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Research Article

Assessing Rainwater Harvesting Potential in Virac, Catanduanes: Sizing Roofs and Storage Tanks for Low-Income Residential Use based on Type II Philippine Climate

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ABSTRACT

The water scarcity in the Philippines remains a challenge in many communities despite the abundance of rainfall. In Virac, Catanduanes, a municipality classified under Climate Type II, characterized by the absence of a dry season and a pronounced rainfall peak, water shortages are still experienced in some areas. This study assessed the potential of integrating rainwater harvesting systems into the initial design of low-income houses by determining appropriate roof collection dimensions and storage tank capacities. The study employed a quantitative descriptive research design, utilizing monthly precipitation data for 2022 obtained from DOST-PAGASA and analyzed using established rainwater harvesting formulas. The amount of collected rainwater was calculated using roof area, precipitation, and a runoff coefficient of 0.80 for corrugated metal roofs, while storage requirements were evaluated through a water balance approach. A minimum household water demand of 10 cubic meters per month was used as the baseline for analysis. Results showed that December recorded the highest rainfall at 576.2 mm, while May had the lowest at 124.9 mm. The results indicated that a roof area of approximately 100.09 square meters is required to collect 10,000 liters of rainwater during the driest month, while a storage capacity of at least 23 cubic meters is recommended. The study demonstrates that integrating rainwater harvesting into the house design can have the potential to enhance water security, support sustainable water management, and promote climate-responsive housing development.

Keywords: *Catanduanes, Low-Income Residential, Rainwater harvesting, Virac*

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Introduction

The Philippines, being a tropical country, has 4 types of Climates and is considered a country to have abundant rainfall. Despite these, parts of the country are still experiencing water scarcity because "water is one of our primary resources, yet it is often overlooked when it comes to the planning and design of our buildings, communities and cities." (Palafox, 2019).

Water scarcity is anticipated to be one of the major global challenges in the future. Although the Philippines typically has abundant rainfall due to its climate classifications, many urban and rural areas have recently experienced water scarcity conditions. Catanduanes is one of the places in the Philippines that has experienced water scarcity. According to reports, on August 20, 2018, Virac Mayor Samuel stated in a letter Laynes "a looming physical water scarcity exists for a large part of the municipality of Virac as the results of an extended dry spell resulted in situation where natural water resources are unable to meet the municipality's demand for safe drinking water and sanitation supply." (Tibay, 2018).

On the other hand, the Philippine Red Cross said that "the crisis has forced residents to travel long distances or spend hours in queues to collect clean water from nearby barangays" (Rosario, 2023). In 2024 "water rationing is now being implemented in nine barangays in Virac, Catanduanes due to weak supply for almost two weeks. (GMA Regional TV News, 2024). "According to the Municipal Disaster Risk Reduction and Management Office (MDRRMO) Virac, water rationing is part of their strategy to manage the situation." (GMA Regional TV News, 2024). "VIWAD is now considering adding more facilities, including deep wells, if the rainfall continues to be scarce." (GMA Regional TV News, 2024).

Rainwater harvesting can help address water scarcity and reduce flooding in Metro Manila. Representatives Manuel Luis T. Lopez, Kit Belmonte, Allan Reyes, and Yul Servo Nieto have proposed "The Rainwater Harvesting Facility (RHF) Act." This bill requires new construction projects to include rainwater harvesting systems. Developers must set aside 3% of the development area for RHF in projects larger than 1,500 square meters to get building permits (Rosario, 2019).

Rep. Romeo Momo Sr. also proposed House Bill 4818, requiring new developments, including malls and subdivisions, to install rainwater harvesting facilities for flood control and clean water supply (Luci-Atienza, 2019). Facilities should manage specific flood situations and follow the guidelines from the Department of Public Works and Highways. With this, the researcher is questioning how well rainwater harvesting systems work. Will effective designs be put into use? This study will look at the challenges of rooftop rainwater harvesting in homes, especially in Virac, Catanduanes.

The research gap addresses how houses in Virac, Catanduanes, can efficiently collect rainwater based on precipitation data to address water scarcity. The sub-problems include the following: What is the minimum roof catchment area required to meet household water demand? What is the optimal maximum rainwater harvesting tank capacity required to meet household water demand?.

These questions will help achieve the goal of providing the potential roof and tank areas and dimensions that efficiently maximize rainwater collection in Virac, Catanduanes. The objectives are to determine the minimum roof catchment area required to satisfy household water needs during dry periods using local precipitation data, and to evaluate optimal rainwater storage tank capacities, considering volume requirements, spatial placement (above or below ground), material selection, and architectural integration.

Many regions are facing water shortages, which greatly affect people's health and livelihoods. This study looks at ways to design roofs and tanks that can help collect and preserve rainwater to address this issue. Rainwater harvesting (RWH) systems are important solutions for conserving water, especially in places where water is scarce. The success of these systems depends on several factors, including local climate, household water demand, and available space. This study will benefit the community of Virac, Catanduanes, which has a Type II climate. The rainfall data collected in this study can also apply to other areas in the prov-

ince with similar conditions. Including rainwater harvesting in house designs can help address both water scarcity and flooding problems in affected areas. This study will provide useful information for architects and designers focusing on sustainability. Additionally, it encourages the conservation of water as a natural resource.

This study focuses on a specific climate type and an urban area experiencing water shortages. It focuses on houses for low-income families and does not include businesses or industrial buildings. The study is located in Virac, Catanduanes, which has Climate Type II. This climate has no dry season and experiences heavy rainfall from December to February. The aim is to determine the optimal sizes of roofs and tanks for collecting rainwater to help address water shortages.

The researcher accessed climatic precipitation data from DOST-PAGASA, focusing on Virac, Catanduanes, for the year 2022, as it was the most recent data available during the study. The study also calculates and analyzes the minimum and maximum sizes of roofs and tanks. It utilizes the runoff coefficient for corrugated metal roofs, which are commonly used by households in the Philippines. This does not address the internal plumbing design for distributing water throughout households. This limitation affects the practical application of the findings and presents an opportunity for future collaboration with consultants and designers.

To determine the minimum roof area and tank size that can accommodate the water balance, the study assumes that the amount of rainwater collected (inflow) will equal the water demand (outflow). It also assumes that the monthly water demand matches household water consumption.

Additionally, the study assumes that for other related literature and studies, there are specific guidelines dedicated exclusively to rainwater harvesting facilities, but none about the integration of this facility within residential buildings. Furthermore, there seems to be a tendency that the design of existing rainwater harvesting facilities does not consider the Philippine Climate Classification, possibly overlooking opportunities for optimization and efficiency of rainwater.

A key premise of the study is that these people express a willingness to adopt an efficient house design that integrates a water harvesting facility. In essence, the research suggests that there is an awareness among the population to align their sustainable water practices with the overall design of their residences.

Related Studies to Test the Efficiency of *Rainwater Harvesting Systems*

Including relevant methodologies on sustainability and efficiency enables the researcher to conduct and understand the study. Based on the recommendations, these literatures serve as a guide and template on what should be done and what should not. To further understand how efficient and effective a rainwater harvesting system is, the research provided the following substantial case studies to be reconfigured:

1. Research shows that rainwater harvesting systems are effective in conserving water and promoting sustainability. Garrison, Kloss, and Lukes (2011) highlighted the NRDC's Robert Redford Building in California, which uses rooftop rainwater capture and graywater recycling, achieving a 60% reduction in potable water use over 60,000 gallons saved annually. Similarly, the Solaire Building in New York incorporates a large cistern for toilet flushing, cooling, and irrigation, resulting in a 48% decrease in drinking water consumption. Chiu, Tsai, and Chiang (2015) developed a Geographic Simulation-Based Design Scheme to assess rainwater harvesting feasibility, while Doctor, Khatkhate, and Rout (2018) reported that Rizvi College of Engineering's system meets 78% of its water needs and helps replenish groundwater. These studies affirm that rainwater harvesting supports sustainable water management and reduces environmental impact.
2. The study "Analysis on the Potentiality of Domestic Rainwater Harvesting in Metro Manila" by Felix, Redillas, Sungho, and Lee (2011) examines factors influencing the effectiveness of rainwater harvesting, including user behavior, rainfall patterns, plumb-

ing fixtures, and storage capacity. It employs the water balance method to assess system efficiency.

This method helped determine whether the amount of rainwater collected could adequately meet the daily needs of three types of toilets across varying rainfall years. The study presents four equations that facilitate the analysis of a rainwater harvesting facility's potential.

Equation 1

Water Balance = Inflow- Outflow

Equation 2

Inflow (m^3) = Rainfall (m) x Catchment area (m^2) x Runoff coefficient Inflow is based on daily rainfall data obtained from the Philippine Atmospheric, Geophysical and Astronomical Services Administration. The catchment area is based on each house's catchment area data obtained from the Housing and Land Use Regulatory Board. And the runoff coefficient of 0.8 was used for smooth corrugated roofs based on United Nations Environment Programme (Felix, Redillas, Sungho, & Lee, 2011).

Equation 3

Outflow = Water demand (m^3)

Water demand = Population (capita) x Average no. of flushes x flushing demand (m^3/flush).

The outflow is based on daily water demand. In terms of water demand, it is significant to know the average household size and population of the study. The values for the average number of flushes per day per capita and the average flush volumes of inefficient, efficient conventional (conventional) and efficient dual-flush (dual-flush) types of toilets, were based on the Water Efficiency Plan of Toronto Works and Emergency Services which were used for estimating water demands for households (Felix, Redillas, Sungho, & Lee, 2011).

Equation 4

Overflow Volume = Water Balance (m^3) – Size of storage (m^3)

The overflow volume is the amount of rainwater that cannot be collected due to insufficient storage capacity. "The storage capacity of the tank was initially assumed to be 60 m^3, which was the storage designed by the DPWH and intended for rainwater harvesting (Department of Public Works and Highways, 2011). To further analyze the efficiency of the assumed storage capacity, five additional storage capacities were considered in relation to the base storage design of 60 m^3. The five additional storage capacities were 30, 120, 240, 480, and 960 m^3, corresponding to half and twice, four, eight and sixteen times of the base storage capacity, respectively." (Felix, Redillas, Sungho, & Lee, 2011).

These four (4) equations can help determine the balance between supply and demand for water resources.

The reviewed literature establishes that rainwater harvesting is an effective approach to water conservation and sustainable water management. The cited building applications demonstrate the potential of integrating rainwater collection and storage systems into building designs to reduce dependence on potable water supplies. Similarly, the studies of Chiu et al. (2015) and Doctor et al. (2018) emphasize the importance of evaluating environmental conditions and system efficiency in determining the feasibility of rainwater harvesting. Among the reviewed studies, Felix et al. (2011) provide a relevant methodological basis for the present research through the application of the water balance method. Their approach demonstrates how rainfall, roof catchment area, runoff coefficient, household water demand, and storage capacity can be evaluated to determine the potential of rainwater harvesting systems. These variables are also essential in establishing the appropriate roof dimensions and storage tank capacities for residential applications. However, the present study further considers the relationship between rainwater harvesting and architectural design, particularly in relation to Philippine Climate Classification. While previous studies have examined the efficiency and potential of rainwater harvesting systems, the present research focuses on determining suitable roof catchment areas and storage tank capacities for

low-income houses in Virac, Catanduanes, based on local precipitation data. It also considers tank placement, material selection, and architectural integration as part of the initial house design process. Thus, the reviewed literature provides the theoretical and methodological foundation for evaluating rainwater collection and storage requirements while supporting the development of climate-responsive residential designs.

Methodology

The study utilized both qualitative and quantitative research methodologies. For the research design, the researcher focused on Virac, Catanduanes, which served as a basis for analyzing the effects of climatic and environmental conditions.

The researcher also performed an analysis of the potential designs of roof and tank sizes through calculations. This enabled the identification of suitable designs and concepts for the proposed prototype, taking into account the preservation and utilization of collected rainwater during both the wet and dry seasons.

In the research tactics, the researcher employed mapping techniques to identify urban areas experiencing water scarcity. The focus is on determining the climate type that allows for the maximum collection of rainfall. Additionally, the researcher accessed climatic precipitation data for Virac, Catanduanes, through online requests to the DOST-PAGASA.

Calculating the roof area helps ensure that the community has access to a reliable water supply, even during the month with the lowest rainfall and throughout water shortage periods. This study used the formula used to determine the appropriate roof area for designing the rainwater harvesting system. The formula was from the websites about Calculating Your Average Rainfall & Ideal Tank Size (Blue Mountain Co, n.d.) and Rainwater Harvesting 101 (Innovative Water Solutions LLC, 2023). And the study used the runoff coefficient based on the Analysis on the Potentiality of Domestic Rainwater Harvesting in Metro Manila (Felix, Maniquiz-Redillas, & Seo, 2011). In this case, a runoff coefficient of 0.8 was used for smooth corrugated roofs based on the United Nations Environment Programme.

$$\textbf{Amount of collected rainwater (Liters)} = Roof\ Area\ (sqm)\ x\ Precipitation\ (mm)\ x\ Runoff\ coefficient\ (0.80)$$

The study used 10 cubic meters, the standard minimum monthly water consumption used by most water utilities in the Philippines for billing purposes for low-income households, as the baseline for estimating the minimum water demand within the community.

To assess the potential of rainwater storage tanks, the study utilized the following equation: (Water Balance = Inflow - Outflow). This is based on the analysis of the potential for domestic rainwater harvesting in Metro Manila. (Felix, Maniquiz-Redillas, & Seo, 2011).

To select appropriate concepts and technologies for integrating sustainable rainwater harvesting systems into the houses in urban areas, the researcher conducted a review of related studies and literature, including books, websites, reports, and other documents. This research aimed to identify efficient methods and concepts for integration, while also assessing the possibility of implementing rainwater harvesting systems in residential dwellings within a tropical climate.

Results

Water Scarcity in Catanduanes

The site of the study is located in the Philippines. The Philippines is a tropical country characterized by high temperatures, high humidity levels, and abundant rainfall. Based on the Modified Corona's Climate Classification, the Philippines has four (4) types of climates. Despite the country's abundant rainfall, certain regions still experience water scarcity, especially those with a Type II climate. This climate type has no dry season and peaks in rainfall from December to February. Despite expected consistent water availability, places like Catanduanes in Type II have faced water scarcity.

Rainfall Data in Catanduanes

Annual Rainfall Data

When considering a rainwater harvesting facility, key factors include roof design based on rainfall data from the Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA) for effective

collection. The tank size and capacity are determined by the amount of rainwater collected and the community's monthly water consumption needs. Rainfall data from PAGASA for Catanduanes serves as the basis for tank and roof design calculations.

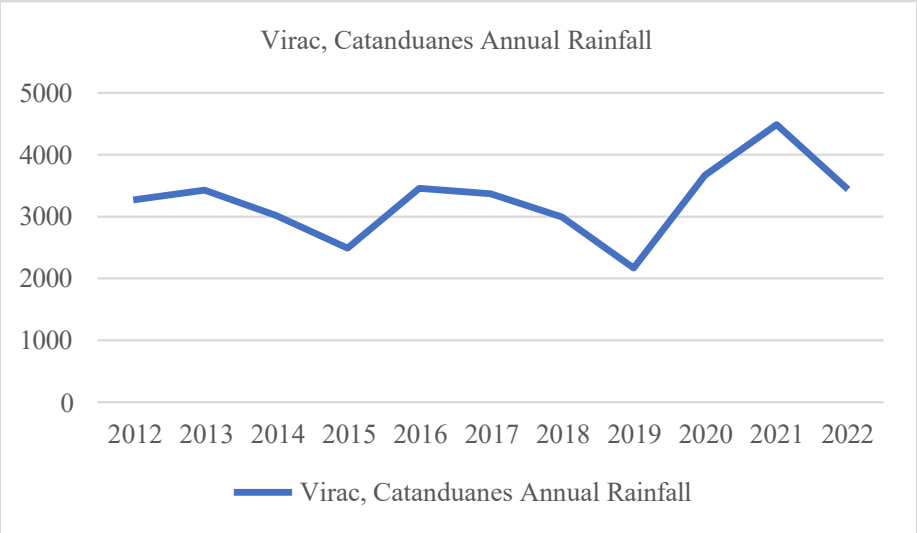


Figure 1. Line graph of Virac Catanduanes Annual Rainfall Data (2012 to 2022)
Source: Data is based on the requested document from Climate and Agrometeorological Data Section (CADS) Climatology and Agrometeorology Division (CAD) and Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA)

Notably, Virac, Catanduanes experiences consistently high rainfall, but with notable fluctuations from year to year. These variations have important implications for agriculture, water resource planning, and disaster risk management in the region.

Monthly Rainfall Data

Based on the monthly precipitation data from PAGASA for Virac, Catanduanes in the year 2022, the wettest month was December with 576.2 mm of rainfall, while the driest month was May with 124.9 mm.

Month	Monthly Precipitation (mm)
January	284.4
February	201.5
March	395
April	276.8
May	124.9
June	174.4
July	279.2
August	231.2
September	161.5
October	371.2
November	368.8
December	576.2

The data shows significant rainfall throughout the year, with a notable increase from October to December, reflecting the typical wet season and peak typhoon period in the region. Overall, Virac experiences a tropical climate with abundant rainfall year-round.

Analysis

Analysis on Roof Area Calculation

Water demand varies per household, respondents reported non-potable water consumption. Based on studies by the Philippine Institute for Development Studies (PIDS), the minimum water consumption for a basic needs household in the Philippines is approximately 10 cubic meters (m^3) per month, which qualifies for the "lifeline rate" and exemption from certain charges for low-income consumers. (Arlene B. Inocencio, 1999). In 2025, 10 cubic meters is still used by water utilities like Manila Water to define the initial consumption block for residential customers, often referring to a family of six.

Water consumption serves as the basis for determining how much water needs to be collected. The needed amount of collected rainwater, in turn, determines the size of the rainwater collection area.

Table 1. Calculated roof area based on the monthly precipitation data for Virac, Catanduanes, in 2022

Roof Area = 10 cubic meters	**Amount of collected rainwater (liters) = Precipitation (mm) x Runoff coefficient (0.80)**			
Months	**Roof Area (sqm)**	**Precipitation (Monthly) (mm)**	**Water Demand (liters)**	**Runoff Coefficient for for smooth corrugated roofs**
January	43.96	284.4	10000.00	0.80
February	62.04	201.5	10000.00	0.80
March	31.65	395	10000.00	0.80
April	45.16	276.8	10000.00	0.80
May	100.09	124.9	10000.00	0.80
June	71.68	174.4	10000.00	0.80
July	44.78	279.2	10000.00	0.80
August	54.07	231.2	10000.00	0.80
September	77.4	161.5	10000.00	0.80
October	33.68	371.2	10000.00	0.80
November	33.9	368.8	10000.00	0.80
December	21.7	576.2	10000.00	0.80

The rainwater collection area can be the entire roof or just a part of the roof area. Since the roof collection area is directly proportional to the amount of rainwater collected and inversely proportional to the amount of precipitation, it is best to consider months with the least precipitation. This approach ensures that the roof is large enough to collect enough rainwater, even during dry periods. By measuring the roof area accurately, it can be estimated how much water can be collected, knowing that 1 mm of rain provides about 1 liter of water for every square meter of roof. A bigger roof collects more water.

In months with less rainfall, having a larger roof is crucial to meet the community's water needs. While the slope of the roof helps with drainage, it does not greatly impact how much rainwater is collected since rain usually falls straight down. By focusing on the roof area and the amount of rain, it can be effectively estimated the volume of rainwater we can harvest to ensure the community's needs are met, even during drier times.

Analysis on Tank Calculation

The size of rainwater tanks vital for effective use in building design, especially for a “dry” rainwater harvesting system. In these systems, tanks are usually placed above ground and near the house.

The minimum tank size is 10 cubic meters. This size is based on the average monthly water use for low-income households in the Philippines. To figure out the largest tank size, it is needed to consider both the minimum size and

the typical amount of extra rainwater collected each year. This ensures the system meets the household's needs while also handling changes in rainfall throughout the year.

Table 2. Minimum tank dimensions based on monthly water consumption and maximum tank dimensions based on the average excess collected rainwater

10 cubic meters									
Roof Area is based on the ideal roof size considering the month with least rainfall (May)				-	Roof Area is based on monthly precipitation (data from PAGASA)				Excess Collected rainwater
Roof Area (May) (sqm)	Precipitation (Monthly) (mm)	Runoff Coefficient for smooth corrugated roof	RW (Liters)	-	Months	Roof Area (sqm)	Precipitation (Monthly) (mm)	Runoff Coefficient for smooth corrugated roof	WD (Liters)	
100.09	284.4	0.80	22772.48		January	43.96	284.4	0.80	10000.00	12772.48
100.09	201.5	0.80	16134.51		February	62.04	201.5	0.80	10000.00	6134.51
100.09	395	0.80	31628.44		March	31.65	395	0.80	10000.00	21628.44
100.09	276.8	0.80	22163.93		April	45.16	276.8	0.80	10000.00	12163.93
100.09	124.9	0.80	10001.00		May	100.09	124.9	0.80	10000.00	1.00
100.09	174.4	0.80	13964.56		June	71.68	174.4	0.80	10000.00	3964.56
100.09	279.2	0.80	22356.11		July	44.78	279.2	0.80	10000.00	12356.11
100.09	231.2	0.80	18512.65		August	54.07	231.2	0.80	10000.00	8512.65
100.09	161.5	0.80	12931.63		September	77.4	161.5	0.80	10000.00	2931.63
100.09	371.2	0.80	29722.73		October	33.68	371.2	0.80	10000.00	19722.73
100.09	368.8	0.80	29530.56		November	33.9	368.8	0.80	10000.00	19530.56
100.09	576.2	0.80	46137.49		December	21.7	576.2	0.80	10000.00	36137.49
									Average	**12988.01**

*Maximum Sized Tank= Minimum Sized Tank x 2.298801

*Maximum Sized Tank= 10 cubic meters + 12.98801 cubic meters

Choosing a small tank prevents excess water retention, allowing it to safely flow to the sewer and recharge groundwater. This option saves space, reduces contamination risks, and ensures harvested rainwater is safe to drink within a month.

If the designer chooses a large tank, it will require a bigger shape if there is available space. A larger tank can also be installed underground with a wet rainwater harvesting system, keeping the area above clear. However, this option may be more costly, particularly if located far from the house. A large tank can be split into smaller tanks placed in various locations to meet water needs. This design works well with sloped roofs, effectively collecting rainwater. Overall, tank design should balance practicality, cost, and the household's specific water requirements.

Discussion

The climate and rainfall in a region affect the need for rainwater harvesting systems. In areas with low rainfall, larger roofs are needed to collect enough water. Efficient rooftop designs are crucial for this. And to ensure enough water during dry spells, storage tanks should at least match household water use. However, trying to collect all rainwater can be challenging due to the need for large collection areas and tanks, which can be costly and require more space. This is especially important for aboveground systems with limited space or complex underground systems. Knowing how much water households need is vital for determining the right roof size and tank volume, particularly during dry months. The goal is to match collected rainwater with community needs, supporting sustainability and conserving groundwater. Setting realistic goals based on actual needs is essential.

Collecting and storing all available rainwater is not always practical, particularly when it requires excessively large roof catchment areas and storage tanks. Imteaz and Shadeed (2022) emphasized the importance of determining the

optimal tank capacity through water balance modeling, noting that oversized tanks may become impractical in urban areas where space is limited and construction costs are considerable. Their findings support the need to establish realistic storage requirements based on rainfall availability and water demand rather than simply maximizing tank capacity. By considering the relationship between roof catchment area, rainfall patterns, household water demand, and storage capacity, residential designs can achieve a more practical and efficient rainwater harvesting system. In the context of houses in Virac, Catanduanes, this approach provides a basis for determining appropriate roof and tank dimensions that can help address water shortages, support sustainable water management, and reduce dependence on groundwater resources. Rather than attempting to collect all available rainfall, the design should prioritize meeting household water requirements while considering the available space, construction costs, and architectural integration of the facility.

Conclusion

In Virac, Catanduanes, homeowners can utilize rainwater harvesting during low municipal water supply. Effective systems should optimize roof types and collection areas, ensuring downspouts connect to above-ground tanks. For limited space, buried tanks are an option, though they complicate design.When planning rainwater harvesting systems, it's important to consider factors like local climate and rainfall amounts to optimize performance and maintenance. The size of the roof plays a crucial role, as larger roofs collect more rainwater. In Catanduanes, where dry periods are minimal, a larger roof is vital to meet community needs. For instance, a household in Virac aiming to gather 10,000 liters of rainwater requires a roof area of at least 100.09 square meters. Additionally, rainwater tanks should hold at least 23 cubic meters to accommodate fluctuations in water availability and match the household's usage.

In general, rainwater harvesting helps manage water use and supports sustainability. It is an important part of modern building practices that take the environment into account.

Recommendation

For the Site of the Study

To get accurate data on water consumption, conduct surveys and interviews with households. It is recommended to focus on building features, instances of water scarcity, rainwater harvesting, and the number of users. It is advisable to measure the dimensions of the site and house to gather useful information. Also, it is suggested to keep track of the latest rainfall data from PAGASA to determine the minimum roof collection area.

For Rainwater Harvesting Systems

When researching rainwater harvesting systems for drinking, it is recommended to focus on advanced filtration methods and check the costs and manufacturing processes to see if they are feasible. It is advisable to look for local materials for roofs and storage tanks to improve implementation. Also, it is suggested to consider the electrical and plumbing needs, as well as the overall design, to ensure efficient water distribution to homes, especially for non-potable uses. Finally, future studies should work closely with consultants, designers, and engineers to make sure the systems are applied effectively.

References

Akruthi Enviro Solution. (n.d.). Rainwater harvesting methods. https://www.neoakruthi.com/blog/rainwater-harvesting-methods.html.

Bacon, E. N. (1974). *The design of cities*. Viking Press.

Barcia, R. B. (2018, August 30). Catanduanes hit by water, power crisis. *Bicol Mail*. https://www.bicolmail.net/single-post/2018/08/30/catanduanes-hit-by-water-power-crisis.

Bartolacci, J. (n.d.). *Let it pour: 8 architectural details to harvest rainwater*. Architizer. https://architizer.com/blog/inspiration/collections/rainwater-collection/amp/.

Belen, G. (2015). *Calumpit municipal disaster risk reduction and management plan (MDRRMP) 2016–2021*.

Blue Mountain Co. (n.d.-a). *Calculating your average rainfall and ideal tank size*. https://rainharvesting.com.au/eu/tanks-

and-storage/calculating-your-average-rainfall-ideal-tank-size/.

Blue Mountain Co. (n.d.-b). *Water storage and rainwater tank selection*. https://rainharvesting.com.au/eu/tanks-and-storage/water-storage-and-rainwater-tank-selection/.

Bolt, O. (2024, February 28). *10 disadvantages of rainwater harvesting*. Energy Theory. https://energytheory.com/disadvantages-of-rainwater-harvesting/.

Bueza, M. (2019, December 30). 'Last resort': Duterte pushes Kaliwa, Wawa dams. *Rappler*. https://www.rappler.com/nation/248227-duterte-pushes-kaliwa-wawa-dams-solve-water-problems-metro-manila/.

BYJU'S. (2024). *Rainwater harvesting*. https://byjus.com/biology/rainwater-harvesting/.

Capacillio, J. (2018, August 17). New rainfall collection system allows schools in Leyte to reuse water. *SPOT.ph*. https://www.spot.ph/newsfeatures/the-latest-news-features/74828/dpwh-rainwater-collection-southern-leyte-a00258-20180817.

Career Power. (2023, October 6). *Rainwater harvesting methods, diagram, model and advantages*. https://www.careerpower.in/school/biology/rainwater-harvesting.

Chiu, Y.-R., Tsai, Y.-L., & Chiang, Y.-C. (2015). Designing rainwater harvesting systems cost-effectively in an urban water-energy saving scheme by using a GIS-simulation based design system. [Publication details and DOI/URL to be verified].

Department of Science and Technology–Philippine Atmospheric, Geophysical and Astronomical Services Administration. (2011, February). *Climate change in the Philippines*. https://dilg.gov.ph/PDF_File/reports_resources/DILG-Resources-2012130-2ef223f591.pdf.

Department of Science and Technology–Philippine Atmospheric, Geophysical and Astronomical Services Administration. (2021). *Climate in the Philippines*. https://bagong.pagasa.dost.gov.ph/information/climate-philippines.

Dr Nic's Maths and Stats. (2012, February 1). *Statistical tests: Choosing which statistical test to use* [Video]. YouTube. https://www.youtube.com/watch?v=rulIUAN0U3w.

Earth Reminder. (2021, October 20). *Advantages and disadvantages of rainwater harvesting*. https://www.earthreminder.com/advantages-and-disadvantages-of-rainwater-harvesting/.

Economist Intelligence Unit. (2011). *Asian green city index: Assessing the environmental performance of Asia's major cities*. Siemens.

Farmland Rainwater Harvesting System. (2023). *Rainwater harvesting in different countries*. Rainy Filters. https://www.rainyfilters.com/about-us/blogs/rain-water-harvesting-in-different-countries.

Felix, M. L., Maniquiz-Redillas, M. C., & Seo, S. (2011). Analysis on the potentiality of domestic rainwater harvesting in Metro Manila. [Publication details and DOI/URL to be verified].

Fernandez, E. G. (n.d.). *Architecture and the hot, humid climate (climate as formgiver)*. [Publisher or source information to be verified].

GMA Regional TV News. (2024, May 16). Water rationing implemented in several barangays in Virac, Catanduanes. *GMA Regional TV*. https://www.gmanetwork.com/regionaltv/community/101967/water-rationing-implemented-in-several-brgys-in-virac-catanduanes/story/.

Hartley, K. (2017, September 22). China's 'sponge cities' aim to reuse 70% of rainwater. *The Third Pole*. https://www.thethirdpole.net/en/climate/chinas-sponge-cities-aim-to-re-use-70-of-rainwater-heres-how/.

Imteaz, M. A., & Shadeed, S. (2022). Superiority of water balance modelling for rainwater harvesting analysis and its application in deriving generalised equation for optimum tank size. *Journal of Cleaner*

Production, 342, 130991. https://doi.org/10.1016/j.jclepro.2022.130991.

Inocencio, A. B. (1999, February). *Determination of basic household water requirements*. Philippine Institute for Development Studies. https://pidswebs.pids.gov.ph/CDN/PUBLICATIONS/pidsdps9902.pdf.

Innovative Water Solutions LLC. (2023). *Rainwater harvesting 101*. https://www.watercache.com/education/rainwater-harvesting-101.

Innovative Water Solutions LLC. (2025). *Rainwater catchment calculator*. https://www.watercache.com/resources/rainwater-collection-calculator.

myGate. (2024). *All you need to know about rooftop rainwater harvesting*. https://mygate.com/blog/housing-society/rainwater-harvesting/.

OHorizons Charitable Solutions. (2018). *Safe drinking water*. https://www.ohorizons.org/wood-mold-intro.

Palafox, F. A. (2019, November 21). Water for cities. *The Manila Times*. https://www.manilatimes.net/2019/11/21/opinion/columnists/water-for-cities/657452/.

Parra, M. V. (2015). *Optimizing rainwater harvesting in urban areas*. [Publisher or URL to be verified].

PDP Services. (n.d.). *Rainwater harvesting*. https://pdp.services/renewables/rainwater-harvesting/.

Richardson, J. (2024, June 23). *History of rainwater harvesting*. The Renewable Energy Hub. https://www.renewableenergyhub.co.uk/main/rainwater-harvesting-information/history-of-rainwater-harvesting.

Rochat, E. (2018, July 3). *The history of rainwater harvesting*. Perfect Water. https://4perfectwater.com/blog/history-of-rainwater-harvesting.

Rosario, R. D. (2023, October 6). PH Red Cross responds to water shortage in Catanduanes. *Manila Bulletin*. https://mb.com.ph/2023/10/6/ph-red-cross-responds-to-water-shortage-in-catanduanes.

Saravanan, J., & Sridhar, M. (2017). Rain towers: An integrated rainwater harvesting and excess flood control structure for Chennai rivers. [Publication details and DOI/URL to be verified].

Savou, J. (2022, September 23). *Best roofing materials for rainwater harvesting*. BlueBarrel LLC. https://www.bluebarrelsystems.com/blog/roofing-materials-for-rainwater-harvesting/.

Silent Gardens. (2021). *Climate: Regional climates for tourists*. https://www.silent-gardens.com/climate.php.

Tibay, R. (2018, August 31). Red Cross helps Virac, Catanduanes, to prevent looming water crisis. *Manila Bulletin*. https://mb.com.ph/2018/08/31/red-cross-helps-virac-canduanes-to-prevent-looming-water-crisis/.

UNICEF Philippines. (2017, July 17). *Two billion people lack safe drinking water, more than twice lack safe sanitation*. https://www.unicef.org/philippines/press-releases/two-billion-people-lack-safe-drinking-water-more-twice-lack-safe-sanitation.

UN-Water Decade Programme on Advocacy and Communication, & Water Supply and Sanitation Collaborative Council. (n.d.). *The human right to water and sanitation: Media brief*. United Nations. https://www.un.org/waterforlifedecade/pdf/human_right_to_water_and_sanitation_media_brief.pdf.

water.org. (2019). *Philippines' water and sanitation crisis*. https://water.org/our-impact/where-we-work/philippines/.

Weida Philippines, Inc. (2025). *Underground water tank*. https://www.weida.com.ph/products/water-storage/underground-water-tank/.