

Water Management and Municipal Climate Adaptation Plans: A Preliminary Assessment for Flood Risks Management at Urban Scale

Simone Corrado[1], Benedetta Giannini[1], Luigi Santopietro[1(✉)], Giuseppe Oliveto[2], and Francesco Scorza[1]

[1] Laboratory of Urban and Regional Systems Engineering (LISUT), School of Engineering, University of Basilicata, Potenza, Italy
{simone.corrado, francescabenedetta.giannini, luigi.santopietro}@studenti.unibas.it, francesco.scorza@unibas.it

[2] Laboratory of Hydraulic Engineering, School of Engineering, University of Basilicata, Potenza, Italy
giuseppe.oliveto@unibas.it

Abstract. Global Covenant of Mayors for Climate and Energy is the largest movement of local governments committed to going beyond their own national climate and energy objectives, fully in line with the UN Sustainable Development Goals and climate justice principles. Every signatory develops a Sustainable Energy and Climate Action Plan (SECAP) to mitigate climate change. In the Plan for the Protection of European Water Resources, the European Commission expresses the urgency that EU-members focus on environmentally friendly growth and make the resources used more efficient, including water resources, in order to sustainably overcome the current economic and environmental crisis, adapt to climate change and increase the possibility of strengthening the competitiveness and growth of the European water sector. A component of urban systems affected by climate change is the hydrological one. The leading causes affecting hydrological component are floods. The Floods Directive 2007/60/EC establishes a framework on the assessment and management of flood risk, aiming at the reduction of the potential adverse consequences of flooding for human health, the environment, cultural heritage and economic activity. In this work, we propose a first-level framework to identify critical areas for water management in urban contexts. This study involves 13 sub-catchments located in the urban area of the Municipality of Potenza, in Southern Italy. The proposed approach could promote, in the ambit of SECAP (Sustainable Energy Climate Action), the development of mitigation actions and investment sizing for urban water management strategies in critical urban contexts.

Keywords: Urban floods · Storm-water management · Detention tanks · Climate change · SEAP/SECAP · Local climate plans

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1 Introduction

In urban areas, local flooding might occur as a combined result of heavy rains and poor or insufficient drainage system that is unable to drain out the water discharges efficiently. Traditional road drainage system, typically designed in accordance with local authority regulation, should convey water as quickly as possible far from the surfaces, thereby ensuring clean and safe roads and avoiding potential damages to the structures. However, many roads drainage systems are combined with sewage schemes, the design of which does not require to cope with extreme rain events. The vulnerability of the land, and therefore of the urban area, is primarily attributable to climate change and to a lack of the concept of "limit" in spatial planning. The impermeability of the soil is one of the effects of urbanization that most impact: the reduction of the amount of water infiltration with the consequent reduction of local groundwater recharging; the increase of runoff; the reduction of the time of concentration of a watershed; and the decay of a natural ecosystem because of pollution over-load [1]. Therefore, there is the need to enable a suitable integrated water management both at basin and urban scale [2]. This study involved 13 sub-catchments area located in the urban area of the Municipality of Potenza, in Southern Italy. The catchments area has homogeneous lithological feature, a very deep and moderately silty clay soils characterized by low permeability, while the slopes are mainly weak or moderate, only locally steep, with an average annual precipitation of 697 mm and maximum daily rainfall of 150 mm [3, 4]. The municipal area is densely populated; the percentage of consumed soil, according to the EEA (European Environmental Agency) in the framework of the Copernicus land monitoring service, is 38.01% of the entire territory, and the urban sprawls on the lowest catchment areas near the Basento River with many clustered settlements [5, 6]. Runoff coefficients were evaluated using the Kennessey method, suitable for small hilly watersheds, and subsequently related to the impervious areas of the catchments [7]. Moreover, the morphological analysis of the urban area allows to identify the potential risk areas in which flooding might occur. Lastly, a spatial analytical hierarchy approach allowed to identify priorities areas for taking action. The proposed framework could support, in the ambit of SECAP (Sustainable Energy Climate Action), the development of mitigation measures and investment sizing for urban water management strategies in critical urban contexts.

2 Methodological Approach to Estimate Flooding Areas in Urban Contexts

In this section, in order to support urban planning decision-makers for mitigating the climate change impacts on metropolitan areas and increasing the urban resilience, a first-level assessment procedure for water management strategy is defined. The analytic methodology is addressed with a Geographical Information Systems (GIS), a tool for spatial data analysis and visualization. The basic concept of the methodology is to combine heterogeneous components in view of an integrated territorial management. Firstly, the sealed sinkhole morphology (i.e. water ponding area) has been evaluated – as a potential area of runoff accumulation – by merging the Digital Elevation Model

(DEM) of the urban area with imperviousness data distributed by EEA (European Environmental Agency) in the framework of the Copernicus land monitoring service [8]. The hydrological analysis of the catchments, performed through the GRASS "*r. watershed"* algorithm, also provided the raster map of surface flow accumulation, which has helped to discriminate the sinkholes in categories as shown in Fig. 1.

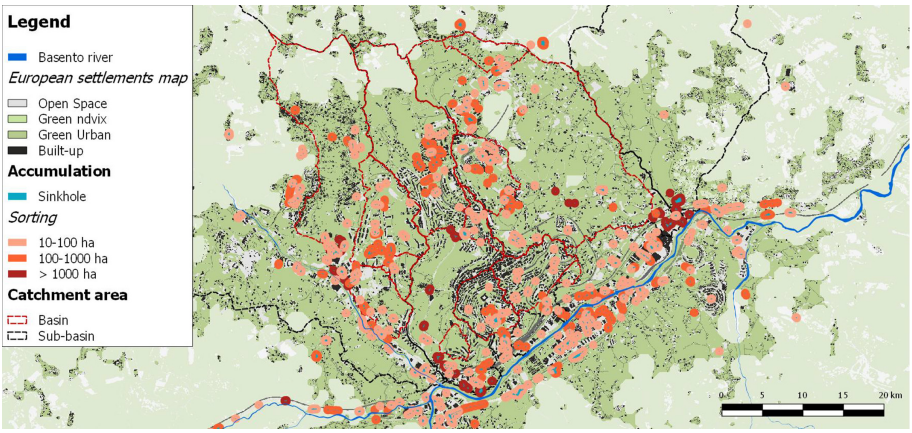

Fig. 1. Map of urban settlements and discriminated sinkholes

Local floods and runoff coefficients are strictly correlated. Here the Kennessey method has been considered to estimate the runoff coefficients [7]. This choice has been justified by the accuracy of this physiographic approach and by its simple adaptability to GIS environment [9]. Specifically, the procedure applied can be summarized as follow:

- Calculation of the Aridity Index using the De Martonne – Gottmann aridity index;
- Study of the areal distribution for the three main parameters: acclivity (i.e. slope), permeability, and vegetational cover of the soil [8];
- multiplication between the percentage areas and coefficients (leading to weighted coefficients) related to acclivity, C_a, permeability, C_p, and vegetational cover of the soil C_v, respectively;
- sum of the three coefficients C_a, C_p, C_v leading to the estimation of the average annual runoff coefficient, R_C, for each sub-catchment.

Table 1 provides estimates of the runoff coefficient for all sub-catchments considered in this study based on the above procedure.

Moreover, in order to identify the hydrological response of each sub-catchments to a rain event, the time of concentration, t_c, has been assessed by the Kirpich's formula which is particularly suitable for very small catchments, as in present case, though developed for agricultural areas [10]. Therefore, in order to identify the potential flood hazard areas and evaluate the priority sites for taking actions, the morphometric and

Table 1. Main characteristics of the sub-catchments considered in this study in terms of area, imperviousness, and run off coefficient.

The main hydrological parameters of the sub-catchments			
Catchment no.	Imperviousness %	Basin area km^2	Runoff coeff.
1	77.8	0.541	0.589
2	85.1	0.166	0.530
3	82.5	0.434	0.590
4	34.2	3.090	0.518
5	59.4	0.416	0.555
6	35.6	4.821	0.547
7	82.5	0.108	0.560
8	44.1	1.791	0.519
9	33.9	0.267	0.559
10	52.9	0.938	0.493
11	53.7	0.141	0.485
12	65.2	0.539	0.514
13	67.1	0.048	0.518

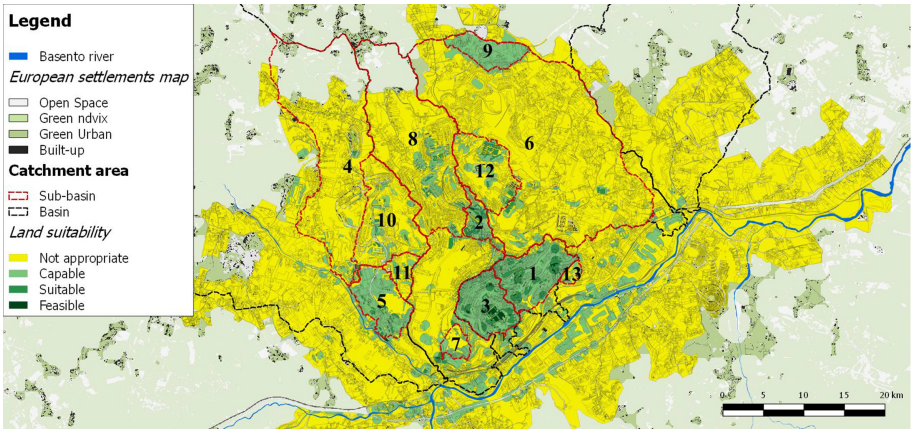

Fig. 2. Land suitability for the sub-catchments considered in this study

hydrological parameters are combined with the distribution map of urban services and infrastructures through a spatial analytical hierarchy approach, thereby achieving a suitability weighted model [11]. Results are shown in Fig. 2.

3 Results and Discussion

The results from the spatial analysis, calculated on seven criteria of land suitability, allow to efficiently evaluating the potentially exposed sites that would require intervention at water management level. The analysis evidences how catchment no.2, no.1, no. 3, in order of importance, require priority measures. Indeed, it is not a coincidence that for these catchments the soil sealing percentages are among the highest recorded in all the sub-catchments analyzed, as it can be observed in Table 2 and Fig. 3.

Table 2. Potentially exposed sites, according to the Floods Directive (2007/60/EC) [12]

Potentially exposed sites, according to the Floods Directive (2007/60/EC)			
Catchment no.	Imperviousness %	Basin area Km^2	Exposed area %
1	**77.8**	0.541	22.2
2	**85.1**	0.166	26.2
3	**82.5**	0.434	33.1

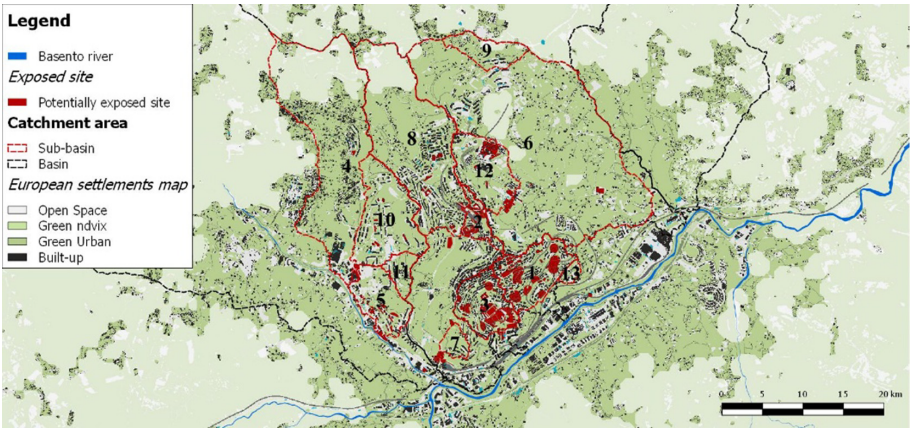

Fig. 3. Identify potentially exposed sites

By making a comparison between catchments with similar geomorphological features, whose the C_a coefficient shows an average of 0.124 and quite limited standard deviation of 0.003, the relationship between imperviousness and runoff coefficient is very tight (Pearson's r equal to 0.93 as shown in Fig. 4). While this is a preliminary flood risk analysis, results look promising for the assessment of potential risk-prone sites in which local flood might be considered likely to occur. Indeed, developed on open source data, this approach results very flexible and can be used as a preliminary tool for urban stormwater management [13].

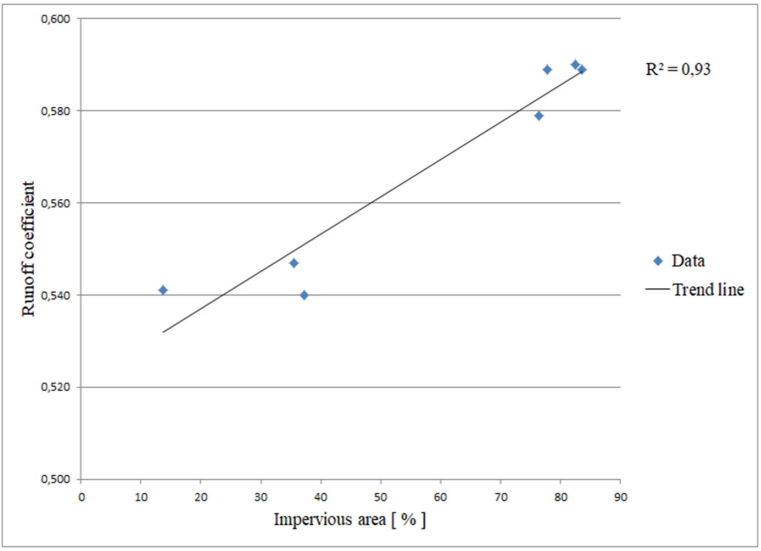

Fig. 4. Runoff coefficient related to impervious area

Hydraulic engineering, in a traditional approach, considers water only as a source of supply for domestic, industrial and agricultural use. Since water is a finite and vulnerable resource, its management and development should be based on a participative approach able to engage stakeholders, urban planners and decision-makers [14–16]. In order to sustainably face the existing crisis of the sector, urban policies for the improvements of water and risks prevention require clear and endorsed strategies and solutions aimed at strengthening the competitiveness and growth in this sector at every level. By including the risk related to climate changes on the whole water integrated cycle, a synergic and integrated approach in the respect of environmental ethics, focused on eco-centric and anthropogenic nature, and social ethics becomes necessary [17, 18].

4 Land Suitability as a Tool for SECAP

The land suitability classification of soil, even at a large scale of detail, might be a useful tool for redirecting investments in the prospective of viewing cities as an adaptive resilient system against the uncertainty of climate change [19, 20]. Previous studies about land suitability gave a general extent of the suitable areas to specific actions planned by SECAP. The support of land suitability can answer to the question "Where is the best location?" and strengthen the place-based approach chosen by the authors. The link between the land suitability and SECAP in a place-based approach could be found in sectors (such as water, agriculture & forestry or environment & biodiversity), that tie actions proposed by SECAP to a territorial dimension.

The proposed framework might be a tool to identify mitigation actions to be developed in the SECAP for Potenza Municipality. These actions, suggested by Charlesworth et al., can be articulated at different scale in: building's stormwater collector tanks, soil permeabilization - such as permeable paving and rain garden, and lastly blue-green infrastructure [21]. They are collected into SECAP template as shown in Fig. 5.

Sector	Title (max. 120 chars)	Short description (max. 300 chars)	Responsible body/department	Implementation timeframe		Implementation status
				Start	End	
Water	Replacing waterproof flooring with materials/techniques that make them permeable	Replacement of waterproof pavements such as parking lots with permeable pavements. The permeable flooring is designed to allow rainwater to infiltrate through the surface, or into the underlying layers (soils and aquifers), or be stored in the layers and released at a controlled speed	Potenza Municipality	2020	2024	Not started
Water	Construction of sinkent wells and trenches [bioretention]	Infiltration trenches are shallow digs filled with rubble or stones. They allow water to infiltrate the surrounding soils from the bottom and sides of the pit, improving the soil's natural ability to drain water. Infiltration trenches can be used around playgrounds, recreation areas or public open spaces. They can be effectively incorporated into the landscape with little space consumption	Potenza Municipality	2020	2024	Not started
Water	Realization of vegetated depressions on the side of the road of rainwater infiltration [Bioswale]	Realization of green depressions in place of artificial drainage canals, for the drainage of meteoric water along the roadways	Potenza Municipality	2020	2024	Not started
Water	Realization/installation of pots/plants where rainwater can be conveyed from the roofs	Realization/installation of pots/flowers on residential buildings that allow to recover meteoric waters, increase urban greenery and redevelop densely built areas.	Potenza Municipality	2020	2024	Not started
Water	Incentive to use/install green roofs	Realization of green roofs or rain gardens on residential buildings, especially condominium buildings. Green roofs are multi-layered drainage technology systems, covering the roof of a building with vegetation. Green roofs can be distinguished into two types according to vegetation characteristics: extensive green roofs (known as: sedumroofs, ecological roofs or living roofs). These roofs have a low-growth, self-sustaining and low-maintenance planting. Vegetation is normally composed of drought-resistant plants, succulents or herbs. Intensive green roofs (known as: hanging gardens). These roofs have a higher load on the roof structure and require continuous and significant maintenance including irrigation, feeding and pruning.	Potenza Municipality	2020	2024	Not started
Water	Incentive to install Rain Garden where rainwater from the roof is transported to disconnect from the sewerage system. Or [Dry wells]		Potenza Municipality	2020	2024	Not started

Fig. 5. Adaptation actions for water sector (adapted from SECAP template)

5 Conclusion

The methodological approach suggested in this paper, while not comprehensive, allows to obtain a preliminary scenario that highlights the weaknesses of a territory due to the obsolescence of urban water infrastructures; stormwater is only regarded as a nuisance, not as an opportunity. In the shared perspective of resilient cities, the proposed approach might be useful not also in the defining of appropriate climate changes adaptation strategies for the delineation of SECAP's actions by the decision-makers, but also in the awareness of the citizens to climate change. How tool to develop local climate plans (i.e. SECAP), is a useful and quick framework to find areas more critical and size the investment and actions to urban scale. In order to carry out the research on the Potenza urban area, the methodology described in this work has been developed on the basis of extreme events occurred in the town during the last years. Indeed, the threshold discriminating the sinkholes was chosen on the basis of past experience and of the territorial knowledge. In order to use this framework in different urban contexts, as a potential future development of this study, a potential integration looks at using remote sensing techniques for searching all the feasible areas in which, over the years,

an unexpected flood has occurred. However, the identification of these areas by applying passive remote sensing might be hindered by the steady cloudy sky that, after a heavy rainfall, does not allow to clearly acquire images from the soil. In this case, the use of satellite active sensors, such as microwaves, is highly recommended, albeit it is currently a very expensive procedure for the treasury of a small municipality like that one of Potenza. This evaluation can be made after a preliminary careful analysis of intervention conducted on the sub-catchments located in the urban area. In this case, therefore, it would be possible to consider the investment sizing with more accuracy.

In this perspective, future developments are oriented to improve this framework as a support system in order to identify more effective actions for SECAP ensuring positive environmental impacts on multiple matrix [22–24], helping local decision makers, public administrator and stakeholders into decision-making process.

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