Resources, Conservation & Recycling 126 (2017) 219–227

Contents lists available at ScienceDirect

Resources, Conservation & Recycling

journal homepage: www.elsevier.com/locate/resconrec

Full length article

Proposal of simple and reasonable method for design of rainwater harvesting system from limited rainfall data

Duc Canh Nguyen[a,*], Moo Young Han[b]

[a] Faculty of Environment and Labour Safety, Ton Duc Thang University, 19 Nguyen Huu Tho Street, Tan Phong Ward, District 7, Ho Chi Minh City, Vietnam
[b] Department of Civil & Environment Engineering #35-518, Seoul National University, 599 Gwanak-ro, Gwanak-gu, Seoul, 151-742, Republic of Korea

ARTICLE INFO

Keywords:
Rainwater harvesting
Developing countries
Rainfall data
Tank size
RWH system performance

ABSTRACT

Recently, rainwater harvesting (RWH) is gaining interest as an alternative source of safe drinking water especially in developing countries. Getting a detailed and suitable rainfall data to have a good design of RWH system is a challenge in developing countries. In RWH system performance predictions, direct use of monthly rainfall data may lead to considerable error instead of using daily rainfall data. This paper proposes a simple and reasonable design method of rainwater harvesting system from available limited data like monthly rainfall data, which can achieve negligible error and conservative predictions. A RWH model that employs the designed rainfall which generates daily rainfall for each month with distribution of uniformly number of wet days in the last days of month as its input gives performance predictions quite similar to that of using actual daily rainfall.

1. Introduction

Due to the rapid population growth and pollution of both groundwater and surface waters, many communities in developing countries are facing water shortages, with the situation expected to worsen in the future (UNEP 2008; ADB 2011). Rainwater harvesting (RWH) has regained interest as an alternative source of safe drinking water (Kim et al., 2016; Mwamilla et al., 2015; Temesgen et al., 2015; Nguyen et al., 2013; Ahammed and Meera, 2006). If RWH system is well designed and operated, rainwater can be a potential source of drinking water without any other treatments (Nguyen and Han, 2014; Mwenge Kahinda et al., 2007; UNEP, 2009; Amin and Han, 2009).

Rainwater tank capacity is one of the most significant design parameters which affect the system performance and cost. There are numerous methods already developed for predicting the performance and tank sizing of RWH systems. Campisano and Modica (2012) reported that the feasibility of RWH systems depends entirely on the storage tank capacity, water demand pattern, rooftop area, and rainfall profile. Khastagir and Jayasuriya (2010) developed a simple spreadsheet based daily water balance model for the performance analysis and design of rainwater tanks. Further, Nguyen and Han (2014) provided a method to determine daily variable demand for optimization of RWH system performance.

Most of the analyses were performed using daily water mass balance model. The reliance on using daily rainfall data for RWH system performance prediction has been noted (Heggen, 1993; Thomas 2002). However, a daily rainfall data in almost of developing countries is hardly accessed due to its high cost and incompleteness. Meanwhile, the use of monthly rainfall data may lead less accurate results as it is too coarse and time-averaged, but it is of some use and quite widely available. Many researchers also found that analysis using monthly average rainfall data overestimates the required rainwater tank size (Imteaza et al., 2011; Zaag 2000).

In the literature review, most of daily rainfall generation models have been developed using the popular Markov chain process (Wilks, 1998, 2006; Wilks and Wilby, 1999). Markov chain models specify the state of each day as 'wet' or 'dry', develop a relation between the state of the current day and the states of the preceding days, and specify daily rainfall totals by an appropriate probability distribution. These parameters could be statistically characterized from daily records for a climatic zone. However, using Markov chain models is too complex and not practical for areas where daily rainfall data records are not available. Therefore it should be avoided unless proven really beneficial. To overcome this problem, Thomas (2002) has developed a method generating pseudo daily rainfall data from actual monthly rainfall data which the wet days are taken to be randomly spaced. However results may not be conservative since it is randomly. The objective of this study is to propose a simple and reliable design method of rainwater harvesting system with limited rainfall data by using monthly data.

2. Material and methods

2.1. Rainwater harvesting system performance determination

Fig. 1 shows a schematic of a rainwater harvesting system. It

* Corresponding author.
E-mail addresses: mrcanhctn@gmail.com (D.C. Nguyen), myhan@snu.ac.kr (M.Y. Han).

http://dx.doi.org/10.1016/j.resconrec.2017.07.033
Received 28 September 2016; Received in revised form 14 June 2017; Accepted 22 July 2017

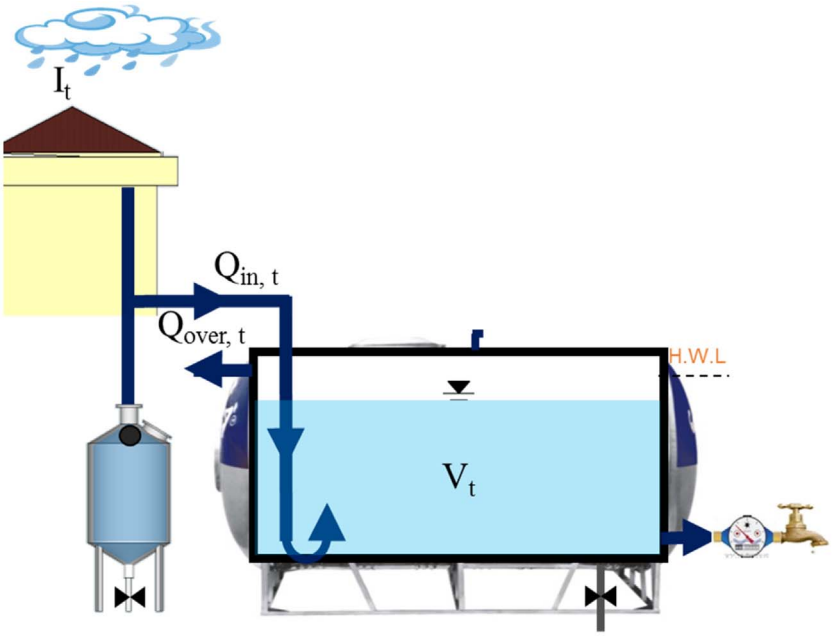

Fig. 1. Schematic diagram of water flow in a rainwater tank.

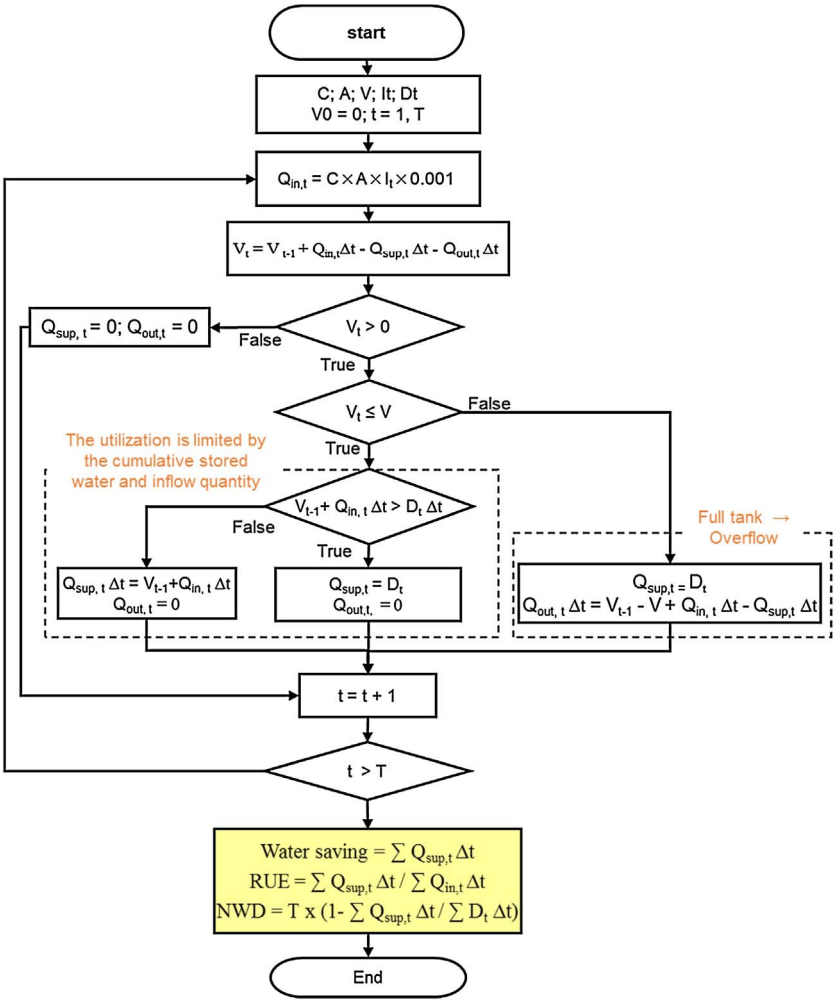

Fig. 2. Simulation used to determine performance of a RWH system.