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Selecting time scale resolution to evaluate water saving and retention potential of rainwater harvesting tanks

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Abstract

Water saving and stormwater retention benefits from Rainwater Harvesting (RWH) tanks can be evaluated by the use of behavioural models able to simulate the long-term water balance of the rainwater tank. However, simulation results may be affected by the computational time step, that is normally chosen according to the aim of the analysis and to the available data.
The objective of the paper is to analyse the influence of the time-step on the evaluation of the performance of RWH systems. Results of the investigation may help modellers deriving indications to select the appropriate time scale resolution when evaluating water saving and retention efficiencies of rainwater tanks.
The analysis was carried with reference to a household case study in the south of Italy. High resolution rainfall data were used to run the water balance simulation of the tank at different daily and sub-daily time steps. In parallel, event-based data of toilet flushes collected during the field monitoring of the household residential water demands were used to derive long-term toilet water demand patterns at the different time scales of aggregation.
Simulations of the tank showed that the daily time step may be reliably chosen for accurate evaluation of both the water saving and the volumetric stormwater retention efficiency of the rainwater tank with the exception for small tanks and high water demand values for which inaccuracies may occur unless higher time resolution are adopted.

Keywords: Behavioural models; Rain water tanks; Storm water retention; Time scale resolution; Water saving.

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1. Introduction

The use of rainwater tanks is an old practice that is reviving nowadays for its potential to address a number of environmental and social issues. In countries coping with water scarcity, rainwater tanks can help reducing the potable water consumption from mains. The volume of potable supply substitution is the primary reason that motivate households to equip houses with rain water harvesting (RWH) systems having the typical function of back-up supply source (Mitchell et al., 2008). Collected rainwater is basically used for local external or internal non-potable consumption (i.e. toilet flushing, garden irrigation, terrace cleaning, car washing, etc.). Although RWH may result expensive, the implementation of such systems in developed countries is increasing more and more, being often considered as a symbol of environmental involvement.

Rainwater tanks can also take part to the mitigation of environmental impacts of urbanization on storm water drainage systems and receiving waters. The increase of distributed retention storage throughout urban catchments can help reducing the frequency and volume of storm water runoff conveyed by drainage systems and contribute to partially restore the altered water balance of the catchment. From this viewpoint, RWH operates as a storage-based source control solution: during storm events, part of the rainfall is stored in the rainwater tank and used locally with the effect of abstracting such rainfall from the runoff component of the water cycle. However, differently from usual storm water storages, the water abstraction from rainwater tanks is demand-driven (Petrucci et al., 2012) with demand magnitude and patterns having a clear effect on the design and efficiency of RWH systems (Mitchell et al., 2008).

Household-scale experiments on water saving performance of rain water tanks have been conducted in various countries, basically using the collected rain water to flush toilets in private or public buildings (Chilton et al., 1999; Fewkes, 1999; Zaizen et al., 1999; Aylward et al., 2006; Ward et al., 2012). Findings of such studies clearly indicate that RWH systems offer significant water saving potential. However, these studies also show that the harvesting system performance is markedly influenced by site-specific variables such as local rainfall, roof area, rainwater tank size, potable water demand and number of people in the household.

Besides, recent experimental analyses based on the monitoring of implemented systems to assess storm water runoff control benefits of RWH show various results. Specifically, the results concerning the impact of a number of small rain water tanks in a suburban catchment of Paris, France show that RWH alone is not able to prevent overflows from the storm water drainage system (Petrucci et al., 2012). Differently, studies on the performance of twelve rainwater tanks in Australia (Burns, personal communication) have shown that, under regular and sufficiently large demands, RWH systems may achieve storm water retention performance approaching that of the same area under the pre-development condition.

Multiple benefits from RWH tanks have also been explored with the use of behavioural modeling methods based on the simulation of the long-term water balance of the tank (Fewkes and Butler, 2000; Villareal and Dixon, 2005; Ghisi and Ferreira, 2007; Mitchell et al., 2007; Coombes and Barry, 2008; Palla et al., 2011; Burns et al., 2012; Brodie, 2012; Campisano and Modica, 2012a; Campisano et al., 2013a, Campisano et al., 2013b). Results from such studies basically show the potential for exploitation of rainwater harvesting. However, findings reveal also that simulation results may be significantly affected by the model structure and parameters such as the computational time step. Although time step selection often depends on the objective of the analysis and on the availability of data, a sensitivity analysis conducted by Mitchell et al. (2008) has shown that it may influence the estimation of the tank volumetric reliability (up to about 8%) depending on the algorithm used to run the water balance simulation.

Early results by Fewkes and Butler (2000) point out that simulations with monthly time steps may provide inaccurate evaluation of the RWH system water saving performance and suggest to use the daily time step resolution for such an evaluation.

However, to obtain more accurate estimation of the tank potential to both reduce potable water volumes and control storm water volumes to the drainage system, higher time resolutions may be required under several conditions. Absolutely, high time resolutions become mandatory if the reduction of storm water flow peaks due to the tank is explored. Clearly, contraindications may emerge due to an increased computational effort to treat extended rain data sets and to arrange detailed information on the demand patterns.