Factor prioritization for multi objectives Green infrastructure design

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Highlights

- The difference between first order and total effect Sobol indices was found to be significant which recommend the use of total effect for design factors.
- Setting the most influential factor as a fixed value influences the ranking of the secondary factors.
- The limiter height was an influential factor for all performance indicators.

Introduction

Green infrastructures can be designed with objectives from multiple fields such as hydrology, biodiversity or greening urban space (Demuzere et al., 2014). Among this variety of objectives, different performance indicators can be defined. For instance, in the case of green roofs, retention or detention hydrologic performance indicators (De-Ville et al., 2018), can be linked to evapotranspiration, total overflowed volumes or peak discharges. Since the objectives of green infrastructure are multiple, design methods or guidelines suitable for such a task are still to be developed or improved. Specifically, it is necessary to identify, given a green roof to be designed, which factors (e.g. the substrate depth, field capacity or alveolar geometry) play an important role depending on the performance indicator to be analysed.
The goal of this study is, throughout a sensitivity analysis, to evaluate the influence of green roof physical factors over different performance indicators, leading to prioritize the design depending on the design purposes. A secondary objective is to study how this prioritization differs depending on the specific set of physical characteristics to be considered in the analysis.

Methodology

Data and modelling

The study was conducted using Urbis software (Bertrand-Krajewski et al., 2020), employing a time series from Orléans, France, available in the software. The time series is a 2-year long and 5 minutes timestep series of precipitation and potential evapotranspiration computed with Penman-Monteith equation.
A virtual 100 m^2 flat green roof with storage layer is considered for this study. The physical factors (parameters) to be varied for the case study are the substrate porosity and thickness, Overflow height, void index of the storage layer, maximum regulated discharge and limiter height (Table 1).

Sensitivity analysis

A sensitivity analysis was conducted using Sobol's first order indices and total effect (Saltelli et al., 2008). A range was chosen for each parameter (physical factor) based on literature values (Stovin et al., 2017) and suggested values in Urbis. Different performance indicators were analysed: *i)* the total overflow volume, *ii)* the total evapotranspiration volume and *iii)* the maximum discharge. Two scenarios were presented: one with all parameters as degrees of freedom (case 1) and another with all but the limiter height (position for the orifice of the discharge limiter between the bottom and the top of the storage layer) as degrees of freedom (case 2) (Table 1).

Table 1. Boundaries for the different parameters of sensitivity analysis scenario

	Boundaries	**Unit**	**Case 1**	**Case 2**
Porosity /field capacity	[0.2, 0.45]	[-]	X	X
Substrate thickness	[30, 200]	[mm]	X	X
Overflow height	[10, 200]	[mm]	X	X
Void index	[0.2, 1.0]	[-]	X	X
Discharge limiter	[0.2, 5]	[L/s]	X	X
Limiter height	[0.0, 1.0]	[-]	X	0
Number of simulations			14000	12000

Results and discussion

The first order and total effect Sobol indices are presented in Figure 1 for the first case. Results shows that the total volume of overflow from the roof depended, in decreasing order, on the discharge limiter height, the void index in the storage layer and to the overflow height. The maximum discharge indicator led to slightly different results since the discharge limiter played an important role (3rd in ranking of total effects). Regarding the evapotranspiration, the substrate thickness played the most important role, followed by the limiter height. The field capacity might not play a relevant role due to the small range of variation allowed, but also due to the hypothesis in the model. In Urbis, the actual evapotranspiration starts to decrease only when the storage layer is empty. A limiter higher than zero allow permanent storage and directly influence the evapotranspiration.

Sensitivity indices ranked the importance of a factor but did not show if its impact was beneficial: increasing the limiter height lead to incentivise the evapotranspiration, but also the total overflow. In this context, an optimal value should be considered for this limiter to meet two different objectives. Increasing the substrate thickness would allow to increase evapotranspiration without increasing the overflow significantly. The value of the discharge limiter influenced principally the maximum discharge, as can be expected. This imply that a fixed value for this factor can be set without influencing significantly the other performance indicators.

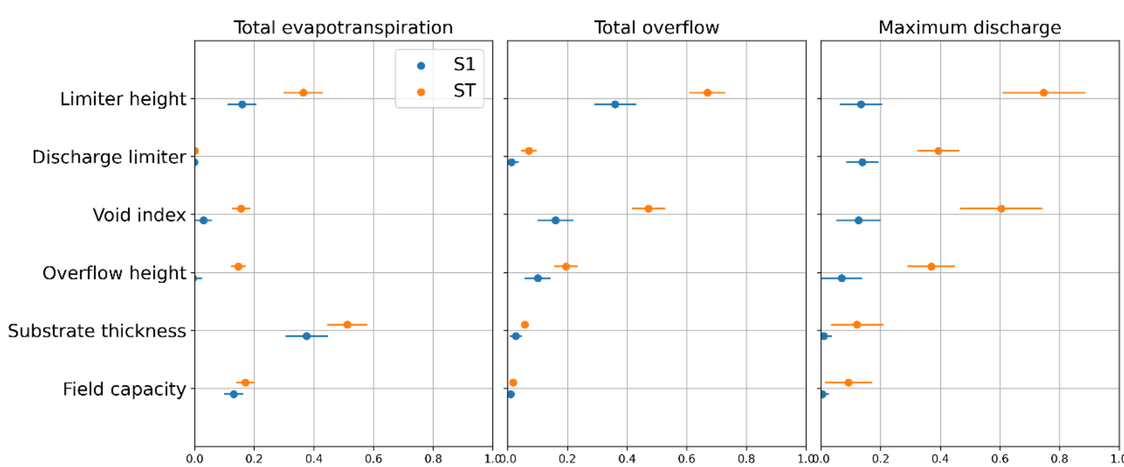

Figure 1. Results of the 6-parameter sensitivity analysis (case 1) depending on the indicator used (total evapotranspiration, total overflow, maximum discharge. S1 is the first order Sobol indices and ST the total effect indices.

The first order Sobol indices and total effect of the second case are shown in Figure 2. In case 1, the void index and overflow height had an effect on the evapotranspiration due to dependencies while in case 2, setting the limiter height to 0, the evapotranspiration was not influenced by the storage layer. In terms of overflow and maximum discharge, the overflow height seemed to be more influential than the void index, while it was the contrary in case 1. This can be explained by dependencies with the limiter height. Comparisons between case 1 and case 2 showed that setting a parameter to a fixed value should be done carefully, as this can alter significantly the ranking of influential parameters, especially when the parameter to be fixed is one of the most influential.

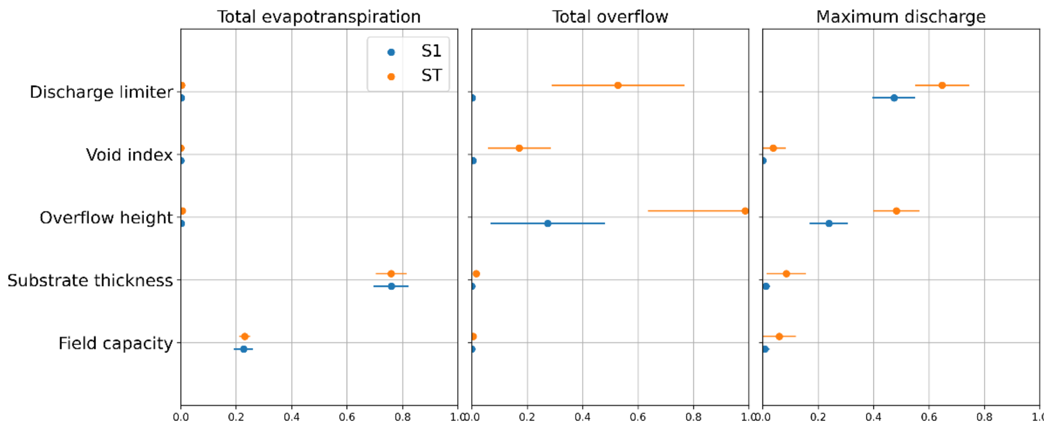

Figure 2. Results of the 5-parameters sensitivity analysis (case 2) depending on the indicator used (total evapotranspiration, total overflow, maximum discharge

Conclusions and future work

The use of total effect Sobol indices allowed to evaluate the importance of some physical factors in order to design green roofs with various objectives. Especially it revealed some hidden dependencies between some of the factors considered in this study. Such a method could be used in order to prioritize which parameter to adjust among the available products (i.e. different green roofs materials and storage) as a pre-design study. It also showed that setting as a fixed value the most influential physical factor will have an influence in the ranking of all factors, therefore such a method has to be applied carefully. The influence of some factors can also be positive for some aspect and negative for others, in which case a thorough analysis of the results is suggested. The influence of the climate variation, location, the type of green infrastructure as well has irrigation strategies has yet to be evaluated.

References

Bertrand-Krajewski, J.-L., Sandoval, S., Beauvisage, L., Sandron, L., Szelenyi, D., Villarreal, E., Houssin, E., Slaoui, H., Nuttens, L., & Filippi, R. (2020). SIMULATIONS DES TECHNIQUES ALTERNATIVES DE GESTION DES EAUX PLUVIALES A L'ECHELLE DE LA PARCELLE ET DU QUARTIER SUR DES CHRONIQUES DE LONGUE DUREE. *Congrès de l'ASTEE*.

De-Ville, S., Menon, M., & Stovin, V. (2018). Temporal variations in the potential hydrological performance of extensive green roof systems. *Journal of Hydrology*. https://doi.org/10.1016/j.jhydrol.2018.01.055

Demuzere, M., Orru, K., Heidrich, O., Olazabal, E., Geneletti, D., Orru, H., Bhave, A. G., Mittal, N., Feliu, E., & Faehnle, M. (2014). Mitigating and adapting to climate change: Multi-functional and multi-scale assessment of green urban infrastructure. *Journal of Environmental Management*. https://doi.org/10.1016/j.jenvman.2014.07.025

Saltelli, A., Ratto, M., Andres, T., Campolongo, F., Cariboni, J., Gatelli, D., Saisana, M., & Tarantola, S. (2008). Global Sensitivity Analysis. The Primer. In *Global Sensitivity Analysis. The Primer*. https://doi.org/10.1002/9780470725184

Stovin, V., Vesuviano, G., & De-Ville, S. (2017). Defining green roof detention performance. *Urban Water Journal*. https://doi.org/10.1080/1573062X.2015.1049279