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How do the soil, the vegetation and the weather affect the water content of a green roof ?

A. Hégo
Université de Lorraine

Supervisor(s): F. Collin (Université de Lorraine) and H. Garnier (Université de Lorraine)

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Address: CRAN-Polytech Nancy - 2 Rue Jean Lamour - 54500 Vandoeuvre-Lès-Nancy

E-mail: axelle.hego@univ-lorraine.fr

Abstract:

In the last decade, soil imperviousness has been one of the main urban issues in the Northeast of France. 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 (GR) can be used to store and delay the release of rainwater to sewers [4]. GR are also considered as a sustainable solution that offers benefits such as building insulation, urban heat island cooling during summer and air pollution control.

The hydrological performances of GR are directly linked to the outflow of a GR which is mainly related to the water content inside the layers. In order to investigate these performances, the water content needs to be measured and simulated. Few models exist to describe the hydrological behavior of soil and can be adapted for GR characteristics such as soil parameters of the different layers, dimension, type of vegetation, etc. In this study, the dynamic of the water content is described by two elements. The first element describes the hydrological infiltration throughout unsaturated porous media and is based on the Richards' equation. This equation is solved by combination with the Van Genuchten - Mualem model which depends on soil parameters. The second element estimates the water extracted from the soil due to the vegetation and the weather conditions. All these models and equations are implemented in Hydrus-1D© software to simulate hydrological behavior [5]. This software allows the set up of the green roof structure, boundary conditions, meteorological data, soil and vegetation parameters in order to reproduce the green roof real conditions.

Figure 1: Experimental green roof of Tomblaine, France.

However, some of the model parameters, as soil or vegetation parameters, are challenging to determine as they are difficult to measure accurately through experiments. All the parameter uncertainties are propagated to the simulation of water retention capacity and need to be analysed with Global Sensitivity Analysis (GSA). A first study has been dedicated to analyse only the influences of soil parameters as saturated water content, porosity, etc. In this case, only the first element of the water content behavior has been taken into account and this study allows to reduce the number of uncertain soil parameters for the following studies [3]. Then, in the next study, the second element of the water content behavior has been added, vegetation parameters and meteorological variables have been taken into account. The effects of vegetation and soil parameters have been simultaneously analysed in order to provide a first calibration of this new configuration of the GR model. In this configuration, the weather variables have been taken into account using Penman-Monteith equation. Nevertheless, the measure of the radiation leads to some uncertainties which could have effects on the simulated water content. In this case, several

issues can be considered: first, the effects of the measure uncertainty can be investigated or second, the natural variability of the radiation can be investigated. The second issue will be more interesting here.

In this proposed study, the GR model has one dynamic output – the simulated water content – and depends on static uncertain parameters – the soil and vegetation parameters – and on one time-varying uncertain input – the net radiation, a weather variable. Boundary conditions, meteorological data and water retention data were measured from an in-situ experimental green roof platform located in Tomblaine, France (see Fig. 1) and are used to simulate water retention with real conditions. The objective of this study is to investigate the influence of soil, vegetation parameters and the radiation variable on the water retention capacity over time with GSA approach. The first challenge is to generate time-correlated samples of the radiation variable that satisfy the natural variations. To do so, the variable can be defined as a random field defined by a time mean, a covariance function and a distribution for each instant. The covariance function contains the time-correlation information between instants. All these statistical information can be extracted from consistent observed data which can be challenging in case of low data set. In fact, when the number of observations is low, a specific procedure can be applied for stationary months. Each day is considered similar and can be concatenated for significantly rise the number of observations and then extract information for a typical day of this month. The analysis of a 1-month period will be first carried out but the ultimate objective is an analysis of a 1-year period which is challenging because of the transition months e.g. March. This concatenation procedure cannot be applied and a procedure based on time-series decomposition will be investigated. After the extraction of statistical information to describe the random field, the time-correlated samples can be generated by Iman and Conover procedure as in [2] or Karhunen-Loève Expansion as in [1]. In these procedures, independent samples following the distribution for each instant are first generated and then the time-correlations are transmitted using the covariance function. The independent samples will be used during the computation of the sensitivity indices and the time-correlated ones for the computation of the output. For each instant, sensitivity indices will be computed using the Polynomials Chaos Expansion [3] or another estimator.

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 hydrological model. The thesis on the same subject is co-funded by MESRI and the Grand Est area.