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Study on Potential and Practices of Rooftop Rainwater Harvesting System in Oxford College of Engineering and Management

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Abstract

The objective of this study was to evaluate the possibility of promoting rooftop rainwater harvesting to address future water scarcity in the Oxford College of Engineering and Management Nawalparasi district. AutoCAD software drew accepted plans and maps; manual measurement was done with measuring tape since some parts were missing.

The results show that the linear forecast 1558.139, 1581.57mm,1548.63mm, 1598.14mm and 1570.64mm. The volume of water is 5135.54, 5028.16, 5188.94, 5099.68 respectively. It also shows the calculation of water demand which is 5,820,000 liters per year, and the water harvested is 5188946.58 liters per year. Finally, with this ratio, we realized we could fulfil 89.15% of water demand through water harvesting. The time series relevant results indicated that the A.R.I.M.A. model of forecasting rainfall was based on (0.1.0), signifying the R Square value is .631 and the p-value is insignificant ($p > 250$), which is better for this forecasting model.

Keywords: *Catchment area, demand, forecasting, measurement, rainfall, roof rainwater harvesting*

1. INTRODUCTION

Millions of people worldwide do not have access to clean water for domestic purposes. In many parts of the world, conventional piped water is either absent, unreliable, or unsuitable for the settlements at high mountains. It is also too expensive for people who are under the poverty line. One of the 21st century's biggest challenges is overcoming the growing water shortage (Nepal Water for Health, 2012). Due to rapid growth in urbanization, roof rainwater is one of the best alternative sources of water supply to all sectors. It can fulfil both potable and non-potable water demands. It is also more economical and socially acceptable to the community (Hasnain, 2018).

With technological advancement, various proven methods have evolved for water collection and distribution through pipes for individual and collective communal systems. With more conventional water supply technologies, Rainwater harvesting (R.W.H.) has become a valuable and viable alternative or supplementary water source. Much of the actual or potential water shortages can be relieved if rainwater harvesting is widely practiced (Bittharia, 2021). From an environmental and socioeconomic perspective, a rooftop R.W.H.S. has many advantages. It can be used for agricultural, domestic and industrial purposes. Rooftop rainwater harvesting systems also play an essential role in flood management and stormwater runoff (Ali et al., 2019).

1.1 Background of the study

Roof rainwater harvesting is a simple, low-cost technique requiring minimum expertise or knowledge. Collected rainwater can be supplement to other water sources when it becomes scarce or is of poor quality. It is also a good alternative during drought or when the water table drops and the wells dry. The collected rainwater is a valuable supplement which would otherwise be lost by surface runoff or evaporation (Adugna, Jensen, Lemma & Gebrie 2018). During the past decade, R.W.H. has been actively reintroduced by government and local organizations as an option for increasing access to water in urban and rural areas. With the increased need for water, innovative approaches to improving the water supply are desperately needed in many parts of developing countries. A wide variety of small-scale rainwater harvesting methods are being applied in some countries for the irrigation of crops and sustainable life (Avis

& Avis 2018). In Nepal, this system of collecting rainwater and using it in washing clothes, and utensils, feeding animals, irrigating the gardens, and even recharging the groundwater table can be seen mostly in rural areas. Many organizations have studied rainwater harvesting to mitigate the scarcity of water. Water scarcity is a problem wherever there is an increasing population.

The R.W.H. technology has rapidly gained popularity, with users realizing the benefits of a relatively clean, reliable, and affordable water source at home (Bittharia, 2021). R.W.H. has now been introduced as part of an integrated water supply system. In many areas, there is adequate precipitation throughout the year. The town water supply fluctuation in the regular supply, i.e., it cannot meet the current demands of the community (Bittharia, 2021). (Salāmah., Shutaywī & Al Ragged 2018) analyze and interpret the collected rainwater and household catchment area together. They found that the potential of water harvesting and collected water could be helpful to domestic sources.

Similarly, (Worm, Tim Van Hattum, Catharina De Kat-Reynen, & Al 2006) conclude that the 'World Economic Forum has ranked the water crisis as the most significant risk to humanity and human economics. The world will face water scarcity by 2025 (Jeevan Kasula (2012). Furthermore, he concluded that only 27 percent of the population could access safely managed water and 62 percent could access basic sanitation services. Due to the pollution of both groundwater and surface water and the overall increased demand for water resources owing to population growth, many communities are approaching the limits of their traditional water resources (Nepal Water for Health 2012). Therefore, each country has begun to resort to alternative or 'new' resources like Rainwater harvesting. It has become a valuable alternative or supplementary water source (Celeste, Novak, Giesen, & Debusk, 2014). Rapid population growth and urbanization have demanded a greater water volume in Nepal.

Additionally, people's awareness of sustainable development along with the Millennium Development Goals is still poor in Nepal (Nepal Water for Health 2012). Therefore, excessive groundwater is environmentally unfavourable and a future threat to sustainable development (Avis & Avis, 2018). Water management is critical to any economy's growth and development, particularly in growing economies like Nepal. However, the resource is currently under stress due to excessive groundwater exploitation in socioeconomic development and to meet the increased needs of the growing population (Adugna et al. 2018). As a result, we should use this valuable resource while conserving it (Umapathi, Pezzaniti, Beecham, Whaley, & Sharma 2019). The primary goal of this study is to give a broad review of rainwater collecting systems and groundwater and their uses in everyday life. Many countries have implemented rainwater harvesting as a long-term strategy to complement public water supplies. Rainwater harvesting systems have overcome many water-related issues. Another source of water that can be counted on is groundwater (Chao-Hsien, En-Hao & Yie-Ru, 2014).

Rainwater harvesting is the best option in areas with inadequate groundwater or surface water supply. Rainwater harvesting is the deposit of rainwater to reuse on-site, rather than runoff, which helps using overloads to water treatment plants. It prevents runoff from going to the drainage system, effectively utilizing the rainwater (Adugna et al. 2018). Similarly, it helps recharge water into aquifers and improves groundwater quality, preventing runoff from going to the drainage system and effectively using the rainwater. Similarly, it helps restoring moisture into aquifers and improves groundwater quality through dilution. (Mouli 2017; Whittington & Xun Wu, 2020). harvested rainwater has fewer pathogens than unprotected surface water.

Rainwater Harvesting Capacity Centre was established in 2006 and promoted the technology of Rainwater Harvesting in Nepal. It provides long-term access to use safe water for vulnerable communities, primarily in 'Type 3 areas. People have no access to surface water, have no alternative sources such as boreholes or spring potential, and suffer from restrictions due to poor water quality (Lalwani, 2022). Some parts of Nepal have been following rooftop rainwater harvesting. It is a cheap process compared to surface runoff. The harvesting system consists of a catchment roof, conveyance pipes, and a storage jar (reservoirs). The pipes include a gutter system made from longitudinally split polyethene pipe, which has a flushing system that allows the system to be flushed clean periodically. Therefore, people can save hundreds of dollars a year instead of buying the popular yet questionable quality water available in jars in the market from USD 0.35 to 1.3 per 20 liters and save between USD 51- 85 each year (Mambretti &

Melgarejo 2019). The general objective of the research was to evaluate the possibility of promoting rooftop rainwater harvesting to address future water scarcity at Oxford College of Engineering and Management. in Nawalparasi district. Evaluation of users' willingness to adapt rooftop rainwater harvesting and its potential in domestic and institutional buildings were the specific objectives for obtaining the primary goal. This study implication would be beneficial to the development of the metrology department, risk disaster management, agriculture (crop development), NARK, and future researchers in foregrounding the need for rainwater harvesting systems and conducting the primary experimental research in the Nepalese context. We are bachelor's students of the Engineering Department at Oxford College of Engineering and Management (OCEM), Gaindakot, Nepal.

2. LITERATURE REVIEW

This review is embedded in the search for roof rainwater harvesting systems to meet the current water demand. Our study is based on journal articles, books, online documents, magazines, and conference papers. This review has analyzed fifteen published journal articles focusing on rainwater harvesting systems and tried to find the research gaps in the reviewed articles.

Rainwater Harvesting System Components

The roof, ground, and rock catchments are three common systems to collect water for domestic Use. Check and sand dams are mainly used for irrigation (See Figure 1) (Mouli 2017**).**

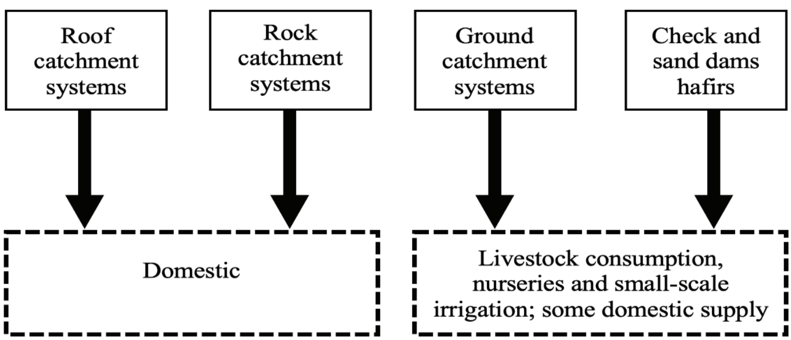


Figure 1. Catchments surfaces of roof rainwater

The roof of a building or a house is an obvious choice for a catchment installation. One can build an open-sided barn—called a rain barn or a pole barn to accommodate additional capacity. Barns can store water tanks, pumps, filters, vehicles, and tools (Celeste et al., 2014). Rooftop rainwater systems are popular at the household and community levels, as the water can be readily used for domestic purposes. An added advantage is that users own, maintain, and control their systems, reducing reliance on other community members (see Figure 2). Water quality in these systems is related to the roof material, climatic conditions, and the surrounding environmental conditions (Al-Houri, Abu-Hadba & Hamdan 2014). Rock and ground catchments Rooftop water tends to be of higher quality and is therefore preferred for human consumption. Where water quality is of less concern, such as small-scale irrigation for food production, livestock, tree nurseries, brickmaking, etc., the livelihood approach promotes the Use of runoff water. Runoff can be stored in ponds; however, loss due to evaporation makes small, underground storage tanks a better option. Rainwater on rock surfaces can be diverted to storage tanks using bunds and gutters (Saeid Eslamian & Faezeh Eslamian, 2020) (see Figure 2).

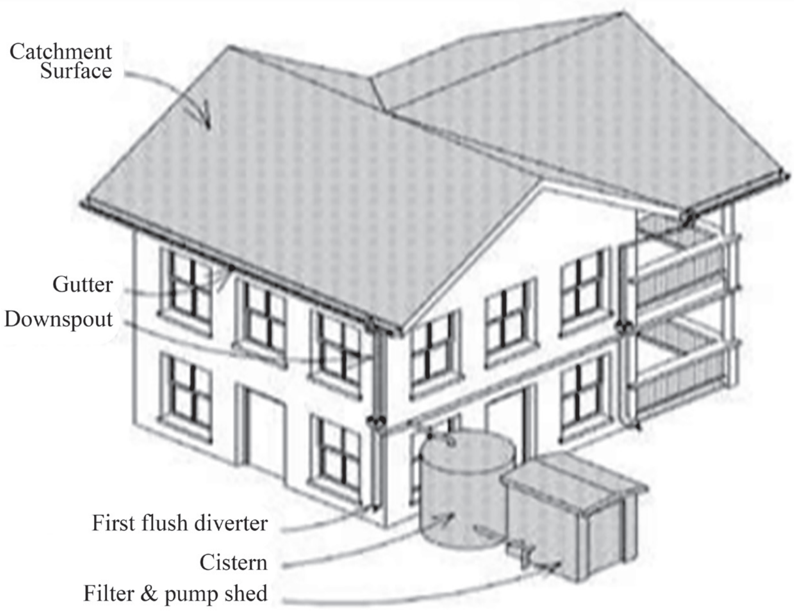


Figure 2. Roof catchments of roof rainwater

Delivery System components

Several types of delivery systems are used to transport water from catchments to Gutters and are installed to capture rainwater running off the eaves of a building. Some gutter installers provide continuous or seamless gutters. Lead cannot be used as gutter solder for potable water systems, as is sometimes the case in older metal gutters (Aniruddha Bhalchandra Pandit & Jyoti Kishen Kumar, 2019) (see Figure 3).

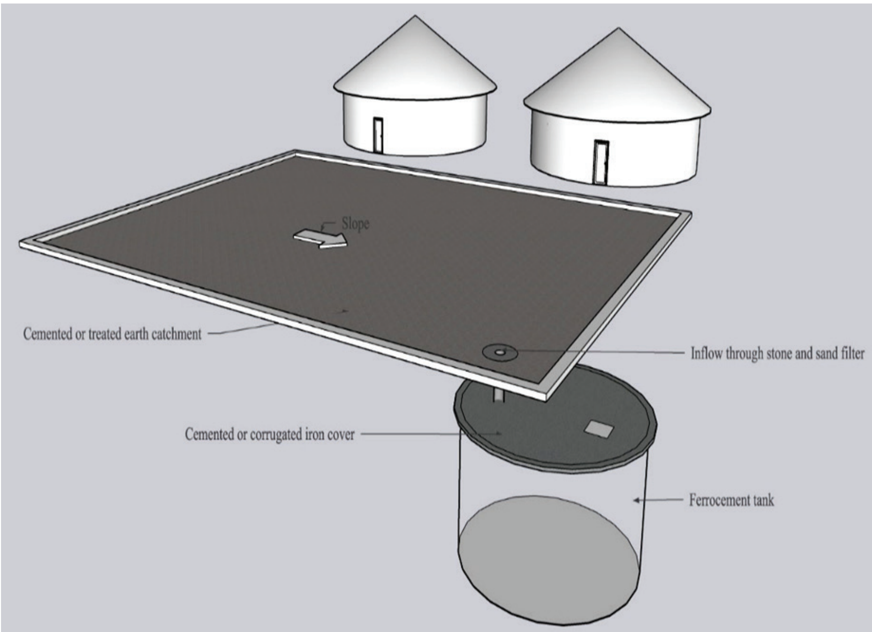


Figure 3. Delivery System component

Gutter Sizing and Installation

Roofs are often built with one or more roof valleys with different slopes—an important consideration in constructing rooftop catchment systems. Roof valleys are the point at which two roof planes meet. The size of roof areas ending in a roof valley, the roof slope, and the rainfall intensity affect the ability of the drainpipe to capture the water (Avis & Avis, 2018). If these factors are not adequately accounted for, spillage or overrunning may result. Other factors that may result in overrunning include inadequate downspouts, excessively long distances from ridge to eave, steep roof slopes, and inadequate gutter maintenance. These variables make it difficult to apply standard rules for drainpipe sizing. Specialized engineers can provide specific guidance on strategies to mitigate overrunning and improve catchment efficiency (Adhikari, Timisina & Lamichhane 2018).

Table 1. Summary of the previous study on rooftop rainwater harvesting systems

Topics	Authors and publication year	Objective	Name of journal	Methods used	Findings
a. Assessing the Potential for Rooftop Rainwater Harvesting from Large Public Institutions b. The Potential of Roof Top Rainwater Harvesting as a Water Resource in Jordan: Featuring Two Application Case Studies c. Design of Rooftop Rainwater Harvesting Structure on a University Campus d. Rooftop Rainwater Harvesting (R.R.W.H.) At Spsv Campus e. Domestic Rainwater Harvesting System: A Model for Rural Development	Dangnachew Adunga, Marina Bergen Jensen, Brook Lemma and Geremew Sahilu Gebrie (2018); Zain M. Al-Houri, Oday K. Abu-Hadba, Khaled A. Hamdan (2014); S. Sangita Mishra, Shruti B.K. and H. Jeevan Rao (2020); (Patel et al.(2014); Panhalkar (2011)	This study assessed the resource potential of rooftop rainwater gathering in Jordan.	a. international journal of environmental research and public health. b. Rural Extension & Innovation Systems Journal. c. International Journal of Recent Technology and Engineering. d. International Journal of Research in Engineering and Technology e. International Journal of Science and Nature	a. A. survey method b. A case studies method c. Review method d. Qualitative and rational method e. Case study	The results indicate that a particular volume of water can be harvested in specific areas to address the scarcity of water in cities
a. Rainwater Harvesting b. Design of a Rainwater Collection System and Possible Use of Harvested Water in a Kindergarten Building: A Case Study in Tirana City, Albania c. The potential of rainwater harvesting in Nepal: a case study	Akther (2014); Blerina Beqaj, Oltion Marko, Entela Cobani and Driean Proska (2022); Gautam (2016)	The primary objective of the research was to determine each family's capacity on various parcels of land by analyzing and interpreting the collected rainwater and household catchment area.	a. JUICE Press Conference Paper b. European Journal and Technology Research c. Norwegian University of Life Sciences	a. A Survey Survey b. Case study method	The study's finding concludes that harvested rainwater can be used for different household purposes

Topics	Authors and publication year	Objective	Name of journal	Methods used	Findings
Adoption and impact of rainwater harvesting technology on rural livelihoods: The case of Makwanpur district, Nepal	Surya P. Adhikari, Krishna p. Timsina and Jeevan Lamichhane (2018)	This case study's main objective was to identify factors that incite the adoption decision of Rainwater harvesting technology.	Rural Extension and Innovation System Journal	A case study method	The finding indicates that the main factors influencing the adoption of R.W.H. technology were the number of years of education, the total value of physical assets, and the organizational membership of household members
Rainwater Harvesting, a Review	Jain, Chandrakar & Yadav (2022).	The main objective of this study was to provide a thorough overview of groundwater and rainfall collection systems and their potential applications in daily life.	Indian Journal of Applied Research	A literature review method	As a long-term plan, rainwater harvesting can be used to supplement the public water supply as well as many water-related problems have been resolved with the Use of R.W.H. systems.
Performance of a large building rainwater harvesting system	Sarah Ward, Fayyaz Ali Memon and David Butler (2012)	This paper aimed to evaluate the performance of a non-domestic R.W.H. system in a British office building empirically.	Journal of Water Research	The intermediate (simple calculations) and detailed (simulation-based) approaches.	The study concludes that the office-based R.W.H. system had an average water-saving effectiveness of 87% over eight months. Also, using a smaller tank rather than a larger one may have produced results of a similar caliber.

Topics	Authors and publication year	Objective	Name of journal	Methods used	Findings
Sustainability of rainwater harvesting systems in multistorey residential buildings	Rahman et al (2010)	This study aimed to investigate alternative water	American Journal of Engineering and Applied Sciences	A water balance model was developed to calculate water savings for multiple scenarios	The results discovered that a larger roof area offers better financial and water-saving advantages. It was shown that a higher roof area is preferable in terms of water savings and economic benefits.
Potential of rooftop rainwater harvesting to meet outdoor water demand in arid regions	Kazi Tamaddun, Ajay Kalra and Sajjad Ahmad (2018)	The main objective of this study was to evaluate the effects of the selected model parameters on the efficiency of rooftop rainwater harvesting	Journal of Water Research	The intermediate (simple calculations) and detailed (simulation-based) approaches	The results indicated that the suggested storage tanks of 1-2m3 rainwater barrels can hold about 80% of the monthly collected rooftop rainwater in Arizona and that there was a variation of 37.5% in the amount of rainfall potential between the expected dry and wet climate conditions
Potential of rainwater harvesting in urban Zambia	Lubinga Handia and Caroline Mwiindwa (2003)	The study aimed to determine whether rainwater collection could be used in urban Zambia.	Journal of Physics and Chemistry of the Earth, Parts A/B/C	Qualitative, rational method	The results indicate that a storage tank with a 10m3 capacity has been chosen, and the construction of 5 systems is in progress.

The findings show that a certain amount of water can be gathered in places (Adugna et al.2014). Similarly, the study concludes that harvested rainwater can be used for different household purposes (Akther 2014; Beqaj, Marko, Çobani & Profka 2022;

Gautam 2016). Likewise, the finding also indicates that establishing the rainwater harvesting system requires a series of years of study along with the total value of physical assets and the organizational membership of household members (Akther 2014; Beqaj, Marko, Çobani & Profka 2022; Gautam 2016). Furthermore, the study concludes that rainwater harvesting devices have been used to solve numerous water-related issues and can be used to supplement the public water supply (Jain, Chandrakar & Yadav 2022). Correspondingly The study found that one effective way to lessen water scarcity is to establish a small rainwater collection system that might collect enough water to meet family needs. A surrounding area's groundwater table can also be maintained for an extended period by using abandoned wells that have been turned into percolation wells (Akther 2014).

Uniformly, the study's findings show office-based rainwater harvesting for eight months. The system had an average water-saving efficiency of 87%. Additionally, the study concludes employing a smaller tank instead of a larger one might have led to outcomes of comparable quality (Ward, Memon & Butler 2012). A bigger roof area was identified to provide higher financial and water-saving benefits. A higher roof area has been demonstrated to be more advantageous regarding water conservation and economic benefits (Rahman 2010).

Similarly, this study discovered that the 1-2 m3 rainwater barrels recommended for storage could contain roughly 80% of the monthly rooftop rainwater collected in Arizona. The difference in rainfall potential between the predicted dry and wet climate conditions is 37.5% (Tamaddun, Kazi, & .2018). Furthermore, this study suggests that a storage tank with a 10m3 capacity has been chosen, and the construction of 5 systems is in progress (Handia Lubinga, Tembo Madalisto James, Mwiindwa & Caroline 2003). Likewise, according to the study's findings, the kindergarten building, which has a 370 m2 catchment area, is responsible for collecting the water used for the school's regular operations, such as flushing the restrooms and washing clothes (Beqaj, Marko, Çobani & Profka 2022).

3. METHODS AND MATERIALS

Our study has followed both primary and secondary data collection procedures during our research. The secondary data for this study came from various literature gathered and evaluated to achieve the study's objectives. We fulfilled all ethical issues of the primary and secondary data collection. We have taken the reference at OCEM, with a catchment area of 3246.86 sqm. We clearly came to know all the advantages which can draw out by implementing this small but highly efficient technique in the periphery of campus. Thus, to increase the potential benefits of this system and draw maximum advantages from it, we need to have larger rooftop areas that will act as catchment areas. The greater the catchment area, the more surface runoff and, thus, the amount of water harvested. To obtain primary data for the research with the help of a letter on (date) from Oxford College of Engineering and Management, we approached the Agriculture Forestry University (A.F.U.) Office. This study has included and considered all the major buildings and larger rooftop areas as much as possible for the primary data collection. Hence study areas include all five blocks (Engineering/B.C.A., administrative. Infirmary+ HM) and all other areas such as the Basketball court, water tap, canteen, parking, storeroom, stationery guard room, and toilet. Plans and maps of the study area were obtained from the respective authorities without further ado to meet 1st objective. Accepted methods and maps were analyzed by AutoCAD software; manual measurement was done with measuring tape since some parts were missing.

A rain gauge was used to collect the rainfall data, but it was unfavourable to place a rain gauge in our study area. The nearest rain gauge station was located at Agriculture Forestry University (A.F.U.), Rampur, Chitwan, Nepal. The rainfall data obtained from the office include 2000-2021. After the competition of the data collection, we then tabulated the linear projection for the upcoming five years. With this area's runoff coefficient and the litres per person, we assumed from our textbook that this study calculated our demand for our catchment. Then we calculated the amount of water that could be harvested from our catchment. After the final calculation of the water volume harvested, we planned the area in which the harvested water could be used. The processes of rainfall harvesting are also addressed in this study (see Figure 1). The methodological review was also based on the secondary data on rainfall.

Hydrological Analysis

Table 2. Data Analysis and calculation

S.N.	Type of area	Value of k		
		Flat land with 0-5% slope	Rolling land 5-10% slope	Hilly land 10-30%
1	Urban areas	0.6	0.65	-
2	Single-family residence	0.3	0.6	0.72
3	Cultivated areas	0.5	0.4	0.42
4	Pastures	0.3	0.4	0.50
5	Wooden land or forested areas	0.3		

The volume of water received from the catchment can be calculated by multiplying the catchment's area, the amount of rainfall and the runoff coefficient. **Harvesting potential or volume of water received () = area of catchment ()Amount of rainfall () Runoff coefficient**.

The runoff coefficient for any catchment is the ratio of the volume of water that runs off a surface to the importance of rainfall that falls on the surface. The runoff coefficient accounts for losses due to spillage, leakage, infiltration, catchment surface wetting, and evaporation, all contributing to reducing the runoff. The runoff coefficient varies from 0.5 to 1.0. in the present problem statement, the runoff coefficient equals one, as the rooftop area is fully waterproof. (Garg) Eco-climate conditions (i.e., Rainfall quantity and rainfall pattern) and the catchment characteristics are the key factors affecting rainwater potential. The table given below shows the value of the runoff coefficient concerning types of surface areas.

Water demand calculation:

The total number of students in our college is 2260, the Total number of staff is 165, the Water demand for one person for one day is 10 litres per person (per capita) per day (lpcd), the total water demand per day is 2425 10 = 24250 lpcd and the Total water demand per year = 5820000 litres, per year (we have considered eight months) (see Table 2)

4. RESULTS

Some techniques transform the data as real-life time series data, usually appearing nonstationary, into a stationary sequence. The basic distributional features of the time series data were analyzed after establishing constant mean and variance and checking for the presence of non-normality. The focus of time series analysis is shifted to empirically investigating the autocorrelation structure of the observations. This study has completed the necessary steps of time series analysis, primarily three steps to forecast the A.R.I.M.A. Model (Brownlee, 2017). The results show that the secondary data were checked to determine whether they were stationary. The results showed the rainfall data were stationary (see Figure 1).

4.1 Status of rainfall around the catchment area

Here, the rainfall data is presented along with the year and projected annual rainfall.

Table 3. Year-wise projected rainfall data.

Year	Projected annual rainfall
2022	1558.14
2023	1581.57
2024	1548.63
2025	1598.14
2026	1570.64

The above table shows the annual rainfall for the upcoming 5 years, obtained with the help of linear projection of data acquired from A.F.U. (2000-2021). This projection shows that the maximum amount of rainfall could be in 2025; likewise, the minimum amount of rainfall could be seen in 2024. Following 2023 has the 2nd maximum projected rainfall; 2026 and 2022 have the 3rd and 4th highest rainfall, respectively. The graphical analysis of these data reveals maximum fluctuation in the past 20 years, whereas the predicted 5 years has the least rainfall fluctuation.

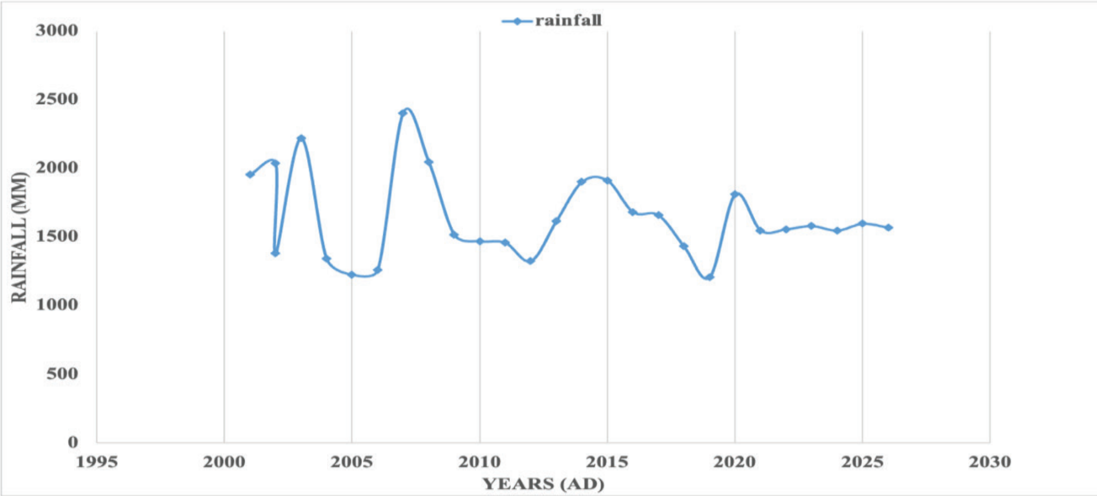


Figure 4 Projected rainfall

The results confirm that there will be a fluctuation in rainfall during the prediction period, indicating 2025 will have more rainfall than 2030 (see Figure 4)

4.2 Fulfilled water demand:

The total volume of water for the projected year 2025 = 5188946.58 litres

Percentage of water demand fulfilled= (total volume projected/ total water demand) × 100 = 89.15 %. So, with our project study, we realized that we could fulfil 89.15 % of the water demand for various purposes.

5. DISCUSSION AND CONCLUSION

This discussion aims to foreground more about using rainwater harvesting as a substitute for water sources and can minimize the water scarcity that might arise shortly in the forthcoming years in Nepal. By analyzing our study as evidence, we were able to show that rainwater can be gathered even in small areas, allowing us to efficiently manage the water supply by fulfilling the demand to some extent of water scarcity. This study result is like Anchan and Prasad (2020). They found the water scarcity issue could be resolved with the help of rooftop rainwater harvesting. The government and private institutions also initiated its establishment to manage the water sustainably.

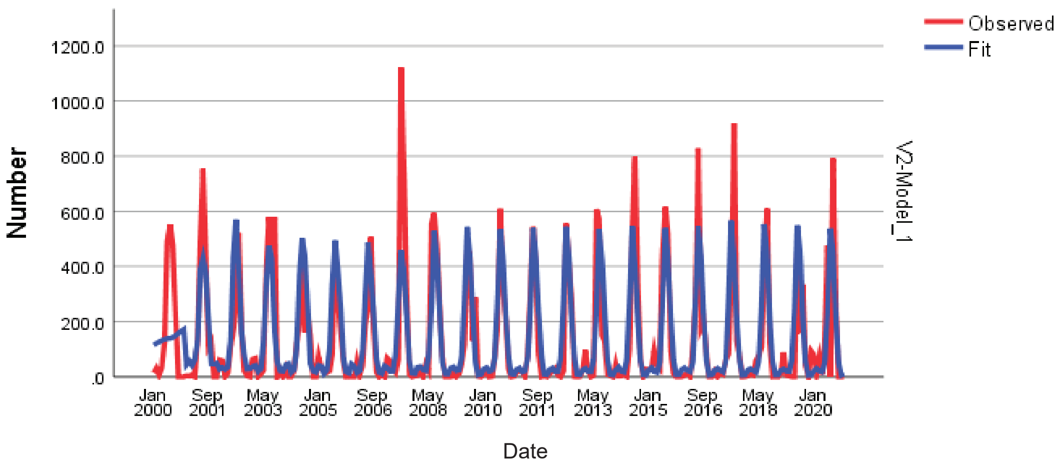
Similarly, while reviewing the Dual-Mode system for harvesting rooftops for non-potable Use, we learned that rooftop rainwater was harvested at a storage tank and distributed for nonportable uses with the help of a pump (Appan,2018). Furthermore, the rainwater harvesting system directly or indirectly helps improve the local people's socioeconomic condition and the public water supply system (Sturm et al. 2009). The water collected at the catchment area is conveyed with the help of a pipeline system in the world context to the storage tank. The selection of a storage tank, capacity, and the type of tank (sedimentation or reservoir tank) are considered (Das & Choudhary, 2021). The level of purification of stored water is determined as per user requirements; for example, if water is used for domestic purposes, simple screening or sedimentation is enough, but if it is used for drinking purposes, high-level purification and treatment are required. Our result differs from the study of Sharma et al. (2021). They highlighted that recent data from the Department of Water Supply and Sewerage Management (D.W.S.S.M.) in 2019 reported that only 51.69% of the population had piped water coverage and the remaining 48.31% relied on un-piped locally and privately managed systems like private tube-wells. Even if Nepal achieved the water supply-related M.D.G. goals, when analyzed by facility type, non-piped coverage has increased from 36% in 2000 to 44% in 2017. The results of the A.R.I.M.A. forecasting model show that the closest model is (1,0,1) (see Figure 4). The results show that the value of R Square is .631and the p-value is insignificant, which is a better-fit value for the forecasting model (see Table 2).

Main findings

The results show that the highest area (995.90 m^2) and volume of rainwater (1591.58 M3 was found in the Engineering Block of OCEM following the lowest area (11.85 m2), and the lowest volume of rainfall water (18.93 m3) was Stationery+ Guardroom (see Appendix 1). The results show that the Engineering Building has the highest area (995.90 m2), the stationery and guard room has the smallest area (11.85 m2) accompanying the highest volume of water (1591.58 m3) and the lowest volume of water (18.93 m3) respectively that can be harvested. We also projected the data for the upcoming 5 years, from which we took the highest annual rainfall (1598.14 mm) for our further calculation. Afterwards, we calculated the demand, 5820000 liters/year then we calculated the percentage of water demand fulfilled, which was 89.15% (see table 4). Our study projected the rainfall for five years from 2022 to 2026, indicating the lowest rainfall in 2024 and the highest rainfall in 2025, respectively (see Appendix 2).,

The results indicate that a particular volume of water can be harvested in specific cities as the best method to address water scarcity (Adugna et al. 2018; Al-Houri, Abu-Hadba & Hamdan.2014; Mishra, & Rao; Jeevan.2020; Patel, Nandsingh, Satpalsingh & Raval 2014; Panhalkar 2011). The study by Chao-Hsien, En-Hao & Yie-Ru 2014) supported the current study's findings. They found rainwater harvesting was one of the best methods to manage water scarcity in the city. They further disclosed that rainfall harvesting from rooftops could increase the water supply for various uses such as constructing new infrastructure buildings, gardening and artificial groundwater recharge.

The results showed that rooftop R.W.H.S are technically feasible regarding monthly average rainfall, catchment area and non-potable water demand in Rampur Chitwan. However, systems cannot meet all of the non-potable demand throughout the year; this only happens during July and August. The research has also shown that rooftop R.W.H.S. offers a feasible solution to provide additional water resources when combined with an existing water supply system. However, it should be noted that these systems are not suited to older housing properties in the lower middle- and middle-class areas. This is due to a lack of relative catchment area and space for storage tanks. On the other hand, R.W.H.S. provides a good option for large catchment areas such as those provided in private housing schemes.



The results show that the rainfall was in the mean average; however, the highest was in 2007 B.S.

Table 6. Monthly average rainfall statistics of Rampur

Average monthly rainfall	
Months	Average Rainfall
January	24.10
February	29.05
March	21.05
April	15.86
May	57.86
June	254.76
July	523.62
August	463.81
September	213.14
October	49.33
November	1.95
December	6.81
Total	138.44

The results indicate that July had the most rainfall (523.62mm), while November saw the least amount (1.95mm). Following that, with an average rainfall of about 254.76 mm, June comes in third place, followed by August, with an average rainfall of 463.81 mm and September, with an average rainfall of 213.14 mm. While October has about 49.33mm of rain, May has approximately 57.86mm. The second-lowest rainfall, 6.81mm, was recorded in December, followed by 15.86mm in April, 29.05mm on average in February, 24.10mm in January month, and 21.05mm in March, with a total average rainfall of 139.44mm in 2021 (see Table 1). The results of the forecasting model show that the closest model is (1,0,1) (see Figure 4). The results show that the value of R Square is .631and the p-value is insignificant, which is a better-fit value for the forecasting model (see Table 2). The secondary data are presented (see Appendix 3).

Review reflection

The major cities of Nepal rely primarily on groundwater resources for domestic purposes. However, groundwater supplies are being over-exploited, and every year, about ten thousand new tube wells are installed to help meet the water demand. In particular, cities such as Kathmandu, the largest metropolitan area in Nepal, have poor access to appropriate water supply systems (Kasula, 2012). To help cope with this situation and to help mitigate this increasingly- challenging water crisis, the research reported herein examines the extent to which rooftop R.W.H.S. can offer either a full or partial solution. About 50% of the water used in Kathmandu is derived from groundwater. Groundwater availability is more limited in populated hill regions because of the lower permeability of the indurated and crystalline rock types. Despite abundant rainfall, agricultural development is restricted by the limited development of irrigation (Das & Choudhary 2021). Although all major cities in Nepal face massive water shortages, when considering the possibility of rooftop R.W.H.S. for any area, it is necessary to first look at the local rainfall data to help identify which regions exhibit the highest potential. It has been shown that it varies significantly across the country, with the general trend of wetter conditions in the east (Taplejung, 1768 m altitude, receives an annual average rainfall of 2024mm) and drier in the west (Baitadi, 1635 m, receives 1037 mm). The average rainfall in Nepal is about 1600 mm, with about 80% falling between June and September (above 5500 m, this falls as snow). It is indicated that the southern slopes of the Himalayas receive the highest rainfall (3477 mm in Pokhara, 850 m). Similarly, 5550 mm in Lumle, 1642 m), whilst the trans-Himalaya lands north of the main Himalayan range (Mustang, Dolpa, Manang and Jumla) are in a rain shadow with a desert-like barren tundra, barely getting 250 mm of annual rainfall (e.g., Jomsom, 2650m, receives 255-295 mm).

Future recommendation

- Our study recommends conducting primary research on the possibility of rainwater harvesting systems in the study area.
- Our study recommends covering the larger area of investigation to find the actual water supply scarcity and an alternative way of rainwater harvesting systems in Nepal.
- Our study recommends applying integrated experimental methods to forecast rainwater in the future in the study area.
- Our study recommends investing the rainwater volume in heavy rainfall areas and working in cooperation with the Water Supply Department to forecasting future

rainfall so that future predictions could be actual to meet the demand of water scarcity.

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APPENDIX 1. Experimental design of rainfall harvesting

Serial no	Building name	Rooftop area ()	Volume ()
1	Engineering block	995.90	1591.58
2	BBA/BCA block	447.77	715.59
3	Administrative block	144.81	231.42
4	Basketball court	837.27	1338.07
5	Infirmary+ HM block	62.41	99.73
6	Water Tap	23.70	37.88
7	Canteen	501.70	801.78
8	Parking	119.83	191.51
9	Stationery+ Guard room	11.85	18.93
10	Storeroom	33.12	52.93
11	Toilet	68.33	109.20

APPENDIX 2. Rainfall prediction

S.No	Year	Volume ()
1	2022	5059.05
2	2023	5135.14
3	2024	5028.16
4	2025	5188.94
5	2026	5099.68

APPENDIX 3. Rampur rainfall data

Year	Annual rainfall data (mm)
2000	1955.6
2001	2037.5
2002	1383.5
2003	2219.6
2004	1342.8
2005	1227.8
2006	1261.5
2007	2405.1
2008	2048.1
2009	1518.8
2010	1470.7

Year	Annual rainfall data (mm)
2011	1460.1
2012	1327.3
2013	1617.5
2014	1901.9
2015	1912.0
2016	1683.3
2017	1660.2
2018	1433.0
2019	1209.3
2020	1811.7
2021	1548.7