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Rainwater harvesting in Greater Sydney: Water savings, reliability and economic benefits

Ataur Rahman[a,*], Joseph Keane[a], Monzur Alam Imteaz[b]

[a] School of Engineering, University of Western Sydney, Locked Bag 1797, Penrith, NSW 2751, Australia
[b] Swinburne University of Technology, Melbourne, Australia

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ABSTRACT

Due to greater environmental awareness and mandatory water restrictions in many Australian cities, rainwater tanks have become popular in recent years. This paper investigates the water savings potential of rainwater tanks fitted in detached houses at 10 different locations in Greater Sydney, Australia. A water balance simulation model on daily time scale is developed and water savings, reliability and financial viability are examined for three different tank sizes, 2 kL, 3 kL and 5 kL. It is found that the average annual water savings from rainwater tanks are strongly correlated with average annual rainfall. It is also found that the benefit cost ratios for the rainwater tanks are smaller than 1.00 without government rebate. It is noted that a 5 kL tank is preferable to 2 kL and 3 kL tanks and rainwater tanks should be connected to toilet, laundry and outdoor irrigation to achieve the best financial outcome for the home owners. The results from this study suggest that government authorities in Sydney should maintain or possibly increase the rebate for rainwater tanks to enhance its acceptance.

1. Introduction

Australia is one of the driest continents in conjunction with being one of the highest consumers of drinking water in the world. A growing urban population and frequent droughts due to climate variability and change have made water supply to be a major issue in Australia (Ryan et al., 2009). A number of alternative water sources have received attention in recent years in Australia, which includes rainwater harvesting, grey water reuse and wastewater recycling (Zhang et al., 2010). Among these, rainwater harvesting has received the greatest attention as rainwater is fresh in nature and can be easily collected and used for non-potable purposes. However, many people in Australia still show reluctance in adopting a rainwater harvesting system (RWHS). Statistics from the Australian Bureau of Statistics (ABS) show that about 47% say that the main reason for not installing a rainwater tank is the perceived 'higher cost' (ABS, 2009). Government authorities in Australia provide financial incentives in the form of rebate to the home owners for encouraging them to install rainwater tanks. For example, Sydney Water Corporation in Australia offers a rainwater tank rebate of up to Aus$1,400 depending on the type of water use and size of the tank (Sydney Water, 2010).

Muthukumaran et al. (2011) found that use of rainwater inside a purpose-built home in regional Victoria in Australia can save up to 40% of potable water use. Farreny et al. (2011) examined the quantity and quality of a RWHS in Spain and found that sloping smooth roofs may harvest up to about 50% more rainwater than flat rough roofs. Mun and Han (2012) developed a design and evaluation method for a RWHS on the basis of water balance equation and found that a design based on sensitivity analysis can notably improve the operational efficiency of a RWHS.

Many house owners do not readily see the benefit of RWHS over longer term, which may be attributed to the limited understanding of the life cycle costs of the system. A study by Rahman et al. (2010) for multi-storey buildings in Sydney found that it could be possible to achieve "pay back" for the RWHS under some favourable scenarios and conditions. They found that a smaller discount rate is more favourable and the greater the number of users the higher the benefit–cost ratio for a RWHS. Domenech and Sauri (2010) investigated the financial viability of the RWHS in single and multi-family buildings in the metropolitan area of Barcelona (Spain). In single-family households an expected payback period was found to be between 33 and 43 years depending on the tank size, while in a multi-family building a payback period was 61 years for a 20 m^3 tank. Imteaz et al. (2011) found that for commercial tanks connected to large roofs in Melbourne, total construction costs can be recovered within 15–21 years time depending on the tank size, climatic conditions and future water

* Corresponding author. Tel.: +61 247360145; fax: +61 247360833.
E-mail address: a.rahman@uws.edu.au (A. Rahman).

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price increase rate. Tam et al. (2010) investigated the cost effectiveness of RWHS in residential houses around Australia and found that this system can offer notable financial benefit for Brisbane, the Gold Coast and Sydney due to the relatively higher rainfall in those cities as compared to Melbourne. Zhang et al. (2009) examined the financial viability of RWHS in high-rise buildings in four capital cities in Australia and found that Sydney has the shortest payback period (about 10 years) followed by Perth, Darwin and Melbourne. Khastagir and Jayasuriya (2011) conducted the financial viability of RWHS in Melbourne, Australia and found that payback period vary considerably with the tank size and local rainfall.

Notable researches have been conducted on the relationship between rainwater tank sizing and water savings. Khastagir and Jayasuriya (2009) used water demand and roof area to develop a set of dimensionless number curves to obtain the optimum rainwater tank size for a group of suburbs in Melbourne. A paper by Su et al. (2009) focused on the development of a relationship between storage and deficit rates for RWHS. Results showed that as the deficit rate increased so too did the storage size of the tanks. Eroksuz and Rahman (2010) conducted research on the use of RWHS for multi-unit blocks in three cities of New South Wales, Australia. They found that in order to maximize the water savings, a larger tank would be more appropriate and that these tanks could provide significant water savings, even in dry years. A study in Brazil by Ghisi et al. (2009) aimed to assess the potential for potable water savings for car washing at petrol stations in the City of Brasilia found that an increase in the tank size enhanced the reliability of the rainwater tank notably in meeting the demand. Kyoungjun and Chulsang (2009) showed that rainwater collection would only be feasible in South Korea for during 6 months of the year. They also found that a benefit cost ratio higher than 20% could not be gained due to the cost of water being so inexpensive in South Korea. They suggested that the cost of water supply would need to be increased by a factor of five approximately for the RWHS to become financially viable in South Korea.

The research on financial viability of RWHS has not had significant presence in the literature thus far and also the findings from these studies are often contradictory. The home owners do not clearly see the financial benefits of a RWHS. Also there is a lack of study on the adequacy of the current government rebate provided to the home owners for installing a RWHS.

This study focuses on the efficiency of RWHS in Sydney, which is the largest city in Australia, with over 4.5 million populations. The city was under severe water restriction for about a decade during 1990s and 2000s, which prompted the search for alternative water supplies in the Sydney region. To enhance the water use efficiency and water conservation, the government authorities in Sydney has introduced BASIX legislation, which requires that every new house in Sydney must have a rainwater tank. However, there has not been any in-depth study to determine an appropriate tank size for a given house in a given location depending on the roof area, family size and local rainfall. As Sydney is quite large and has a high rainfall gradient, it is most likely that different parts of the City need different tank sizes for achieving the best possible water savings and financial returns. This study examines the water savings potential, reliability of water supply, financial benefits, and the adequacy of the current government rebate for a RWHS in detached house at different locations in Greater Sydney.

The research presented in this paper is undertaken in the light of the current knowledge gaps to assess the financial viability of a RWHS in Sydney to provide guidance to water authorities to enhance the acceptance of a RWHS.

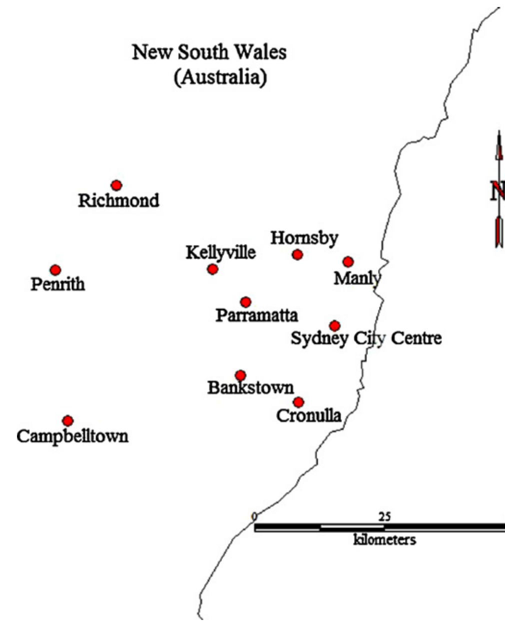

Fig. 1. Selected study locations in Greater Sydney, Australia.

Table 1
Summary of selected locations in Greater Sydney and rainfall statistics.

Location	Rainfall station	Rainfall records	Average annual rainfall (mm)
Bankstown	066054	1986–2009	1009
Campbelltown	068007	1900–2009	743
Cronulla	066058	1910–2009	1085
Hornsby	066158	1936–2009	1325
Kellyville	067042	1978–2009	880
Manly	066182	1957–2009	1376
Parramatta	066124	1966–2009	963
Penrith	063185	1970–2009	971
Richmond	067021	1902–2003	800
Sydney City Centre	066062	1859–2009	1214

2. Description of data

The study considers 10 different locations across Greater Sydney in Australia (Fig. 1). These locations are Bankstown, Campbelltown, Cronulla, Hornsby, Kellyville, Manly, Penrith, Parramatta, Richmond and Sydney City Centre. The daily rainfall data at each of these locations is obtained from the Australian Bureau of Metrology. The length of these rainfall data ranges from 31 to 150 years (average: 73 years) as shown in Table 1. Typical average monthly rainfall distribution in the study region is shown in Fig. 2.

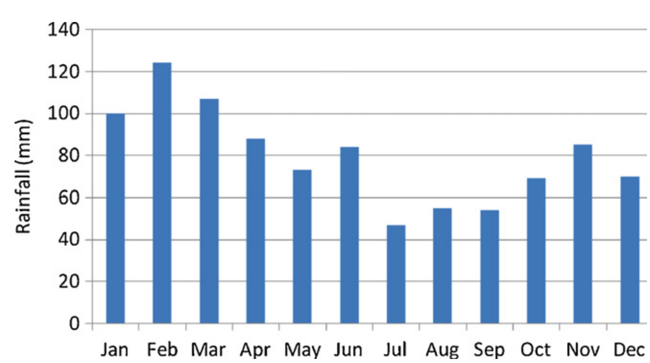

Fig. 2. Average monthly rainfall in the study area.