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Estimation of Actual Water Savings from a Household Rainwater Harvesting System Using MyWell App

Shuvra Sikder[1] and Dharmappa Hagare[2]

[1]Graduate (MEng), Western Sydney University, NSW, Australia
[2]Senior Lecturer, Western Sydney University, Kingswood, Penrith, NSW, Australia
Corresponding author's E-mail: shuvrasikder12@gmail.com

Abstract

The declining access to the renewable fresh water sources is likely to result in inadequate water supply worldwide. Experts have recently tried to identify reliable, sustainable, and cost-effective fresh water supply sources. Hence, a great number of research on water savings suggest the rainwater harvesting system as one of the reliable alternatives to save fresh water. According to studies, a household rainwater harvesting system can supply 12% to 100% of its non-potable water demand based on household size, roof area, rainfall patterns and other relevant factors. The aim of this study is to estimate water savings from a roof-top based rainwater harvesting system. The daily data are collected using MyWell app. This smartphone app is developed under a groundwater monitoring project which allows public in real time monitoring of rainfall, water level, water quality and others. Primarily, this research focuses on water savings for a specific household located in Pendel Hills, a suburb of Greater Sydney region. The study household has a rainwater tank of 5 kL. All the study data from MyWell app and other secondary sources are collected for a one-year period from June 2020 to June 2021. To calculate the water savings, authors have used two approaches- (a) the theoretical approach using 'Behavioural-Storage model' and (b) Real-time water demand and supply estimation. This study only considered non-potable uses of the harvested rainwater. The results show that the selected rainwater tank is about to save approximately 6.39 m^3 water each month (40% of demand) in the theoretical approach. While the rainwater tank is saving an average of 2.42 m^3/month water in real-time which is only 19.75% of monthly water demand. The results of this study will help to improve rainwater harvesting system performance and will contribute to achieve water related sustainable development goals.

Keywords: Rainfall, Water Savings, MyWell App, Theoretical Model and Water Tank.

1. INTRODUCTION

In recent times, rainwater harvesting system (RWHS) has drawn massive global attention due to rising water crisis. Australia, one of the driest countries across the world, is facing frequent droughts over last decades (Chubaka et al., 2018). The water crisis has become a concern to the Australian people. However, experts believe that a set of reasonable and efficient water savings practices can mitigate water shortages to a certain level. According to Rahman and Eslamian (2017), rainwater harvesting is one of the ancient practices worldwide as well as a preferred water saving method in modern times. In the late 1970s, RWHS got a revived attention as a sustainable water conservation tool (Rahman and

Eslamian, 2017). A properly constructed RWHS is capable of saving water up to 100% of a family's potable water need (Musayev et al., 2018). To be specific, RWHS refers to an integrated method which includes collection, storage, and preservation of rainfall runoff from impervious surfaces such as roofs and porches (Rahman and Eslamian, 2017). And the term water saving means cutting pressure on the groundwater or surface water based municipal water supply (Campisano et al., 2017).

Recent research on RWHS show comprehensive assessments on water saving models, water quality, cost-benefit analysis, socio-economic acceptance, energy usage, and tank design considerations. Some of the major research works have been found converging on water availability (e.g., rainfall) correlation to community water demand. Among them, estimation of water saving involves various methods i.e., simulation model (Fewkes and Butler, 2000), probabilistic model (Campisano et al., 2017), economic approaches (Piemontese et al., 2020), spatial and temporal variability (Fewkes, 2002). However, the number of available research works focusing on the greater Sydney region is few in records (Preeti and Rahman, 2021). That's why, this research will try to do an analysis on actual rainwater saving in Greater Sydney region following the lessons acquired from recent practices in South-East Queensland and Melbourne region. This study will focus on a contemporary mass balance model, and it will be a guideline to the future studies.

2. STUDY AREA

The selected study area refers to a single household located at Pendle Hills as shown in figure 1. This area is about 29 km away from the Sydney CBD and lies within the jurisdiction of Cumberland City Council, NSW. The climatic condition is classified as humid subtropical with two major seasons- hot summer and cool winter. The roof area of the household is measured as 233.65 m^2.

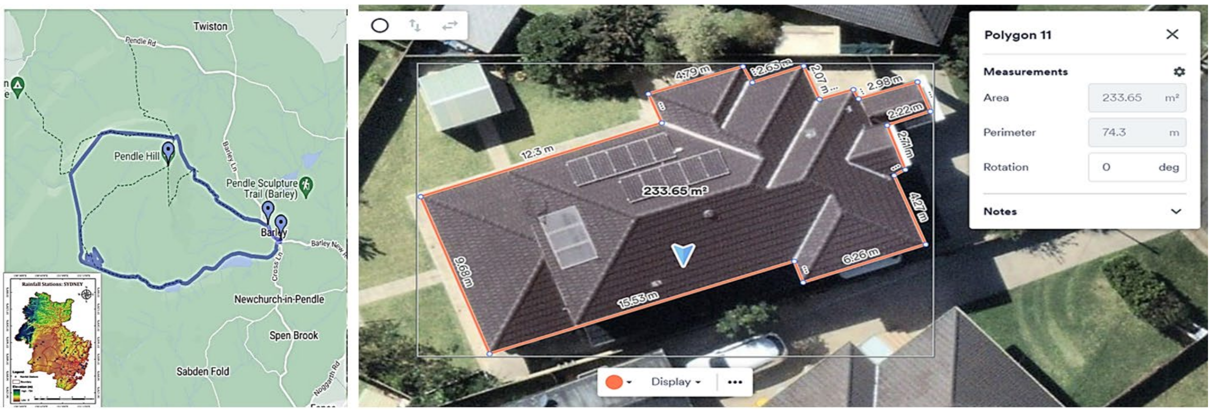

Figure 1. Location of the study area

3. MATERIALS & METHODS

3.1. Rainfall Data Collection & Processing

Dr. Basant Maheswari has developed this smartphone app. This app provides information on regular rainfall, water levels, check dam, local geographic conditions and water quality. Anyone who owns a smartphone can participate in data collection voluntarily because of crowdsource data assembly. Professionals involved in this MARVI project which is managed by Western Sydney University

(WSU) and sponsored by ACIAR have declared this app as a 'highly successful project' considering imminent research prospects, knowledge and awareness sharing, village-community intervention, and water savings (Vessels Tech, 2023). Initially, collected rainfall data from MyWell app provides readings on date, time, resource type (well or rain gauge), and quantity per hour. As a part of data pre-processing, filling in all the missing rainfall and water level data was required. Authors used ten rainfall station data to adjust all missing records. In reference to collected rainfall data, this study used 'rational model' to calculate rainfall-runoff.

3.2. Estimating Theoretical & Actual Water Savings

Water savings estimation helps to identify the amount of water needed from the main water supply. To elaborate further, it defines how effectively the collected rainwater can fulfill the water demand of a household. However, this research is considering that the collected rainwater will be used for non-potable uses only (for toilet uses, outside cleaning and gardening). This refers to an inversely proportional relationship between 'non-potable demand' and 'non-potable supply'.

Table 1. Water consumption composition for a household in Sydney

	Total water demand
Showers	26%
Outdoors	23%
Toilets	20%
Washing cloths	12%
Inside taps	12%
Bath tubes	6%
Dishwasher	1%

Source: Sydney Water (2022)

This study has used 'Behavioural Storage' method because of its easy applicability. Usually, this method is an adaptation of 'water mass balance' concept. This research has used a set of total 12 parameters to estimate theoretical water savings. These parameters are- rainfall (mm), runoff (m^3), first flush (m^3), net runoff (m^3), total demand (m^3), storage level before use (m^3), storage level after use (m^3), main water supply (m^3), storage level after main water supply (m^3), spill (m^3), demand met by RWHS (yes/no), and main water supply requirement (yes/no).

For actual water savings calculation, tank's water depth is recorded using MyWell app. Later, the amount of used rainwater for non-potable purposes is calculated from the water level differences in consecutive days. The outcome is showing how much water has been used for the selected household in one day and how much it is saving from the main water supply.

4. RESULTS & DISCUSSION

4.1. Theoretical and Actual Water Savings Outcomes

Table 2 denotes that the theoretical water saving is significantly higher than the actual water savings for all months. This difference may come due to parameter variations and numerical assumptions. The theoretical approach has used several parameters including first flush, total runoff, storage level before and after usage, spill, and others. Among them some values have been assumed based on either previous studies or calculation suitability. Such as, the first flush is considered zero for all 16 months which can vary over the time in actual scenario. Indeed, theoretical approach considers everything in a perfect condition.

Table 2. Comparison between theoretical and actual water savings outcomes

Month	*Theoretical Water Saving (m^3)*	*Actual Water Saving (m^3)*	*Month*	*Theoretical Water Saving (m^3)*	*Actual Water Saving (m^3)*
Jun 20	7.224	1.445	*Feb 21*	7.224	2.328
Jul 20	7.024	2.989	*Mar 21*	7.998	1.892
Aug 20	7.551	0.722	*Apr 21*	5.783	1.667
Sep 20	5.644	2.389	*May 21*	4.815	3.094
Oct 20	3.283	3.778	*Jun 21*	6.966	4.230
Nov 20	7.615	1.722	*Jul 21*	7.169	1.086
Dec 20	7.74	2.875	*Aug 21*	2.964	3.740
Jan 21	7.114	2.695	*Sep 21*	6.192	2.056

Conversely, the actual approach has used values directly collected from the study area through field surveys. And the rainfall and water depth data were collected using the MyWell app. Hence, some variations may happen from the actual conditions considering surveyor's approach, instrumental or device issues and other reasons. That does not mean that theoretical approaches should be avoided. They are essential when measuring water saving from a rainwater tank for validation purposes. A good number of previous works have used the same approach, and this study has maintained this.

4.2. Theoretical and Actual Water Savings Outcomes

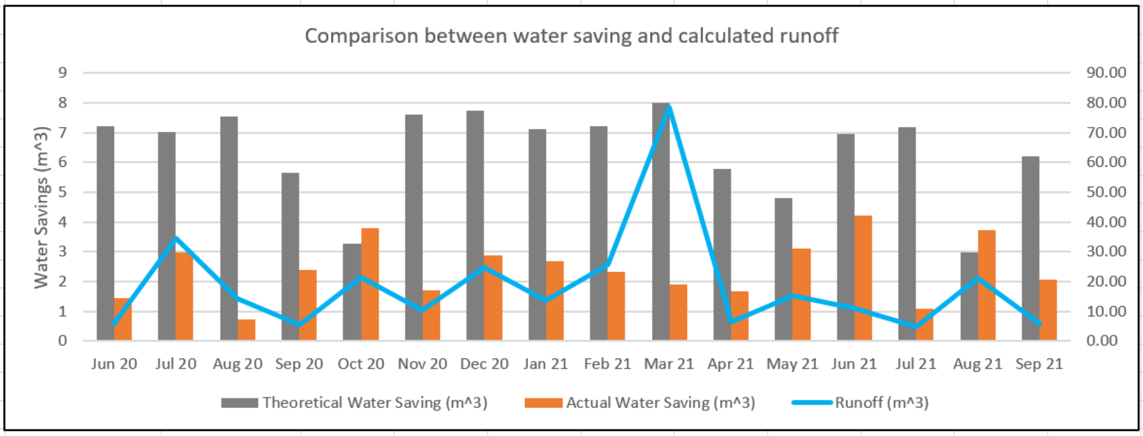

Figure 2. Comparison between calculated water saving and runoff

Figure 2 is showing that the calculated rainfall-runoff values are not following the water saving trend properly. This phenomenon may happen due to several reasons. First, in practical settings, the household member's daily water consumption may vary for different factors. That's why, even the runoff is higher the water saving can be less. Second, the subject building has roof gutters which may be overflowed during heavy rainfall and can reduce the water flow into the tank. Along with gutter and valley overflow, the design of rooftop and its material forces the rainfall to splash out from the roof rather than flowing into the tank. A roof catchment may receive a range of intensified runoff but don't process all of it. During high volume runoff, the RWHS passes excess runoff to linked drainage or sewer point. That's why, current studies on rainwater harvesting are focusing on the importance of installing large capacity tanks to ensure optimal water savings.

4.3. Water Saving Impacts on Main Water Supply

Table 3 is showing the main water supply requirements after consuming the saved rainwater for household non-potable uses. According to following results, the collected rainwater saves around 40% of main/municipal water supply annually based on theoretical calculations. As the theoretical approach considers perfect conditions, outcome is validating with the BASIX NSW requirement of saving at least 40% water. But the actual approach is showing an annual saving of 19.75%. Because it is quite unreasonable for the actual approach to calculate considering all perfect situation.

Table 3. Main water supply requirement obtained from Sydney Water bills

Month	*Main water supply by Sydney Water kL/month*	*Total water demand kL/month*	*% water saving (Actual)*	*Total water demand (Theoretical) kL/month*	*% water saving (Theoretical)*
Jun 20	10.59	12.03	12.00	17.81	40.55
Jul 20	10.95	13.93	21.44	17.97	39.07
Aug 20	10.98	11.70	6.17	18.53	40.74
Sep 20	10.63	13.01	18.34	16.27	34.68
Oct 20	10.93	14.70	25.68	14.21	23.09
Nov 20	9.9	11.62	14.81	17.51	43.47
Dec 20	10.23	13.10	21.93	17.97	43.07
Jan 21	10.23	12.92	20.84	17.34	41.01
Feb 21	8.22	10.54	22.07	15.44	46.77
Mar 21	9.1	10.99	17.21	17.09	46.77
Apr 21	8.78	10.44	15.95	14.56	39.71
May 21	8.83	11.92	25.94	13.64	35.28
Jun 21	8.08	12.30	34.36	15.04	46.29

5. RECOMMENDATION

5.1 Encouraging Water Saving Monitoring at Community Level

To build a sustainable RWHS, it is essential to engage community people or rainwater tank users in the practical level monitoring process. Although this study has tried to create simpler understandings of water saving estimation from a rainwater tank, local people may still find it harder to understand all the numerical concepts. Thence, this study has reviewed six market available wireless water level indicators to select one of the cost-effective alternatives. So that, it can ensure people's participation in monitoring process.

By using level indicators, one can easily keep track on increasing and declining tendencies of tank water level without understanding theoretical concepts. Moreover, it gives information on how much rainwater is received, how much is under harvesting process and how much need to export from the external sources. Also, a level meter can avoid overflowing seepage. The assessed six level indicators for this study are- (a) Desk-Mount by Smart Water, (b) LS1-R-Radar by Automation group, (c) RH Tank Gauge Plus by Blue Mountain Co., (d) H2F-BT12 by Topargee, (e) Fluid Level - D110-C by Aquatel and (f) R3 Level Meter by TankMate. They have been analysed based on their market availability, costs, battery life, installation process and data receiving frequency. Among them, this report suggests the R3 Level Meter by TankMate due to its affordability and long-term functionality.

Figure 3. R3 Level Sensor for water saving monitoring

6. CONCLUSION

RWHS has shown benefits including reduction of main water or freshwater usage and appropriate management of stormwater. Water savings estimation helps to identify the amount of water needed from the main water supply. The principal objective of this project is to estimate the amount of main water that can be saved up annually by installing a 5kL rainwater tank. This research is considering that the collected rainwater will be used for non-potable uses only. According to the assessed theoretical approach, a 5kL rainwater tank is saving an average of 6.39 m^3 per month (40% of total demand). On the other hand, in actual situation as stated in MyWell app, the rainwater tank is saving on average 2.42 m^3 per month (around 29% of total demand). The reasons behind this water saving variance between the theoretical and actual approach has been discussed in this report's results and discussion segment. Throughout the process, this research has dealt with some unintentional errors e.g., data limitation or missing data. However, the missing data were estimated using proven methods of data filling. Indeed, this research has highlighted the water saving convenience of a RWHS.

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