Municipal climate adaptation plans: an assessment of the benefit of Nature-Based Solutions for urban local flooding mitigation

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Abstract: The proposed framework aims to evaluate the effectiveness of the NBS small-scale interventions on five densely urbanized sub-catchments located in the urban area of the Municipality of Potenza. Starting from the definition of the hydrological response of each basins the SCS curve number method was applied in different CN scenarios modeled through geospatial analysis. The results allowed to quantify the reduction in peak flood that reaches the ponding area due mainly to the part of precipitation retained temporarily at the ground surface as interception brought by more permeable soils in urban context.

Keywords: urban flooding; nature-based solution; suds; secap; spatial planning

1. Introduction

The intensive exploitation of the land as a result of an uncontrolled urbanization has always affected the relationship between cities and climate negatively [1]. This is due mainly to the urban and territorial policies that over the past decades have been unable to recognize the centrality of the local context planning in the fight against climate change and global warming. Urban settlements are inherently characterized by large impervious surfaces. Infrastructure, buildings, commercial and industrial sites have a relevant and negative impact on the natural water cycle. Less and less permeable surfaces, available for the infiltration, as well as tree canopies, available for the evapotranspiration, determine an increase in run-off which the drainage network cannot effectively convey even for frequent, low intensity rainfall. A traditional approach to the urban drainage consists into gathering all the pluvial outflows from the impermeable surfaces within the sewage system which, in case of extreme events, should directly drain into the nearby streams in order to prevent any local flooding and conveying the precipitation as far as possible from the drop point. Therefore, a paradigm shift in urban water management planning is needed, promoting Nature-Based Solution (NBS) instead of invasive gray infrastructure, in order to reduce the vulnerability and increase the capacity of the cities to cope with the direct and indirect effects of urban local flooding [2].

2. Area of study

The study was conducted over 5 of the 12 urban sub-catchments within the settlement area of the municipality of Potenza, in Southern Italy. A recent paper highlighted that these 5 basins require priority measures for stormwater management because they show a high percentage of soil sealing [3]. Geographically, the region is between 40°38' 54.10" and 40°38' 10.33" Nord and 15°48' 54.94" and 15°49' 05.32" Est and the whole area has a homogeneous lithological feature with moderately silty clay subsoil characterized

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by medium-low permeability [4]. Furthermore, the particular geomorphological conformation of the territory, mainly due to the steepness of the slopes, emphasizes the hydrological issues, in fact 66% of municipality belongs in the 600-900 m altimetric zone [5].

3. Methodology

To assess the hydrological hazard over the whole examined area, a preliminary geomorphometric analysis was carried out with the support of geospatial algorithms in GIS environment [6]. Following the definition of the hydrological response of each sub-catchment, through the VA.PI. method, performed with a probabilistic model based on the use of a Two Component Extreme Value (TCEV) distribution, the intensity-duration-frequency (IDF) curves of precipitation were defined in accordance with statistics from the Potenza rain gauge station [7]. The definition of the IDF curves allowed to model the peak flow rates at different return period according to the Soil Conservation Service-Curve Number (SCS-CN) approach [8]. This methodology assumes that the CN parameter is strictly related to soils infiltration capacity compared to land use and moisture condition antecedent the rainfall event. Therefore, in order to have the most accurate data for a better discretization of the diversity in spatial distribution of the city, a reclassification of the CN values was performed according to the 2013 Technical Regional Cartography (TRC) land use data[9]. Based on the objectives of this research and the available information and according to the Corine Land Cover (CLC) 3-level hierarchical classification system, urban tessellation has been reclassified.

Subsequently, a retrofit scenario analysis at urban pattern level was carried out to evaluate how the NBS for stormwater management can effectively contribute in decreasing of the CN value and consequently in reducing the flood peak in the ponding area. In a preliminary step, Scenario 1, priority was given to Sustainable Urban Drainage System (SUDS) in proximity of schools, gathering places and most used parking lots [10]. This choice was brought forward to develop interest and focus on reducing vulnerability, improving the resilience of a given local system, and improve interest in a bottom-up approach [11][12]. Instead, Scenario 2 is a useful extreme case to emphasize and provide additional knowledge to decision makers and local authorities on the effectiveness of SUDS in mitigating the effects of climate change in densely urbanized catchments [13].

Figure 1. In this figures are represented the reclassification of the urban pattern derived from TRC data in line with the 3-level hierarchical CLC classification system: (a) Status quo map with high grade of waterproof surfaces; (b) Scenario 1 in which the most suitable areas for NBS for each location have been identified and transformed as urban green type.

4. Results

This methodology allowed to quantify the reduction in peak flood due mainly to the increase in surface storage and interception brought by SUDS. The results of the study are summarized in the following table, Table 1, where for each sub-catchments, peak flows at the outlet points are shown in both the status quo and the two scenarios previously described.

Table 1. Peak discharge for every sub-catchment at different land configuration and return time scenario.

Basin code	Return period [yr]	Status quo		Scenario 1		Scenario 2	
		CN	[m ³ /s]	CN	[m ³ /s]	CN	[m ³ /s]
1	5	87.6	1.93	85.0	1.53	81.6	1.07
	30		4.02		3.49		2.83
2	5	89.6	0.98	87.2	0.82	82.6	0.56
	30		1.87		1.67		1.32
3	5	90.6	1.85	87.1	1.38	81.1	0.76
	30		3.53		2.95		2.04
10	5	85.3	2.17	81.3	1.43	79.3	1.11
	30		5.03		3.83		3.34
12	5	86.6	1.56	83.8	1.18	79.0	0.63
	30		3.43		2.89		2.08

Moreover, by comparing hydrographs, the lag time, the distance from peak rainfall to peak discharge, is greater in the Scenario 2, where all the suitable areas have become permeable, than in the existing one, Figure 2. The hydrographs also show a flatter discharge curve at peak time that is more evident for small return period. This means a less outflow that reaches the ponding area and thus a reduction of hazard at the outlet point.

Figure 2. Computed hydrographs for 1 hour storm duration for the different CN scenarios in sub-catchment number 10. (a) Hydrograph at 5 years return period; (b) Hydrograph at 30 years return period.

5. Conclusion

The proposed framework applied to the study area is a necessary basis knowledge to decision makers for the definition of the municipal climate adaptation plan. This work can be seen as an informative basis in the land-use planning process particularly related to the most appropriate NBS location in the urban context for a sustainable stormwater management. The strategy in land retrofit offered by the NBS is in line with the 2030 Agenda for Sustainable Development of the United Nations and furthermore could promote the ecological transition toward a new economic and social development model on local scale.

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