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: Towards a sustainable urban stormwater management: modelling Low Impact Development (LID) systems at large-scale
STSM start and end date: 01/02/2020 to 29/02/2020
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PURPOSE OF THE STSM

Urban floods, recently increased due to the combine effect of climate change and urbanization, represent a potential risk to human life, economic assets and environment. In this context, the traditional urban drainage techniques seem to be inadequate, thus a transition towards an innovative, sustainable and smart urban stormwater management is necessary. One promising strategy is the implementation of Low Impact Development systems (LIDs), including Nature-Based solutions (NBS) (e.g. green roof, permeable pavement, green wall, stormwater filter) that, by reintroducing pervious area in urbanized spaces, provide several environmental benefits at multiple scales. In addition, recently advances in Real-Time Control (RTC) technology can act as supporting tool to optimize NBS' performance regarding multiple objectives on several scales. The aim of STSM was to apply different RTC optimization strategies to LID solutions from building to the urban-large scale, by using PCWMM [1] and PySWMM [2]. This would allow to find optimal solutions that will favor the spread of the NBS in urban environment, and help mitigate the challenges of urbanization and climate change.

DESCRIPTION OF WORK CARRIED OUT DURING THE STSM

The experimental extensive green roof (GR), located at University of Calabria (Figure 1) was chosen as LID system. Based on the physical features of this GR, a PCSWMM model was developed and calibrated by considering one year (October 2015 – September 2016) hydrological data (rainfall and runoff) collected on the site, while the temperature data were used to calculate evapotranspiration. For the model development, the physical data related to the thickness of each layer and the soil hydraulic properties, evaluated in a previous study [3], were considered. To evaluate the accuracy of the hydrological model, the Nash–Sutcliffe model efficiency coefficient (NSE) was estimated.
Thus, the calibrated GR model was considered to be optimized in RTC by using PySWMM, as a Python wrapper for SWMM5. PySWMM supports a step-by-step simulation of SWMM5 input files and allows the implementation of advanced control strategies for NBS based on current system states.
In the first phase, the RTC optimization was tested at building scale, in order to evaluate different strategies and possibilities for multiple objectives (runoff reduction and drinking water saving). In this regard, the GR's observed data were compared with the results obtained by the RTC optimization. The RTC was applied by considering first the smart optimization of the only GR and then the integrated optimization of the GR and the RainWater Harvesting (RWH) system. The RWH-model was developed based on the features of RWH at the experimental site that supports the water supply to the GR during drought period. For both cases, a python code was developed. The RTC strategies were finalized, by controlling the irrigation, based on the

soil moisture value, and the retention capacity of GR by the opening of the drain valve. When the RWH was considered, the model was updated with this information and the reuse of the rainwater was also considered in the optimization strategy.

Figure 1 (adapted from [3])

Finally, the LID RTC control strategy was applied at urban catchment scale, by considering the subcatchment of Cosenza (Figure 2), a city in the vicinity of the experimental GR, whose SWMM model was calibrated in a previous study [4].

Figure 2

The developed RTC strategy allows to automatically implement different percentages of the GR in the city and classifies them into different control groups, then the python code opens and closes the drain valves based on the current filling level of the sewer system. The control groups differ in the opening time of the GR drain valve, while the penetration parameter, establishes the percentage of GRs implemented at subcatchment. To evaluate the potential performances of this strategy the results in term of total inflow at the final outfall were evaluated by considering different rate of GR penetration in subcatchments.

DESCRIPTION OF THE MAIN RESULTS OBTAINED

Results from the calibration of GR model are shown in Figure 3, where the observed (blue dash-line) and modeled (red line) runoff from the GR is reported, by considering one-year data, with a total precipitation of around 1300 mm and one snow event. Figure 4 shows the same results considering 6 selected events, by demonstrating the accuracy of the model that well fit the observed data, supported by the high NSE values, all greater than 0.84. Thus, this PCSWMM GR model calibrated configuration was considered to find RTC optimization strategy first at building scale and then at urban-large scale.

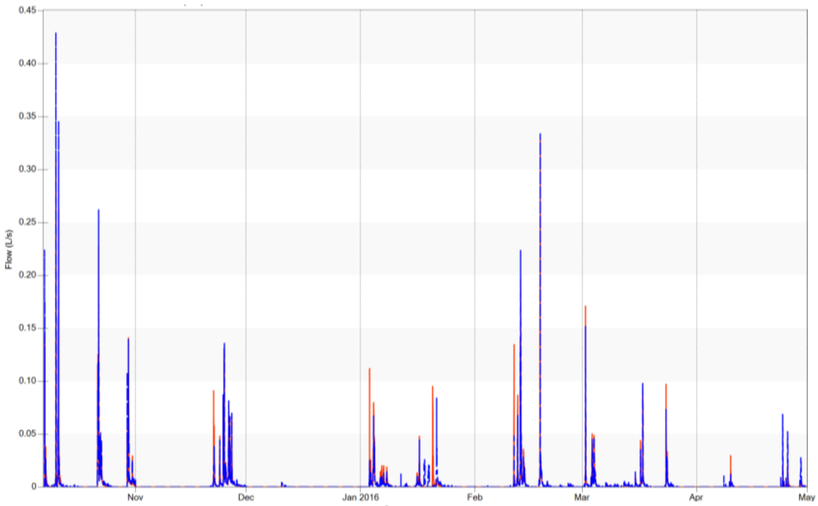

Figure 3

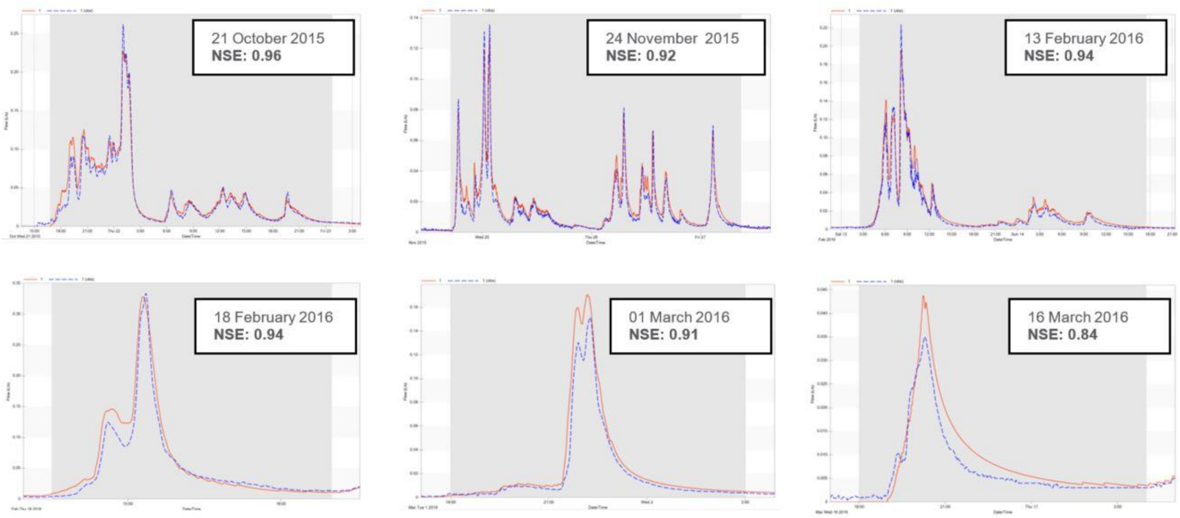

Figure 4

As stated in previous section, the results of the RTC strategy applied to the calibrated GR at building scale was evaluated by considering the smart optimization of the only GR (controlled GR) and the integrated smart optimization of the GR and RWH system (controlled GR+RWH). The python code was run for a period of 5 months (01 May 2016 – 01 October 2016) with a total precipitation of 246.77 mm. The results, in terms of rainwater used, drinking water needed and total outflow are shown in Table 1 .

	Controlled GR	Controlled GR+RWH
Rainwater used (m^3)	0	2.2
Drinking water needed (m^3)	9.9	7.7
Total outflow (mm)	75.5	29.4

Table 1

Thus, considering that the total observed runoff from the experimental GR was of 98.68 mm, it was possible to detect that the implementation of the conventional GR achieved a runoff reduction of around 60% for these 5 months, the same GR optimized in RTC increases its efficiency to 69%, while the smart combination of GR and RWH system can provide a runoff reduction of 88%. By this Table it is possible to observe also a drinking water saving of 22.22% obtained by the optimize introduction of the RWH system.
Similar considerations can be done by the graphs shown in Figure 5 and 6, where the results in terms of observed runoff ("uncontrolled outflow") and "controlled outflow" are reported, as well as the physical processes occurring in the green roof optimized by the RTC for both cases (Figure 5: controlled GR; Figure 6: controlled GR+RWH).

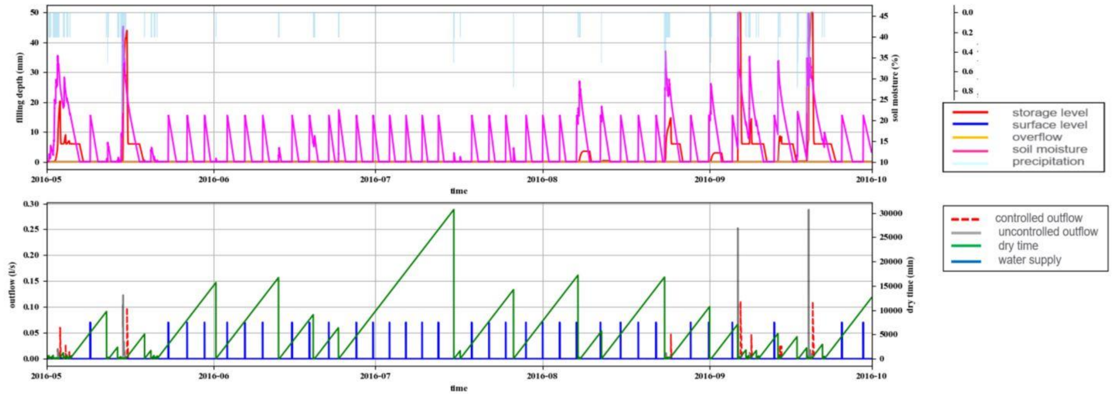

Figure 5

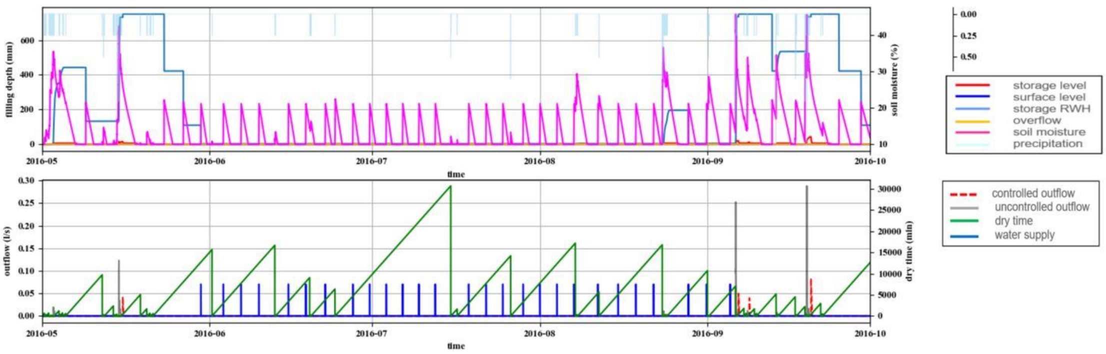

Figure 6

Finally, as stated above, the results obtained by the development of a RTC strategy for the optimal integration of GRs with the conventional urban drainage systems at urban large-scale, were evaluated by comparing: the modeled results of the current situation, i.e. without GRs, (Scenario 0); the “uncontrolled” scenario, which considers different penetration rates of GRs, automatically implemented; and the “controlled” scenario, which considers the RTC applied to the different percentage of GRs based on the filling level in the sewer. In this regard, Figure 7 shows the total inflow into the outfall, by considering the response of the models to the different types of precipitation depth and duration, that affects the results. By observing the findings, it emerges as the optimal control and integration of the GR at subcatchment scale (blue line) provides to achieve a better result in terms of runoff reduction than the situation of conventional GR implementation (orange line).

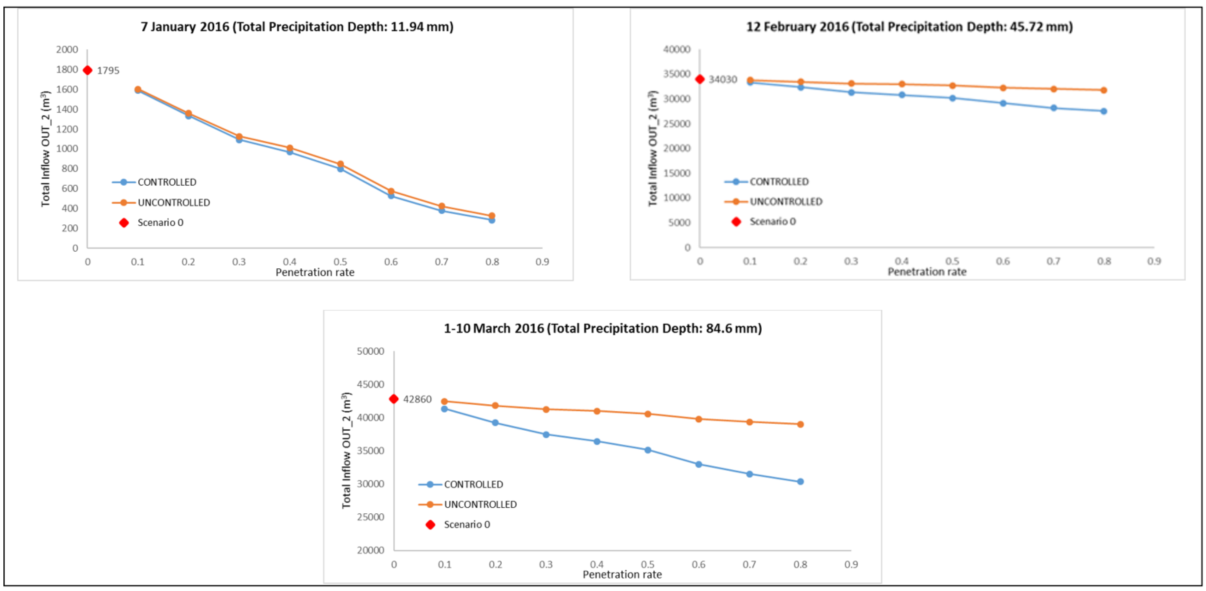

Figure 7

FUTURE COLLABORATIONS (if applicable)

This work represents an advanced way to consider NBS, on example of as green roofs, and can support the spread of these solution at large scale. The period spent at the Department of Infrastructure Engineering at University of Innsbruck (Austria) under the supervision of Prof. Dr. Robert Sitzenfrei and Prof. Dr. Wolfgang Rauch, opened up the possibility of future collaborations in this field. We are already working to expand the work carried out during the STSM in order to finalize it with at least one publication (Palermo S.A., Oberascher, M., Rauch W, Sitzenfrei, R, Piro, P. *Increasing green roofs hydrological efficiency using Real-Time Control strategies*) in an international journal. Moreover, further studies have been started together to evaluate the RTC optimization of the smart campus of University of Innsbruck where other NBS, as rain gardens, and open channels are integral part of the drainage system.

References

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