COMBINED ANALYSIS OF SOCIOECONOMIC VULNERABILITY AND FLOOD HAZARD IN THE URBAN CONTEXTS OF SOUTHERN ITALY

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Introduction

The evolution of hazards into disasters is due to the impact that natural events have on structures, infrastructures and population. Since natural and social dynamics depends upon several spatial and temporal factors, the interaction between natural hazards and the socioeconomic environment is a challenging aspect of disaster studies. A multidisciplinary approach, consisting in the quantification and mapping of socioeconomic vulnerability and natural hazard, could be useful to highlight the most affected areas and to provide instruments for risk reduction. With this purpose, this study combines the dimensions of socioeconomic vulnerability with flood hazard at the suburban scale, across three different urban contexts (capitals of the metropolitan cities of Bari, Napoli and Reggio Calabria) in Southern Italy (Puglia, Campania and Calabria, respectively) by using data provided by national open-source platforms.

Following a local spatial approach at the submunicipality level, the analysis looks at the intertwining between the spatial dimensions and the degrees of potential vulnerability and flood hazard by means of a Geographic Information System (GIS).

Results could be useful to inform knowledge-based risk-reduction policies (s.c. place-based policies) and provide specific strategies based upon the degree of socioeconomic vulnerability population's subgroups.

Brief theoretical background and state of the art

Floods represent the highly hazardous natural events, causing severe damage to ecosystems, infrastructures, and population. Floods occur most commonly due to heavy rainfall, when natural watercourses lack the capacity to convey excess water, but they can also result from storm surges associated with tropical cyclones, tsunamis, or high tides in coastal areas (UNISDR, 2017). According to the last assessment carried out by the Italian Institute for Environmental Research and Protection (ISPRA), about 94% of Italian municipalities (around 7400) are prone to flooding and about 6.8 million inhabitants, nearly 34,000 cultural heritages (such as architectural, monumental and archeological sites) and 1,549,759 buildings can be considered at risk of floods in case of medium probability scenario (ISPRA, 2021). The expected impacts result from the complex interaction between the characteristics of the physical process, expressed in terms of frequency and severity, the number of people or assets exposed and the susceptibility of people and economic assets to be damages. Since losses vary geographically, vulnerability differs over time and space (Cutter et al., 2003). The analysis of socioeconomic vulnerability becomes crucial in the study of natural risks (Karácsonyi, et al., 2021). One of the approaches to identify vulnerable people is the definition of a specific spatial tailored vulnerability index (Birkmann, 2014; Benassi & Naccarato, 2017). A social vulnerability index is defined as an aggregated or composite measurement of selected vulnerability indicators, such as that it results in a numerical value of the social vulnerability of a given geographical unit (Birkmann, 2006).

Several studies were proposed to measure social vulnerability to flood hazard in different countries such as Russia (Lipatov et al., 2024), United States (Tate, 2021), New Zeland (Kirby

et al., 2019), United Kingdom (Garbutt et al., 2015), Zimbabwe (Mavhura et al., 2015), while 53 case studies were analyzed in Europe over the last twenty years (Lapietra et al., 2024).
The integration between hazard assessment and vulnerability implies the application of a multidisciplinary approach, which requires the merging of disciplines such as Earth Sciences, population-based studies and Engineering. In this paper, basing on such an interdisciplinary approach, we try and address the following points:

1) How socioeconomic vulnerability is spatially distributed at the sub-urban level across the municipalities?
2) How flood hazard is spatially distributed at the sub-urban level across the municipalities?
3) Are the two distributions spatially correlated at the sub-urban level? What kind of spatial correlation (positive/negative) and where are located these clusters? Which are the sub-municipality areas that need special attention in risk management strategies?

Data and methods

Empirical analyses were performed using the last national census data for the year 2021 at the census tracts level for the city of Bari, Napoli and Reggio Calabria, provided by the Italian National Statistics Institute (ISTAT). More specifically, we collected data of the age of specific groups of individuals, citizenship, number of household members, level of education and non-employment status of residents, which were merged to housing conditions drawn from the 2011 Census[1].

To address the first point, we built a composite indicator to measure the socioeconomic vulnerability using several items that covers 3 dimensions: sociodemographic (shares of individuals over 70 years old among total population and households with more than four components), socioeconomic (shares of male/female population with at most the first level of secondary education and shares of not-employed males/females between 15 and 64 years old) housing conditions (share of residential buildings in bad or very bad state of preservation). A Principal Component Analysis (PCA) was then run to reduce the former six indicators into three principal components (PCs) that account for 73% of the total original variability. The resulting composite index was built up for each census tract with the PCs retained, weighted by their eigenvalues (Benassi et al., 2023). Finally, the indicator was standardized using the min-max method to obtain a Composite Index of Potential Socioeconomic Vulnerability (CIPSV) which was classified into 6 natural breaks (Jenks) and reclassified in a range between 0 and 5 (SV0, SV1, SV2, SV3, SV4, SV5).

For the flood hazard assessment (Point 2), we collected open national mosaic layers provided by the Italian Institute for Environmental Research and Protection (ISPRA) 2020–2021. The informative layer defines the extension of the floodable areas for each of the probability scenarios envisaged in art. 6 of the European Union Floods Directive (2007/60/EC): High-Probability Hazard (HPH—a high probability of floods); Medium-Probability Hazard (MPH—a medium probability of floods); Low-Probability Hazard (LPH—a low probability of floods). According to the Legislative Decree 49/2010, these scenarios correspond to the areas that can be flooded following flood events, with return periods between 20 and 50 years (HPH—high probability of or frequent floods), between 100 and 200 years (MPH—medium probability of or infrequent floods), and with a return period exceeding 200 years (LPH—low probability of extreme event scenarios). In order to create a flood hazard map, we determined the percentage of the territory potentially affected by calculating the extent of the HPH scenario in m^2 in each census tract. We then compared the extent of each scenario with the total extent of the census tracts, in order to measure the percentage of the territory potentially affected by

[1] Till date, this is the most recent information available.

HPH. This percentage was then classified into 6 natural breaks (Jenks) and reclassified in a range between 0 and 5 (FH0, FH1, FH2, FH3, FH4, FH5).
Concerning the third point, the different flood hazard levels were combined with the potential socioeconomic vulnerability classes through a GIS-based raster analysis tool and the results were classified into 6 classes (R0, R1, R2, R3, R4, R5) in order to obtain the different integration level[2].

Lastly, in order to investigate the correlation between the indexes of potential socioeconomic vulnerability and flood hazard (Point 3), an estimation and interpretation of the local versions of bivariate Moran's I between the indexes was carried out.

Preliminary results

Figure 1 shows an example of the preliminary results derived from the analysis of the socioeconomic vulnerability. The map highlights the significant differences across the census tracts of Bari. As shown in the figure, light orange spots represent census tracts with lower levels of vulnerability, while black ones indicate those that are more vulnerable in socioeconomic terms. The distribution of these spots follows a particular "island-type" spatial distribution. In particular, the sub-urban areas of high vulnerability are either spatially clustered or clustered-disperse. The most vulnerable groups seem to be spatially isolated not only in certain areas but also across several sub-municipalities.

The flood hazard assessment is shown on Figure 2 that represents the different hazard level for each census tract based on the percentage of territory potentially affected by floods in case of HPH. The figure shows that the census tracts likely affected by floods are mostly located outside the downtown area (submunicipality 9). Most of them are characterized by very low and medium level of flood hazards. However, the submunicipality that shows the highest number of census tracts affected by flood hazard is the area across the suburb's district Carbonara, Ceglie and Loseto.

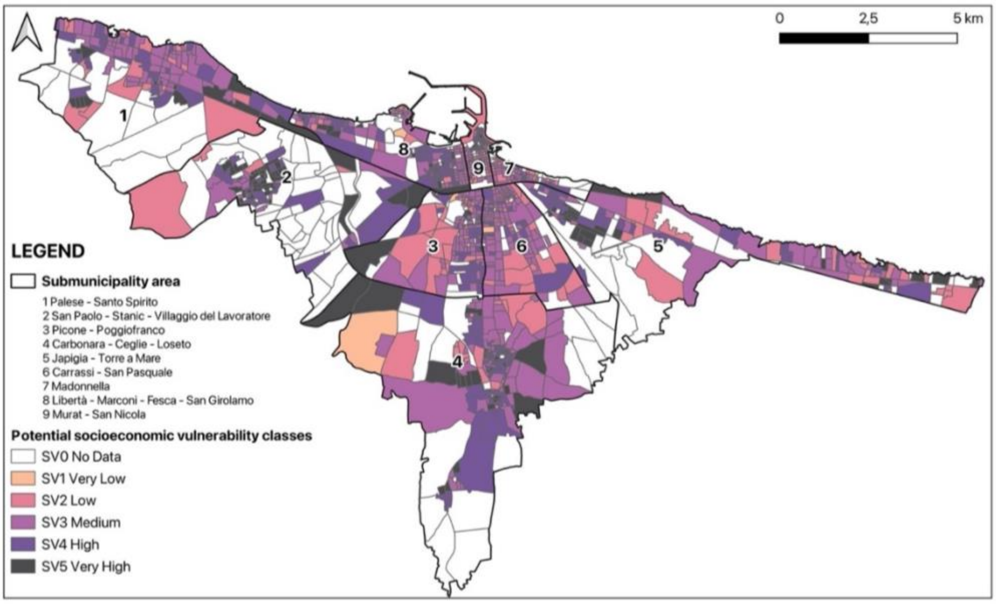

Figure 1 – Index of Potential Socioeconomic Vulnerability of Bari.

[2] For the sake of brevity, we present here some preliminary results (Point 1, Point 2 and part of Point 3) for the municipality of Bari.

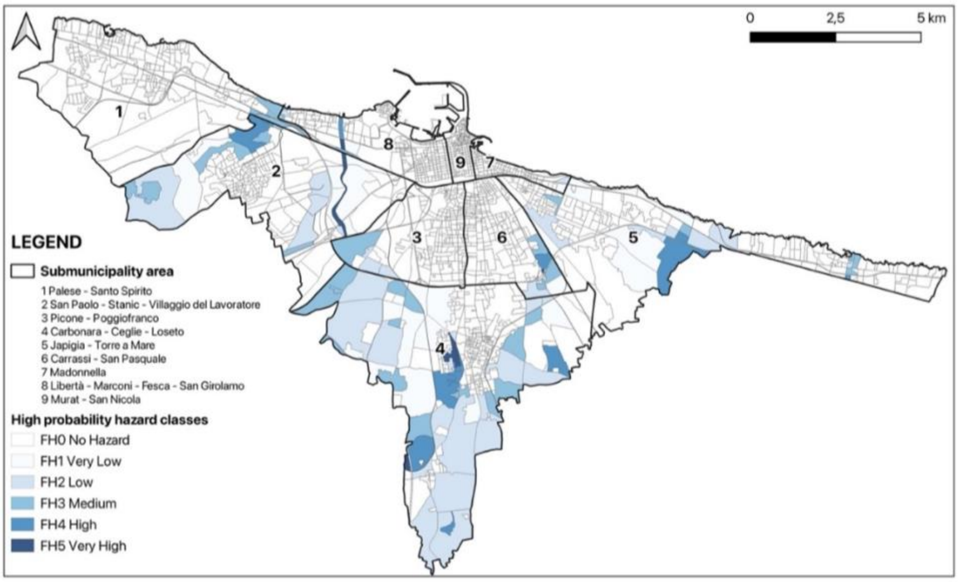

Figure 2 - Flood hazard maps of Bari for high probability scenario.

Figure 3 represents the final result of the spatial analysis of the combined physical and the socioeconomic components. The map shows that the social index and the hazard index contribute with the same weight to the final result. Also in this case, the submunicipality 4 (Carbonara, Ceglie, Loseto) shows the majority of census tracts with the highest level of risk in terms of both hazard and socioeconomic vulnerability requiring a higher attention in risk management strategies.

The analysis conducted in this work represents a multidisciplinary approach that could provide a significant development in emergency planning at the local level and that could be applied to investigate the correlation between population and any type of hazards.

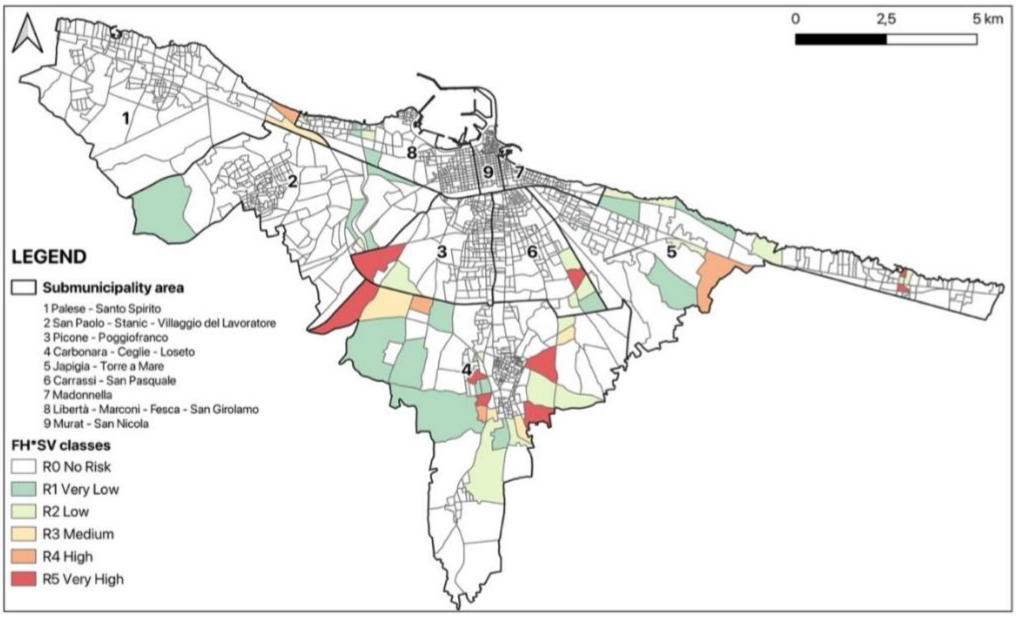

Figure 3 – Census tracts with different level of integration between flood hazard and potential socioeconomic vulnerability.

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