MascotNum2021 conference - Sensitivity Analysis applied to a green roof dynamic model

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Abstract:

In the last decade, soil imperviousness has been one of the main urban issues in North Europe. In case of strong rain events, runoff can lead to the discharge of high volume of water and can cause water system saturation. Among all urban-water regulation systems, green roofs can be used to store and delay the release of rainwater to sewers [4]. Green Roofs (GR) are composed of a soil layer (ii) (substrate) on top of which vegetation (i) is growing. Under the soil layer, a geotextile (iii), a drainage layer (iv) and an insulating layer (v) protect the building (see Figure 1).

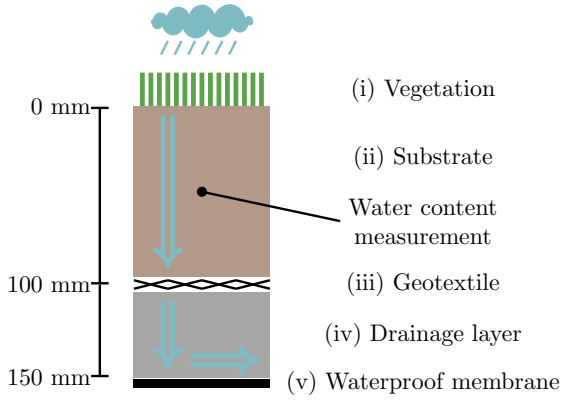

Figure 1: Profile view of the experimental site including dimensions, materials typically used in green roof and the volumetric water content sensor location within the substrate.

GR are considered as a sustainable solution that offers benefits such as building insulation, urban heat island cooling during summer, air pollution control and biodiversity enhancement. Collectivities are interested in GR and need recommendations to optimize their efficiency. These recommendations can be defined by the French expertise centre named Cerema[1] in Nancy. However, the hydraulic performances of GR are difficult to predict and control, and requires to model and simulate the green roof dynamics [1]. The expertise of the CRAN research centre in model analysis leads to a collaboration between the two institutes.

The outflow of a green roof is mainly related to the water content inside the layers which depends on the soil physical properties. Few models exist to describe the hydrological infiltration throughout soil and they are based on the Richards's equation. This highly nonlinear partial differential equation describes the water retention capacity and the outflow in unsaturated porous media.

[1]Expertise Centre on Risk, Environment, Mobility and Arrangement - https://www.cerema.fr/fr

The Van Genuchten - Mualem model is used, in this study, to simulate hydrological behavior and is applied on each layers of a green roof. The model considered has one input – the rainfall – one output – the water content in the growing soil – and six parameters. Saturation water content θ_s, residual water content θ_r, porosity distribution in the soil n and saturation hydraulic conductivity K_s are parameters linked to soil properties. Parameters α and l are empirical. The six soil parameters are affected by aging, soil compaction, plants development, and their characterization is challenging. All this parameters are considered uncertain and these uncertainties spread in the model and affect the output. In order to better understand the model, uncertainties are analysed with Global Sensitivity Analysis (GSA) methods.

This study has a twofold objective. First, exploratory analyses of the model uncertainties are carried out. The Cerema is interested in a better understanding of the retention capacity dynamics of their GR. To achieve it, GSA is performed on the water content of two layers of the green roof, substrate and drainage. The model parameters are fitted from real data given by the Cerema and a 5 months period of time has been chosen from June to November 2013 which represents different seasons and different hydrological phenomena. Second, a comparison of sensitivity analysis methodology is carried out. Sequential sensitivity indices providing the parameter influence at each time instant are computed. They give an insight into the dynamic behavior of the parameter influence. A method based on polynomial chaos expansion [2] have been applied and optimized. However, this approach can become very time consuming and lead to a huge amount of indices, not always informative. To overcome this, multivariate approaches are used. They rely on principal component analysis of the model output [3]. It allows to sum up the influence dynamics into a few number of sensitivity indices and save the computation time.

The results of this study highlight three influential parameters which follow different trends in function of rainfall. The same trends are observed in the two layers with different intensities and are pointed out with the sequential and multivariate methods. No matter the season, the θ_s and α index follows the water content dynamics, its influence rises when it rains and decreases when it dries. On the contrary, the n index decreases when it rains and rises when it dries.

This results provide a better understanding of the water content behavior over time in the substrate and the drainage layer of green roofs by taking into account soil parameter uncertainties. Futher studies on outflow will be carried out and may require different sensitivity analysis methods. This will be investigated in the upcoming months.

References

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Short biography – Graduated from the Université de Lorraine (France) with a control engineering degree and a complex system engineering master degree, I am interested in environment issues and modeling. During my final master internship, I worked on sensitivity analysis applied to a green roof hydraulic model. The thesis on the same subject is co-funded by MESRI and the Grand Est area.