International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

From Scarcity to Sustainability: Water Management in Green Construction in Bengaluru, Karnataka

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Abstract

Water is a vital resource for any nation's growth, well-being, and sustainability. But since less than 1% of the freshwater on Earth is easily used by humans, managing water resources effectively and fairly is a major problem, particularly in areas that are developing quickly. India's semi-arid state of Karnataka depends significantly on groundwater to supply its industry, agriculture, and population. Severe water stress has resulted from this reliance, unpredictable rainfall, and increased urbanisation. A significant approach to deal with water constraint is green construction, which incorporates environmental sustainability into building design and operation. This study analyzes sustainable water management within the framework of green building practice in Karnataka with Bengaluru as a case study given its high-urbanization development and pressing water issues. Using a mixed-method research methodology, the study uses primary data from a Google Forms survey of over 100 residents of Bengaluru housing societies along with secondary sources. The research investigated the awareness, problems faced, and suggestions of employing sustainable water. The research identifies economic, environmental, and social benefits to be linked to the employment of sustainable water interventions, which comprise improved efficiency in water utilization, cost-saving, and participation of people. Simultaneously, the study points out critical impediments raised by the issue of inadequate provisioning of funds, insufficient technical professionals, and existing policy gaps. The paper sums up with real-world suggestions regarding policy reform, capacity building, and public outreach in enhancing Karnataka's water resilience and contributing to the meaningful realization of the Sustainable Development Goals. Water is a critical resource for the survival and progress of any nation, yet the availability of usable freshwater is extremely limited.

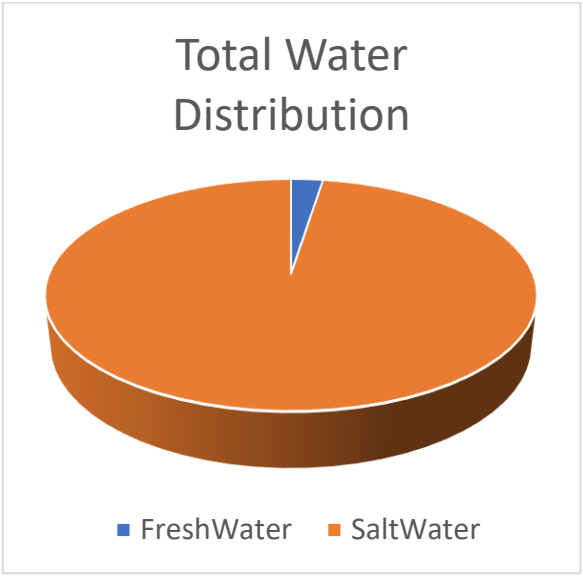
Keywords: Ground Water, Green Construction , Sustainable Development Goals, Manufacturing, Population, Water conservation

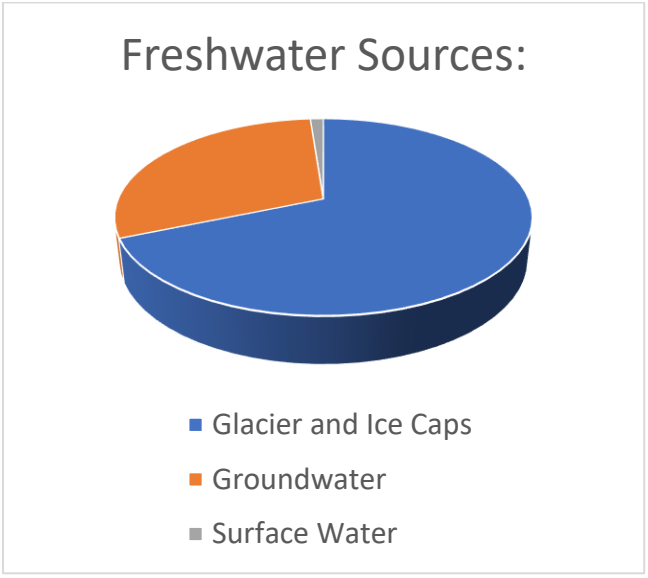
Water Scarcity and Sustainable Management

Water is among the world's most valuable resources, yet it is frequently taken for granted. Water is required to provide health, sanitation, and hygiene needs. Water is, therefore, crucial to food security, economic development, and livelihoods (Winkler, 2012). It is crucial for supporting life and plays a key role in sustainable development, economic growth, and the thriving environments and ecosystems that all organisms depend on. Water usage has grown remarkably over the years. Over the last thirty years, total water withdrawal per person has surged by over 650% worldwide.

Currently, freshwater extraction stands at 4.3 trillion cubic meters (m3) annually, with agriculture utilizing 70%, industry accounting for 20%, and municipal uses representing 10% (FAO, 2025). Future projections indicate that we are likely to experience heightened drought conditions and water scarcity. By the year 2050, it is anticipated that around 5 to 6 billion individuals, constituting over half of the global population, will reside in regions facing water stress. (WWAP,2018)Based on existing patterns, the World Bank estimates that by 2030, 40% of the global demand for water will not be satisfied (World Bank Group,2022). Two billion people in 44 countries will suffer from severe water scarcity by 2050 while over two billion people now lack access to safe drinking water and an additional 3.6 billion people face annual shortages. The growth of cities and economies combined with climate change puts extreme stress on water systems which endangers both natural ecosystems and human survival.

Untreated sewage, agricultural runoff, and industrial effluent pollution have made these issues worse and reduced the amount of clean water available(Salamé , 2021). The Earth contains a total of 1.386 billion km³ (333 million cubic miles) of water, of which 97.5% is saltwater and just 2.5% represents freshwater. The surface freshwater percentage amounts to only 0.3% of Earth's freshwater total (Eakins & Sharman 2010).





Water resource systems are under unprecedented strain due to human activities on land and in water, such as infrastructural expansion and industrial operations (Kåresdotter et. al.,2022). Freshwater consumption varies significantly across sectors. Agricultural activities utilize around 70% of the earth's water supply. Improving water efficiency in the agricultural sector promises substantial advantages. The industrial sector uses about 20% of water resources primarily for manufacturing purposes and domestic use takes up 10% which increases because of population expansion and urbanization. Water scarcity develops because of supply-demand imbalances together with population growth as well as unsustainable use and inefficient management according to FAO (2012). In other words, Global population growth has raised the need for clean water in a number of sectors, such as manufacturing, energy, residential consumption, and irrigation (Tortajada and Biswas, 2018). This conflict has resulted in harm to the environment, economic pressure, social disparities, depletion of groundwater resources, and heightened sensitivity to climate fluctuations, especially in developing areas (Ali and Chu ,2023).

Traditional systems, originally designed without considering these fluctuations, have faced significant challenges in addressing these problems (Wani, 2024). Groundwater extraction became widespread in areas with scarce surface water; however, over-extraction resulted in aquifer depletion, land sinking, and ongoing issues related to the sustainability of water resources (Hung et.al., 2024). Traditional methods of water management that emphasize extensive infrastructure such as dams and groundwater extraction have faced challenges in addressing the increasing demands and complexities related to worldwide water scarcity (Kinzelbach et.al., 2022).

Untreated sewage, agricultural runoff, and industrial effluent pollution have made these issues worse and reduced the amount of clean water available (Salamé, 2021). The limited availability of water requires sustainable practices to meet human demands and environmental requirements (Shiklomanov, 1993). The most common indicator for scarcity is 'per capita renewable water,' where less than 1,000 m^3 per capita/year implies scarcity, and less than 500 m^3 signifies absolute scarcity (FAO, 2012). More than a quarter of the world's people and nearly 40% of the world's agricultural production are fed through dependence on unsustainable groundwater pumping. Comprised supply sets back agriculture, industry, and household states in the economy and society through economic and social damage (Stanke et al., 2013). The same affects the very of climate change in turn betraying global efforts like SDG 6 to share equal water access for all by 2030 (UN-Water, 2019).

The Human Development Report (2006) notes that there are disparities in access, with 85% of the wealthiest enjoying piped water as opposed to just 25% of the poorest. Water management is crucial to attaining SDGs by ensuring efficient allocation and sustainable utilization across sectors (OECD, 2010).The Sustainable use of water will directly contribute to number of Sustainable Development Goals, including the food security (SDG 2), health (SDG 3), urban resilience (SDG 11), and climate adaptation (SDG 13) (UN-Water, 2019).The Brundtland Report defines sustainability as meeting the present needs without compromising the needs of future generations (World Commission on Environment and Development, 1997).

Effective irrigation progresses agricultural productivity (SDG 2), while clean water access augments public health (SDG 3). Sustainable urban water infrastructure supports SDG 11, while water conservation mitigates climate risks (SDG 13). Protecting freshwater ecosystems aligns with SDG 15. Sustainable water management balances social, economic, and environmental objectives to guarantee water availability for the long term (Butler et al., 2014) . Rainwater harvesting, better irrigation methods, wastewater treatment, conservation efforts, and legislative changes are some of the solutions. To stop depletion and ensure water for future generations, investments in water infrastructure and governance reforms are crucial. Further encouraging responsible water use can be achieved by enacting pricing mechanisms and increasing conservation awareness.

Water Scarcity Challenges in Karnataka

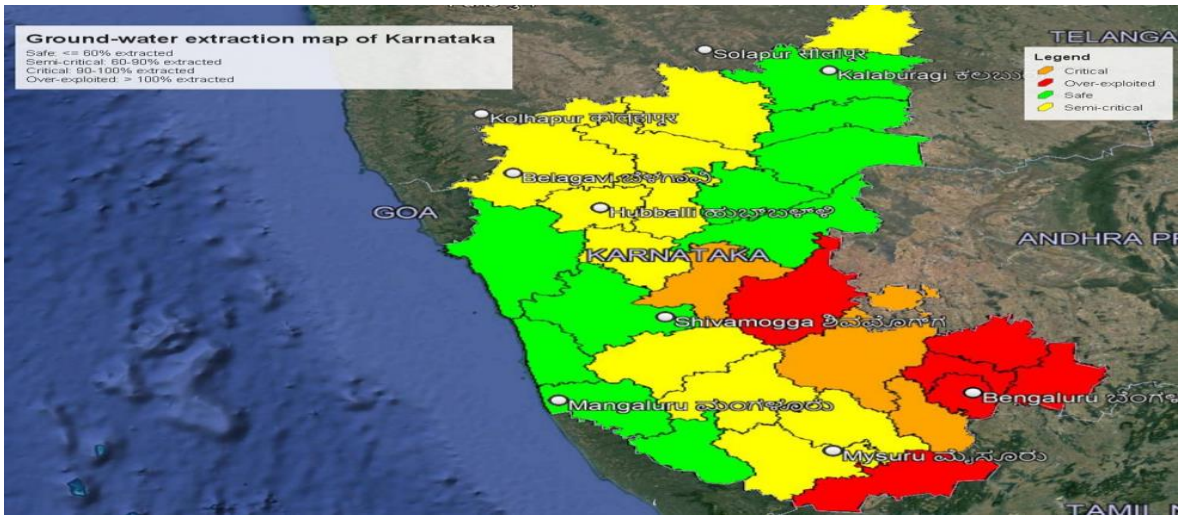
Karnataka is the eighth largest state in terms of population, with an estimated 67.56 million people in 2020 (UIDAI, May 2020). Its 1,91,791 sq. km. area makes up 5.83 percent of the nation's total area, and its two main river systems are the Cauvery and its tributaries in the south and the Krishna and its tributaries in the north. Karnataka has limited water resources (1,608 cubic meters/person/year overall and approximately 1,072 cubic meters/person/year in eastward flowing rivers), so irrigation water use is crucial because a large portion of the state is in a drought-prone area.

Approximately 1,608 cubic meters of water are available per person per year here, but in some areas, that

amount drops even lower to 1,072 cubic meters. Due to its heavy reliance on groundwater—26 percent of its total water consumption—Karnataka is susceptible to its depletion.

With 56% of the state's irrigated land derived from groundwater, groundwater is the most common type of irrigation in the state. A department policy note stated that rising groundwater contamination and a declining groundwater table are serious concerns.

Agriculture and rural communities are being particularly hard hit by issues like fluctuating rainfall patterns and diminishing groundwater levels. For Karnataka, this is the reason why region-specific sustainable water management strategies are so important.



Source: Ministry of Jal Shakti ,Stage of groundwater extraction in Karnataka districts.

The Karnataka groundwater extraction map displays the current state of groundwater use in different districts. Green areas on the map indicate safe groundwater use (less than 70% extracted), yellow semi-critical areas (70–90% extracted), orange critical areas (90–100% extracted), and red over-exploited areas (more than 100% extracted). The majority of safe zones are located in the northern and western coastal regions of the state, including Kalaburagi, Uttara Kannada, and the areas surrounding Mangaluru. Belagavi, Vijayapura, and portions of Shivamogga and Mysuru are among the semi-critical zones located throughout central Karnataka. The central-southern belt contains the majority of the critical zones, whereas the areas surrounding Bengaluru, Mysuru, and the surrounding districts are the most over-exploited.

Water conservation is becoming increasingly important in the construction sector as a means of encouraging sustainable practices(Evans et.al.,2024). It is estimated that construction activities are responsible for more than sixteen percent of the world's water use (Dixit et al., 2022).The construction industry is particularly susceptible to water scarcity problems, which are getting worse as a result of climate change, because of its substantial reliance on water. Water demand in buildings includes daily usage during the operating period (for heating systems, domestic use, etc.) and goes beyond the construction phase. The industry may lessen environmental stressors and avoid the negative effects of water shortages, like ecosystem deterioration and disputes over resource allocation, by optimizing water use at every level. One significant source is groundwater extracted from borewells and open wells. Groundwater depletion is a result of the building industry's high reliance on groundwater.

Sustainable construction water management offers significant financial advantages in addition to safeguarding natural resources. Residents can drastically save operating costs, such as those associated

with water supply and wastewater treatment, by using less water. Water demand in buildings includes daily usage during the operating period (for heating systems, domestic use, etc.) and goes beyond the construction phase. By maximizing water use at every level, the industry may assist reduce environmental stressors and avoid the adverse consequences of water shortages, like resource distribution disputes and ecosystem deterioration. In terms of ecology, reducing a building's water footprint immediately aids in protecting nearby water bodies and groundwater supplies, both of which are critical for biodiversity. The demand for water rises exponentially as the population and urbanization speed up. Water consumption is addressed in a number of ways by green buildings.

The notion of sustainability in construction and architecture has changed over the years. At first, the emphasis was on addressing the problem of finite resources, particularly energy, and minimizing environmental effects. Technical concerns including materials, architectural elements, construction technologies, and energy-related design concepts were prioritized.

Green construction is the process of planning and constructing buildings with an eye on reducing their negative effects on the environment and encouraging the sustainable use of resources, particularly water. The idea of sustainable development through green construction is becoming more and more popular in the modern day due to the increased energy and resource consumption in metropolitan areas.

Green Construction: A Sustainable Approach

Green construction is a progressive method that maximizes efficiency during a building's lifecycle while minimizing its negative effects on the environment. It integrates sustainable practices like waste reduction, water conservation, renewable energy sources, and energy-efficient equipment. Green construction improves quality of life and fosters long-term sustainability by incorporating environmentally friendly materials and technologies.

Utilizing solar energy is one of the main strategies in green construction, as solar cookers and panels capture renewable energy, minimizing carbon emissions and reducing reliance on fossil fuels. Another crucial method for reducing flooding, preventing runoff, and conserving water is rainwater harvesting, which is gathering and holding onto rainwater.

One advantage of green construction is that it creates healthier living areas devoid of harmful chemicals, which improves indoor air quality and lowers health risks. By minimizing pollution, greenhouse gas emissions, and ecosystems, it also contributes to environmental conservation. Sustainable structures can endure severe weather conditions and require less maintenance since they are more robust and long-lasting. Additionally, by reducing energy consumption, utility bills, and long-term operating expenses, green building guarantees cost and energy savings. Another significant benefit is water conservation, which is ensured by rainwater collection systems and effective plumbing fixtures that cut down on water waste and promote sustainable resource management.

Green construction has advantages, but it also has drawbacks, such as high upfront expenses because of the high cost of sustainable materials and technology. Implementation is made more difficult by the scarcity of skilled staff and environmentally appropriate products. Strict legal and compliance requirements, such as permitting regulations and environmental certifications, can further raise project complexity and expenses.

Green construction is crucial for a sustainable future in spite of these obstacles. Adopting eco-friendly construction techniques can help us save resources, lessen our carbon footprint, and produce a more resilient and healthier built environment for coming generations.

Importance of the Study

Water is a fundamental commodity for survival and growth of any nation, yet the availability of freshwater supply is extremely limited. In Karnataka, especially its capital city Bengaluru, water scarcity has turned out to be a major issue with irregular rain patterns, overdependency on groundwater, and a rapid rate of urbanization. In order to address this crisis, one needs to take a holistic approach that addresses not only water resource management but also green construction practices. This study is pertinent in the sense that it intersects on three imperative subjects—Sustainable Water Management (SWM), Green Construction, and Sustainable Development—and examines how their intersection can provide long-term environmental and economic sustainability. The following Venn diagram visually depicts the connection among these ideas. It means that the integration of SWM and green construction yields economic benefits, such as cost savings and increased return on investment. The overlap of SWM and sustainable development emphasizes social equity, with fair and inclusive access to water. Meanwhile, the integration of green construction and sustainable development enhances climate resilience in urban infrastructure. Underpinning all three spheres is a vision of sustainable future, which this research attempts to enhance by evidence-based knowledge and public involvement. With Bengaluru as the case study and employing primary and secondary data, the study examines both the challenges and potential benefits of embracing sustainable water practices within the construction sector, contributing Karnataka's efforts towards achieving its Sustainable Development Goals(SDGs).

Objectives of the Study

The main objectives of this study are fourfold:

1. To assess awareness and adoption of sustainable water practices.
2. To analyze the economic impacts of these practices, such as cost savings and property value increases.
3. To identify the barriers to adoption, such as financial and technical challenges.
4. To provide recommendations on how to promote wider adoption through financial incentives, technical training, and better policy support.

Materials and Methods

In this study to analyze Karnataka's water management, Bengaluru is used as a case study because of its increasing urbanization. Primary and secondary data were merged in a mixed-method approach. More than 100 inhabitants of the Bengaluru housing society participated in a Google Forms survey to gauge their knowledge, difficulties, and recommendations on sustainable water practices. Frequency analysis was performed on categorical responses, and important themes were discovered through qualitative analysis. The survey's conclusions were contextualized and influenced by government papers, policy documents, and scholarly literature. While secondary data guaranteed a theoretical foundation, primary data offered firsthand community observations. By connecting real-world experiences with policy frameworks, this combination improved the study's dependability and relevance. While qualitative analysis recorded people's experiences, frequency analysis measured category replies. Because of data constraints, advanced statistical techniques were not used.

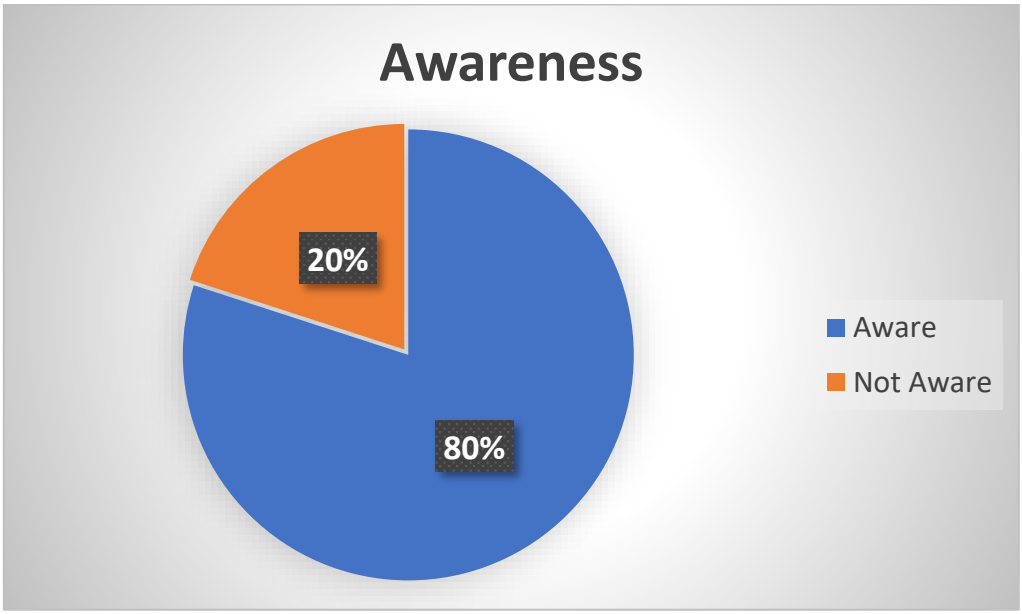
Findings and Discussion

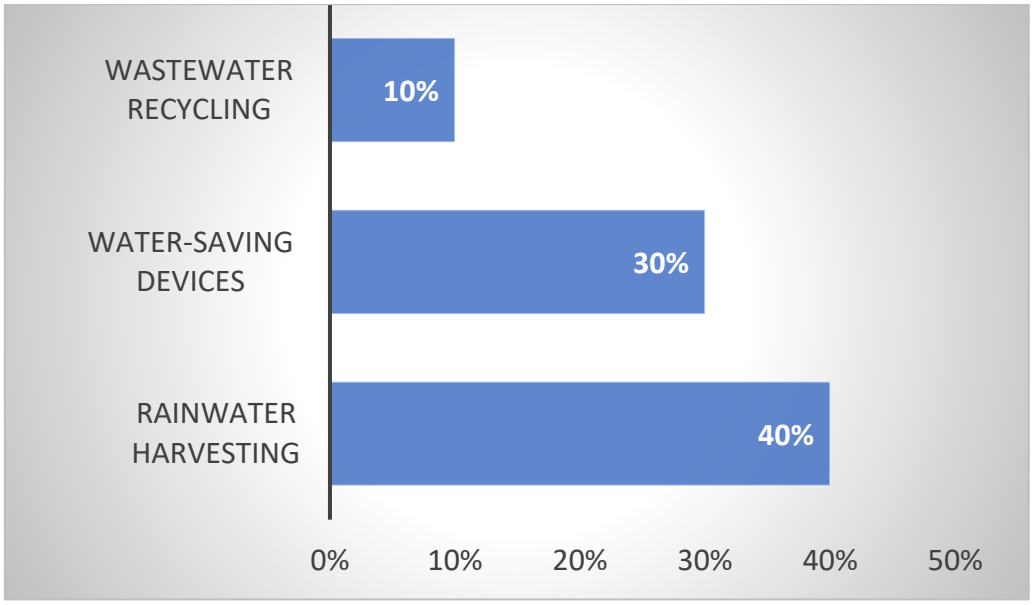
The study integrates survey and secondary data for a holistic view, highlighting important insights into awareness, implementation, economic aspects, and obstacles in sustainable water management across Bengaluru's housing societies.

Awareness and Adoption levels of Sustainable water management

Although 80% of people are aware, the significant disparity suggests that awareness by itself cannot be transformed into action. This implies that in order to turn awareness into action, creative solutions are required.

Although 80% of respondents were aware of sustainable water practices, only a small portion had actually put them into effect, according to one of the main findings.

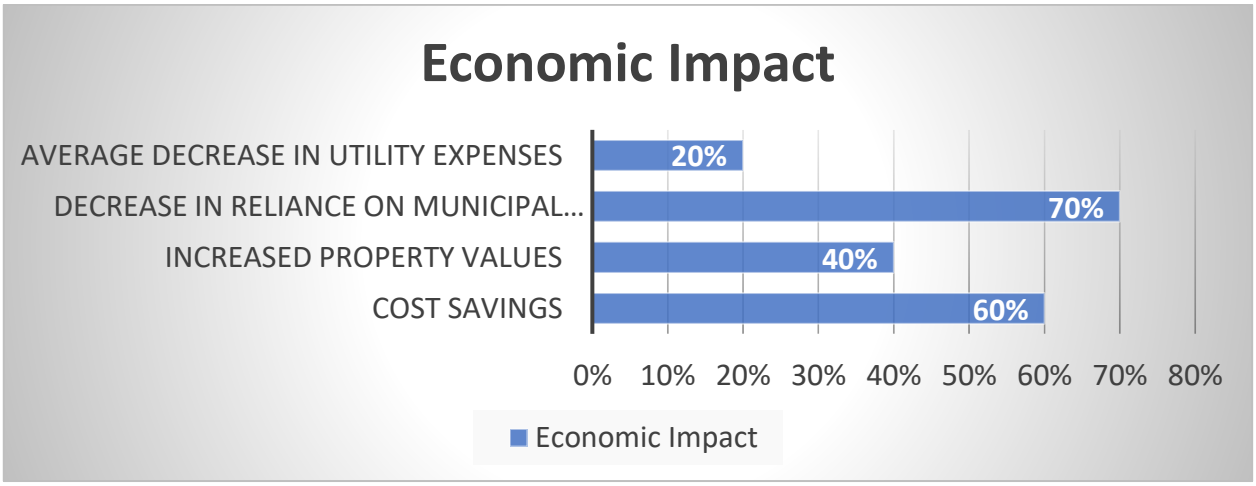




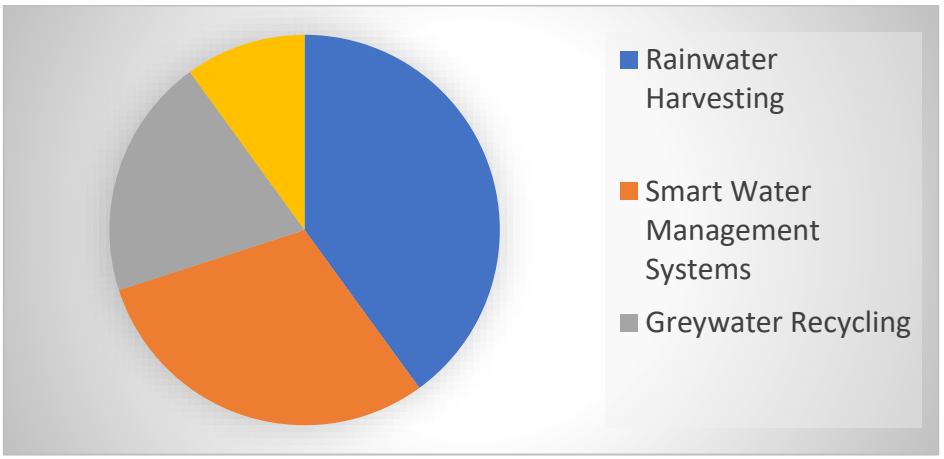
The graph shows the disparity between adoption and awareness of sustainable water management techniques. Even though about 80% of people are aware of techniques like rainwater collection, water-saving gadgets, and wastewater recycling, their actual use is still far lower. The highest adoption rate is 40% for rainwater harvesting, 30% for water-saving technologies, and 10% for wastewater recycling. This discrepancy suggests that awareness by itself may not always translate into action. This disparity could be caused by a number of things, such as exorbitant expenses, a dearth of incentives, restricted access to technology, or the belief that individual efforts make little difference. Consequently, creative solutions that make these techniques more widely available, reasonably priced, and enticing are required to convert awareness into measurable outcomes.

Economic Impact

Significant economic benefits result from the implementation of sustainable water management practices. According to 60% of respondents, these activities lower water bills, and 40% say they have a favorable effect on property values. Furthermore, 70% say they are less dependent on municipal water supplies, which lowers their utility costs by 20% on average. These observations emphasize the financial benefits of implementing sustainable practices.

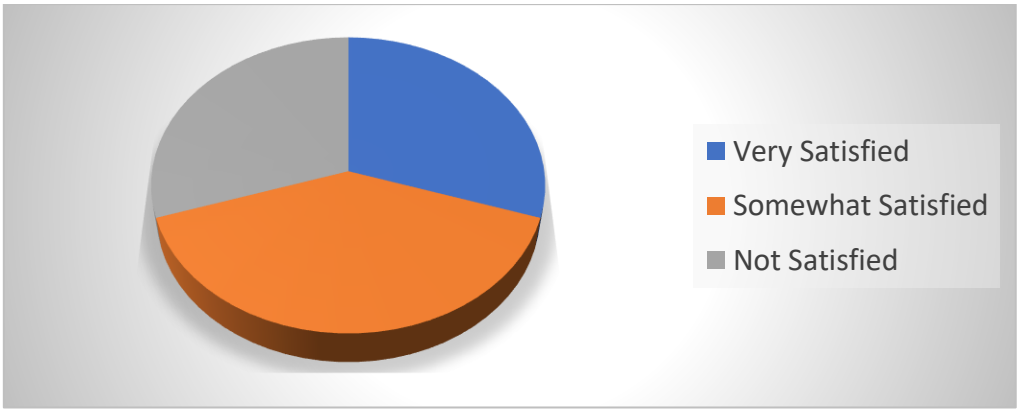


Innovations in Green Construction



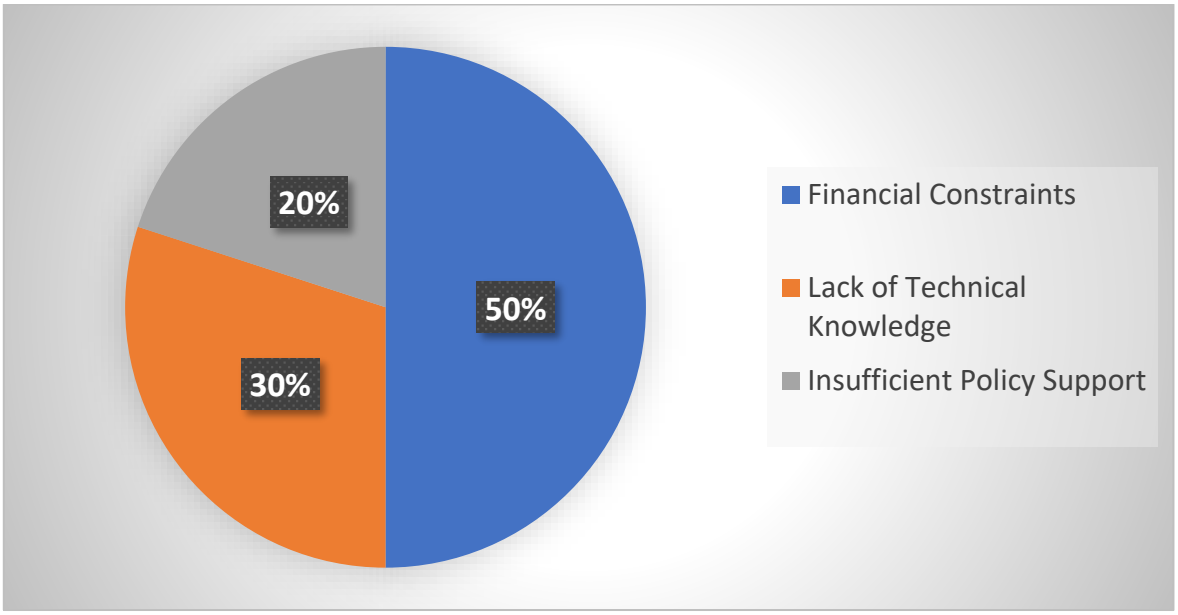
Enhancing water conservation requires innovations in sustainable water management. Rainwater harvesting systems are effective, as evidenced by the fact that 40% of respondents have implemented them. Thirty percent of responses were about smart water management systems, suggesting that people are becoming more interested in using technology efficiently. Twenty percent of participants recognize greywater recycling, underscoring its contribution to water conservation. However, just 10% of energy comes from renewable sources, indicating room for growth. These findings highlight how crucial it is to keep supporting the latest innovations in order to enhance sustainable water management techniques.

Sustainable Water Management: Innovations in Green Construction



With 30% of consumers saying they are extremely satisfied; the satisfaction data shows a solid basis for improvements in sustainable water management. The 40% who are only moderately satisfied, however, point to areas that could use work, especially in assistance and maintenance. Improving overall system performance and user experience requires addressing the issues raised by the 30% of users who are dissatisfied.

Main Challenges in Adoption



The main challenges impeding broader adoption of sustainable practices include a lack of funding, deficiencies in technical understanding, and inadequate policy backing.

Financial restrictions: The cost of adopting sustainable water management systems is one of the most urgent issues. According to the survey, a significant barrier mentioned by 60% of participants was the high cost of installation. This result is in line with earlier research that shows that many building projects put short-term financial gain ahead of long-term expenditures in environmentally friendly methods.

Insufficient Technical Knowledge: Another significant concern is the absence of technical knowledge and experience among stakeholders. According to the survey, 40% of participants believed they lacked sufficient knowledge on sustainable practices, which may result in improper system installation and design. This concern is supported by secondary evidence, which suggests that a large number of architects and contractors might lack sufficient training in sustainable water management practices.

Inadequate policy support: Although many current policies are insufficient, regulatory frameworks are essential for encouraging sustainable behaviors. According to the findings, the industry's adoption of sustainable practices is inconsistent since regulatory frameworks frequently lack clarity and enforcement. Many respondents stated that although rainwater collecting is mandated in some places, non-compliance and poor effectiveness may arise from unclear regulations and a lack of support for enforcement.

To encourage wider use, these issues must be resolved.

Recommendations

The following recommendations have been offered in order to address these issues:

Financial Incentives: Reducing the high installation costs of sustainable technology can be achieved by bolstering financial assistance through government grants, subsidies, and low-interest loans. Rainwater harvesting and wastewater recycling are two examples of measures that this strategy will encourage broader adoption.

Technical Assistance and Training: To close the knowledge gap, specific training courses and seminars for architects, contractors, and housing society members should be established. In the construction

industry, cooperation between academic institutions, business executives, and governmental organizations can foster innovation and knowledge sharing.

Fortifying Regulatory Structures: Improving both the clarity and implementation of regulations concerning sustainable activities is crucial. Encouraging industry-wide compliance and efficacy will need the development of comprehensive regulations that specify sustainable practices, establish legally binding requirements, and offer funding.

Conclusion

The present study emphasizes how crucial sustainable water management techniques are to promoting green construction in Karnataka's housing societies. Despite broad awareness among stakeholders, policy limits, technical knowledge gaps, and financial constraints continue to impede regular implementation.

In addition to helping to resource conservation and long-term savings, the study emphasizes the substantial economic and environmental advantages of techniques like rainwater harvesting and wastewater recycling. High upfront expenses, however, frequently deter developers from using these technologies. Furthermore, improper system design and execution are caused by industry professionals' lack of technical understanding.

Stronger financial incentives, thorough technical training, and more resilient regulatory frameworks are some of the specific solutions required to remove these obstacles. By addressing these challenges, we can fully harness the potential of sustainable water management, ensuring a more resilient and sustainable future for Karnataka and beyond. To protect water resources for future generations, action must be taken immediately.

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