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A Review Paper on Residential Rainwater Harvesting

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ABSTRACT: Rainwater collecting is now a recurrent topic in urban building as part of sustainable practices. The user who wants to profit from such a practice is concerned about the economic feasibility of constructing a system capable of collecting, treating, and distributing rainwater for residential purposes. To that aim, twelve single-family homes in Belém, Pará, Brazil, were chosen for this study, each with a distinct building quality. For each home, a design and budget for the installation of a rainwater collecting system were created. Using rainwater harvesting modeling software, the hydrological performance and economic viability were assessed under various consumption and economic policy scenarios. The primary finding is that rainwater systems, independent of catchment area size, are more economically viable in homes with greater water demands. The cost of installing rainwater systems varies slightly depending on the building quality of the home where it is placed. In any situation when water usage is below the social tariff or a fixed price water bill is received, the tariff system renders rainwater harvesting economically impossible. The economic viability of rainwater collecting is improved by a combination of increasing water prices to the same level as water production costs and lower implementation costs.

KEYWORDS: Economic, Harvesting, Rainwater, Software, Technology.

1. INTRODUCTION

Natural resource management has been one of the most significant problems for the existence of humanity since the beginning of the twenty-first century. One of the Millennium Development Goals set by the United Nations was the sustainable use of resources, particularly water resources, with the goal of preserving these resources for future generations' needs.

Water resources have been heavily used, and this tendency is expected to continue. World water consumption is projected to rise by 55 percent by 2050, resulting in shortage and competition among water users (WWAP, 2015). Water resource management is unbalanced due to the variability of water availability. Residential piped water delivery reaches 79 percent in urban regions throughout the globe, compared to 32 percent in rural areas (WHO/UNICEF, 2015). In this context, rainwater collection may be a viable option for human water supply. Economic study of RWH systems, according to Amos, is underrepresented in scientific literature but plays a considerable role, particularly in emerging economies such as Brazil, Mexico, China, and India. A RWH may be a cost-effective solution for these countries where there is insufficient access to safe drinking water in cities and rural regions, and a major section of the population has to store water in tanks or buy from trucks if the government subsidizes the initial costs. These findings, we believe, will stimulate the interest of public and private water and construction players[1]–[5].

Rainwater harvesting has two major benefits: it saves water for drinking and non-drinking uses (depending on the treatment used in the system) and it improves storm water drainage systems.

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The proportion of total water demand that rainwater harvesting (RWH) systems may possibly meet is determined by a variety of variables, including permitted water uses, amount and seasonality of precipitation at the installation site, tank size, catchment area, and total water demand. When it comes to storm water drainage, large-scale RWH systems reduce peak flow during heavy rains and increase overall long-run flow volume. Peak flow reductions may assist to extend the usable life of municipal drainage infrastructure in regions where additional impervious surfaces are being built, while lowering the overall volume drained reduces the effluent discharged into water bodies.

Government policies are a critical component in society's adoption of sustainable behaviors. With more than half a million cisterns constructed by 2016, the Brazilian Semiarid Articulation (ASA) has created one of the world's biggest social initiatives for the use of rainwater in the northeast area. Other initiatives have been conducted in other parts of the nation, including activities in Belém-Pa and the neighboring islands.

The artificially low cost of drinking water tariffs, on the other hand, is one of the major obstacles to recruiting new customers to the rainwater collecting program. According to the Brazilian National Sanitation Information System, the average total cost per m3 in 2014 was greater than the average rate paid in 12 of the 26 states, including Pará. In approximately half of the Brazilian states, this statistic reveals a discrepancy between the real cost of supply and the price charged by the concessionary. As Amos et al. point out, this scenario also exists in other parts of the globe, such as Kenya and Sub-Saharan Africa[6]–[8].

Pannell proposes a system for evaluating public policy in which government officials' actions are based on the value produced for both the general public and individual users. The utilization of rainwater produces favorable externalities for the public that may or may not outweigh the individual installation expenses. An economic analysis for private actors, which is part of the current study's goal, and another for the externalities produced by the initiative are required to identify the impacts of rainwater systems. Economic studies, according to Amos, are still restricted in the literature and important when searching for cost-efficiency in RWH systems, especially in poor countries.

There are many instances of legislation throughout the globe that aims to regulate and promote rainwater collecting. Rainwater harvesting programs have been adopted at various levels of government in countries such as the United States, Germany, Spain, and Australia. Several laws and regulations exist in Brazil, mostly in the municipal realm that promote or mandate the use of rainwater for civil construction, commerce, industries, and other enterprises. Future study should be focused on understanding the role of institutional support in RWH system effectiveness[9], [10].

Three measures are responsible for Germany's status as a global leader in the utilization of rainwater. These include decentralized technology investment subsidies, the enforcement of water extraction fees, and the billing of drinking water and drainage separately. These policies come under the category of "smart regulations," as those that achieve three primary goals:

- mobilize all key players

- establish horizontal rather than vertical relationships between actors and state institutions
- Concentrate on the objectives rather than the means for achieving them.

Subsidies to users of essential services are intended to increase coverage while also improving the allocation of resources across socioeconomic groups. Infrastructure subsidies, even when wasteful, are justified by universal access to essential services. The average water rate in the Brazilian state of Pará was 1.70 R$/m3 in 2014, but the average total expenditure was 3.48 R$/m3, suggesting that roughly 48.85% of the cost is subsidized. The price of the water tariff has a negative relationship with water usage and is often a key element in RWH system financial analysis. As a result, this kind of subsidy raises water use while decreasing the appeal of alternate water delivery systems. Subsidies may be used as incentives for the installation of RWH systems, thereby increasing the number of people who utilize these systems. According to Rahman, partial compensation of early installation expenses makes some system designs economically feasible.

The partial subsidies, according to Domènech and Saur, not only make rainwater collecting economical, but also motivate users to participate in the project, raising their environmental consciousness. The author confirm the global diversity of economic outcomes and emphasize the need for further study into the impact of institutional and socio-political policies on RWH deployments.

To offer authorities, designers, and users with important information for the decision-making process of this technology, this study evaluates the economic feasibility of RWH deployment in homes under various circumstances of water consumption and incentive programs.

Historical daily precipitation data from the Brazilian Meteorological Bureau (INMET) weather station (Code 82191-Belém-Brazil) were utilized for system performance simulations. Despite the fact that observations at this station began in 1921, the simulations were conducted over a period of 25 years, from January 1, 1991 to December 30, 2015. With just two missing dates out of 9132 available, this era was selected for its chronological significance and data completeness, resulting in a 99.98 percent full series. No precipitation was recorded on days when no measurements were taken. Ghisi found that series longer than thirteen years are acceptable for the simulation technique they selected.

Case studies were chosen from a total of twelve homes, three of which were single-family dwellings that met each residential criterion. Figure 1 depicts the spatialization of these homes and weather station. The INMET weather station is between 2.1 and 12.6 kilometers away from all dwellings.

1.1 Software for simulating RWH system performance:

The rainfall program NETUNO 4.0, created by Ghisi and Cordova, was used to carry out simulations for this research. Several studies have used this tool to determine the potential economic and water savings generated by the implementation of RWH systems in various types of buildings, yielding acceptable and better results than other approaches (Rocha, 2009; Rupp

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et al., 2011). With their respective input and output variables, the software offers two distinct and complimentary options:

- To evaluate the RWH system's hydrological performance for various reservoir volumes. This stage is referred to as Water Performance Evaluation for the purposes of this project (WPE).
- Calculate the Net Present Value (NPV), Internal Rate of Return (IRR), and Payback Period for a specified storage volume recovery solution. This step was dubbed Economic Analysis for the sake of this study (EA).

1.2 Design and budget for RWH systems:

Simulations were run for various building standards to account for the variation in installation costs and the potential water savings for RWH systems under various circumstances. With this in mind, three instances were assessed for each residential subtype (R1, R2, R3, and R4), resulting in twelve case studies, according to COSANPA's home categorization (Table A1). For non-metered water connections, this classification is determined by the water utility provider based on the house's building standard and is linked with an anticipated usage. Figure 1 shows the Flowchart of the research methodological procedure.

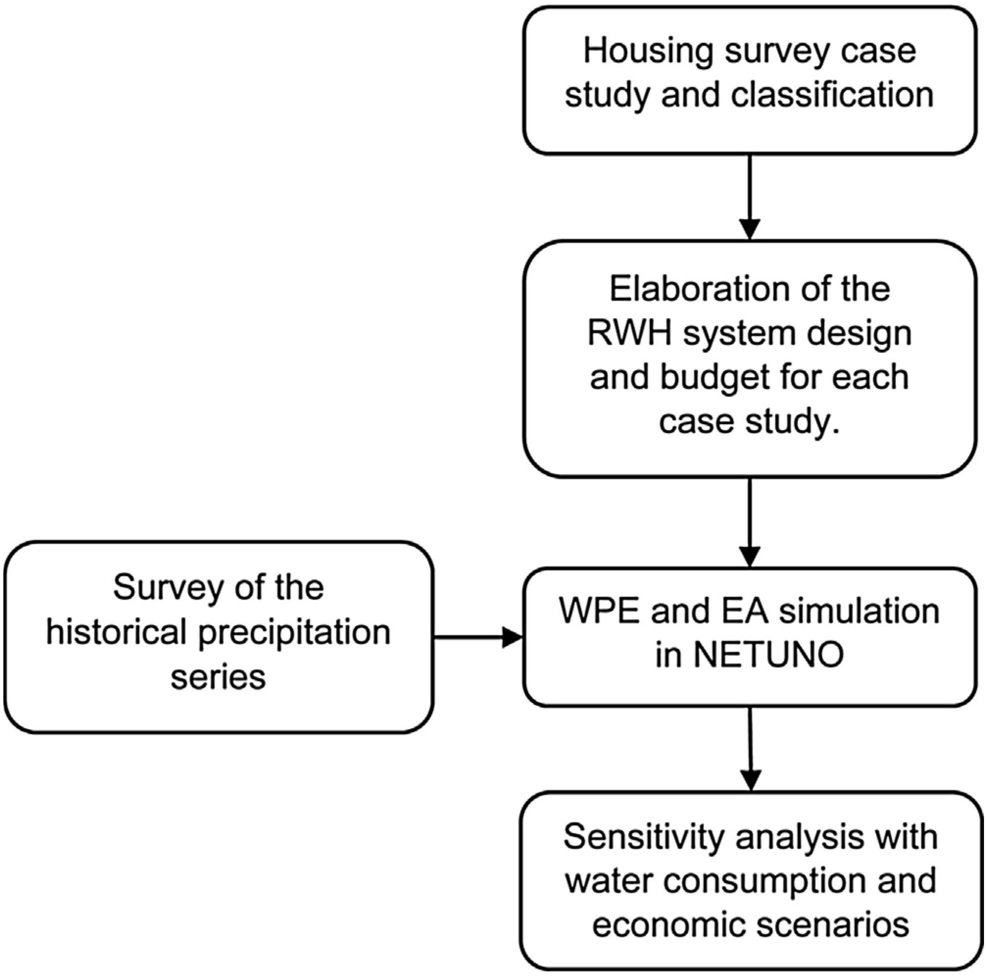

Figure 1: The above figure shows the Flowchart of the research methodological procedure.

According to the National Institute of Construction Sciences of the United States, building information modeling (BIM) is "a digital representation of the physical and functional features of a building with access to all relevant graphical and non-graphical information." Using Autodesk's BIM REVIT STUDENT VERSION 2016 program, a 3D model was produced for each home based on the measurements, materials, and water spots assessed during the house visits. The RWH system designs were developed using these models and the ABNT Brazilian requirements.

2. DISCUSSION

The author has discussed about the residential rainwater harvesting, this provides useful information for making decisions regarding the impact of government policies and users' water consumption patterns on rainwater harvesting systems, which is one of the most recent water-saving technologies. The use of RWH technologies in homes with already low water usage is discouraged by a tiered pricing structure with a set charge at the lowest end, which may restrict the use of these systems in disadvantaged socioeconomic housing. High water users, on the other hand, may reap significant personal advantages from the installation of RWH systems, which will help to relieve the increasing demands on municipal drinking water systems.

According to Amos, economic analysis of RWH systems has a limited representation in scientific literature but plays a significant role, especially in emerging nations like Brazil, Mexico, China, and India. If the government subsidizes the initial expenses, a RWH may be a cost-effective option for these nations where there is insufficient access to clean drinking water in cities and rural areas, and a significant portion of the population has to store water in tanks or buy from trucks. We believe and hope that these results will pique the attention of public and private water and construction stakeholders.

3. CONCLUSION

The author has concluded about the residential rainwater harvesting, for the decision-making process, the RWH stakeholders (users and government) received many key findings from the analysis conducted in this research. To summarize, the following are the most important points:

- It is feasible to save more than 40% of drinking water demand in most instances. Savings potential is influenced by a number of variables, including unit catchment area, reservoir size, and rainwater usage types.
- Houses with a larger unit catchment area have more seasonal stability in terms of water conservation.
- Rainwater systems are more economically feasible in homes with greater water consumption, independent of the size of the catchment area, even in fewer wet months, since the water supply capacity per precipitation event is larger in proportion to the demand. As a result, high-demand consumers are losing out on the technology's potential individual economic advantages.

- The water pricing system renders rainwater usage economically impossible in homes with use below the social tariff or fixed collection regime in any scenario. The economic feasibility of rainwater collecting is improved by a combination of increasing water prices to the same level as water production costs and lower implementation costs.

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