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Feasibility of Roof Top Rainwater Harvesting Potential (RTRWH)

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Abstract: *Shortage of water sources has been a major problem for rapidly growing cities in countries like India due to an increase in water consumption. Besides this, coastal cities like Mangaluru are currently challenged by temporary floods due to increased precipitation. Hence, it demands flawless planning for managing water resources. Rooftop Rainwater Harvesting (RTRWH) has proven to be the most economical and environmentally friendly method*

Keywords: Rainwater harvesting, Rooftop rainwater harvesting, Rainwater management, Sustainable campus, Green campus.

I. INTRODUCTION

For the survival of any living being on Earth, water is one of the most important resources—just as vital as food and air. It plays a crucial role in the development of communities as well as in economic and social activities. Unfortunately, not enough attention is given to conserving this precious resource

To address these challenges and ensure a backup plan for water requirements, systems must be developed to conserve storm water, which could help resolve many water scarcity issues. Excessive use of groundwater through over-pumping has caused groundwater levels to drastically decline in many regions. If this issue is not addressed, future generations may face severe water shortages.

Rainfall is the primary source of potable water. Therefore, harvesting rainwater can significantly reduce—and even eliminate—water scarcity issues. It is a well-known fact that rainwater collection and storage have been practiced for centuries (Khaleq and Ahmed, 2007). Rainwater harvesting is a technique that captures, stores, and reuses rainwater for various purposes (Stec and Kordana, 2015).

Various studies have recommended using harvested storm water for domestic and landscape purposes (Abdulla and Al-Shareef, 2009). Research conducted by Sturm et al. (2009) demonstrated the economic and technical feasibility of rainwater harvesting systems. Marlow et al. (2013) critically reviewed sustainable urban water resource management by evaluating its advantages and limitations.

An advanced, modified technique of decentralized water management—which combines grey water recycling with rainwater harvesting—has been examined for densely populated cities (Zhang et al., 2009). This study reported positive outcomes and improved water resource management. Similarly, several other studies have emphasized the importance of adopting rainwater harvesting techniques on both small scales (individual dwellings) and large scales (cities or towns).

A typical rooftop rainwater harvesting system consists of various elements that convey storm water through pipes or drains, collecting it from the catchment area into storage tanks. During the first rain event, the initial flow of storm water is flushed out of the system to prevent contaminants from entering the storage tank.

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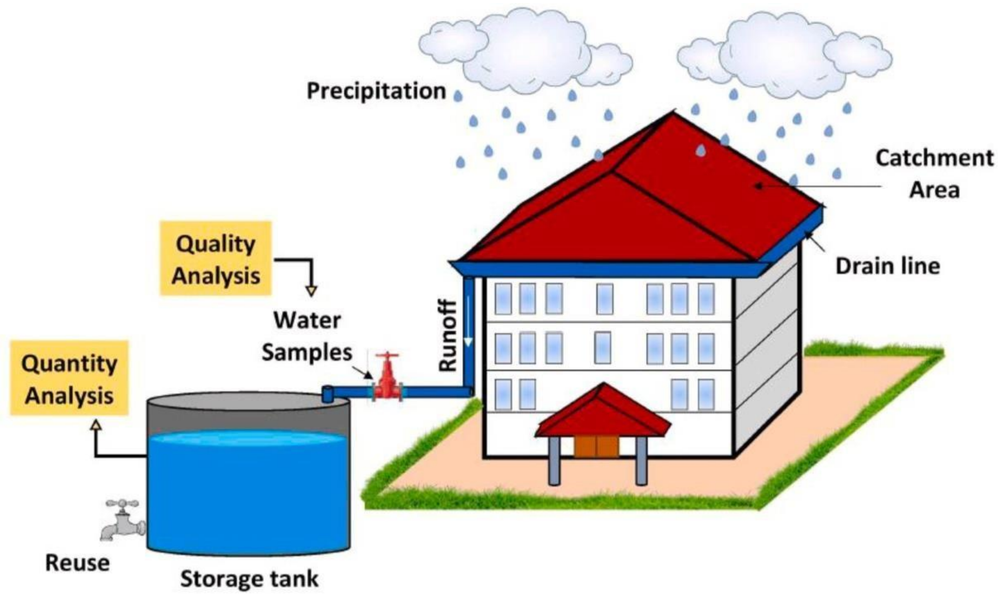

II. STUDY AREA

The South Indian University (SIU) is located in Mangalagangothri, approximately 20 km southeast of Mangaluru city at coordinates 12.9141°N, 74.8560°E. The campus covers 353 acres and is situated overlooking the Netravathi River to the west and the Western Ghats to the east.

Since its establishment as an independent university in 1980, SIU has grown significantly, evolving into a self-sustained institution that excels in higher education. The campus houses various facilities such as:

- Administrative Block
- Science Block
- Central Library
- Student Hostels (Boys & Girls)
- Staff Quarters
- Microtone Centre
- Humanities Block
- Cooperative Society
- Instrumentation Centre
- Sports Complexes

A Google Map depicting various zones of establishments within the campus is shown in Fig. 2.

The campus terrain is laterite in nature, with highly undulated ground surfaces. The highest recorded altitude is 119.24 meters, while the lowest point is 56.78 meters across the campus.

Water Source and Supply System

The main source of water is the Netravathi River, located about 15 km from the SIU campus. The water transfer system consists of two stages of pumping and a gravity flow line stretching approximately 10 km. Upon arrival at the campus, the water undergoes a thorough treatment process, which includes aeration, seven stages of filtration, and clarification before being distributed across the campus.

On average, 1.4 million liters of water are received and treated daily at the treatment facility.

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III. METHODOLOGY

The step-wise methodology adopted for this study is illustrated in Fig. 3. Initially, a **preliminary field survey** was carried out to assess land characteristics and verify rooftop areas. The **rooftop catchment areas** were measured using remote sensing and GIS tools, cross-referenced with data from the SIU Engineering Department, and validated through field visits.

Subsequently, **representative storm water samples** were collected from rooftops of selected buildings. These were analyzed for various water quality parameters at the Environmental Engineering Laboratory, Department of Civil Engineering, Manipal Institute of Technology (MIT).

A **campus-wide population and water demand assessment** was conducted based on inquiry and records from the SIU water supply unit. Meteorological data, including rainfall from 2000–2014, were obtained from the Meteorological Department, Mangaluru.

Statistical analysis of the data was performed using IBM SPSS software. The **potential for rooftop rainwater harvesting (RTRWH)** was estimated using Equation (1), and the **mass curve method** was applied to design storage tank volumes. A detailed **economic analysis and rebate period** evaluation was also conducted to determine system feasibility.

Rainwater Harvesting Potential Equation:

Q=C×I×AQ = C \times I \times AQ=C×I×A

Where:

QQQ = Discharge volume (m³/s)

CCC = Runoff coefficient

III = Rainfall intensity (mm)

AAA = Rooftop catchment area (m²)

IV. RESULTS AND DISCUSSION

Preliminary Survey and Site Assessment

A comprehensive survey validated data from reliable sources and established rooftop harvesting potential based on 15 years of rainfall data. Suitable **tank installation sites** were proposed with basic design parameters.

Storm water Quality Analysis

Rainwater quality is influenced by **roofing materials**, **maintenance frequency**, and **local environment**. Fifteen samples were tested for pH, conductivity, TDS, TSS, calcium, magnesium, and chlorine (Table 4). The results showed water was within **IS 10500:2012 drinking water standards**, suggesting that only a **basic gravel-based filtration unit** is needed before storage.

Population and Water Demand

SIU campus hosts a mix of residents and approximately 1000 daily visitors. Detailed **population data** is provided .Monthly **water demand** was collected from the water supply department, with **staff quarters** consuming the most (7500 m³), followed by the Science Block, Ladies and Boys Hostels.

Rainfall Statistics

Rainfall data (2000–2014) revealed:

Average annual rainfall: ~3779.26 mm

High variability: Standard deviation = 334.33 mm

Peak rainfall: June & July (~1000 mm/month)

Dry season: April–May

Regression analysis on rainfall days showed a **declining trend** over years ($R^2 = 0.088$).

Effective Rooftop Area

Nineteen buildings were selected. Largest rooftop areas:

Staff Quarters: 11.1%

Boys Hostels: 9.6%

Science Block & Central Library: 8.5% each

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Detailed rooftop distribution

Rainwater Harvesting Potential

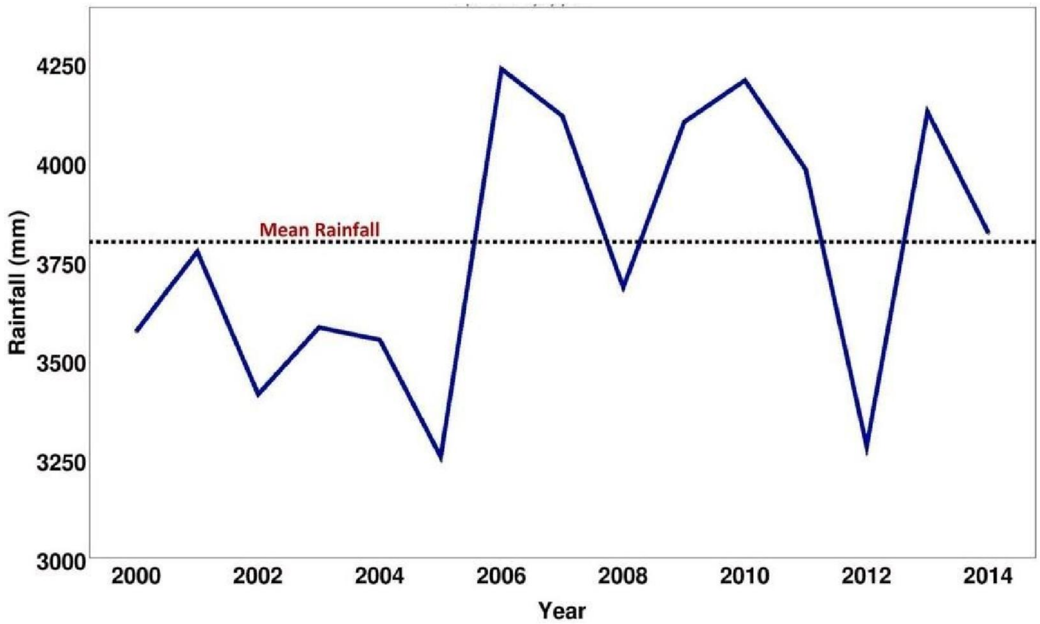
Based on historical monthly rainfall, the **highest RWH potential** occurred in:

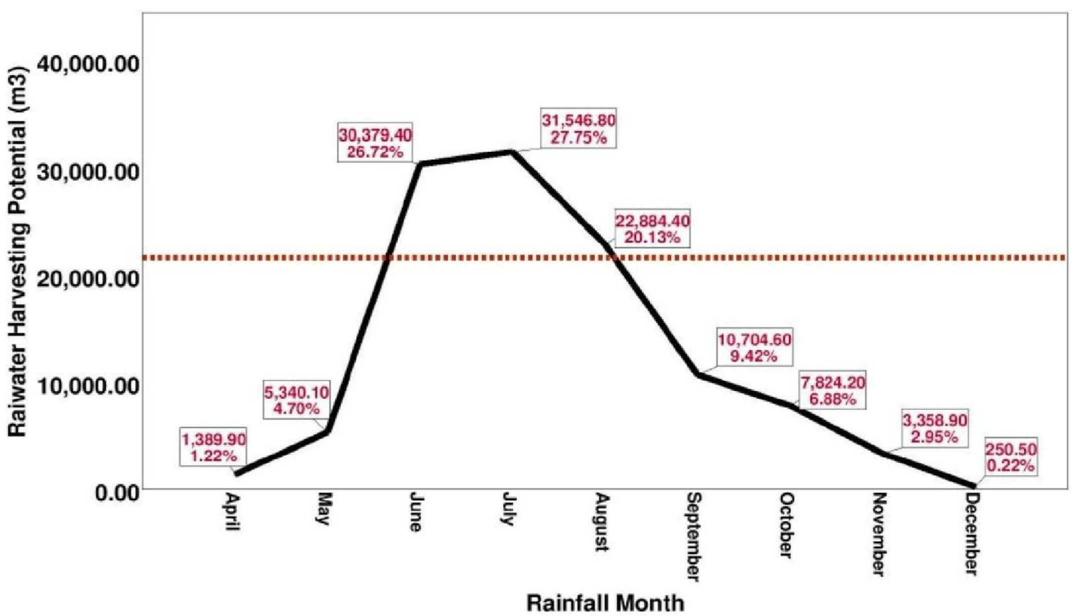
June: 26.72%

July: 27.75%

August: 20.13%

Staff quarters showed **maximum harvesting potential** (12,671.80 m³/year), followed by Boys Hostel (10,863.20 m³), Central Library (9708.70 m³), and Science Block (9612.40 m³). Full distribution is illustrated.





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Design of Storage Tanks

Storage volumes were optimized based on inflow and building-specific water demands. Seven tank locations were selected with **modular compartments** (2–4 per tank) for ease of maintenance Tanks were designed using **RCC and late rite stone**, with a **vertical gravel filtration system**.

Cost Estimation

Tank construction accounts for ~95% of project cost include:

- Construction materials
- Labor
- Waterproofing
- Land preparation

Tank Two and Seven had higher costs due to larger volume. Currently, **50HP and 100HP pumps** draw water daily from the Nethravathi River, costing ~₹3,59,160/month in electricity. With RWH supplementing 3 months of water use, the **payback period** is ~13 years (excluding maintenance).

Reuse of Harvested Water

Storm water can be reused for:

- **Gardening**
- **Washing**
- **Cleaning**

No complex treatment is required, though **testing for non-potable use** is essential. For **drinking or cooking**, conventional water sources or advanced treatment are recommended.

Total **garden water demand** is ~50,000 L/day. Harvested rainwater is suitable for garden irrigation, aided by gravity-based distribution. Overflow can be directed toward **groundwater recharge systems**, contributing to a **sustainable water management strategy**.

V. CONCLUSION

If hydrological opportunities are considered, the Rooftop Rainwater Harvesting (RTRWH) system is one of the supplementary systems to the conventional water supply method. The success rate of RTRWH in Mangaluru may be high, since rainfall is not extremely variable in the region. Therefore, precipitation plays a vital role in determining the efficiency of RWHS.

The present study illustrates the potential of implementing an RTRWH system on the South Indian University (SIU) campus using an Eco-geospatial RWHS for the community. Approximately 1, 13,678.9 m^3 of storm water can be captured from 19 selected building rooftops. A comprehensive quantitative and qualitative analysis of storm water and its rooftop harvesting potential is presented in this work. Additionally, the article provides insight into the economic aspects, including a rebate concept.

The cost of implementation is justifiable, as rainwater harvesting methodology for supplying good-quality water is a social responsibility, and a public institution is an ideal place to begin. While RWHS, like other technologies, has its merits and demerits, this method is particularly well-suited for the SIU campus, which currently depends on a long-distance pipeline from the Nethravathi River to meet its water needs.

Given that Mangaluru is one of the fastest-growing cities in the state, where water demand is increasing and groundwater levels are rapidly depleting, institutes like SIU — being part of the Smart City Program and an education hub — should serve as role models, potentially qualifying for the CII Award for Excellence in Rainwater Harvesting. This initiative could help SIU become self-sustainable in terms of water resources.

Rather than completely replacing the conventional water supply with RWH, it is advisable to use both systems in tandem. The centralized water supply should be synchronized with the decentralized RWHS. The captured storm water can be directly used for non-potable purposes such as gardening, cleaning, flushing, and washing. However, necessary quality analysis must be conducted to ensure safe usage for these purposes.

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From the cost estimation, the payback period for implementing RWHS is about 13 years. The cost of RWHS is directly dependent on storage capacity; hence a structured planning approach is essential before implementation. The majority of the designed storage tanks can effectively meet water demand for 2 to 3 months. Under such scenarios, RWHS is economically justified compared to the existing system.

In case of low rainfall, however, the RWHS may not yield economic benefits for the current study area. The University may also explore the possibility of capturing groundwater runoff and storing it in an open lake or pond, taking advantage of the existing terrain and pond within the campus.

Further, such RWH initiatives should be supported by government incentives to encourage adoption across sectors. Policies, water pricing, and promotional activities should be practical and effectively structured prior to implementation. Future work will include a detailed survey of water demand by activity, which will guide further efficiency improvements and complete cost estimation.

In conclusion, RTRWH is a simple, economical technique that is socially accepted and environmentally sustainable.

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