Runoff coefficient of a green roof located in Belo Horizonte Brazil – results from 2017-2018

Coefficient de ruissellement d'une toiture verte située à Belo Horizonte, Brésil – résultats de 2017-2018

Priscilla MOURA ; Tulio Soares Lima

Universidade Federal de Minas Gerais – Departamento de Engenharia Hidráulica e Recursos Hídricos – Programa de Pós Graduação em Saneamento, Meio Ambiente e Recursos Hídricos
(priscilla.moura@ehr.ufmg.br; tuliosoareslima7@gmail.com)

RÉSUMÉ

L'urbanisation implique la modification du cycle urbain de l'eau, amenant des inondations. Les toitures vertes sont vues, ainsi comme d'autres types d'infrastructure verte, comme essentielles pour améliorer la résilience et la durabilité des villes. Malgré ses avantages, leur performance concernant les impacts hydrologiques, le rôle de la végétation et exigences d'entretien sont toujours incertaines, notamment dans des conditions de climat tropical, où le nombre de jours consécutifs de temps sec est important. Le présent travail a pour but de présenter les résultats d'un suivi hydrologique de la saison des pluies de trois toitures vertes extensives dans des conditions tropicales, à Belo Horizonte, Brésil. Les toitures vertes diffèrent les unes des autres à propos de la végétation une est engazonné, la deuxième plantée de Sedum et la troisième n'a aucune végétation. Les événements pluvieux sont encore en analyse, mais les résultats préliminaires ont montré que la réduction du coefficient ruissellement est importante et le retard du ruissellement de la toiture verte est d'environ 10 minutes.

ABSTRACT

The urbanization process brings modification in the urban water cycle, causing floods. The green roofs are being seen, together with other kinds of green infrastructure, as essential to improve resilience and sustainability in cities. Despite its advantages, the performance concerning hydrological effects, vegetation importance and maintenance requirements are still uncertain notably in tropical climate conditions, where the number of consecutive dry days are important. The present work aims to present the results of hydrological monitoring during a rainy season of three extensive green roofs under tropical conditions, in Belo Horizonte, Brazil. The green roofs differ from each other in vegetation, one was planted with grass, the second one has Sedum plants and the third one was not vegetated. The rain events are still in analysis, but preliminary results show that the runoff reduction is important and the runoff delay caused by the green roof is about 10 minutes.

MOTS CLÉS

Experimental Green roof, flood control, runoff coefficient

1 INTRODUCTION

Floods in urban areas are a reality in many parts of the world, due to significant hydrological impacts caused by the urbanization process. Many improvements in stormwater management are actually been developed through structural and non-structural measures, trying to reestablish the pre-development hydrological cycle.

The green roofs are seeing, together with other kinds of green infrastructure, as essential to improve resilience and sustainability in cities (Nascimento, Mary, & Silva, 2018). Although its performance concerning hydrological effects, vegetation importance and maintenance requirements are still uncertain notably in tropical climate conditions, where the number of consecutive dry days are important.

The extensive green roofs are conceptualized as lightweight growing media while intensive green roofs have more deeply-planted vegetation. Extensive green roofs are generally inaccessible and require low or no maintenance and irrigation system is not needed, unless there are extremely long periods of dry weather conditions.

The green roofs present great potential for deployment in urban areas, including those already consolidated (Cipolla, Maglionico, & Stojkov, 2016; Costa, Aleandri, & Poleto, 2011).

Several benefits resulting from the installation of green roofs on buildings have been reported in scientific studies: attenuation of peak flow and volume of runoff (Mentens et al., 2006; Voyde et al., 2010), reduction of air temperatures and improvement in urban air quality (Feng et al. 2010), contribution in removing pollutants from urban stormwater (Berndtsson et al., 2010; Razzaghmanesh et al., 2014), reduction of noise in urban environments (Dunnett and Kingsbury, 2004) and effects of urban heat islands mitigation (Wong et al. 2003, Castleton et al., 2010, Coutts et al., 2013). Green roofs also contribute to the increase urban biodiversity and promote the creation of habitat for plants and animals (Vijayaraghavan et al., 2012; Emilsson et al., 2007). In addition to the hydrological and environmental benefits, green roofs have the potential to reduce energy consumption (Wong et al., 2003, Alexandri and Jones, 2008) and provide amenity and aesthetic value (Razzaghmanesh et al., 2014).

2 METHODS

2.1 Experimental green roofs

The experimental green roofs are located in Belo Horizonte, Brazil, at the Federal University of Minas Gerais Campus.

Belo Horizonte climate is tropical, are in an altitude of 900 m with mean annual rainfall 1400 mm, two seasons are identified in the year: the rain season from October to Mars and the dry season from April to September. The annual mean of maximum number of consecutive dry days (CDD) are 60 (Nunes, 2018).

A flat roof was divided in three green roofs and a reference roof each one with approximately 11 m². The three green roofs have the same structure differing only about the vegetation species planted. They are composed by an impermeabilization layer, a geocomposite drainage layer MacDrainJ, the substrate of regular garden soil, having thickness of 5 cm. One compartment was plated with grass (*Zoysia japonica*), the second one with (*Graptopetalum paraguayense*), and the third one has no vegetation. Figure 1 shows the green roofs compartments.

Figure 1 – Left:Grass compartment 10 days after planting; Right: view of three roof compartments

The aim is to compare the reference roof and the vegetation role in hydrological performance besides the maintenance requirements.

2.2 Sampling devices

Runoff flow from each roof compartment is measured each 5 minutes at the outlet of the downspouts with tipping buckets (the same type from those used by Gromaire et al., 2013) with a resolution of 0.003 mm.

Rainfall is measured with a tipping buckets rain gauge located at the campus, 800 m distance from the roof, with a resolution of 0.25 mm.

The cumulated rain for the whole period (29/09/2017 to 31/03/2018) is 1469 mm. The maximum number of consecutive days without rain was 11.

3 PRELIMINARY RESULTS AND DISCUSSION

More than 100 events are in analysis, the result from the 34.75 mm rain event of 23 October 2017 illustrate the results (Figure 2). The runoff coefficients calculated are 0.37, 0.26 and 0.45 to the sedum, grass and no vegetation compartments respectively. The runoff delay caused by the green roof's compartments are 10 minutes.

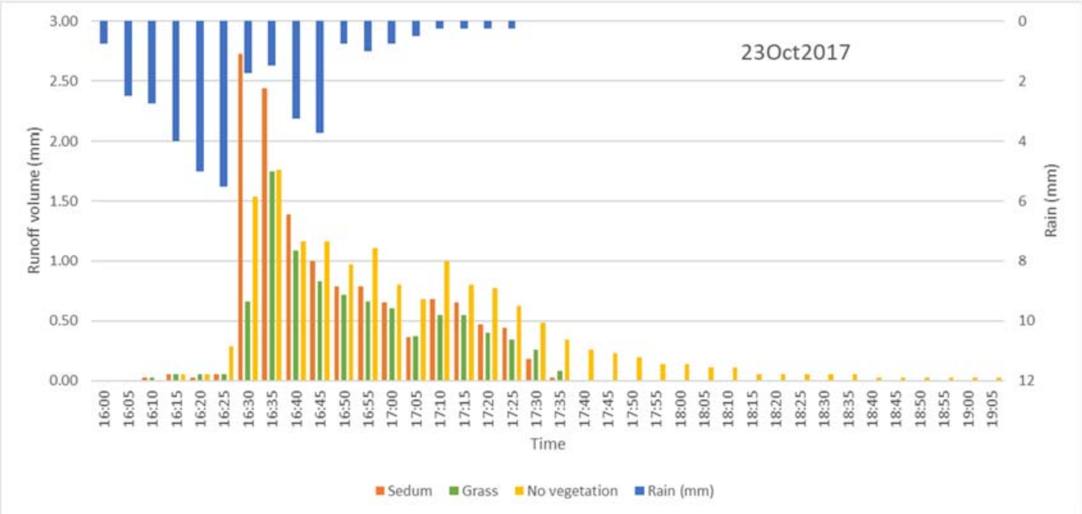

Figure 2 – Runoff and rain volume of the green roof

During the dry season the plants couldn't survive without irrigation. To the complete article the authors will to finish the evaluation of all rain events of the period, including statistical analysis of the results.

4 FINAL CONSIDERATIONS

As a result, it was observed that with the used plant species the extensive green roof in the Belo Horizonte climate conditions require frequent irrigation during the dry season.

The data are still in analysis; the authors expects as results to find that the plants transpiration affects the performance of green roof, as noted by Ramier et al. (2013). In terms of reducing runoff, the expected results are that the green roof reduces the runoff volumes in at least 50% as observed from Oliveira (2012), Mendiondo & Cunha (2004) and Perch et al. (2012) in field studies in Brazil.

ACKNOWLEDGEMENTS

The authors acknowledge CNPq - Conselho Nacional de Desenvolvimento Científico e Tecnológico, Capes - Coordenação de Aperfeiçoamento de Pessoal de Nível Superior and Fapemig - Fundação de Amparo à Pesquisa do Estado de Minas Gerais for their financial support granted for this research; Maccaferri for underdrain supply and INMET- Instituto Nacional de Meteorologia for the rain gauges data.

LIST OF REFERENCES

Alexandri, E., Jones, P., (2008). Temperature decreases in an urban canyon due to green walls and green roofs in diverse climates. Build. Environ. 43 (4), 480e493.

Berndtsson J.C., L. Bengtsson, K. Jinno, (2009) Runoff water quality from intensive and extensive vegetated roofs. Ecol Eng, 35pp. 369- 380.

Castleton, H., Stovin, V., Beck, S., Davison, J., 2010. Green roofs: building energy savings and the potential for retrofit. Energy Build. 42 (10), 1582e1591.

Cipolla, S. S., Maglionico, M., & Stojkov, I. (2016). A long-term hydrological modelling of an extensive green roof by means of SWMM. Ecological Engineering, 95, 876–887. https://doi.org/10.1016/j.ecoleng.2016.07.009

Costa, J., Aleandri, G. A., & Poleto, C. (2011). Experimental Studies of Green Roof Systems as part of Sustainable Urban Watershed in order to minimize the problems of flooding, (September), 11–16.

Coutts, A.M., Tapper, N.J., Beringer, J., Loughnan, M., and Demuzere, M., 2013. Watering our cities The capacity for Water Sensitive Urban Design to support urban cooling and improve human thermal comfort in the Australian context. Progress in Physical Geography, 37 (1), 2–28.

Emilsson T., Berndtsson J.C., Mattson J.E., Rolf K. Effect of using conventional and controlled release fertiliser on nutrient runoff from various vegetated rood systems. Ecol Eng, 29 (2006), pp. 260-271.

Gromaire, M. C., Ramier, D., Seidl, M., Berthier, E., Saad, M., & de Gouvello, B. (2013). Impact of extensive green roofs on the quantity and the quality of runoff – first results of a test bench in the Paris region. Novatech 2013, 1–10. Retrieved from http://documents.irevues.inist.fr/handle/2042/51380

Mentens J., Raes D., Hermy M. Green roofs as a tool for solving the Rainwater runoff problem in the urbanized 21st century? Landscape and Urban Planning, 77 (2006), pp. 217-226.

Nascimento, C. M. L., Mary, W., & Silva, L. P. (2018). Hydrological performance of modular-tray green roof systems for increasing the resilience of mega-cities to climate change. Journal of Hydrology. https://doi.org/10.1016/j.jhydrol.2018.01.004

Nunes, A. A.; Pinto, E. J. A.; Baptista, M. B. Detection of trends for extreme events of precipitation in the Metropolitan Region of Belo Horizonte through statistical methods. REVISTA BRASILEIRA DE RECURSOS HÍDRICOS, v. 23, p. 9, 2018.

Oliveira C. C; Magalhães F R.; Marques M.; Silva L. P. Telhados verdes em regiões de clima tropical e subtropical: revisão crítica preliminar. In: IX Encontro Nacional Águas Urbanas. Belo Horizonte: 2012.

Persch, C. G.; Tassi, R.; Allasia, D. G. Avaliação do comportamento de um telhado verde no controle quantitativo do escoamento pluvial a partir de um modelo de balanço de volumes de longo prazo. IX Encontro Nacional Águas Urbanas. Belo Horizonte: 2012.

Ramier, D.; Berthier, E.; Gallis, D.; Dussuchale, A.; Pinta, P.; Versini, P.A.; De Gouvello, B. (2013). Analyse du fonctionnement hydrologique de toitures vegetalisées: observations et modelisation. Quelles innovations pour la gestion durable des eaux pluviales en milieu urbain, Dez 2013, Nantes, France.

Razzaghmanesh, M.; Beecham, S.; Kazemi, F.. (2014) Impact of green roofs on stormwater quality in a South Australian urban environment. Elsevier. Adelaide, Australia, p. 1-9. 1 fev. 2014.

Vijayaraghava, K., Joshi, U.M., Balasubramanian, R, (2012). A field study to evaluate runoff quality from green roofs. Water Res, 46, 1337-1345.

Voyde, E., Fassman, E., Simcock, R., (2010). Hydrology of an extensive living roof under sub-tropical climate conditions in Auckland, New Zealand. J. Hydrol. 394 (3–4), 384–395.

Wong N. H., Chen Y., Ong C. I, Sia A. (2003). Investigation of termal benefits of rooftop Garden in the tropical environment. Build. Environ. 38, 261-270.