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A comparison between conceptual and physically based models in predicting the hydrological behavior of green roofs

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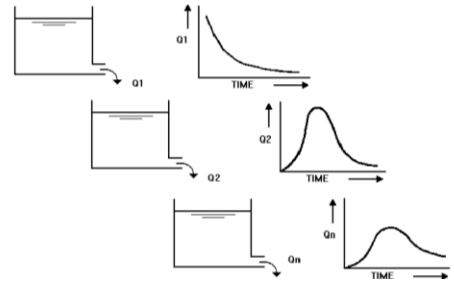
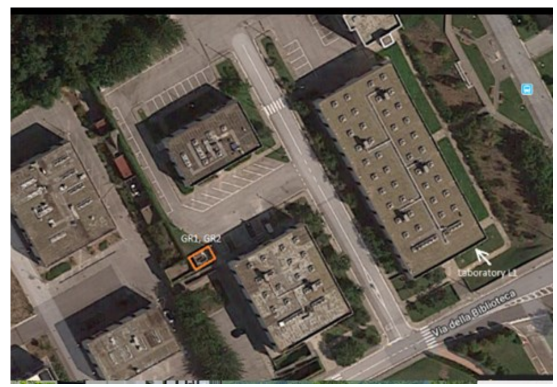
INTRODUCTION

The aim of this paper is to evaluate the accuracy of two different hydrological models (SWMM and Nash models) in simulating the hydrological response of two green roofs plots to storm events.



The two test beds are located in the campus of University of Salerno, in a typical Mediterranean climate and they differ for the composition of the drainage layer.



The models have been calibrated against hourly data of twenty-five rainfall-runoff events observed at the experimental site and compared using three goodness of fit indices. Beside the comparative purpose, a multiple regression analysis has been carried out looking for a relationship between the model errors and the rainfall characteristics.

THE CASE STUDY

The experimental site includes two green roof test beds (GR1, GR2) and a meteorological station.

The green roofs are composed of four layers:

1) The vegetation layer (10 cm)

2) The growing medium layer

3) A Non-woven filter mat

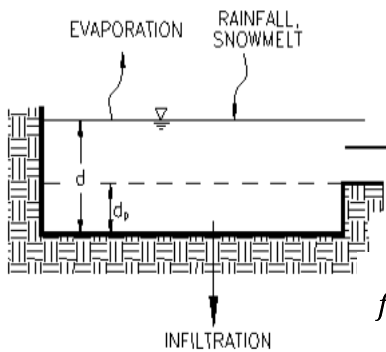
4) The drainage layer (5 cm)

For GR1, the drainage layer is made up of expanded clay, for GR2 of a commercial drainage panel MODì filled with expanded clay

SWMM AND NASH MODELS

The goal of this research is to calibrate and compare the accuracy of two hydrological models in predicting the behavior of the two green roof test beds in terms of runoff production. The selected models are:

- *SWMM*



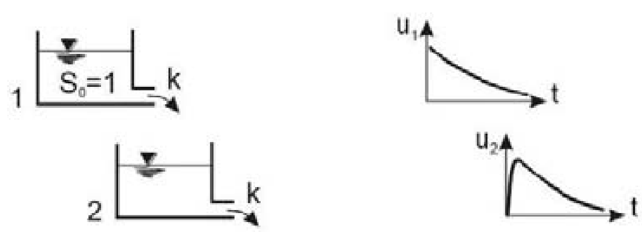
$$Q_s = \left(\frac{S_1}{nA}\right) W D^{\frac{5}{3}}$$

$$f = k_{sat}\left[1 + \frac{(\phi - \theta)\psi}{F}\right]$$

Parameter to be calibrated:
ψ= suction head

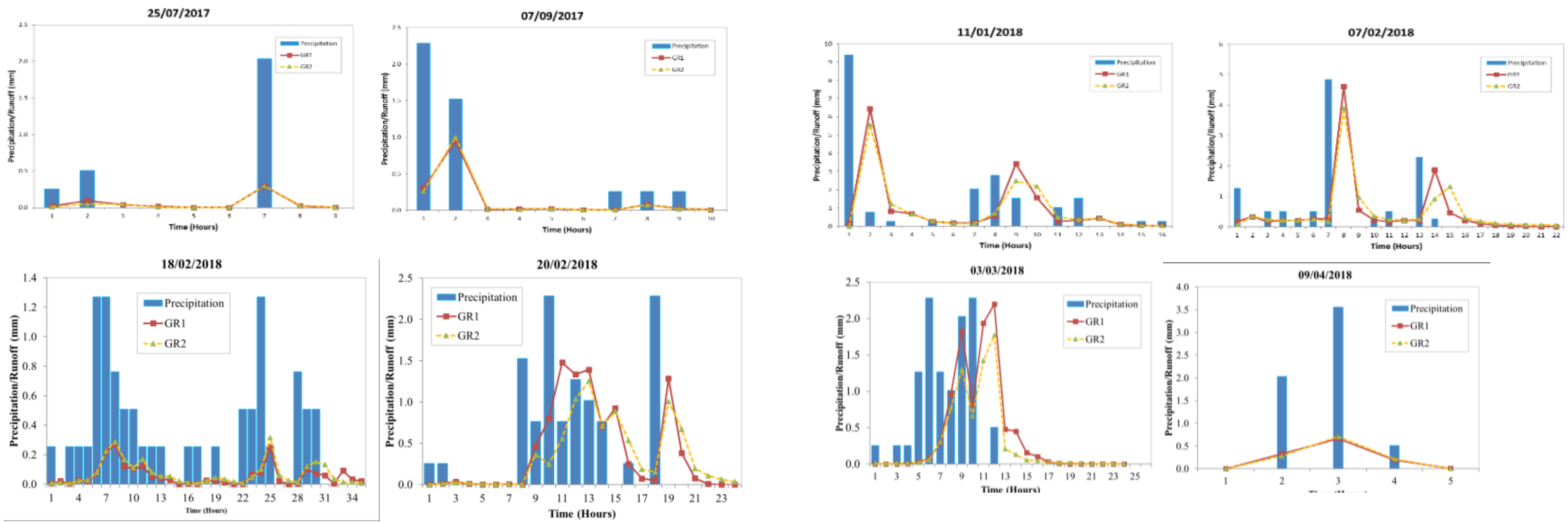
- *THE NASH CASCADE MODEL*

Parameter to be calibrated:
k= outflow coefficient



DATASETS AND MODELS EVALUATION

Twenty-five measured rainfall/runoff events have been considered for the calibration of the models.



The Nash–Sutcliffe efficiency (NSE) index, the root mean square error (RMSE) and the mean absolute error (MAE) have been used to quantitatively assess how well the observed runoff vales have been reproduced by the applied models for each event.

$$NSE = 1 - \frac{\sum_{i=1}^{n}(R_{obs.i} - R_{mod.i})^2}{\sum_{i=1}^{n}(R_{obs.i} - \bar{R}_{obs.i})^2}$$

$$\mathrm{RMSE(mm)} = \left[\frac{1}{\mathrm{n}}\sum_{\mathrm{i}=1}^{\mathrm{n}}(R_{\mathrm{mod.i}} - R_{\mathrm{obs.i}})^2\right]^{\frac{1}{2}}$$

$$MAE\,\mathrm{(mm)} = \frac{1}{\mathrm{n}}\sum_{\mathrm{i}=1}^{\mathrm{n}}|R_{\mathrm{mod.i}} - R_{\mathrm{obs.i}}|$$

RESULTS

-The average values of NSE, higher than 60%, indicates an acceptable level of performances for both models and test benches.

Event	SWMM-GR1			SWMM-GR2			NASH-GR1			NASH-GR2		
	NSE (-)	RMSE (mm)	MAE (mm)	NSE (-)	RMSE (mm)	MAE (mm)	NSE (-)	RMSE (mm)	MAE (mm)	NSE (-)	RMSE (mm)	MAE (mm)
25/07/2017	0.80	0.04	0.03	0.87	0.03	0.02	0.87	0.03	0.02	0.95	0.02	0.01
07/09/2017	0.78	0.13	0.07	0.74	0.15	0.08	0.39	0.22	0.13	0.51	0.21	0.12
....												
05/10/2018	0.22	0.06	0.04	0.35	0.09	0.05	0.86	0.03	0.02	0.87	0.04	0.03
07/11/2018	0.68	1.16	0.85	0.47	1.64	1.17	0.04	1.88	1.21	0.06	1.94	1.05
MEAN	0.64	0.30	0.22	0.61	0.31	0.22	0.72	0.38	0.25	0.67	0.38	0.25

-The errors are slightly lower for SWMM than for Nash cascade model.

Event	SWMM-GR1			SWMM-GR2			NASH-GR1			NASH-GR2		
	NSE (-)	RMSE (mm)	MAE (mm)	NSE (-)	RMSE (mm)	MAE (mm)	NSE (-)	RMSE (mm)	MAE (mm)	NSE (-)	RMSE (mm)	MAE (mm)
25/07/2017	0.80	0.04	0.03	0.87	0.03	0.02	0.87	0.03	0.02	0.95	0.02	0.01
07/09/2017	0.78	0.13	0.07	0.74	0.15	0.08	0.39	0.22	0.13	0.51	0.21	0.12
....												
05/10/2018	0.22	0.06	0.04	0.35	0.09	0.05	0.86	0.03	0.02	0.87	0.04	0.03
07/11/2018	0.68	1.16	0.85	0.47	1.64	1.17	0.04	1.88	1.21	0.06	1.94	1.05
MEAN	0.64	0.30	0.22	0.61	0.31	0.22	0.72	0.38	0.25	0.67	0.38	0.25

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-No substantial differences exist between the hydrological behavior of GR1 and GR2 since the corresponding indices are very similar.

Event	SWMM-GR1			SWMM-GR2			NASH-GR1			NASH-GR2		
	NSE (-)	RMSE (mm)	MAE (mm)	NSE (-)	RMSE (mm)	MAE (mm)	NSE (-)	RMSE (mm)	MAE (mm)	NSE (-)	RMSE (mm)	MAE (mm)
25/07/2017	0.80	0.04	0.03	0.87	0.03	0.02	0.87	0.03	0.02	0.95	0.02	0.01
07/09/2017	0.78	0.13	0.07	0.74	0.15	0.08	0.39	0.22	0.13	0.51	0.21	0.12
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05/10/2018	0.22	0.06	0.04	0.35	0.09	0.05	0.86	0.03	0.02	0.87	0.04	0.03
07/11/2018	0.68	1.16	0.85	0.47	1.64	1.17	0.04	1.88	1.21	0.06	1.94	1.05
MEAN	0.64	0.30	0.22	0.61	0.31	0.22	0.72	0.38	0.25	0.67	0.38	0.25

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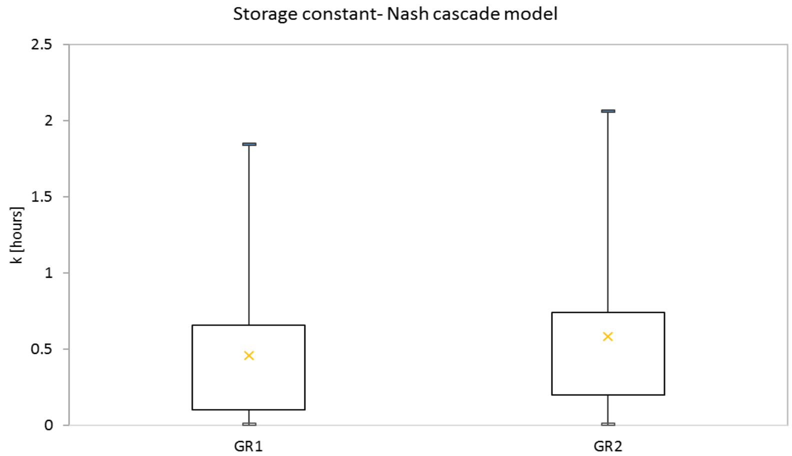
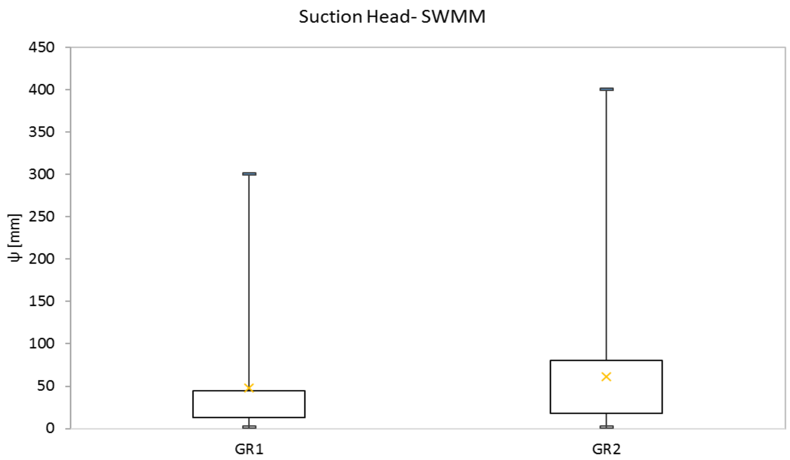
RESULTS

1)





From the calibration process it results that GR2 has a higher suction head and storage coefficient than GR1 probably due to the trays of the plastic panels which compact the expanded clay and delay the water flow.

2)

Dependent variable	Indipendet variable	P-value (SWMM-GR1)	P-value (SWMM-GR2)	P-value (NASH-GR1)	P-value (NASH-GR2)
RMSE	d	9.0E-03	1.6E-01	3.0E-04	1.2E-02
	C	3.5E-05	2.2E-02	4.2E-06	2.0E-03
	I	4.6E-01	5.3E-01	4.3E-02	8.3E-01
MAE	d	4.4E-02	2.0E-01	2.3E-04	1.4E-03
	C	1.6E-03	4.5E-02	3.8E-06	7.2E-05
	I	6.6E-01	4.1E-01	6.7E-02	8.5E-01

A multiple regression analysis revealed a relationship between the errors and the rainfall characteristics. Specifically, the MAE and RMSE increase with increasing cumulative rainfall and duration of the events.

Thanks for your attention

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