Territorial Inequalities in Real Estate Markets' Flood Resilience: Evidence from the Forlì-Cesena Province (Italy)

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Abstract. Climate change is increasing the frequency and severity of extreme weather events, with significant implications for economic and territorial systems. Among these events, floods have emerged as a major threat due to their widespread geographical reach and their capacity to produce both severe damage and long-term socio-economic impacts. While a growing body of literature has examined the impact of flood risk on real estate prices, limited attention has been devoted to the resilience of real estate markets and spatial heterogeneity. This paper investigates the resilience of residential real estate markets to flood risk in Italy, a territory characterized by high hazard conditions and pronounced territorial disparities. We resort to a "stage-damage" methodology for the ex-ante evaluation of flood damages and derive a "critical stage" as a proxy for market resilience across municipalities. The results, based on the case study of Forlì-Cesena province (Italy), reveal a clear spatial pattern, with resilience systematically declining from central to peripheral municipalities, reflecting the climate resilience counterpart of existing socio-economic and demographic disparities. These findings highlight the need to integrate equity considerations into risk management and spatial planning policies.

Keywords: Inequalities · Flood risk · Resilience · Damage curves · Real estate market

1 Introduction

In recent years, climate change has emerged as one of the most pressing global challenges, with significant implications for economic systems, territorial structures, and human well-being [1, 2]. A growing body of studies shows that climate change is negatively impacting the frequency and severity of extreme events, including floods, storms, and heatwaves [3, 4].

Among these events, which generate severe disruptions for infrastructure, productive activities, and the safety of the population, floods are emerging as a severe threat due to their widespread geographical reach and their capacity to produce both severe damage and long-term socio-economic impacts [5].

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Given their strong spatial dependence and economic relevance, real estate markets provide a valuable lens to observe the impacts of flood risk. Many international studies have investigated how flood risk affects real estate prices, primarily focusing on the US context and housing markets [6, 7]. By contrast, a limited number of studies have focused on a central theme in national and international planning agendas: the resilience of real estate markets to this climate-related risk and its variation across locations. Italy offers a relevant setting for analyzing this theme, which reveals the tight connection between risk management and distributive equity in spatial planning. Indeed, about 20% of the Italian population lives in flood-prone areas [8]. According to the Bank of Italy, the value of housing exposed to flood risk amounts to approximately €1.000 trillion, and the expected annual losses in real estate wealth, related to flood events, can reach €3 billion [9]. However, this information, on its own, offers only a partial measure of the impact of flood risks on real estate markets.

Italy, indeed, exhibits significant spatial disparities between central areas and marginal areas - the so-called "inner areas" - which are likely to influence the resilience of real estate markets to flood risk. Italian inner areas[1] account for about 60% of the national territory (about 49% of Italian municipalities) and host about 23% of the national population [10]. Since 2014, these territories have been targeted by the National Strategy for Inner Areas (NSIA) - one of the most interesting laboratories of the EU's territorial cohesion policy - to tackle the ongoing marginalization and depopulation phenomena [11, 12].

While the NSIA proposes a differentiated, place-based approach to intervention for these territories, aimed at promoting local development and addressing deficits in essential services [13], the same level of "specific" attention is not devoted to managing climate-related risks. Given their lower population density and the lower value of other exposed assets, such risks may initially appear less relevant in absolute terms than those affecting urban areas. However, the vulnerability of their socio-economic systems - and, within them, of real estate markets - makes them less resilient to the impacts of climate events that, if not properly managed, can become a catalyst for the ongoing depopulation and marginalization dynamics. Understanding the extent of this phenomenon is crucial to not undermining NSIA's planning efforts.

Based on these premises and adopting the housing real estate market as the lens to observe the impacts of flood risk, the paper proposes a comparative analysis among different typologies of municipalities – in terms of NSIA's classification according to their accessibility conditions (centers, peri-urban areas, intermediate areas, peripheral areas, and ultra-peripheral areas) – to understand the differences in their markets' resilience to flood risk. To this aim, it resorts to an ex-ante evaluation of direct flood damages,

[1] Inner areas identification is based on a classification of Italian municipalities according to their accessibility conditions. Specifically, the national territory is divided into five zones (centers, peri-urban areas, intermediate areas, peripheral areas, and ultra-peripheral areas). The adopted accessibility indicator is measured in the number of minutes required to reach the closest center, i.e., a municipality or a cluster of neighboring municipalities, offering all secondary education provisions, hospitals with I-level DEA, and at least a silver railway station, according to RFI classification. Based on this indicator, the classification of "inner areas" applies to all municipalities, resulting in intermediate (20–40 min to reach the closest center), peripheral (40–75 min), and ultraperipheral (more than 75 min).

based on "stage-damage" curves, and compares the obtained damages with the average housing market value at the municipal level to identify the municipal "critical stage". Such a "critical stage", representing the most probable "water depth" causing economic damage equal to the property's market value, is adopted as a proxy of the real estate market resilience, thus allowing for comparison among different municipalities. After describing the adopted methodology in Sect. 2, Sect. 3 provides its application to a case study: the municipalities of Forlì-Cesena Province in the Emilia Romagna Region (Italy), which in 2023 was affected by a severe flood event. The comparison of results obtained for municipalities, characterized by different accessibility and marginality conditions, allows for reflecting on the methodology's contribution to detecting territorial inequalities in real estate markets' flood resilience and discussing its potential to better orient planning actions toward spatial equity.

2 Methodology

The willingness to understand the climate resilience conditions of different real estate markets (center vs. peripheral areas), as a basis to orient equity-based planning actions, calls for the definition of a robust methodological approach.

The methodology proposed for the ex-ante evaluation of direct damages is based on the "Stage-damage" curve as the most trusted and reliable forecasting tool to assess the Expected Annual Damage (EAD) from flood events. The "Stage-damage" curves are functions that relate the intensity of a hazardous event (hazard) to the resulting damage of a certain type of assets exposed [14–16]. These curves assume that the expected economic damage can be quantified based on both the vulnerability of the exposed elements and the level of water during flooding. Therefore, Total Damage (DT) is expressed as a function of the asset's economic value and its level of vulnerability. The economic value of an asset may be determined using different criteria: the market value, which reflects the conditions of the real estate market in which the asset is located, or the cost value, which may refer either to the depreciated replacement cost or to the restoration cost associated with repairing and eliminating the damage [17].

The methodology adopted for the case under analysis and shown in Fig. 1 is based on an analytical engineering approach that involves:

1. Identification of the reference building typology. Once the study area is selected, the choice of the building typology must be based on a combination of territorial, risk-related, and architectural criteria. Specifically, to allow comparability among different municipalities within the study area, the reference building typology must be representative of construction techniques in the area and widespread.
2. Breakdown of the identified building typology into its main components [18]. According to this approach, damage is assessed by types of standardized building elements, which can be considered "prototypes" of the exposed structural, mechanical, and finishing elements.
3. Estimation of a restoration/replacement cost for each at-risk element based on its conditions of intrinsic vulnerability to water.
4. Determination of a damage percentage for each component, exposed at different and significant water levels, based on the existing literature and expert opinions gathered through *ad hoc* interviews.

5. Estimation of the total damage to the property at different water levels, calculated as the sum of the estimated intervention costs for each component of the property and expressed in unit terms (€/sqm). These costs can be estimated through a synthetic or an analytic procedure [19].
6. Construction of the typology-specific stage-damage curve and comparison with the average unit market value for the building typology in different municipalities. Such a comparison allows to identify a "critical stage" for each municipality included in the analysis. Such a "critical stage", defined as the most probable water depth at which economic damage equals the market value of the reference property, can be used as a proxy for real estate market resilience, enabling comparisons across municipalities.

3 Investigating Territorial Inequalities in Real Estate Markets' Climate Resilience: The Case of Forlì-Cesena Province

3.1 Introduction to the Case Study

The opportunities and limitations of the proposed methodology toward detecting territorial inequalities in the climate resilience of different real estate markets in Italy are investigated through its implementation in a case study: the Province of Forlì-Cesena, located in the south-eastern part of the Emilia-Romagna Region (Italy). This province represents a relevant study area due to its recent and severe exposure to flood events, such as the 2023 Emilia-Romagna floods, which caused severe damage to the built environment, infrastructures, and population.

Furthermore, the Province of Forlì-Cesena is characterized by a heterogeneous territorial structure, including mountains and hills, plains and coastal zones. This morphological diversity is coupled with the presence of major rivers, channels, and proximity to the Adriatic coast. All these characteristics make the area prone to flooding at different scales. According to the flood hazard maps produced by ISPRA, the area presents different levels of flood hazard, from low to high probability scenarios, making it particularly

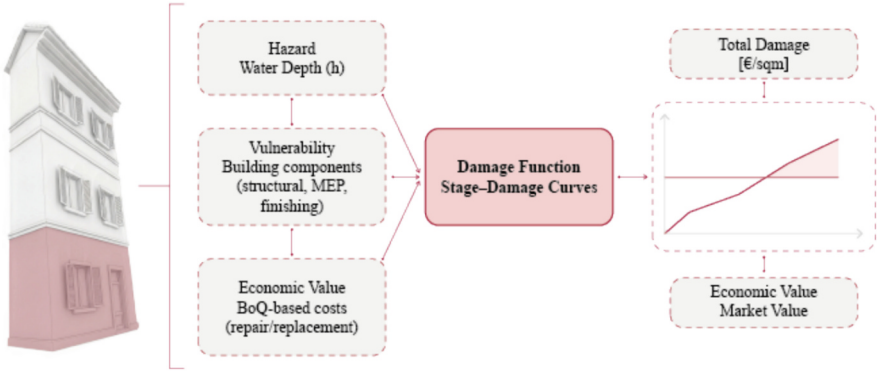

Fig. 1. Methodology adopted for the typology-specific assessment of ex-ante evaluation of flood damage and comparison with the market value (Authors' elaboration)

suitable for the application and testing of the proposed methodology in different risk conditions.

Within this context, municipalities in the Forlì-Cesena province are first analyzed in terms of the NSIA's classification according to their accessibility conditions (centers, peri-urban areas, intermediate areas, peripheral areas, and ultra-peripheral areas). Based on these classifications, the methodology is applied to eight municipalities, belonging to different classes:

- Forlì and Cesena are selected as municipalities classified as "centers", since they offer all secondary education provisions, hospitals with I-level DEA, and at least a silver railway station, according to RFI classification [20];
- Forlimpopoli and Montiano are selected as "peri-urban" municipalities, characterized by good accessibility conditions (less than 20 min to reach the closest center);
- Predappio and Mercato Saraceno are selected as "intermediate municipalities" (20–40 min to reach the closest center);
- Premilcuore and Santa Sofia are selected as "peripheral" municipalities (40–75 min to reach the closest center).

3.2 Methodology Implementation

Once the eight municipalities in the Forlì-Cesena Province were selected as representatives of the different marginality conditions affecting the Italian territory, the methodology implementation (Fig. 1) first required identifying a reference and comparable building typology. Based on the analysis of the main characteristics of the built environment in the study area, the reference building typology was identified in a residential masonry building with three above-ground floors, no basement, and a medium state of conservation. This typology, indeed, is commonly found in the historic centers of the selected municipalities (see Fig. 2).

Its choice, thus, allowed for controlling variations in architectural and structural characteristics, enabling the analysis to focus on territorial differences rather than on the building dimension. For this reason, the methodology implementation focused on an ordinary unit located on the ground floor of the reference building.

The reference property was, then, described in terms of its main building components: structural, mechanical, and finishing elements (see Table 1).

Coming to the estimation of a restoration/replacement cost for each at-risk element, it was based on a detailed Bill of Quantities (BoQ) by resorting to the 2025-edition of the Official Price List of the Emilia-Romagna Region [21]. The following step in the methodology implementation – the definition of a damage percentage of each element exposed to different and significant water depths – was based on integrating data provided by existing literature [22–24] with expert opinions gathered through ad hoc semi-structured interviews [25] (see Table 2). Specifically, interviews involved three experts with complementary backgrounds and expertise on the topic in two steps:

- First, they were asked to identify, among the selected building components, the ones more prone to being damaged in different flooding scenarios and express a qualitative judgement on the magnitude of the damage (low-medium-high);
- Later, they were involved in validating and refining the obtained preliminary "Stage-damage" curves.





Fig. 2. Selected municipalities in the Forlì-Cesena Province and examples of properties corresponding to the reference building type (Authors' elaboration)

Such a step was used as the basis for estimating the total damage to the property at different water stages, calculated as the sum of the estimated intervention costs for each component of the property and expressed in unit terms (€/sqm). Finally, a specific "stage-damage" curve was built for the reference building typology by relating the identified water levels to the corresponding expected economic damage. Such a curve was used as the basis for comparing the estimated total damage with the average unit market

Table 1. Breakdown of the reference building typology into its main structural, mechanical, and finishing components (Authors' elaboration)

Categories of components	Building components
Structural	Solid-brick masonry
	Timber floors
	Pitched roofs with a timber roof structure covered in clay tiles
Finishing	External smooth painted plaster finish
	Timber windows and wooden shutters
Mechanical	Electrical system
	Stormwater drainage system: gutters and downspouts in copper
	Water and gas system
	Heating system

Table 2. Damage assessment percentage of the identified building components according to different levels of water (Authors' elaboration)

Functional Elements	h30cm % damage	h 60 cm % damage	h 150 cm % damage	h 270 cm % damage	Source
Floors	30.0%	50.0%	80.0%	100.0%	[24]
Internal coverings – wall coverings	12.5%	25.0%	62.5%	100.0%	[23]
External finishing – Facades	12.5%	25.0%	62.5%	100.0%	[23]
Internal doors	15.0%	35.0%	60.0%	80.0%	[24]
Internal walls	12.5%	25.0%	62.5%	100.0%	[23]
External windows and doors	15.0%	35.0%	60.0%	80.0%	[24]
Elevation structures	20.0%	30.0%	35.0%	40.0%	[24]
Electrical system	30.0%	50.0%	80.0%	90.0%	[24]
Heating system	30.0%	50.0%	80.0%	90.0%	[24]

value (€/sqm) of the reference building typology in the case-study municipalities, thus identifying the "critical stage" for each municipality. Given the predominantly residential use of the reference typology, the unit market value for each municipality was placed equal to the average unit market value of civil housing in a normal conservation state, provided by the Italian Observatory for the Real Estate Market (OMI) for the 1st semester of 2025 [26].

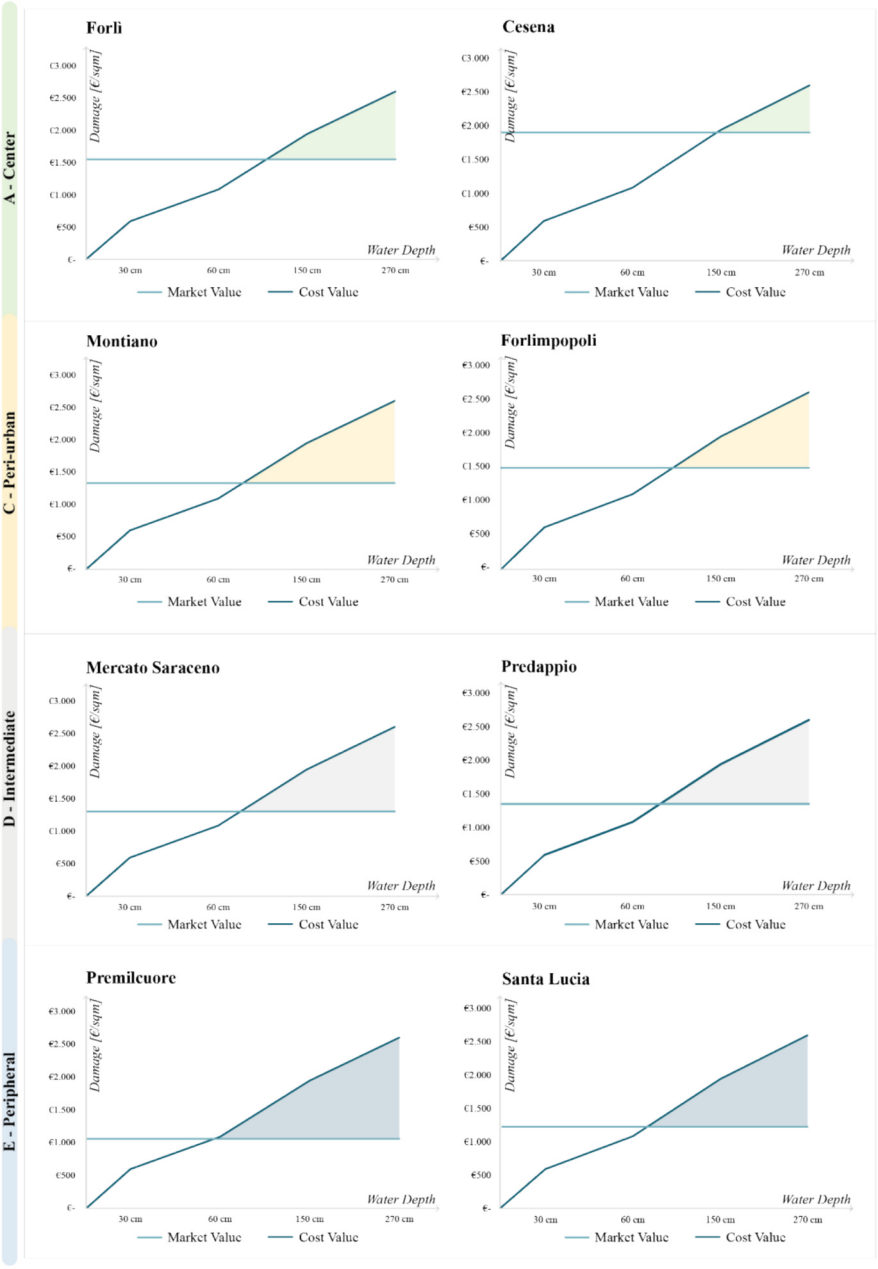

Fig. 3. Comparison between stage-damage curves and market values in the different municipalities and identification of each municipality's "critical stage" (Authors' elaboration)

3.3 Results

The analysis of the results obtained from the methodology implementation in the eight municipalities in the Forlì-Cesena Province allows for interesting reflections about their housing real estate markets' resilience to flood risk (see Fig. 3). The comparison among the different municipalities' "critical stages" – i.e., the most probable water depths at which economic damage equals the market value of the reference property – indeed, highlights that the existing disparities between central and peripheral areas are also mirrored in the resilience of real estate markets to flood risk. Specifically, moving from central to peripheral municipalities, a clear gradient of decreasing real estate market's resilience – proxied by the "critical stage" of water - can be observed.

Indeed, in the "center" municipality of Cesena, the "critical stage" is equal to about 1.5 m. Moving to the "intermediate" municipalities in the Province (Mercato Saraceno, Predappio), the "critical" threshold of water depth drops to about 0.70 m, coming respectively to about 0.65 and 0.6 m in the cases of the "peripheral" municipalities of Santa Lucia and Premilcuore. Given the inverse relationship between the magnitude of water depth/stage and the probability of a flood event with such a depth/stage, these results provide a relevant reading key to interpret the lower resilience to flood risk of real estate markets in peripheral municipalities. Indeed, such a lower resilience does not strictly depend on the magnitude of the hazardous event, but rather on the broader panels of possible flood events that can be "critical" compared to the central areas.

4 Discussion and Conclusions

The paper investigates the resilience of residential real estate markets to flood risk in Italy, a territory characterized by high hazard conditions and pronounced territorial disparities, well expressed by the dichotomy between central areas and "inner areas". By resorting to a multi-step methodology for the ex-ante evaluation of flood damages and their comparison with market values in different municipalities, it allows for reflecting on the existing territorial inequalities in real estate markets' resilience to flood risk, proxied by the "critical stage", defined as the most probable water depth at which economic damage equals the market value of a property.

The results from the methodology implementation, based on the case study of eight municipalities in Forlì-Cesena province (Italy), characterized by different conditions of accessibility to essential services, reveal a clear spatial pattern, with resilience systematically declining from central to peripheral municipalities. In this sense, these results reflect the climate resilience counterpart of the existing socio-economic and demographic disparities, clearly identified by the debate about the future of Italian "inner areas" and the related policy output: the National Strategy for Inner Areas". Furthermore, the lens of the real estate market clearly reveals the close link between climate resilience and other key issues of Italian inner areas, i.e., depopulation. Indeed, given their higher probability of experiencing a flood event with a "critical stage" of water, the obtained results reveal that in "peripheral" areas, climate events can be, more than in other territories, a catalyst for depopulation dynamics.

From this perspective, these findings can inform the spreading of a broader and climate risk-sensitive approach to the planning agenda for Italian peripheral areas, strongly

committed to reducing spatial inequalities. It highlights the need to transpose the differentiated and place-based approach, adopted to the design of intervention for marginal territories, also to the management of climate-related risks, which, till now, has not received the same level of "specific" attention. Specifically, the preliminary findings from this study point to the need to place climate-related risk mitigation and adaptation at the core of planning actions for these territories, which may appear to be less exposed to risk. Moreover, the results hint at the opportunity to adopt a place-based approach to risk planning in marginal territories, based on a more nuanced interpretation of risk beyond simplified application of the traditional hazard-exposure-vulnerability framework. Specifically, they clearly reveal that, in this context, exposure cannot be merely assessed in absolute terms based on the economic value of the assets at risk.

The proposed study, thus, offers insight that, if extended to other territories, may inform the rethinking of traditional planning approaches for risk mitigation and adaptation at the national scale by incorporating principles of spatial equity.

To this aim, future research perspectives will be devoted to extending the proposed analyses to other Italian territories, thus providing a more comprehensive picture of spatial inequalities in real estate markets' resilience, which can really contribute to strengthening the effectiveness and equity of the ongoing policy efforts. Furthermore, the informational value of the proposed approach could be further enhanced by extending the analysis to other building typologies, in terms of both function and structural characteristics, and by using more granular market data than the OMI one, to better capture the underlying mechanisms of spatial heterogeneity.

References

1. OECD: The Economic Consequences of Climate Change. OECD Publishing, Paris (2015). https://doi.org/10.1787/9789264235410-en
2. Weissbecker, I. (ed.): Climate Change and Human Well-being. Global Challenges and Opportunities. Springer, New York (2011). https://doi.org/10.1007/978-1-4419-9742-5
3. Goodess, C.M.: How is the frequency, location and severity of extreme events likely to change up to 2060? Environ. Sci. Pol. **27**(Supplement 1), S4–S14 (2013)
4. Behera, S.K.: Understanding the impact of climate change on extreme events. Front. Sci. **2**, 1433766 (2024). https://doi.org/10.3389/fsci.2024.1433766
5. Allaire, M.: Socio-economic impacts of flooding: a review of the empirical literature. Water Security. **3**, 18–26 (2018). https://doi.org/10.1016/j.wasec.2018.09.002
6. Beltrán, A., Maddison, D., Elliott, R.J.R.: Is it flood risk capitalized into property values? Ecol. Econ. **146**, 668–685 (2018). https://doi.org/10.1016/j.ecolecon.2017.12.015
7. Contat, J., Hopkins, C., Mejia, L., Suandi, M.: When climate meets real estate: a survey of the literature. Real Estate Econ. **52**(3), 618–659 (2024). https://doi.org/10.1111/1540-6229.12489
8. ISPRA. Rapporto sulle condizioni di pericolosità da alluvione in Italia e indicatori di rischio associati (2021). https://www.isprambiente.gov.it/files2021/pubblicazioni/rapporti/rapporto_alluvioni_ispra_353_16_11_2021_rev2.pdf, last Accessed 20 Mar 2026.
9. Loberto, M., Spuri, M.: L'impatto del rischio alluvione sulla ricchezza immobiliare in Italia. Questioni di Economia e Finanza. Banca d'Italia (Occasional Papers), 768 (2023). https://doi.org/10.32057/0.QEF.2023.0768.

10. Rossitti, M., Oteri, A.M., Torrieri, F.: Understanding geographies of architectural heritage abandonment in inner areas: a multi-dimensional investigation. In: Gervasi, O., et al. (eds.) Computational Science and its Applications – ICCSA 2024 Workshops. ICCSA 2024 Lecture Notes in Computer Science, vol. 14819, pp. 3–16. Springer, Cham (2024). https://doi.org/10.1007/978-3-031-65282-0_1
11. ISTAT: La Geografia delle aree interne nel 2020. Vasti territori tra potenzialità e debolezze (2022). https://www.istat.it/it/files/2022/07/FOCUS-AREE-INTERNE-2021.pdf, last Accessed 25 Mar 2026.
12. Cotella, G., Vitale Brovarone, E.: The Italian National Strategy for inner areas: a place-based approach to regional development. In: Banski, J. (ed.) Dilemmas of Regional and Local Development. Routledge, Abingdon-on-Thames (2020). https://doi.org/10.32057/10.4324/9780429433863-5
13. Rossitti, M., Torrieri, F.: The THEMA tool to support heritage-based development strategies for marginal areas: evidence from an Italian inner area in Campania region. Region 9(2), 109–129 (2022). https://doi.org/10.18335/region.v9i2.394
14. Merz, B., Kreibich, H., Thieken, A., Schmidtke, R.: Estimation uncertainty of direct monetary flood damage to buildings. Nat. Hazards Earth Syst. Sci. **4**(1), 153–163 (2004). https://doi.org/10.5194/nhess-4-153-2004
15. Thieken, A.H., et al.: Methods for the evaluation of direct and indirect flood losses. In: Simonovic, S.P., Bourget, P.G., Blanchard, F. (eds.) Proceedings 4th International Symposium on Flood Defence (ISDF), vol. 98,
16. Molinari, D., Ballio, F., Menoni, S., Handmer, J.: On the modeling of significance for flood damage assessment. Int. J. Disaster Risk Reduction. **10**, 381–391 (2014). https://doi.org/10.1016/j.ijdrr.2014.10.009
17. Torrieri F., Rossitti M. (2020). Spatial cost benefit analysis in flood risk management: evidence from a case study in Italy. Sustainable Mediterranean construction. Special Issue 4, 51–55 (2020). https://www.sustainablemediterraneanconstruction.eu/en/download/si-2020-04-051, last Accessed 30 Mar 2026.
18. Manganelli, B.: Il deprezzamento degli immobili urbani. FrancoAngeli Editore, Milano (2011)
19. Torrieri, F., Oppio, A., Rossitti, M.: Damage assessment for architectural heritage: the Cavallerizza Reale complex in Turin. Valori e Valutazioni. **30**, 71–84 (2022). https://doi.org/10.48264/vvsiev-20223005
20. DPS – Dipartimento per lo Sviluppo e la Coesione Economica: Le aree interne: Di quali territori parliamo? Nota esplicativa sul metodo di classificazione delle aree. (2014). http://www301.regione.toscana.it/bancadati/atti/Contenuto.xml?.id=5081285&-nomeFile=Delibera n.32 del 20-01-2014-Allegato-A, last Accessed 30 Mar 2026
21. Regione Emilia Romagna. Elenco Regionale dei prezzi delle opere pubbliche della Regione Emilia-Romagna (2025).
22. Giuliani, F., De Falco, A., Cutini, V., Di Sivo, M.: A simplified methodology for risk analysis of historic centers: the world heritage site of San Gimignano, Italy. Int. J. Disaster Resilience Built Environ. **12**(3), 336–354 (2021). https://doi.org/10.1108/IJDRBE-04-2020-0029
23. Davis, S.A., Skaggs, L.L.: Catalog of Residential Depth-Damage Functions Used by the Army Corps of Engineers in Flood Damage Estimations. U.S. Army Corps of Engineers, Fort Belvoir (1992)

24. FEMA: Hazus Flood Technical Manual. Hazus 5.1 (2022), https://www.fema.gov/sites/default/files/documents/fema_hazus-flood-model-technical-manual-5-1.pdf, last Accessed 15 Mar 2026.
25. Dell'Ovo, M., Torrieri, F., Oppio, A.: How to model stakeholder participation for flood management. In: Dargam, F., Delias, P., Linden, I., Mareschal, B. (eds.) Decision Support Systems VIII: Sustainable Data-Driven and Evidence-Based Decision Support. ICDSST 2018 Lecture Notes in Business Information Processing, vol. 313, pp. 67–75. Springer, Cham (2018). https://doi.org/10.1007/978-3-319-90315-6_6
26. Agenzia delle Entrate. Osservatorio del mercato immobiliare, https://www.agenziaentrate.gov.it/portale/aree-tematiche/osservatorio-del-mercato-immobiliare-omi, last Accessed 20 Mar 2026.