SHORT TERM SCIENTIFIC MISSION (STSM) SCIENTIFIC REPORT

This report is submitted for approval by the STSM applicant to the STSM coordinator

Action number: CA17133
STSM title: MODELLING OF HYDROLOGICAL PROCESSES OF A GREEN ROOF
STSM start and end date: 06/03/2019 to 25/03/2019
Grantee name: Dr. Michele Turco

PURPOSE OF THE STSM:

(max.200 words)
To mitigate the effects of urbanization, Low Impact Development systems (LIDs), including nature-based solutions, an innovative stormwater management "green" approach, have gained popularity. LIDs consist of a series of facilities whose purpose is to reproduce the site's pre-developed hydrological processes using design techniques that infiltrate, filter, evaporate, and detain runoff close to its source. Green Roof (GR), represent one of the most popular LID considering also that rooftops may represent as much as 40%–50% of the total impervious surfaces in cities. Although in the literature there are several stormwater models to simulate GRs behaviour, most of them lack a comprehensive description of the hydrological processes involved. Models to analyse GRs behaviour can be dived in building scale models (BSM) and urban scale models (USM). BSM include conceptual and physically based models. Although physically based models have been widely and often successfully used at building scale their use is very limited at urban scale due to the complexity of the physically based processes. Thus, the purpose of STSM was to provide a simple methodology to spread the effects of a GR, based on physically based model at building scale, on a real urban catchment using the SWWM model as engine.

DESCRIPTION OF WORK CARRIED OUT DURING THE STSMS

(max.500 words)
The work was developed as follows. The physically based modelling was completed using the HYDRUS-1D model considering two different soils as substrate layer and drainage layer of the GR. The hydraulic properties of the soil substrate were measured using a simplified evaporation method while the hydraulic properties of the drainage layer were assumed as gravel material. Then the outflow of the GR, resulting from the Hydrus modelling, was spread on a part of the urban drainage network of the city of Cosenza using the SWMM model just as engine for the hydrological effects. The schematization of the urban drainage network of the city of Cosenza was already calibrated on the basis of several experimental campaign. Both modelling phases was performed using precipitation, climate, and experimental data for a three-month long period. The Green roof considered in this work is a simple schematization constructed in 4 layer (Figure 1). From the bottom to the top, we can consider: a protection layer with a depth of 0.25 cm, a drainage layer composed of natural gravel material with a depth of 8 cm, a soil substrate layer composed of mineral soil with 74% of gravel, 22% of sand, and 4% of silt and clay with a depth of 12 cm. A highly permeable geotextile of 0.25 cm depth is considered between the soil substrate and the drainage layer to prevent soil from migrating into the underlying layers.

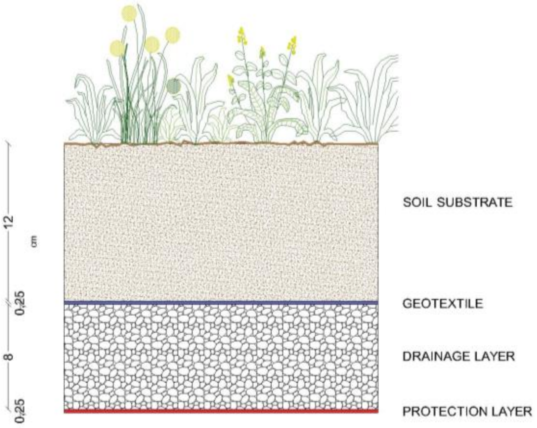

Figure 1

A three months data set was selected for our analysis from a weather station that measured precipitation, velocity and direction of wind, air humidity, air temperature, atmospheric pressure, and global solar radiation. Reference evapotranspiration was calculated using the Penman-Monteith equation. An average value of albedo of 0.23 was assumed considering that the albedo for vegetated areas was 0.23. The HYDRUS-1D was used to model the hydraulic behaviour of the GR at building scale. The studied GR was interpreted as a one-dimensional, single-porosity, porous medium system, which could be described by the Richards equation used in HYDRUS-1D using the van Genuchten – Mualem relation to describe the soil hydraulic properties.
The hydraulic properties of the soil substrates was measured in the laboratory using a simplified evaporation using the HYPROP® device. The urban scale modelling phase was performed to a specific part of an urban catchment located in the city of Cosenza, south of Italy (Figure 2).

Figure 2

Thus, the selected area includes 223 sub-catchments and 245 conduits which develop along 13.3 km. To study the hydrological response of the GR (considered in this study) at urban scale, two scenarios were considered. The first scenario is blank, no GRs were considered. The second scenario considered the 25% of GRs spread on the 223 sub-catchments. To combine the effects obtained from the physical based modelling phase in the SWMM model, the total surface of each sub-catchment was diminished of the amount of the 25% and an additional flow, obtained from the GR modelling in the HYDRUS model, is considering as Inflow in each conduits of the drainage network.

DESCRIPTION OF THE MAIN RESULTS OBTAINED

(max.500 words)
Results from esperimental investigation (Table 1) on soil substrate of the GR, indicated a soil characterized by a very high permeability, which corresponds well with the textural composition of the GR substrate. This characteristic is well suited for GR substrates, which must guarantee fast drainage and avoid water ponding on the surface even during intense precipitations.

Layer	θr [cm^3cm^{-3}]	θs [cm^3cm^{-3}]	α [cm^{-1}]	n [-]	Ks [cm day^{-1}]	l [-]
Soil substrate	0.00	0.58	0.09	1.25	3000	0.5
Drainage	0.00	0.20	0.30	3.00	72000	0.5

Table 1

Parameters of the soil substrate and drainage layer were used in HYDRUS-1D to describe the hydrological behaviour of the GR at building scale. Cumulative inflow and outflow fluxes of the GR are reported in Figure 3. The GR was able to reduce the runoff volume by 38% during the considered period without runoff phenomena. The steep gradients in cumulative outflow indicate that the GR had a fast response to precipitations. During simulations, mass balance errors were always below 1% and they are generally considered acceptable at these low levels.

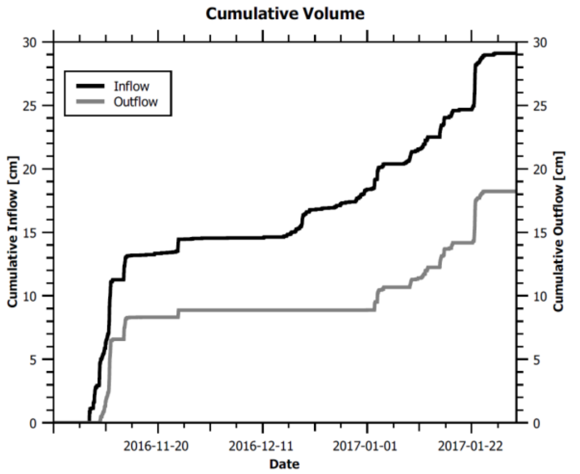

Figure 3

As stated in the previous paragraphs, the effects of the physically-based model have been tested on a real catchment using the same simulation period by exploiting the SWMM model as engine. Simulations were conducted to explore the volume reduction at the final conduit of the catchment and the reduction of flooding events. Volume reduction is reported in Figure 4

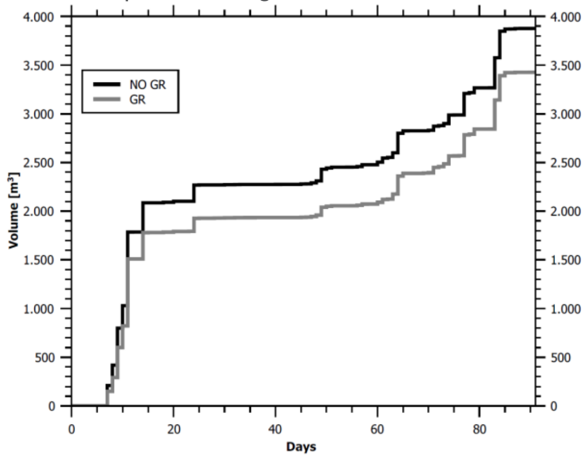

Figure 4

It is evident from the analysis as the implementation of the physically-based modelling of the GR at urban scale produced a volume reduction of 12%.
During simulations, mass balance errors (flow routing) were always below 1% and they are generally considered acceptable at these low levels. This has significant implications with regard to the phenomenon of flooding. With the Scenario 1 (No GR) the operating conditions of the drainage network during the simulation period had some crisis situation consisting in the achievement of the maximum capacity of some nodes of the network, (e.g. see Figure 5 node 94), and consequently the occurrence of the flooding. From the analysis carried out in this study, a total amount of 24 m3 of Volume leaked from the node in the selected period. The flooding phenomena was significantly reduced with the Scenario 2 in general (Figure 6) and considering, again, the node 94 the total amount of Volume leaked from the node was 7 m3 with a reduction of 71%.

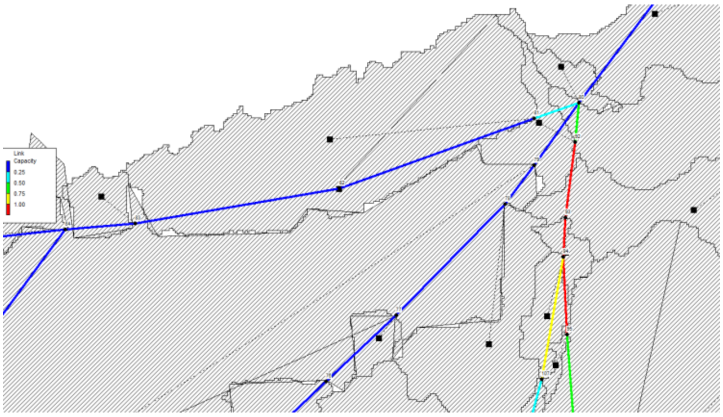

Figure 5

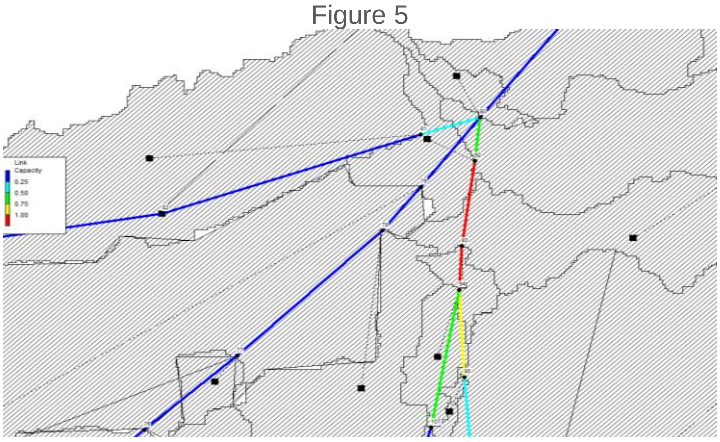

Figure 6

Results from simulations showed that the possibility to connect and combine these models is possible and this work represents a first step to define a more accurate model to simulate the hydrological processes of the nature-based solutions at urban scale with a physically-based methodology. Further investigations on how to connect directly the models cited in this work should be carried out

FUTURE COLLABORATIONS (if applicable)

(max.500 words)

This work represents a starting point in the physically based modeling of the hydrualic behavior of a green roof (GR) at urban scale. The period spent at the Department of Water, Atmosphere and Environment, Institute of Hydraulics and Rural Water Management, University of Natural Resources and Applied Life Sciences, Vienna under the supervison of Prof. Dr. Christine Stumpp and its research group, opened up the possibility of future collaborations in this field. We are already working to expand the work carried out during the STSM period by studying the propagation of the uncertainty of the hydraulic parameters, obtained from building scale modeling, on a catchment scale in particular on the effects that these parameters could have on the hydrological benefits (retention, volume reduction, etc.). Furthermore, further studies have been started together to study the effects of particular water retention curves of particular GR media prepared in the laboratory for the choice of the most appropriate model for interpreting experimental data.

April, 10, 2019

The Applicant

The Host Supervisor