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Rainwater Harvesting for Sustainable Water Use

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ABSTRACT

The rainwater harvesting system is an innovative method based on green technology that is suitable for countries that receive high annual rainfall throughout the year. This system is also appropriate because heavy rainfall in large quantities will accelerate surface water flow. Rainwater harvesting is a solution to several water sustainability problems. It reduces the risk of water rationing and helps reduce the risk of flooding. This technology is inexpensive and easy to implement in both new and existing buildings. This paper aims to examine the sustainability of the rainwater harvesting system and its effectiveness in a project conducted in the residential area of Desa KEDA Singkir Badong, Kedah. The project was carried out using a short-term training method, both theoretical and practical, to make rural youth more skilled and innovative in producing sustainable products. This project also has the potential to solve water supply problems in areas experiencing low water pressure.

1. Introduction

Water security has become a critical issue worldwide, even in regions with abundant rainfall. Climate change, urban expansion, and inefficient water management have intensified the challenges of providing consistent and safe water access—particularly in developing countries. Malaysia, with its tropical climate and high annual rainfall, might appear water-rich; however, rural and semi-rural communities often experience inconsistent water supply, especially during peak usage periods. These challenges are worsened by infrastructure limitations, rapid population growth, and increasing demand from domestic, agricultural, and industrial sectors [1,2,4].

Water is a vital and irreplaceable natural resource, fundamental to life and human development. Its unique molecular properties make it an essential solvent, responsible for transporting oxygen, electrolytes, and nutrients in living organisms [1]. However, the management and use of water resources must be both efficient and sustainable. The experience of countries like India, where

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rainwater harvesting systems (RWHS) have been widely promoted to combat water scarcity, illustrates the importance of adopting alternative water strategies [3].

Rainwater harvesting is increasingly recognized as a viable solution to address water-related challenges. Compared to surface water or groundwater—which often suffer from contamination and depletion—rainwater offers a cleaner and more readily accessible resource for non-potable uses, such as flushing toilets, watering plants, and cleaning [10,11]. RWHS can be implemented in various settings, from small residential rooftops to large-scale institutional buildings such as airports, stadiums, and schools [9]. These systems contribute to water conservation, reduce surface runoff, and offer cost-effective alternatives to piped water [7,8].

In Malaysia, the rainwater harvesting system is regarded as a "Best Management Practice (BMP)" to reduce surface runoff while supplementing water supply needs [7]. Most RWHS are simple, cost-effective, and easy to maintain—making them ideal for rural communities. Components are locally available, and the system design can be adapted based on household size and available roof area [12-14]. However, harvested rainwater is typically used for non-potable purposes due to possible contamination [15].

While numerous studies have explored the technical aspects, environmental benefits, and water-saving potential of rainwater harvesting systems—particularly in urban and institutional settings—there remains a significant gap in the literature concerning their implementation in rural Malaysian communities. Specifically, there is limited focus on the integration of community education, youth empowerment, and long-term sustainability in small-scale, community-led RWH initiatives. Existing research often overlooks the socio-economic, behavioural, and maintenance challenges faced in rural settings where infrastructure and engagement levels differ markedly from urban contexts.

This study addresses that gap by evaluating the practical implementation, community response, and sustainability potential of a rainwater harvesting system in Desa KEDA Singkir Badong, Kedah. By combining technical installation with educational training and awareness programs, this research contributes a context-specific model that emphasizes community participation, youth skill development, and the viability of low-cost environmental solutions in underserved areas.

1.1 Project Area

The study area is located in the KEDA village of Badong Singkir, Yan, Kedah, which is a rural area. The village consists of 38 households, with a population of 367 people. The village receives clean water from Syarikat Air Darul Aman (SADA), but due to low water pressure, the water supply is often disrupted, particularly during peak demand periods.

Yan, a district in Kedah, is undergoing significant development challenges. The rapid population growth and the swift expansion of local municipalities are expected to bring about complex socio-economic and political issues. In this context, the Yan District Office plays a vital role in addressing these emerging challenges, with particular emphasis on managing water supply issues in areas like Kuala Kedah, Yan, and Merbok.

1.2 Project Objectives

The primary objectives of this project are as follows:

i. To encourage and educate people on how to use natural resources (rainwater) as efficiently and effectively as possible.
ii. To educate the public on methods to prevent natural resource waste and pollution.

iii. To create opportunities for local youth to engage in small-scale industry operations, such as the manufacturing of rainwater harvesting systems.
iv. To raise community awareness about the importance of protecting every water source.

2. Literature Review

2.1 Rainwater Harvesting and Resource Efficiency

Rainwater harvesting has proven to be a valuable solution for addressing water shortages, especially in areas with inconsistent water supply. It encourages the efficient utilization of rainwater as an alternative resource, supporting conservation efforts at both household and community levels. Rooftop rainwater systems play a crucial role in decreasing reliance on centralized water networks, providing a cost-effective and decentralized approach to water access, particularly in rural regions [11].

2.2 Preventing Resource Waste and Pollution

Poor water management often results in environmental pollution and degradation [2]. Uncontrolled stormwater runoff can lead to soil erosion and contaminate water sources. When combined with community education, rainwater harvesting (RWH) systems help mitigate these effects by reducing surface runoff and encouraging responsible water use. Additionally, awareness programs can discourage improper greywater disposal and strengthen efforts to protect local water catchments.

2.3 Health Risks and Mitigation Strategies

Although rainwater is typically clean at its source, it can become contaminated due to rooftop pollutants, animal waste, and stagnant water in storage tanks [10]. Poorly maintained systems may expose users to harmful bacteria and heavy metals. To minimize these risks, several precautionary measures are recommended:

i. First flush systems to divert the initial runoff, which is often the most contaminated.
ii. Filtration units to remove physical debris and sediments.
iii. Disinfection methods such as UV treatment or chlorination to eliminate harmful microorganisms.
iv. Regular system maintenance, including thorough cleaning of gutters and storage tanks.
v. Community training programs, aligned with WHO guidelines, to equip local residents with knowledge on safe water management.

These strategies help maintain water quality and ensure the safe use of harvested rainwater. Including these strategies in rural RWH projects ensures water safety and improves community acceptance.

2.4 Youth Participation and Community Empowerment

Community-driven environmental initiatives are more successful when local stakeholders actively participate. Engaging citizens, particularly young people, in planning, execution, and management fosters a sense of ownership and enhances long-term sustainability. Involvement in small-scale

industries, such as manufacturing rainwater harvesting (RWH) system components, not only helps develop vocational skills but also supports local economic growth [9]. Additionally, green technology training programs designed for youth encourage innovation and strengthen community resilience.

2.5 Awareness, Education, and Water Stewardship

Raising public awareness plays a crucial role in driving behavioural change. Educational campaigns, interactive workshops, and participatory learning initiatives empower communities to embrace sustainable practices such as rainwater harvesting (RWH) [6]. In rural Malaysia, incorporating environmental education into local development efforts enhances understanding of water-related challenges and fosters a culture of stewardship, ultimately ensuring long-term water sustainability.

3. Methodology

The rainwater harvesting (RWH) system was implemented at the Surau Desa KEDA in Singkir Badong, Kedah. This rural village falls under the jurisdiction of the Kedah Regional Development Authority (KEDA) [5]. The pilot project aimed to provide basic technical training to local youth on the design and construction of small-scale RWH systems. The initiative emphasized low-cost, scalable solutions with direct benefits for rural communities and the potential for youth-led commercialization and entrepreneurship [6].

The methodology involved practical training sessions in system construction and design, where 20 local youth were guided through each step of the installation process. These sessions included instruction on selecting suitable materials, designing an efficient layout, ensuring proper water flow, and applying basic construction techniques. The training emphasized the importance of utilizing rainwater to reduce dependence on piped clean water, minimize water bills for households or community premises, and raise awareness of water conservation.

Following the training, youth participants were encouraged to replicate the system in their respective areas, with continued access to technical and entrepreneurial guidance. The project also included a community outreach component, encouraging participants to advocate for the system's use and promote its benefits to the broader community, positioning it as a viable low-cost business opportunity.

3.1 Long-term Monitoring and Maintenance Plan

To ensure the sustainability and long-term viability of the rainwater harvesting system, a basic monitoring and maintenance plan has been proposed. This plan includes:

i. Monthly Visual Inspections: Community members and trained youth will be responsible for checking tanks, gutters, pipes, and foundations to identify any blockages, leaks, or physical damage.
ii. Quarterly Cleaning Schedule: System components such as tanks, filters, and gutters will be cleaned every three months to prevent contamination and maintain water quality.
iii. User Feedback Logs: Simple logbooks will be maintained at the surau and by trained participants to record usage, problems encountered, and any repairs conducted.

iv. Annual Evaluation Workshop: Once a year, a local workshop will be organized (in collaboration with KEDA) to assess system performance, share user feedback, and reinforce maintenance practices.
v. Water Quality Testing (Optional): Subject to available resources, occasional water sampling may be conducted to monitor biological and physical water quality parameters.

Although the RWH system is not directly linked to groundwater extraction, its widespread adoption in rural areas could positively influence the local water table by reducing surface runoff and promoting aquifer recharge in nearby areas. However, ongoing observation is recommended to assess any unintended hydrological impacts. This community-based monitoring approach empowers local stakeholders to take ownership of the system, ensuring its sustained use and contributing to water resilience in underserved areas.

4. Result

The rainwater harvesting (RWH) initiative implemented in Desa KEDA Singkir Badong, Yan, Kedah, successfully achieved its intended objectives by empowering rural youth, raising community awareness, promoting sustainable water use, and demonstrating a replicable low-cost system. The project involved 15 youth participants and directly benefited over 30 households, particularly during periods of low water pressure.

4.1 Educating Youth on Efficient Use of Rainwater (Objectives i & iii)

A total of 15 local youth (aged 18–25) participated in both theoretical and practical training modules. The practical training involved the full installation of a RWH system at a designated pilot site, and included:

i. Identifying and selecting appropriate and durable tanks (500L capacity).
ii. Assembling suitable piping systems with correct gradients for efficient water flow.
iii. Installing rooftop gutters positioned to maximize rainwater collection.
iv. Constructing a stable concrete base for tank support.
v. Placing outlet pipes for accessible use in household cleaning and gardening.

Pre- and post-training surveys showed a 75% increase in participants' understanding of rainwater harvesting systems, and 80% expressed interest in applying these skills in future projects or micro-enterprises. The hands-on experience developed technical competencies in plumbing, construction, and basic system design.

4.2 Raising Awareness and Preventing Resource Waste (Objectives ii & iv)

The project also raised awareness within the wider community about the importance of water conservation and resource efficiency. A community dialogue session, attended by over 40 residents, emphasized the environmental benefits of rainwater harvesting and encouraged proper use and maintenance practices.

Post-implementation observations revealed that several households adopted new water-saving behaviors, such as using rainwater for washing and gardening. Informal feedback from community

members highlighted increased understanding of water quality issues and the importance of preventing pollution from runoff and domestic waste.

4.3 Practical Impacts and System Benefits

The installed RWH system has a storage capacity of 500 liters, and during a typical rainfall (average 25mm/day), it can collect approximately 250–400 liters/day depending on roof surface area. Although intended for non-potable purposes, the system significantly reduces reliance on piped water during peak periods.

Initial monitoring suggests an estimated 10–15% monthly reduction in household water bills, especially in homes using rainwater for cleaning and outdoor purposes. In addition to these economic benefits, the system's low-cost installation (estimated at RM300–RM350) and ease of maintenance make it ideal for broader adoption in other Desa KEDA communities.

Although the current study focuses on short-term outcomes, initial observations suggest strong potential for long-term sustainability of the rainwater harvesting (RWH) system. The system requires minimal maintenance, with locally available components and easily transferable skills among trained youth. Households reported no major issues in the first three months of use, and maintenance guidelines have been disseminated among users to ensure proper upkeep.

From a cost-effectiveness perspective, the system’s one-time installation cost (estimated at RM300–RM350) is relatively low and projected to yield savings of approximately 10–15% in monthly water bills for non-potable use. Over the span of one year, this could result in household water savings ranging from RM120–RM200, making the system economically viable.

However, we acknowledge that a longer-term evaluation (e.g., 12–24 months) is needed to assess sustainability indicators such as maintenance behavior, continued usage rates, water quality monitoring, and user satisfaction. Future research is recommended to track these metrics systematically and to compare outcomes across different geographic or socio-economic settings.

Table 1
Financial cost for RWH system

Financial Cost for the System	
Construction Materials	Price (Ringgit Malaysia)
Water Tank (100 gallons) Gutter	RM 450.00 x 2 unit
(uPVC) Conveyance System Plumbing Works	RM 200.00 x 2 set
	RM 200.00 x 2 set
	RM 400.00 x 2
Steel, Granite Aggregates, Cement and Sand	RM 1000.00
Labour Caj	RM 2000.00
Total	RM 5,500.00

4.4 Potential for Replication and Community Empowerment

The successful implementation in Singkir Badong presents a scalable model for other rural villages within the KEDA network. Given its affordability, minimal technical complexity, and strong community support, the project has the potential to be replicated in areas facing similar water access issues.

Desa KEDA Singkir Badong now serves as a pilot village, showcasing how simple technology and local empowerment can address sustainable development challenges at the grassroots level.

(a) (b)

Fig. 1. Rainwater Harvesting System (RWH) (a),(b)

5. Conclusions

Rainwater harvesting offers several benefits, such as providing users with easier access to water, which should be utilized optimally for daily activities. This system becomes particularly useful during water crises or natural disasters, such as floods, when water resources are scarce. Additionally, the rainwater harvesting system helps users manage water in a more systematic and disciplined manner, and it can reduce monthly water bills for households or buildings.

The Rainwater Harvesting System should be embraced by all communities, especially in today's modern development. The government encourages the application of green technology in all development projects, particularly in housing. This serves as a technique for preserving the green Earth and maintaining natural resources. It also protects the environment from further destruction caused by natural factors or human activities. Rainwater Harvesting should be enhanced and expanded to all areas in Malaysia, whether urban or rural, as a means of fostering sustainable development based on green technology.

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