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How Green Roof Performance Depends on Climatic Conditions and Climate Change? First Results of Simulation Scenarios.

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Abstract

Hydrological simulations were used to analyse the performance of an advanced green roof with additional underlying storage. Simulations were done with 20-year data series of precipitation and evapotranspiration or temperature for the cities of Lyon, Melbourne, and Seoul, considering a current climate scenario (2000-2019). Additionally, two future scenarios for the city of Lyon (2035-2044 and 2090-2099) were simulated. Simulations were done for substrate depths ranging from 60 to 240 mm. The advanced green roof has an additional underlying storage layer, which was simulated with storage capacities from 52 to 150 mm. This abstract shows some of the first results regarding retention performance. There is a significant variability between the three cities (climate context) and, in Lyon, between past (2000-2019) and future (2090-2099) climates.

Introduction

Event and long-term hydrological performance indicators of green roofs (retention, actual evapotranspiration, peak flow attenuation, outflow, etc.) depend on the meteorological and climatic conditions prevailing at their locations. For a given green roof with a particular design (e.g. substrate depth, additional storage volume, controlled outflow, etc.), its performance will vary according to its geographical location and to the meteorological time series. In addition, for a given location, the performance will also vary in the future due to climate change. The Olympluie project aims to evaluate and compare the performance of various green roofs for different cities around the world, and, for some of these locations, estimate how the performance will change by using future time series derived from the IPCC RP 8.5 scenario. In this abstract, some of the first results obtained for Lyon, Melbourne and Seoul are presented.

Material and methods

Green roofs

The advanced green roofs simulated in this work include i) a substrate depth ranging 60 to 240 mm, and ii) an additional underlying storage layer below the substrate ranging from 52 to 150 mm (or L/m²) [1]. The green roofs are vegetated with sedums and equipped with outflow controllers. The advanced green roof (commercial name: OASIS) is manufactured by the French company Le Prieuré and will be installed on the roofs of the Athletes' Village building

managed by the SOLIDEO company for the Paris 2024 Olympic Games (hence the project name “Olympluie”, i.e. Olympic rain).

Historical time series

Rainfall intensity (I, mm/h) and potential evapotranspiration (PET, mm/h) time series have been created from raw data sets collected for various cities around the world with time steps ranging from 1 to 60 minutes. Intensity raw data on the one hand, and PET or air temperature raw data on the other hand, were available with time steps from 1 minute to 1 hour (resp. 1 day). In case PET data were not available, PET was estimated from the measured or calculated mean daily temperature by means of the Oudin *et al.* (2005) formula [2]. The resulting time series used for modelling scenarios are summarized in Table 1. Other cities are presently considered to extend the list of cases.

Table 1. Cities and time series used for simulation scenarios.

Due to limited space, only cities marked with * are illustrated in this abstract.

City, Country	Historical I and PET time series	Future I and PET time series	Simulation time step of I and PET time series
Lyon*, France	2000-2019	2035-2044, 2090-2099	6 min
Melbourne*, Australia	2000-2019		6 min
Seoul*, South Korea	2000-2019		1, 6 and 15 min
Montreal, Canada	2005-2021		1, 6 and 15 min
Los Angeles, USA	2000-2019		1 hour
Dourados, Brazil	2000-2019		15 min and 1 hour
Cape Town, South Africa	2000-2019		1 hour

Future time series

For some cities, IPCC RCP 8.5 scenario regional modelling results are available. In this case, these data, combined with historical time series, have been used to create future time series by downscaling IPCC data by means of a method based on the MRC (multiplicative random cascade) approach [3]. In this abstract, only future time series for Lyon are shown.

Green roof model

The model used for the simulations is the Gepeto model developed by INSA Lyon in partnership with Le Prieuré. The model was previously tested and calibrated with experimental data [1, 4]. In the following simulations, the green roof settings are default values, the most important ones being the substrate depth (80 mm), the substrate storage capacity (52 mm), the cells capacity just below the substrate (4 mm), the additional storage layer (52 mm), the controlled outflow (10 L/s/ha), the controlled outflow starting depth in the storage layer (9.83 mm), and two outflow controllers.

Simulation scenarios

Simulations are carried out with historical and future time series given in Table 1. In the first phase of work presented in this abstract, two design elements were varying: i) the thickness of the substrate, from 60 to 240 mm, and ii) the rainwater underlying storage capacity, from 52 to 150 mm. All simulations are run with a 6-min time step.

Results

Some examples of simulation results are given hereafter for Lyon, Melbourne, and Seoul. The selected performance indicator is the interception efficiency, i.e. the percentage of rainwater volume that is retained and/or evapotranspired by the green roof. An interception efficiency

of e.g. 60% means that 60% of the rain falling over the green roof is stored and/or evapotranspirated. Consequently, 40% of the rainfall volume is discharged by the green roof either as controlled outflow or as overflow in case the green roof maximum storage capacity (in both substrate and storage layers) is reached. Other results and performance indicators (peak flows, overflows, etc.) for various green roof configurations will be presented during the conference.

In the case of Lyon, the global interception efficiency for the period 2000-2019 for a substrate depth of 80 mm and a storage layer depth of 52 mm is 66.7%. The interception efficiency is only 60.0% for the future climate period 2090-2099, showing the effect of the climate change on the performance. The box plot of the annual interception efficiencies for both periods is shown in Figure 9. For the period 2000-2019, the annual interception efficiency varies from 58.3% to 87.6%. For the period 2090-2099, it varies from 51.8% to 70.8%.

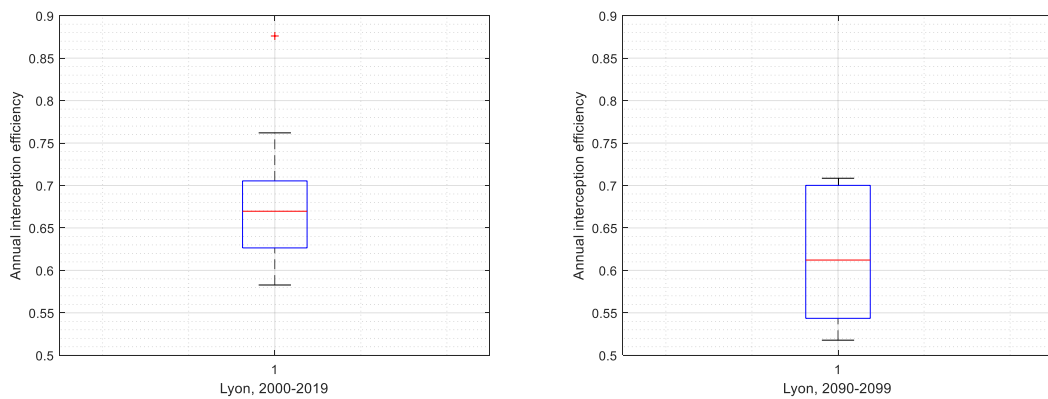


Figure 9. Box plot of annual interception efficiency in Lyon for the periods 2000-2019 (left, $n = 20$) and 2090-2099 (right, $n = 10$). $H_{\text{substrate}} = 80$ mm, $H_{\text{storage}} = 52$ mm.

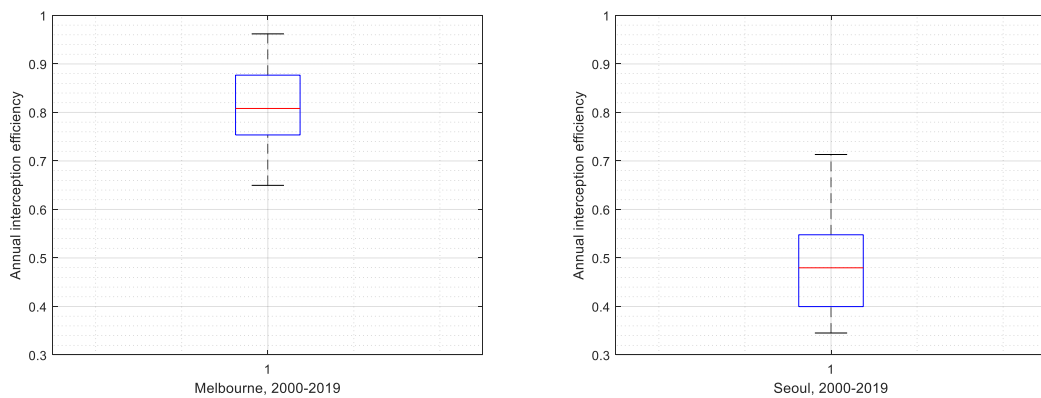


Figure 10. Box plot of annual interception efficiency in Melbourne (left) and Seoul (right) for the period 2000-2019 ($n = 20$). $H_{\text{substrate}} = 80$ mm, $H_{\text{storage}} = 52$ mm.

Simulations for Melbourne and Seoul over the period 2000-2019 gives global interception efficiencies equal to 79.9% and 47.1% respectively. Figure 10 shows the comparison of annual interception efficiencies for the same roof as in the case of Lyon simulated in Melbourne and Seoul. In Melbourne, the annual interception efficiency ranges from 65.0% to 96.2%, which is better than in the case of Lyon due to differences in climatic conditions (not detailed here). In Seoul, the annual interception efficiency ranges from 34.5% to 71.3%: this lower performance, compared to Lyon and Melbourne, is due to the very strong rainfall events which are observed during the monsoon period from mid-June to mid-September. In this case, the green roof design must be adapted, with higher substrate depth, or with a higher storage layer depth, or a combination of both (results not shown here) to reach a given level of performance.

Conclusion

The Olympluie project simulates various green roof design scenarios for different climatic contexts, including future climate derived from IPCC data sets. Many performance indicators will be evaluated for a detailed comparison of scenarios, allowing to adapt the green roof design to each geographical and climatic context.

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Biography



The presenting author is Professor at the University of Lyon, France, in INSA Lyon (National Institute of Applied Sciences). He was head of the laboratory DEEP (Wastes, Water, Environment, Pollutions) in the period 2014-2022 and is co-president of the multidisciplinary OTHU – Field Observatory for Urban Hydrology (www.othu.org) since 2023. His main research topics are related to urban hydrology and urban water systems, especially hydraulic and pollutants transport modelling in sewer systems, field monitoring and metrology, stormwater management, and integrated approach for urban water systems. More information and publications are available on his website at jlbkpro.free.fr