Nature-Based Solutions for flooding risk mitigation in an urban area: The case study of Catania (Sicily, Italy)

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ABSTRACT

Introduction

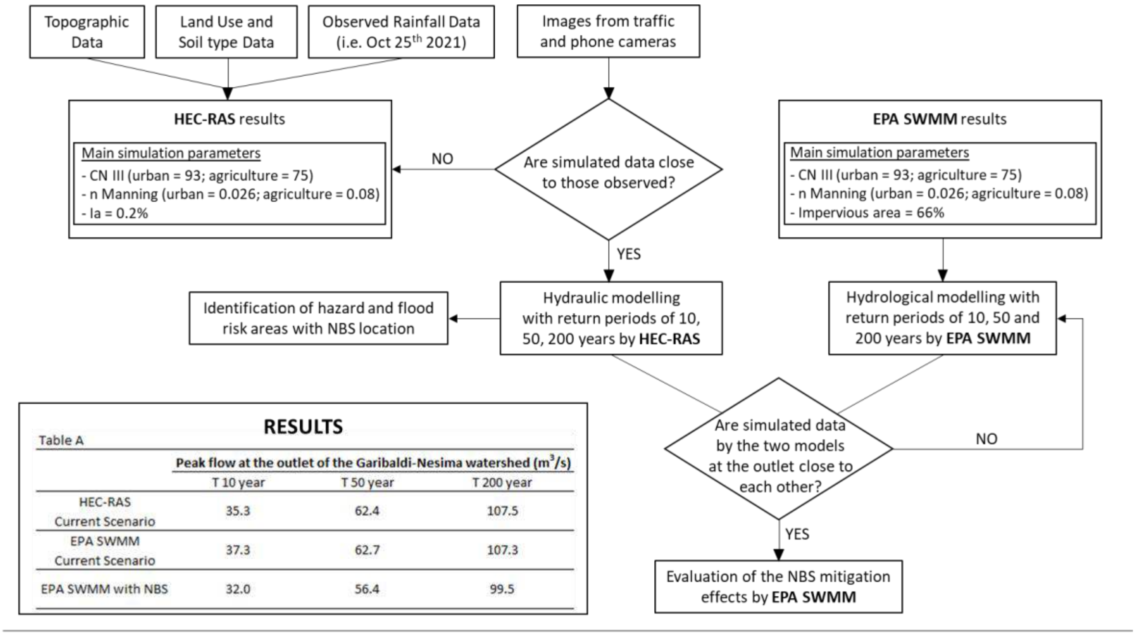
Urban floods, especially flash floods, are one of the main common challenges at global level related to intensified rainfall due to a changing climate and increased surface runoff due to urbanization. Central Mediterranean Regions are particularly affected to extreme rainfall events with ever-greater flow rates and runoff volumes in low-lying coastal urban areas (Abdessamed & Abderrazak, 2019). It is notable that urban flooding causes huge economic losses and serious threats to public safety. Reducing the impacts of adverse consequences by using adaptation and mitigation measures it is necessary to minimize the potential damages for the risk receptors (i.e. human health and life, environment, cultural heritage, economic activity and infrastructure). Traditional responses and interventions, focused on grey infrastructures approaches, are showing their failure to manage storm water in urban environment. A new response towards flood risk reduction is currently passing under the name of Nature-Based Solutions (NBS) that are strategies increasingly popular in the urban storm water management to minimize water quantity and to improve water quality (Vojinovic et al., 2021). A suitable combination of NBS with traditional grey infrastructures should be adopted to retain, decelerate, infiltrate and slowly release rainwater.

The aim of this study is to identify the flood risk areas, through the application of a hydraulic model (HEC-RAS), and to locate NBS (i.e. green roofs, rain gardens, porous pavements, rain barrels and infiltration basins) in a Sicilian hydrological watershed. HEC-RAS model is tested by using images from traffic and phone cameras, due to the lack of hydrological observations in this urban catchments. Finally, the effectiveness of the implemented small and large-scale NBS is evaluated, in terms of flood peak reduction and delay, and runoff volumes reduction, through EPA SWMM model. This research activity is carried out within a cross-border cooperation project GIFLUID (www.gifluid.eu) funded by the INTERREG V-A Italia-Malta 2014-2020 programme.

Material and methods

A small Sicilian watershed, named as Garibaldi-Nesima, is selected for the risk areas assessment, in order to identify the most suitable locations for the NBS implementation, and for flood mitigation effect evaluation of such green solutions. The Garibaldi-Nesima watershed is located in the Metropolitan Area of Catania (Sicily, Italy) and is a sub-basin of the larger Acquicella watershed extending from the territory of Misterbianco municipality and flowing into the Ionic Sea crossing the city of Catania. The watershed is chosen because, in recent decades, it was often subjected to short but intensive storm events, like the entire metropolitan city of Catania, causing the whole traditional drainage system to fail with several damages to the Garibaldi-Nesima hospital and to the numerous commercial activities in the area. The chosen Garibaldi-Nesima watershed, considering the hospital as basin outlet, covers an area of 8.75 km^2. Garibaldi-Nesima watershed elevation ranges from 95.6 to 313.3 m above sea level, the mean elevation is 197.6 m above sea level and the mean basin slope is 9.8%. The main and longest water pathway is about 6.8 km. According to the Land Use (Corine Land cover, 2018), most of the Garibaldi-Nesima watershed is covered by urban areas (56.5%), including industrial areas, while the second most represented land use is the agriculture (42.6%); the remaining part of the catchment is covered by areas of natural vegetation (0.9%). Figure 1 shows a summary of the methodology followed in this study to identify hazard and flood

risk areas where NBS should be effectively located and to evaluate their mitigation effects in the Garibaldi-Nesima watershed.



	Peak flow at the outlet of the Garibaldi-Nesima watershed (m^3/s)		
	T 10 year	T 50 year	T 200 year
HEC-RAS Current Scenario	35.3	62.4	107.5
EPA SWMM Current Scenario	37.3	62.7	107.3
EPA SWMM with NBS	32.0	56.4	99.5

NBS = Nature-Based Solutions

Figure 1- Workflow applied to identify hazard and flood risk areas and to evaluate NBS mitigation effects, and results obtained in the Garibaldi-Nesima watershed.

In particular, the hydraulic model (HEC-RAS) is tested at flood event scale by using images from traffic and phone cameras of an extreme rainfall event occurred in Catania on the 25th October 2021. In figure 2 the rainfall probability curves for return periods (T) of 5, 10, 50 and 200 years of the Catania pluviographic stations (based on the database recorded from 1967 to 2022) and the event occurred in October 2021 are reported. The graph in figure 2 shows that this event ranks near the T of 10 years only for a six hours' duration; for all the other durations it has a higher probability of occurrence (more or less 5 years).

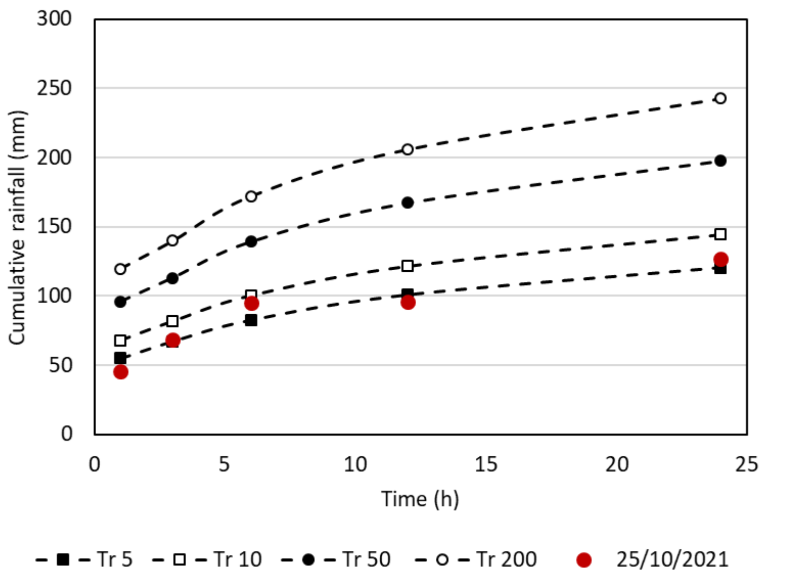


Figure 2 - Rainfall probability curves for different return periods of the Catania pluviographic stations with the placement of the event occurred on 25th October 2021 (data by the SIAS, 2021).

After the T assessment for the event considered, the testing phase of the HEC-RAS model reliability is carried out. The observed runoff depths in correspondence of some fixed points (i.e. cars headlights, bumpers and wheels) are compared with those simulated with the hydraulic model for the same T of the rainfall event occurred in October (Figure 3).

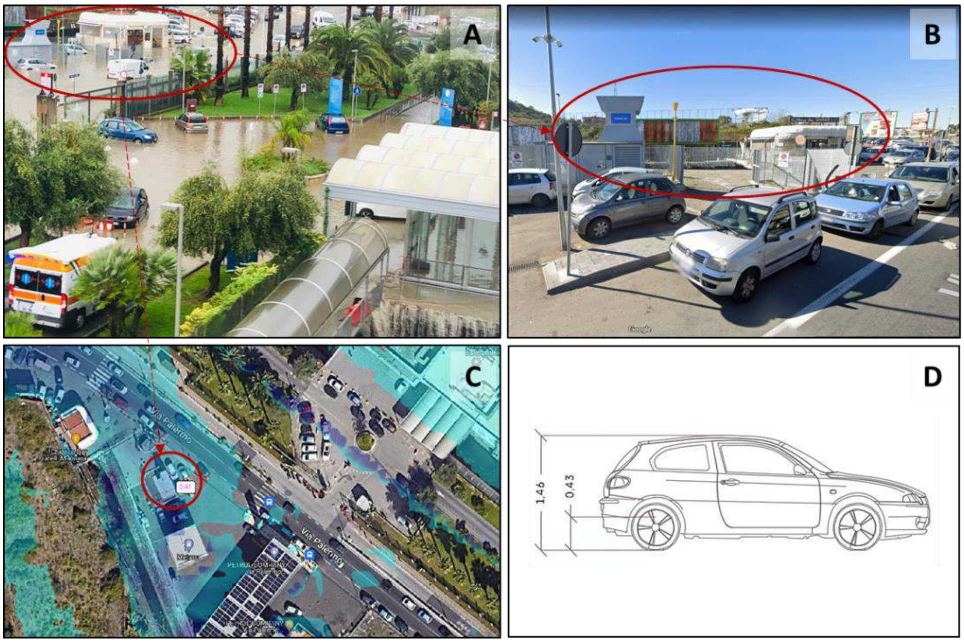


Figure 3 – Example of how the HEC-RAS model testing phase is carried out. A) Observed runoff depths by using an image of the event occurred in October from Garibaldi-Nesima hospital security camera; B) Google Maps image; C) Simulated runoff depths by using HEC-RAS model; D) Fixed point, back bumper of an Alfa Romeo 147.

After the positive model testing phase, the flood risk areas identified by the hydraulic model (HEC-RAS) are considered for the location of the NBS. Then, the EPA SWMM model was applied in order to obtain peak flows value at the outlet of the watershed similar to those obtained by HEC RAS in the current scenario. Then, the NBS mitigation effects (in terms of peak flow and runoff reductions) into the identified risk areas are evaluated at sub-catchment scale (0.20 km^2) through EPA SWMM model. Model simulations are performed with T of 10, 50, 200 years and by considering an area of 0.07 km^2 of NBS (in EPA SWMM model) that means 36.8% of the sub-catchment area (Figure 4).

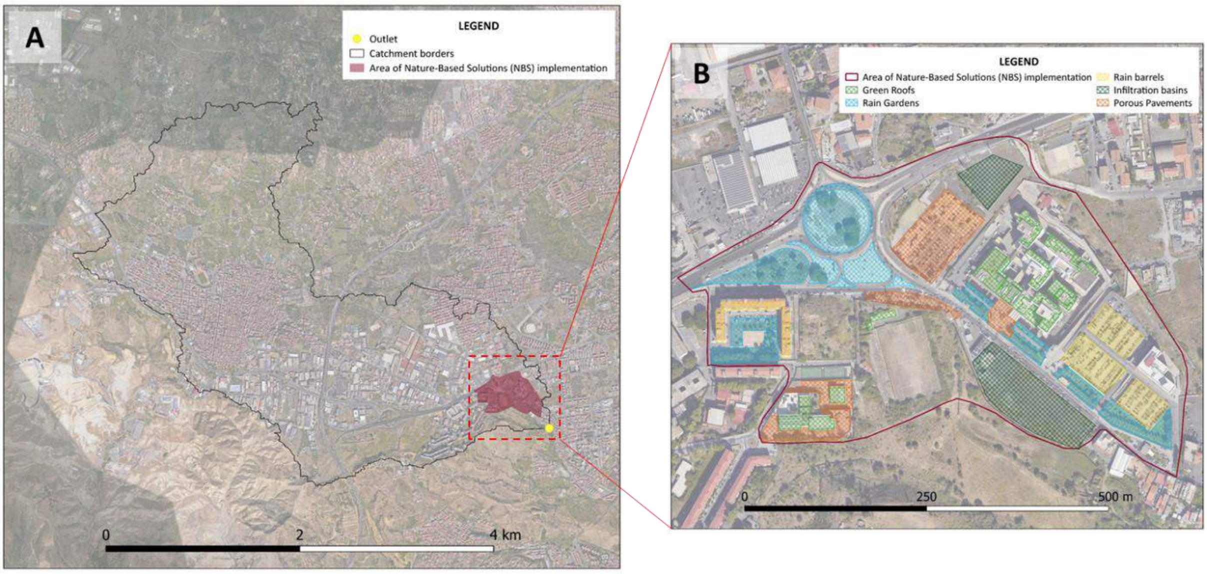


Figure 4 – A) Area of Nature-Based Solutions (NBS) implementation within the Garibaldi-Nesima watershed; B) Location of the different NBS typologies within the sub-catchment.

Results and discussion

Preliminary results from the testing process showed satisfactory results. At the four randomly chosen test points, the observed and simulated runoff depth are very close to each other with a difference in the range of 0.01 m - 0.10 m. Table A in figure 1 shows the estimated peak flows (m^3/s) obtained from the simulations performed for all the different T in the current scenario using HEC-RAS and EPA SWMM models. In particular, the estimated peak flow values obtained, at the outlet of the Garibaldi-Nesima catchment, using HEC-RAS and EPA SWMM models are very closed to each other (with a variation of 5.2%, 0.5% and 0.2%, respectively, for T 10, 50, 200 years). In addition, the model EPA SWMM shows its sensibility to NBS implementation at sub-catchment scale with a peak flow reduction up to 14% and a runoff volume reduction up to 9% at the outlet of the Garibaldi-Nesima watershed (Table A in figure 1). NBS mitigation effects are higher for the lower return periods. Figure 5 shows the flood risk map in the Garibaldi-Nesima catchment based on the current scenario with a focus on the area of NBS implementation.

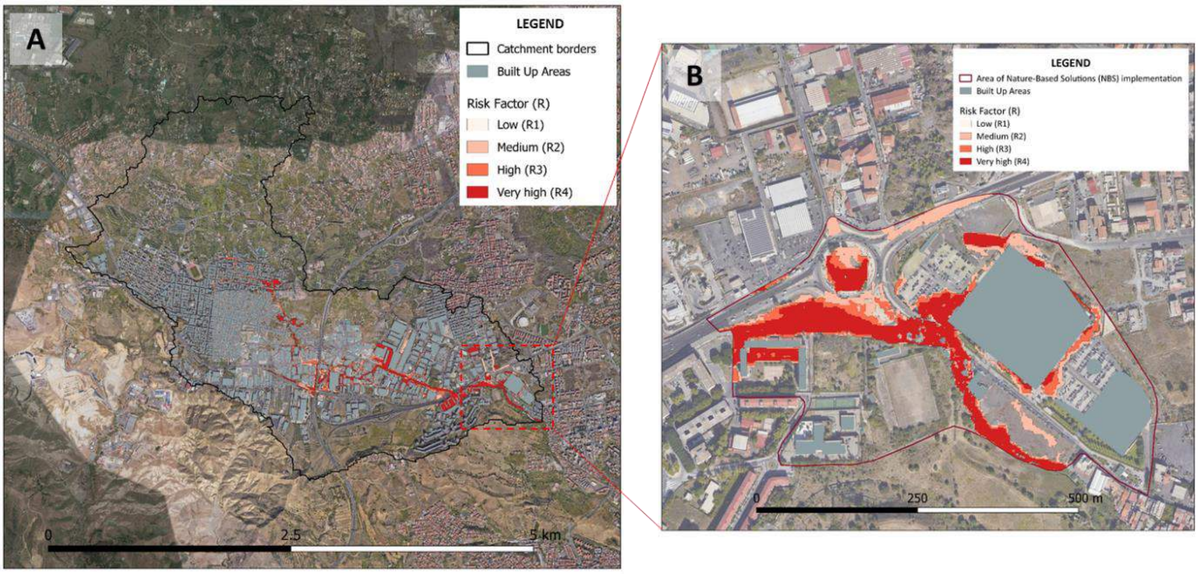


Figure 5 – A) Flood risk map for Garibaldi-Nesima catchment; B) Risk areas in the area of Nature-Based Solutions (NBS) implementation.

Conclusion

The approach proposed in the present study to evaluate NBS mitigation effects in flood risk urban data scarce areas through the application of HEC-RAS and EPA SWMM models, based on images from traffic and phone cameras, is promising. Both the preliminary testing process of HEC-RAS model to simulate observed peak flows in different points in the areas and the comparison of peak flows calculated at the outlet of the Garibaldi-Nesima watershed showed satisfactory results. In addition, the model EPA SWMM is able to simulate the effects in terms of peak flow and runoff volume reduction due to the implementation at sub-catchment scale NBS. The proposed approach is easy to apply and has high replication capacity in urban hydrological scarce areas. Further tests are necessary to test the approach performance by using different datasets also observed in different environments. More in general, the results confirm that the integration of NBS with grey infrastructures in urban area could have hydrological and hydraulic positive effects, in terms of peak flow and runoff volume reduction. Therefore, the proposed approach could be used as a tool to support decision makers, planners and stakeholders to investing in NBS as a green adaptation strategy against climate change in Mediterranean Regions.

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