Fostering Pluvial Flood Resilience in Heritage Cities: Insights from Practice in the City of Florence

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FOSTERING PLUVIAL FLOOD RESILIENCE IN HERITAGE CITIES: INSIGHTS FROM PRACTICE IN THE CITY OF FLORENCE

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Abstract

The increase in the frequency of extreme events due to climate change, as well as the evolution of socio-economic scenarios have intensified the water-related challenges of urban socio-ecological systems. In this context, heritage cities represent a hotspot due to their exposure and vulnerability to pluvial flood events that can cause extensive damage to property and people, and loss of unique pieces of art. Indeed, the growth of impervious surfaces very often combined with outdated drainage systems, have increased the necessity to develop suitable strategies of mitigation against pluvial flood risk.
Starting from the outcomes of two research projects carried out for the city of Florence (Italy), a UNESCO World Heritage Site, this work aims at summarizing the lesson learnt regarding the possibility of fostering pluvial flood resilience in heritage cities.
The proposed approaches present flexible assessment techniques that can be replicated in other heritage contexts, providing useful support for defining the most effective strategies to control and mitigate urban flood risk.

Keywords: city of Florence, cultural heritage, pluvial flood, hydraulic modelling, nature-based solutions.

1 Introduction

City environment evolution of many Italian cities has been characterized by the progressive increase in impermeable surfaces that considerably alter the water balance, drastically reducing the volumes of water infiltrated into the soil, thus increasing the surface runoff. These problems, combined with increasingly intense and violent rainfall events due to climate change (Zölch et al., 2017), highlight the necessity of going beyond the classic drainage solutions (i.e. sewer systems) that have often shown their inadequacy to face the complexity of present water management in urban environment (Zhou et al., 2014).

In order to properly address the pluvial flood management challenges in heritage cities, this work provides some insights derived from two projects implemented in the city Florence, addressing the necessity of properly identifying the hotspots associated with pluvial flood (i.e. evaluating flood risk hazard) and introducing Nature Based Solutions (NBS) to address them. Particularly, the objective of

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this work is to show the methodology and the results of two projects, which have been applied on the heritage city of Florence to foster pluvial flood resilience.

The first project (TALETE - Tutela del pAtrimonio cuLturale da evEnti esTremi di prEcipitazione: il quartiere di Santa Croce a Firenze) was concentrated on the historic center of Florence, and specifically on the Santa Croce district where the National Central Library is located. A detailed hydraulic model of the area has been built to perform comprehensive flood hazard assessment, to identify critical points in the drainage infrastructure and to define technical solutions to protect the cultural heritage preserved in the site (Tamagnone et al., 2022).

The second project (FLORENCE - FLOod risk and water Resources management with Nature based solutions on City Environment) investigated the effectiveness of implementing NBS to enhance the rainstorm regulating potential of the entire city environment. The outcomes revealed the positive impact of NBS strategy against pluvial flooding in the city, highlighting their limitations and exploring the possible synergies with existing infrastructures (Pacetti et al., 2022).

2 Materials and methods

The proposed methodologies address two complementary aspects of pluvial flood: the flood hazard assessment and the identification of the most suitable areas for the installation of NBS within the Municipality of Florence with the primary target of pluvial flood risk mitigation.

The flood hazard assessment is carried out by modeling different extreme rainfall scenarios with InfoWorks Integrated Catchment Modeling (Innovyze's product), a dual drainage hydraulic model. The input of the model are synthetic scenarios generated combining different hyetographs shapes and the 100 years and 200 years rainfall events. Moreover, since the study area is close to the Arno river, compound flooding scenarios are also considered in which the spillways of the drainage network are closed since the water depth in the river is high.

On the other hand, to identify the areas with the highest priority in the implementation of NBS for runoff management, a Spatial Multi-Criteria Evaluation (SMCE) is proposed. In particular, the SMCE module of ILWIS (Integrated Land and Water Information System; ITC, 2001) software is used to define different types of criteria, according to the contribution they give to the definition of the final map, and to assign a weight to each of these criteria. The criteria are divided into benefits/costs, which respectively contribute positively and negatively to the definition of the final map, and constraints, which identify the areas excluded from the analysis.

The final map shows the Pluvial Flood Index (PFI), i.e. a composite indicator with range between 0 and 100, and that shows the areas prone to pluvial flood. Particularly, zero values of PFI correspond to areas excluded from the analysis, while values from 1 to 100 indicate potentially floodable areas and the higher values, are associated with greater exposure of the area to flooding.

The indicators used in the spatial multi-criteria analysis are five: imperviousness, slope, hydrologic soil groups, density of sewer system and social vulnerability.

Among the used indicators, imperviousness, social vulnerability index and hydrologic soils group are classified as "benefits" with high values identifying areas with high impermeable surface, poorly permeable soils and high social vulnerability. The slope and the density of the sewer system are instead classified as cost with low values identifying areas with a tendency to flood and collect water and a sewer system that is often inadequate for the load.

Two constraints are also defined, i.e. river areas, as areas where no intervention is required, and areas with a slope of more than 10%, where NBS cannot be correctly installed.

3 Results

The results obtained are twofold. On one hand, the results of the hydraulic model show how the city center of Florence is exposed to pluvial flood hazard, which can cause severe damages to the cultural heritage of the city, as the overflowing of manholes causes the flooding of historic buildings also for the 100 year rainfall event with the Chicago hyetograph.

On the other hand, the SMCE provides the possibility of mapping the areas that need a higher priority of intervention for the installation of NBS (Figure 1).

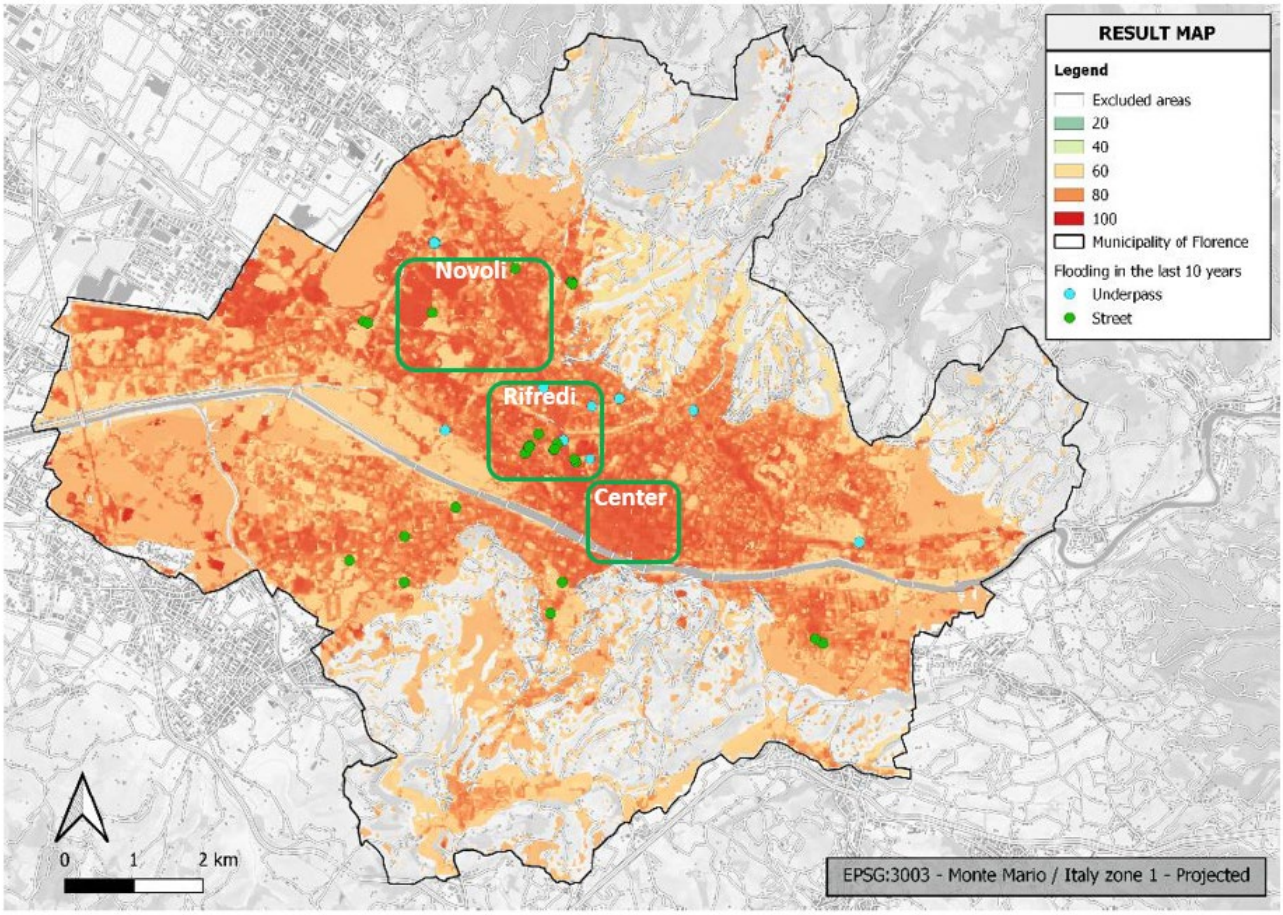

FIGURE 1:
Pluvial Flood Index of Florence Municipality, with values between 0 (no exposure) and 100 (greatest exposure). Flood events that occurred in the last ten years, used to validate the results map, are shown.

The highest values are concentrated in the historical center of Florence and the Rifredi and Novoli districts located in the western part of the city. Indeed, the historical center is completely paved with very small green and blue areas. The Rifredi and Novoli districts also have large areas with high levels of imperviousness due to the dense urbanization of the area. The obtained results are validated by comparing them with the locations of recent flooding due to pluvial extreme events, determined through archive reconstructions of such events (as highlighted in Figure 1). Moreover, the results of the Spatial Multi-Criteria Evaluation confirm the results of the hydraulic model, highlighting the city center as one of the more critical parts of Florence.

4 Conclusions

Rainwater management is a major challenge in heritage urban environments. The proposed approaches aim at supporting the decision makers in the quantification of pluvial flood hazard and the identification of the areas where to intervene. The results provide a detailed analysis of the issues associated with pluvial flooding in a district located in the city center while exploring on the wider scale the potential of introducing NBS.

The methodology can be potentially complemented by taking into account other sources of risk such as heat islands, noise or water pollution thus providing the starting point to develop a multi risk management strategy for heritage cities.

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