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Sustainable strategies for flood risk management in urban areas. Enhancing city resilience with Green Roofs

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Highlights

- Urbanization led to an increase of the built up area and an alteration of the hydrological cycle
- Land use changes increased the flooding risk and the situation will worsen due to the climate change
- SuDS can support traditional drainage systems (sewers) in the management of stormwater runoff
- The retention coefficient of SuDS can be directly connected to the resilience of urban systems

Abstract

Urbanization dynamics that affected Italian cities in the last twenty years, led to significant land use changes. This phenomenon, mainly resulted into a progressive extension of the impervious surface, gave rise to an alteration of the hydrological cycle and an increase in urban flooding phenomena.
In this scenario, Sustainable Drainage Systems (SuDS) and in particular Green Roofs, topic on which experimental research activities were carried out at the University of Salerno, can be considered effective solutions useful to reduce the hydraulic risk and to enhance city resilience.
Analysing land use variations of a small urban catchment in the city of Mercato San Severino (SA) it was observed a soil imperviousness increase of 18% between 1995 and 2016. This phenomenon inevitably led to an overload of the drainage network, actually affected by several criticalities, and to an increase of urban flooding. Therefore, in this context, sustainable drainage strategies able to restore the drainage pattern prior to the soil sealing, influencing stormwater generation, can be considered a valid solution for the management of an ever increasing stormwater runoff.
However, in order to make the implementation of these sustainable infrastructures more effective in the management of urban flooding, a large portion of the current impermeable surface, almost 70% should be retrofitted. The preferable strategy, so, is that of using sustainable drainage systems only as mitigation techniques, aiming not at the total restoration of the conditions prior to construction but at a partial reduction of the sewer load.

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1. Introduction

1.1 *Challenges of the contemporary city*

Italy, due to its geological, morphological and hydrographic characteristics, is naturally prone to the hydro-geological risk. The vulnerability of the Italian territory is often underestimated and administrations usually take the action only after the occurrence of catastrophic events, trying to mitigate landslides and urban flooding impacts implementing hard-engineering infrastructures (i.e. drainage systems, banks, flood retention basins). Therefore, what is lacking is the desire to implement specific strategies for the prevention of such phenomena or, at least, for the improvement of risks management. However, prevention, which is certainly more effective, requires a careful hydrogeological assessment of the catchment areas in which these phenomena occur most frequently.
Urbanization and soil sealing, moreover, contributed to worsen the situation. The increase in built-up area led to an inevitable increase in the impervious surfaces and a consequent alteration of the hydrological cycle (Recanatesi & Petroselli, 2020; Galuppini et al., 2020; Palermo et al., 2020). In particular, as a result of this transformation, significant reductions in the rate of infiltration, evapotranspiration and the contribution destined to the groundwater recharge were detected with a consequent increase in flooding phenomena, heat islands and drought (Luino et al., 2012; Brandolini et al., 2012; Albano et al., 2014; Pistocchi et al., 2015). In this scenario, therefore, the stormwater runoff is an increasingly serious problem for contemporary cities no longer able to dispose of excess flow through the drainage patterns typical of natural systems and, in most cases, equipped only with traditional urban drainage systems, unable to implement sustainable water management. These infrastructures, in fact, although they manage to solve the problem of wastewater disposal, often fail to quickly drain the runoff, generating "sewer floods", being also one of the main cause of widespread freshwater pollution. Moreover, the situation just presented should be carefully investigated also in the perspective of the ongoing climate change that will see, according to the latest Report of the Intergovernmental Panel on Climate Change, major modification to the meteorological phenomena occurring in the Mediterranean climate regions (D'Ambrosio et al., 2020).

In the last few years, finally, something changed. Slowly the awareness that it is not enough to intervene after the phenomena occurred is growing up and the belief to implement preventive strategies to manage the hydrological risk is taking off.

1.2 *Sustainable urban drainage systems: zero-impact solutions able to increase the resilience of urban areas*

It is considered essential, today more than ever, to begin to tackle the problems related to the progressive soil sealing of increasingly large urban agglomerations in a more structured and responsible? (Bertilsson et al., 2019; La Loggia et al., 2012). In this regard, however, there are two different approaches to the problem: the first can be defined "traditional", the second "integrated" (D'Ambrosio et al., 2019). The traditional approach, therefore, essentially involves the possibility of enhancing the system's response capacity through the reconfiguration of elements that are part of the existing traditional network or through the installation of detention tanks. The problem linked to the implementation of a strategy of this type mainly consists in the fact that, although it is able to reduce the load that the traditional drainage network must handle, it is not able to implement a sustainable management of precipitation runoff and to implement land restoration strategies. Therefore, a new, integrated approach to experimentation began, in which sustainable technologies, called green and blue infrastructure, come into play, capable of reducing the flow introduced into the network and bringing numerous benefits to the territory in which they are installed (Larsen et al., 2016; Kabisch et al., 2017). Such solutions, called in different parts of the world with different acronyms and subsequently identified as Sustainable Drainage Systems (SuDS), are able to partially restore the permeable surface and allow the territory to return to the drainage configuration prior to massive edification (Fletcher et al., 2015; Lashford et al., 2019).
Surely these infrastructures, even if capable of retaining, holding and filtering stormwater (Johannessen et al., 2018; Ghofrani et al., 2019; Longobardi et al., 2019; D'Ambrosio et al., 2020), cannot completely manage the problem of runoff on their own. Nevertheless, if used in combination with traditional drainage systems, they are able not only to support the pre-existing network (reducing the inlet flow and reducing the polluting load) but also to contribute to the generation of numerous additional benefits for human beings and the environment. SuDS, although all capable of reproducing the drainage configuration of the natural soils, differ in construction technology and in their different locations in urban contexts (Woods Ballard et al., 2015). Basins of bio-retention and bio-detention, rain gardens, draining trenches, green roofs and permeable parking lots are just some of the types of Sustainable Urban Drainage Systems that are spreading, a little at a time, also in Italy.

Figure 1: Sarno Basin, Hydrogeological Plan (P.S.A.I.), Hydraulic Risk. Watershed and its subdivision into five macro-areas. *Source: Campania Region Basin Authority and author's elaboration.*

1.3 *Objectives of the research*

This study aims to illustrate the performance of a specific sustainable drainage system, the green roof, in Mediterranean Regions in terms of stormwater retention capacity and to investigate if sustainable drainage techniques in general could represent a useful tool to make cities more resilient in particular to hydraulic risk. The resilience, here intended also as "resistance", is the ability of a system to adapt and return to the initial conditions after a phenomenon that generate pressures on it. Starting from the results in terms of retention capacity of experimental analysis carried out on experimental Green Roofs set-up at the University of Salerno (IT), this research focused on the identification of land use changes and hydraulic vulnerability increase in a catchment in the Municipality of Mercato San Severino (Sa, Campania Region, IT). Moreover, the assessment of the Green Roofs retrofitting surface able to restore drainage patterns prior to the urban development was carried out, solving the criticalities related to the stormwater management.

2. Materials

2.1 *The Case Study: an urban catchment in the Municipality of Mercato San Severino (SA)*

In order to quantify the impact of soil sealing on the effectiveness of drainage network, it was decided to analyse the variations in terms of impermeable surface in an urban catchment in the Municipality of Mercato San Severino (SA).
Mercato San Severino's climate is classified as warm and temperate. According to Köppen and Geiger, this climate is classified as Csa. The average temperature is 15.4 °C. The average rainfall is around 868 mm per year.The least amount of rainfall occurs in July (24 mm on average). Most of the precipitation falls in November, averaging 128 mm while the highes temperatures occurs in August (on average 23.4°C). January is the coldest month, with temperatures averaging 8.2 °C. The variation

in the precipitation between the driest and wettest months is 104 mm while throughout the year, temperatures vary by 15.2 °C.
The study area, inclued in the Sarno catchment, experienced over the years a substantial anthropization, which altered its natural conformation increasing flooding risk. Therefore, several floods affected the area during the years (1995-2016) with a substantial increase (+350 %) of this phenomena in the last decades (2005-2016), characterized by invasive urbanization dynamics and soil sealing (Longobardi et al., 2016).
In addition, for a correct evaluation of the Hydraulic Risk in the study area, from the Hydrogeological Plan (P.S.A.I.) of the Campania Region Basin Authority, maps with specific reference to the hydraulic risk were downloaded and analysed. The cartography shows that the territory in which the case study is located, is mainly characterized by a moderate and medium risk with numerous areas potentially prone to high risk.
In Figure 1 the identification of the watershed and its subdivision in 5 areas (A1, A2, A3, A4, A5) is represented.

2.2 Green Roofs retention capacity: the experimental site of the University of Salerno

The retention capacity of green roofs depends on many factors but, in the Mediterranean regions, characterized by wet winters and long period of drought during the summer, the moisture content of the substrate is considered one of the key elements (Chenot et al., 2017). Starting from the assessment of the hydrological performance of two experimental green roofs (Figure 2) installed in 2017 at the Department of Civil Engineering of the University of Salerno (SA, IT) (Mobilia & Longobardi, 2017; Mobilia & Longobardi, 2019), a

Figure 2: Green Roofs experimental plant at the University of Salerno. *Source: author's photo 2019.*

previous study (Longobardi et al., 2019) focused on the assessment of their retention capacity, a factor generally correlated with city resilience.
Specifically, analyses investigated the experimental relationship between retention capacity (RC) and soil moisture content within the substrate layer prior to the rainfall event occurrence, VW %, of 35 rainfall-runoff event collected for the two Green Roof (GR1 and GR2), different for the drainage layer, of the experimental site of the University of Salerno (Longobardi et al., 2019; Mobilia et al., 2019). The retention capacity was calculated for each of the events as follow:

$$RC = 1 - C^* \quad (1)$$

where C*= Runoff Volume/ Rainfall Volume.
Contrary to what was conceptually expected, but quite common in the literature, RC displayed a broad variability. A detailed investigation of the scatter plot between RC and VW revealed more reasonable and interesting results, showing a tendency of the events to distribute themselves according to three distinct groups (Figure 3). The first group of events, identified with the letter A, consists of all those events characterized by a cumulative total of rainfall of less than 11.2 mm. These events, defined by a retention always greater than 75% and by a low initial content of soil moisture (range 7-21%), can be considered events not so important from the hydrological point of view due to their value of rainfall depth and intensity. Here, the hydrological behaviour of the green roof seems not to be influenced by the initial soil water content. The second group of events, group B, consists of events characterized by a particularly low moisture content, less than 4%, and a retention capacity never less than 50% and which in some cases isolated reaches the 100%. The high variability of the retention coefficient, in this case led us to believe that there was a significant relation between the element of this group and the characteristic of the rainfall events such as the duration, the cumulative rainfall and the five-minute peak intensity (Figure 4). In particular, the latter, fundamental in the methodology of assessment of Green Roof retrofitting percentages presented in this research, was identified plotting the retention capacity of the 35 rainfall-runoff events against the maximum value of five-minutes intensity of each analysed event. A linear relation was found between retention properties and peak five-minute intensity. The third group of events, group C, represents the set of events characterized by the lower retention performances associated to the larger soil water content prior to the triggering rainfall event. As in the case of group B, a high variability is highlighted for the values of the retention coefficient (never higher than 50%), which does not appear strongly dependent on initial substrate soil moisture content but can be actually explained, also in this case, according to the characteristics of the rainfall events.

3. Methodology

3.1 SAR images elaboration for the detection of variation in build-up area

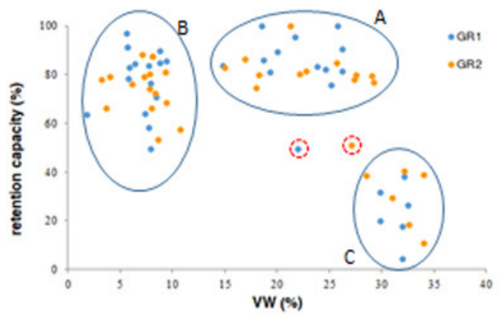

Figure 3: Retention Capacity as a function of soil moisture content. *Source: Longobardi et al., 2019.*

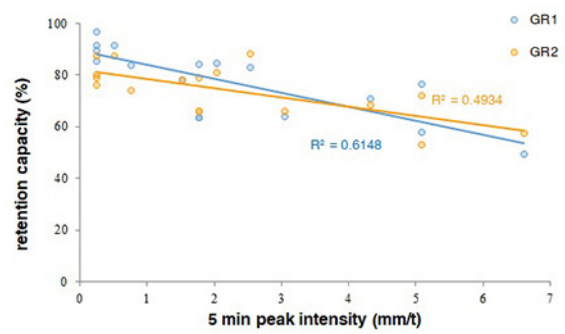

Figure 4: Retention Capacity as a function of 5-minute peak intensity. *Source: Longobardi et al., 2019.*

The land use change in the study area between 1995 and 2016 was investigated by means of elaboration of SAR images (Mobilia et al., 2018). The proposed processing chain (Figure 5) includes three major blocks: the data download, the pre-processing phase and the feature extraction. The first step consists in the acquisition of SAR images relating to the years 1995 and 2016 and respectively provided by ERS and Cosmo-SkyMed missions. The pre-processing chain aims at the data coregistration and at the coherence estimation. The coregistration is a key procedure to be carried out before the analysis can start and it is a process where two SAR images are matched at up to one- or two-pixel accuracy. In the next step, the coherence (γ) of the images is extracted, it represents the spatial correlation of the interferometric phases of two SAR images (v1 and v2) given as:

$$\gamma = \frac{E[v_1 v_2^*]}{\sqrt{E[v_1]^2 E[v_2]^2}} \qquad (2)$$

where E[.] means the expected value and the * the complex conjugate. It moves from 0 to 1 where 0 refers to the natural land cover and 1 to the built-up area.
The feature extraction block includes: the execution of the temporal average of the multitemporal SAR images in order to reduce the speckle; the coherence threshold assessment using Otsu's algorithm for the conversion of grey level image to monochrome (or binary) image where the white pixels represent the impervious surfaces while the black one the pervious ones; and the threshold application which allows to subsequently quantify the paved and non/paved surfaces using the QGIS software.
For each sub-catchment of the municipality, the white and black pixels have been identified in the threshold images and the corresponding area has been calculated according to the following equations:

$$A_{imp} = (N_{pixel\ white} * A_{tot}) / N_{pixel\ tot} \qquad (3)$$

$$A_{perv} = (N_{pixel\ black} * A_{tot}) / N_{pixel\ tot} \qquad (4)$$

where:
$N_{pixel\ white}$ = number of white pixels;
$N_{pixel\ black}$ = number of black pixels;
$N_{pixel\ tot}$ = number of total pixels;
A_{perv} = pervious area;
A_{imp} = impervious area;
A_{tot} = total area.

3.2 *Estimation of basins characteristics in 1995 and 2016*

In order to investigate the effect of land use change between 1995 and 2016 on stormwater generation, a series of fundamental parameters have been calculated and compared for each year and for each sub-basin. The selected parameter are: critical duration (d) runoff coefficient (C*), average rainfall intensity for critical duration (i_md), average flow rate (Q_m) and peak flow rate (Q_T).

$$d = 1.40 \cdot L^{0.24} \cdot P_i^{-0.24} \cdot P_m^{-0.16} \qquad (5)$$

$$C^* = 0.8 \cdot \frac{A_{imp}}{A_{tot}} + 0.1 \cdot \frac{A_{per}}{A_{tot}} \qquad (6)$$

$$i_m(d) = \frac{i_0}{\left[1 + {}^{d}/_{d_c}\right]^{C-DZ}} \qquad (7)$$

$$Q_m = C^* \cdot A_{tot} \cdot i_m(d) \qquad (8)$$

$$Q_T = K_T \cdot Q_m \qquad (9)$$

Where L is the is length of pipe, Pi is the ratio between the imperviousness area of the basin (A_{imp}) and the total area (A_{tot}), P_m is the slope of the pipe, A_{per} is the pervious area of the basin, i_0, dc, C, D are constant values given by the regional law in four parameters of VAPI Campania report (Rossi & Villani, 1994) and tabulated according to homogeneous areas, z is the altitude of the basins, K_T is the probabilistic factor of growth expressed as:

$$K_T = -0.0373 + 0.517 \cdot \ln(T) \qquad (10)$$

where T is the return period set at 10 years.

3.3 *Green roof retrofitting scenario*

In order to return to the pre-development condition, a widespread implementation of green roofs has been hypothesized within the studied catchment. The quantitative estimation of potential area for green retrofit (A_{GR}) has been made by equaling the runoff coefficient relating to the year 1995 (C^*_{1995}) which corresponds to the pre-development scenario, to the runoff coefficient which refers to a GR conversion scenario (12) (C^*_{GR}):

Table 1: Pervious and Impervious area variation in each sub-area of the analysed basin between 1995 and 2016.

Surface	Type	Proportion pixel-area (1995) Number pixels	Total Area (m²)	Area (m²)	Proportion pixel-area (2016) Number pixels	Total Area (m²)	Area (m²)
A1	pervious	448	246288,23	244108,69	389	246288,23	211960,45
	impervious	4		2179,54	63		34327,78
A2	pervious	149	101065,52	96530,53	123	101065,52	79686,28
	impervious	7		4534,99	33		21379,24
A3	pervious	1029	608945,02	602504,26	896	608945,02	524629,56
	impervious	11		6440,76	144		84315,46
A4	pervious	1562	944519,04	937914,01	1403	944519,04	842441,33
	impervious	11		6605,03	170		102077,71
A5	pervious	1974	1140431,12	1128992,49	1796	1140431,12	1027188,71
	impervious	20		11438,63	198		113242,41

Data source: authors 2019

$$C^*_{1995} = 0.8 \cdot \frac{A_{imp}}{A_{tot}} + 0.1 \cdot \frac{A_{per}}{A_{tot}} \qquad (11)$$

$$C^*_{GR} = 0.8 \cdot \frac{A_{imp}}{A_{tot}} + 0.1 \cdot \frac{A_{per}}{A_{tot}} + c_{GR} \frac{A_{GR}}{A_{tot}} \qquad (12)$$

Where c_{GR} can be deducted from the RC curves of Figure 4, once know the rainfall intensity of each sub-basin from equation (7). The runoff coefficient c_{GR} can be expressed as:

$$c_{GR} = 1 - RC \qquad (13)$$

Figure 5: Elaboration of SAR images processing chain. *Source: Mobilia et al., 2018.*

4. Results

Table 1 summarizes the assessment of permeable and impermeable surfaces (expressed in m²) referred to the year 1995 and 2016. The results of this first analysis made it possible to understand that the impervious surface of 1.17% of the year 1995 changed into 19.17% in the year 2016. From the difference between the percentages of impervious areas recorded in the two years, a variation of the impervious fraction of 18% was obtained for the case study area.
From the observation of the plots shown in Figure 6, we notice that over time, together with a clear and predictable increase in the impermeable surface, the values of the parameters listed above also

Table 2: Percentage of impervious area concerned by retrofitting intervention.

Sezione	Area	Q_{1995}	Q_{2016}	H [m]	B [m]	h/H_{1995}	h/H_{2016}	h*	Q*	%conv
C	A1	1.14	1.73	0.7	0.8	0.84	1.00	0.63	1.25	83
C	A2	0.62	0.91	0.6	0.6	0.78	1.00	0.54	0.75	45
D	A3	2.67	4.15	1	1.2	0.71	1.00	0.90	3.21	66
E	A4	3.76	5.73	1.2	1.2	0.77	1.00	1.08	4.22	80
F	A5	4.67	6.72	1.3	1.3	0.78	1.00	1.17	5.15	76

Data source: authors 2019

increased. The critical duration is an exception as an increase in impervious areas is usually associated to an enhancement of flash flood phenomena and a lowering of this variable. The parameters which appeared to be affected at a larger extent by the land use changes are the critical duration and the runoff coefficient. These variables, both dependant on the imperviousness of the soil, recorded an average percentage of variation of 32% and 42% respectively, which than translated into a flow rate increase of about 50%. Overall, land use changes led to an overload of the drainage network, actually affected by several criticalities in many sections of the drainage network, and to an increase of urban flooding phenomena.
The previously analysed parameters are inextricably linked to the percentage of imperviousness of the basin. Therefore, the only chance to restore the initial conditions of the territory is to implement retrofitting actions of the urbanized areas through typical urban greening strategies that directly affect the flood coefficient C and, indirectly, the flow rate Q that the drainage network must handle.
However, as we can see from Table 2, in order to make the implementation of these sustainable infrastructures more effective in the management of urban flooding, a too large portion of the current impermeable surface should be retrofitted, almost 70%. The preferable strategy, so, is that of using sustainable drainage systems only as mitigation techniques, aiming not at the total restoration of the conditions prior to construction but at a partial reduction of the load introduced into sewer.

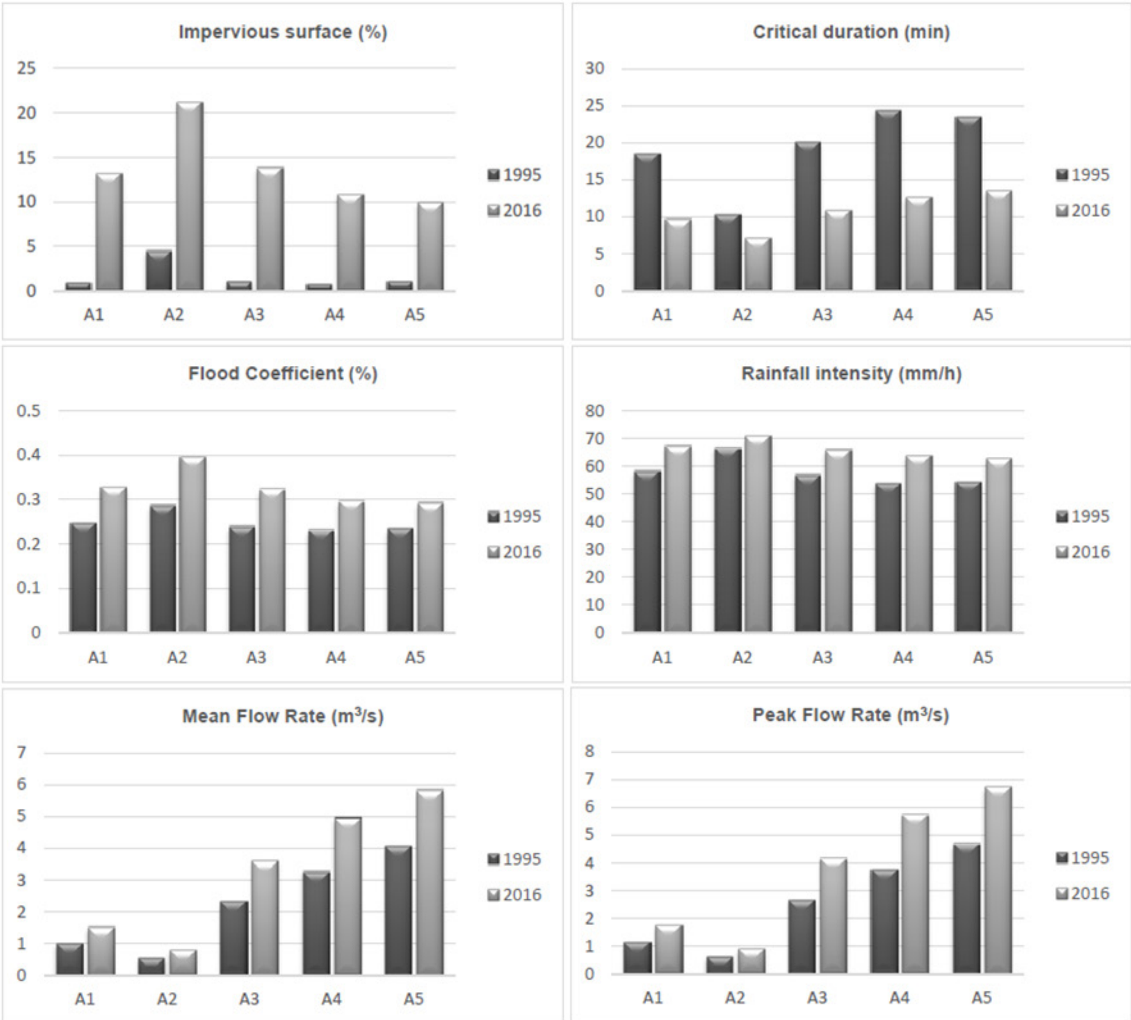

Figure 6: Plots representing the variation of impervious area fraction, critical duration, flood coefficient, rainfall intensity, average flow and maximum flow between the year 1995 and 2016 for each subcatchment. *Source: authors, 2019.*

5. Discussion and conclusions

The research illustrated that urbanization and soil sealing undoubtedly altered the natural hydrogeological cycles in the study catchment, enhancing the hydrological and hydraulic criticalities and increasing urban flooding phenomena.
The experimental studies showed that SuDS, specifically Green Roofs, could represent a useful tool to make cities more resilient against hydraulic risk due to their stormwater retention and detention capacity. However, the retention capacity, meant to be directly correlated to the aptitude of urban systems to be more resilient, is manly affected by both design and climatic variables. The performance of SuDS, in fact, seemed to be influenced by both soil moisture content prior to the rainfall event and severity of precipitations.
In addition, it is clear that in order to make the implementation of these sustainable infrastructures more effective in the management of urban flooding and in the improvement of city resilience, a too large portion of the current impermeable surface should be retrofitted. For these reasons, probably, a combined approach in which the traditional urban systems of flood management are associated with a more widespread use of SuDS can represent the optimal solution, thus including the multiple benefits (not only hydrological) that these green infrastructures succeed to implement in particular with regard to ecosystem services. A further consideration to be made in the design of risk mitigation interventions is that related to the climate change.
The latter ought absolutely to be taken into account, due to the effect that they are able to carry out not only on the SuDS performance but also on traditional urban drainage systems.

References

Albano, R., Sole, A., Sdao, F., Giosa, L., Cantisani, A., & Pascale, S. (2014). A Systemic Approach to Evaluate the Flood Vunerability for an Urban Study Case in Southern Italy. *Journal of Water Resources and Protection*, *6(4)*, 351-362. doi: 10.4236/jwarp.2014.64037

Bertilsson, L., Wiklund, K., de Moura Tebaldi, I., Moura Rezende, O., Pires Veról, A., Gomes Miguez, M. (2019). Urban flood resilience – A multi-criteria index to integrate flood resilience into urban planning. *Journal of Hydrology, 573*, 970-982. doi: 10.1016/j.jhydrol.2018.06.052

Brandolini, P., Cevasco, A., Firpo, M., Robbiano, A., & Sacchini, A. (2012). Geo-hydrological risk management for civil protection purposes in the urban area of Genoa (Liguria, NW Italy). *Natural Hazards and earth System Sciences*, *12*, 943-959. doi: 10.5194/nhess-12-943-2012

Chenot, J., Gaget, E., Moinardeau, C., Jaunatre, R., Buisson, E., & Dutoit, T. (2017). Substrate Composition and Depth Affect Soil Moisture Behaviour and Plant-Soil Relationship on Mediterranean Extensive Green Roofs. *Water, 9*(11), 817. doi: 10.3390/w9110817

D'Ambrosio, R, Rizzo, A., Balbo, A., Longobardi, A. (2019). Assessing the Performance of SuDS in the Mitigation of Urban Flooding: The Industrial Area of Sesto Ulteriano (MI). *Proceedings, 48* (1). doi: 10.3390/ECWS-4-06449

D'Ambrosio, R., Longobardi, A., Schmalz, B., Romano, B. (2020). Sustainable Drainage Systems as an adaptation strategy to climate change consequences: a case study in Northern Italy. In Water resources and climate adaptation and mitigation, EO for Water Cycle Sciences 2020, International Conference, November 16-19, 2020.

Fletcher, T. D., Shuster, W., Hunt, W. F., Ashley, R., Butler, D., Arthur, S., Trowsdale, S., Barraud, S., Semadeni-Davies, A., Bertrand-Krajewski, J. L., Steen Mikkelsen, P., Rivard, G., Uhl, M., Dagenais, D., Viklander, M. (2015). SUDS, LID, BMPs, WSUD and more – The evolution and application of terminology surrounding urban drainage. *Urban Water Journal, 12(7)*, 525-542. doi: 10.1080/1573062X.2014.916314

Galuppini, G., Quintilliani, C., Arosio, M., Barbero, G., Ghilardi, P., Manenti, S, Petaccia, G., Todeschini, S., Ciaponi, C., Martina, M.L.V., Creaco, E. (2020). A unified framework for the assessment of multiple source urban flash flood hazard: the case study of Monza, Italy, *Urban Water Journal, 17(1)*, pp. 65-77. doi: 10.1080/1573062X.2020.1734950

Ghofrani, Z., Sposito, V., & Faggian, R. (2019). Modelling the impacts of blue-green infrastructure on rainfall runoff: a case study of Eastern Victoria, Australia. *International Journal of Water, 13(2)*, 151. doi: 10.1504/IJW.2019.10020979

Johannessen, B. G., Muthanna, T. M., & Braskerud, B. C. (2018). Detention and Retention Behaviour of Four Extensive Green Roofs in Three Nordic Climate Zones. *Water, 10(6)*, 671. doi: 10.3390/w10060671

La Loggia, G., Fontanazza, C.M., Freni, G., Notaro, V., Olivieri, E., Puleo, V. (2012). Urban drainage and sustainable cities: how to achieve flood resilient societies? *Urban Water, 122*, 203-2014. doi: 10.2495UW120181

Lashford, C., Rubinato, M., Cai, Y., Hou, J., Abolfathi, S., Coupe, S., Charlesworth, S., Tait, S. (2019). SuDS & Sponge Cities: A Comparative Analysis of the Implementation of Pluvial Flood Management in the UK and China. *Sustainability, 11(1)*, 213. doi: 10.3390/su11010213

Longobardi, A., Diodato, N., Mobilia, M., 2016. Historical storminess and hydro-geological hazard temporal evolution in the solofrana river basin—Southern Italy. *Water, 8(9)*, 398.

Longobardi, A., D'Ambrosio, R., Mobilia, M., (2019). Predicting Stormwater Retention Capacity of Green Roofs: An Experimental Study of the Roles of Climate, Substrate Soil Moisture, and Drainage Layer Properties. *Sustainability, 11(24)*, 6956. doi: 10.3390/su11246956

Luino, F., Turconi, L., Petrea, C., Nigrelli, G. (2012). Uncorrected land-use planning highlighted by flooding: the Alba case study (Piedmont, Italy). *Natural Hazards and Earth System Sciences, 12*, 2329-2346. doi: 10.5194/nhess-12-2329-2012

Mobilia, M., D'Ambrosio, R., Longobardi, A., (2020). Climate, Soil Moisture and Drainage Layer Properties Impact on Green Roofs in a Mediterranean Environment. In: Naddeo V., Balakrishnan M., Choo KH. (eds) Frontiers in Water-Energy-Nexus—Nature-Based Solutions, Advanced Technologies and Best Practices for Environmental Sustainability. Advances in Science, Technology & Innovation (IEREK Interdisciplinary Series for Sustainable Development). Springer, Cham. doi: 10.1007/978-3-030-13068-8_41

Mobilia, M., & Longobardi, A. (2019). Event scale modelling of experimental green roofs runoff in a Mediterranean environment. In: Naddeo V., Balakrishnan M., Choo KH. (eds) Frontiers in Water-Energy-Nexus—Nature-Based Solutions, Advanced Technologies and Best Practices for Environmental Sustainability. Advances in Science, Technology & Innovation (IEREK Interdisciplinary Series for Sustainable Development). Springer, Cham. doi: 10.1007/978-3-030-13068-8_37

Mobilia M., Longobardi A. (2017). Smart Stormwater Management in Urban Areas by Roofs Greening. In: Gervasi O. et al. (eds) Computational Science and Its Applications – ICCSA 2017. ICCSA 2017. Lecture Notes in Computer Science, 10406, 455-463. Springer, Cham. doi: 10.1007/978-3-319-62398-6_32

Mobilia, M., Longobardi, A., & Sartor, J. (2015). Green Roofs Hydrological Performance under Different Climate Conditions. *WSEAS Trans. Environ. Dev., 11*, 264–271.

Mobilia, M., Longobardi, A., Amitrano, D., Ruello, G., 2018. Analisi dei cambiamenti climatici e di uso del suolo in un bacino peri-urbano prono al rischio idrogeologico. In XXXVI Convegno di Idraulica e Costruzioni Idrauliche - ISBN:9788894379907 vol. 106

Nawaz, R., McDonald, A., & Postoyko, S. (2015). Hydrological performance of a full-scale extensive green roof located in a temperate climate. *Ecological Engineering, 82*, 66-80. doi: 10.1016/j.ecoleng.2014.11.061

Palermo, S.A., Talarico, V.C., Turco, M. (2019). On the LID systems effectiveness for urban stormwater management: case study in Southern Italy. *IOP Conference Series: Earth and Environmental Science, 410*. Sustainability in the built environment for climate change mitigation: SBE19 Thessaloniki 23–25 October 2019, Thessaloniki, Greece. doi: 10.1088/1755-1315/410/1/012012

Pappalardo, V., La Rosa, D., Campisano, A., La Greca, P. (2017). The potential of green infrastructure application in urban runoff control for land use planning: A preliminary evaluation from a southern Italy case study. *Ecosystem Services, 26*, 345-354. doi: 10.1016/j.ecoser.2017.04.015

Pistocchi, A., Calzolari, C., Malucelli, F., & Ungaro, F., 2015. Soil sealing and flood risks in the plains of Emilia-Romagna, Italy. *Journal of Hydrology: Regional Studies 4(B)*, 398-409. doi: 10.1016/j.ejrh.2015.06.021

Recanatesi, F., Petroselli, A. (2020). Land Cover Change and Flood Risk in a Peri-Urban Environment of the Metropolitan Area of Rome (Italy). *Water Resources Management, 34(5)*. doi: 10.1007/s11269-020-02567-8

Rossi F., Villani P. (1994) A project for regional analysis of floods in Italy. In: Rossi G., Harmancioğlu N., Yevjevich V. (eds) *Coping with Floods*. NATO ASI Series (Series E: Applied Sciences), vol 257. Springer, Dordrecht. doi: 10.1007/978-94-011-1098-3_11

Samouei, S., Ozger, M. (2020). Evaluating the performance of low impact development practices in urban runoff mitigation through distributed and combined implementation. *Journal of Hydroinformatics, 22 (6)*, 1506–1520. doi: 10.2166/hydro.2020.054

Sims, A. W., Robinson, C. E., Smart, C. C., Voogt, J. A., Hay, G. J., Lundholme, J. T., Powers, B., O' Carroll, M. (2016). Retention performance of green roofs in three different climate regions. *Journal of Hydrology, 542*, 115-124. doi:10.1016/j.jhydrol.2016.08.055

Soulis , K. X., Ntoulas, N., Nektarios, P. A., & Kargas, G. (2017). Runoff reduction from extensive green roofs having different substrate depth and plant cover. *Ecological Engineering, 102*, 80-89. doi: 10.1016/j.ecoleng.2017.01.031

Stovin, V., Vesuviano, G., & De Ville, S. (2015). Defining green roof detention performance. *Urban Water Journal, 14(6)*, 574-588. doi: 10.1080/1573062X.2015.1049279

Szota, C., Farrel, C., Williams, N., Arndt, S. K., & Fletcher, T. D. (2017). Drought-avoiding plants with low water use can achieve high rainfall retention without jeopardising survival on green roofs. *Science of The Total* Environment*, 6*. doi: 10.1016/j.scitotenv.2017.06.061

Woods Ballard, B., Wilson, S., Udale-Clarke, H., Illman, S., Scott, T., Ashley, R., Kellagher, R. (2015). The SuDS Manual. CIRIA.