity that can support domestic water requirements during dry periods. Considering average household water consumption for non-potable uses and the supplementary water supply provided by the Jal Shakti Vibhag, a storage tank capacity of approximately 45,000 litres is proposed.

This capacity allows households to effectively capture monsoon rainfall and utilize it gradually during low rainfall periods while complementing the piped water supply system.

Table: Household Rainwater Storage and Water Supply Balance

Parameter	Value	Source / Explanation
Average annual rainfall in plains of HP	1200–1300 mm	Regional rainfall data
Average roof catchment area	150 m²	Typical residential house
Runoff coefficient	0.8	Standard rooftop runoff factor
Total annual rainwater potential	~150,000 litres	Rainfall × area × runoff
Household size	5 persons	Average family
Daily non-potable demand	500–600 L/day	Bathing, washing, cleaning, flushing
Monthly household demand	~15,000–18,000 L	Calculated from daily demand
Jal Shakti Vibhag supply	~70 LPCD/person	Typical rural water supply norms
Household water from Jal Shakti	~350 L/day	Partial household requirement
Remaining water requirement	~250 L/day	Can be supplied from rainwater storage
Recommended tank capacity	45,000 litres(12x12x10ft)	Provides ~4 months supplementary supply

Interpretation

Water Source	Contribution
Jal Shakti piped supply	~350 L/day
Rainwater storage	~250 L/day
Total household supply	~600 L/day

A 45,000 L tank can supply:

45,000 ÷ 350 ≈ 128 days (≈ 4 months) of supplementary household water.

VII. PROPOSED INTEGRATED DOMESTIC RAINWATER UTILIZATION FRAMEWORK

The study proposes an integrated household rainwater utilization framework designed to maximize rainwater collection and ensure efficient domestic use. The framework consists of several interconnected

components.

7.1 Rainwater Collection

Rainwater can be collected primarily from rooftop surfaces, which act as effective catchment areas. Sloped roofs commonly found in mountainous regions provide efficient runoff channels that can direct rainwater into collection systems.

Additional catchment sources may include courtyards and paved surfaces that allow runoff water to be diverted into storage tanks.

7.2 First-Flush Mechanism

The first rainfall event typically carries dust, leaves, and other contaminants accumulated on roof surfaces. A first-flush diverter system is therefore recommended to remove this initial contaminated water before directing cleaner rainwater into storage tanks.

This improves the overall quality of stored rainwater and reduces the need for extensive filtration.

7.3 Storage Infrastructure

Rainwater storage is a critical component of the system. Households may adopt different types of storage structures depending on available space and financial capacity. Common storage options include:

- Underground storage tanks
- Surface tanks
- Ferrocement tanks
- Modular plastic tanks

Proper storage allows households to conserve rainwater during the monsoon season for use during dry periods.

7.4 Household Distribution and Utilization

Stored rainwater can be used for several non-potable domestic activities, including:

- Toilet flushing
- Washing clothes
- Cleaning and floor washing
- Gardening and irrigation
- Vehicle washing

Utilizing rainwater for these purposes can significantly reduce the demand for treated potable water.

7.5 Overflow and Recharge Management

When storage tanks reach capacity during heavy rainfall events, excess water can be diverted to:

- Recharge pits
- Percolation tanks
- Small infiltration trenches

These structures help replenish groundwater resources and prevent water wastage.

VIII. HOUSEHOLD WATER DEMAND ANALYSIS

Understanding domestic water consumption is essential for evaluating the feasibility of rainwater utilization.

In typical rural households, water is used for various daily activities such as cooking, washing, cleaning, sanitation, and gardening. However, a significant proportion of water is required for non-drinking purposes, which can be effectively substituted with harvested rainwater.

An approximate estimate of household water use is shown below:

Household Activity	Average Daily Water Requirement
Cleaning and floor washing	20–30 litres
Clothes washing	40–60 litres
Toilet flushing	30–50 litres
Kitchen gardening	20–40 litres

Thus, the total daily demand for non-potable activities may range between 100 and 150 litres per household. If rainwater is effectively stored and utilized, a considerable portion of this demand can be met without relying entirely on external water supply systems.

IX. RESULTS AND DISCUSSION

The findings of this study indicate that households located in high rainfall regions possess considerable potential for rainwater harvesting. The estimated volume of rainwater collected from rooftops is often sufficient to meet a substantial portion of non-potable household water requirements.

By adopting simple storage and distribution mechanisms, households can significantly reduce their dependence on municipal water supply networks operated by the Jal Shakti Vibhag.

Moreover, rainwater utilization contributes to multiple

environmental benefits, including:

- Reduction in surface runoff
- Decreased pressure on groundwater resources
- Improved resilience against seasonal water shortages
- Promotion of sustainable water management practices

However, certain challenges remain, including lack of awareness, financial constraints, and absence of proper technical guidance.

X. POLICY IMPLICATIONS

The results of this study highlight the importance of integrating rainwater harvesting practices into local water management policies.

Government agencies and local institutions should promote household-level rainwater utilization through supportive policy frameworks. Measures such as financial incentives, technical assistance, and awareness campaigns can encourage households to adopt rainwater harvesting systems.

Furthermore, building regulations in hilly regions should incorporate mandatory rooftop rainwater harvesting provisions to ensure that new constructions utilize available rainfall effectively.

Active involvement of departments such as the Jal Shakti Vibhag can help scale up implementation and improve water security in vulnerable regions.

XI. CONCLUSION

The findings of this study highlight the significant potential of rainwater harvesting as an effective and sustainable strategy for enhancing domestic water availability in mountainous regions. Areas such as Himachal Pradesh receive considerable annual precipitation, with average rainfall ranging between 1,000 mm and 1,500 mm in many districts. Despite this relatively high rainfall, a large proportion of households continue to face seasonal water shortages due to inadequate storage infrastructure, inefficient rainwater utilization practices, and increasing dependence on centralized water supply systems.

This study demonstrates that rooftop rainwater harvesting systems can yield substantial water volumes at the household level. For a typical residential roof of 120–150 m² in regions with ~1,250 mm annual rainfall and a runoff coefficient of 0.75–0.80, potential harvest ranges from 110,000–150,000 litres per year. This volume can fulfill a significant portion of non-potable domestic needs, such as cleaning, washing, sanitation, and gardening, thereby alleviating pressure on municipal supplies from agencies like the Jal Shakti Vibhag and bolstering household water security during dry seasons. Given the estimated ~150,000 litres annual potential per household, a 45,000-litre storage tank is recommended to meet non-potable demands, supplemented by Jal Shakti Vibhag supplies, ensuring reliable usage in arid periods.This capacity allows households to effectively capture monsoon rainfall and utilize it gradually during low rainfall periods while complementing the piped water supply system.

The integrated domestic rainwater utilization framework proposed in this study offers a practical and scalable approach for maximizing the capture, storage, and utilization of rainwater at the household level. By incorporating key components such as rooftop catchment systems, first-flush mechanisms, storage tanks, and controlled distribution systems, households can effectively manage rainfall resources that would otherwise be lost as surface runoff. Moreover, the implementation of overflow management systems such as recharge pits and infiltration trenches can contribute to groundwater replenishment and improved hydrological balance in mountainous ecosystems.

Beyond its technical feasibility, rainwater harvesting also offers several environmental and socio-economic benefits. It can help reduce pressure on groundwater resources, decrease energy consumption associated with water pumping and distribution, and improve resilience to climate variability and changing rainfall patterns. Furthermore, decentralized rainwater utilization promotes community-level water management practices and encourages greater awareness of sustainable resource use.

However, the adoption of rainwater harvesting systems in many regions remains limited due to factors such as lack of awareness, financial constraints, and insufficient technical guidance. Therefore, policy interventions and institutional support are essential to promote widespread implementation. Government authorities should consider incorporating mandatory rainwater harvesting provisions within building regulations, particularly in high rainfall and water-

stressed regions. In addition, financial incentives, subsidies for storage infrastructure, and technical training programs can encourage households to adopt rainwater harvesting systems.

Community participation and awareness campaigns are equally important for ensuring the long-term success of such initiatives. Educational programs and demonstration projects can help illustrate the economic and environmental benefits of rainwater utilization, thereby motivating households to adopt sustainable water management practices.

In conclusion, rainwater harvesting represents a viable and sustainable solution for addressing domestic water challenges in mountainous regions. When supported by appropriate policy measures, technological interventions, and community engagement, household-level rainwater utilization can significantly enhance water security and contribute to the broader goals of sustainable water resource management in regions such as Himachal Pradesh.

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