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The MOVIDA Project to Support the Update of Flood Risk Maps in the Po River District: methodology for flood damage assessment

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Abstract

Effective planning of flood risk mitigation strategies requires to assess costs and benefits of alternatives of intervention, in terms of required investments and impacts avoided. For this reason, the European Commission asks Member States to develop and periodically update flood hazard and risk maps, to be used at the basis of Flood Risk Management Plans. Flood damage assessment and mapping is a critical step in such a process, due to the lack of consolidated practice both in the literature and the technical domains; this results in the present availability of mostly qualitative damage maps, with limited usability for flood risk management. By allowing scientists and practitioners working together, the MOVIDA project developed a newly procedure, embracing state of art damage models and knowledge on damage mechanisms, for an analytical assessment and mapping of flood damage in the Italian territory, with specific reference to the Po River District (North of Italy). The procedure was specifically conceived to support cos-benefits or multi-criteria analyses of flood risk mitigation measures, focusing on all categories of exposed assets and suppling, when achievable, a monetary evaluation of flood damage. The procedure was successfully implemented in the areas of potentially significant flood risk (APSFRs) in the district; results represent a significant improvement with respect to presently available damage maps, both in terms of assets considered and information supplied.

Keywords: Flood damage, Floods Directive, MOVIDA, Po River District, Italy

1. INTRODUCTION

The European Floods Directive (2007/60/EC) requires Member States to develop and update, every six years, flood hazard and risk maps, to be used as the information basis for the development of Flood Risk Management Plans (FRMPs). To support such a process, the Po River District Authority (North of Italy) signed in May 2020 an agreement with 20 Italian Universities and the Italian National Research Council (CNR) with the aim of transferring the state of the art about hydrology (including climate change effects), hydraulics and damage modelling into the production of the new maps, to be delivered by December 2021. This contribution describes the methods and tools developed by the consortium devoted to flood damage modelling (composed by 8 Universities and the CNR), in the MOVIDA (MOdello per la Valutazione Integrata del Danno Alluvionale) project. The objective of the project was to develop tools to perform an analytical evaluation and mapping of expected flood damage in the areas of potentially significant flood risk (APSFRs) of the district (Figure 1), overcoming the limitations of present maps where the evaluation of risk remains highly qualitative and subjective (Molinari et al. 2016). Proper damage assessment tools were identified for all the five categories of exposed assets included in the Floods Directive (i.e., population, infrastructures, economic activities, environmental and cultural heritage, and na-tech sites) and collected in a procedure for flood damage assessment at the district level. These tools are thought to address specific requirements: (i) being valid/applicable for the whole District, (ii) being based on standardized and institutional data, available at national level, and (iii) being calibrated (and possibly validated)

in the Italian context. The focus was mainly on direct damage, although indirect damage assessment was unavoidable for certain assets.
The level of analysis achieved by the procedure varies with the considered type of assets, according to the inhomogeneous level of development of flood damage models and the present limited knowledge of flood damage mechanisms.
A dedicated open source geographic information system was finally developed to support the implementation of the procedure by technicians or non-expert users (ISYDE – open source Information System for Damage Estimation).
It is worth noting that the procedure has been though with the specific objective of meeting planning requirements linked to the Floods Directive; still, results of its application can be useful also for the analysis of other hazards or for other mitigation scopes (e.g., for emergency planning)

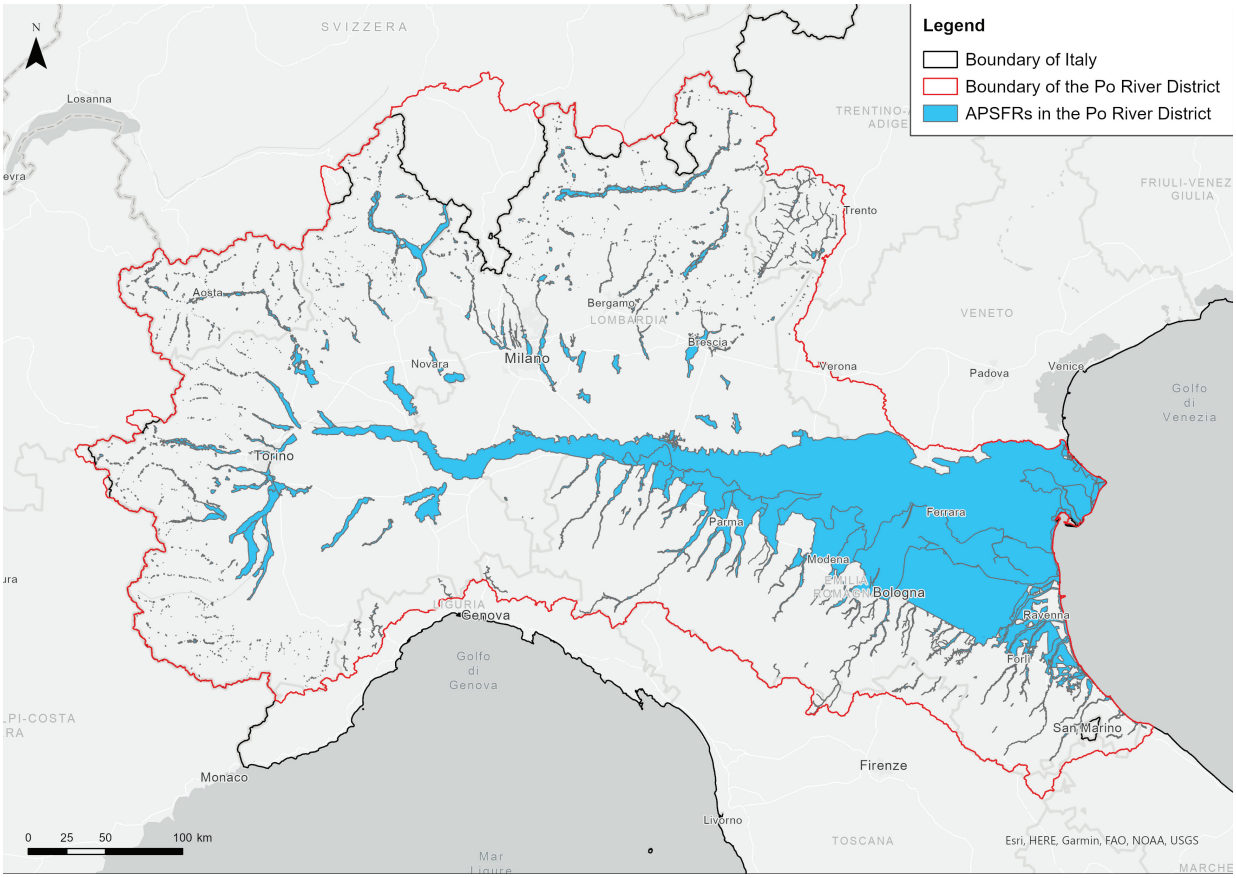

Figure 1. Areas of potential significant flood risk (APSFRs) in the Po River District.

2. METHODS

In the procedure, damage assessment is carried out differently for the various categories and sub-categories of exposed assets identified by the Floods Directive: population, infrastructures (classified as: strategic buildings, roads and railways), economic activities (classified as: residential buildings, industrial/commercial activities and agricultural activities), environmental and cultural heritage, and na-tech sites. For each category, a different level of analysis is achieved, according to the current state of the art on flood damage modelling. In detail, the evaluation may refer to actual expected damage or to potential/maximum damage. Moreover, damage may be quantified in quantitative or qualitative terms (i.e., high, medium, low damage); in the first case, damage assessment can support the comparison of different mitigation strategies by means of cost-benefit or multi-criteria analyses. In the second, cost-benefit analyses are not supported anymore but damage evaluation can still feed multi-criteria approaches. A final remark regards the possibility of evaluating damage in monetary terms only for tangible assets. Table 1 shows the different assets considered, and the corresponding level of analysis, which can be achieved thanks to the MOVIDA tools.
The modularity of the procedure (working for different categories of exposed assets and various levels of analysis) makes it flexible to be applied in different implementation contexts, being characterised, for example,

by the lack of data on certain assets or the lack of information on the distribution of water depth within the flooded area.
To support risk assessment in the APFSRs, the procedure is implemented for various hazard scenarios. According to the Floods Directive, almost three scenarios must be considered, corresponding to low, medium and high probability of occurrence. The characterisation of each scenario, in terms of the return period of the flood, varies within the APFSRs, according to the considered river catchment.

Table 1. Level of analysis achievable by means of MOVIDA for the different categories of assets. The symbol "€" indicates those assets for which damage is estimated in monetary terms

LEVEL of ANALYSIS	Potential damage	Expected damage
Qualitative assessment		Roads and railways Cultural heritage
Quantitative assessment	Population Strategic buildings Industrial/commercial activities (€) Na-tech sites Protected environmental areas	Residential buildings (€) Agricultural activities (€)

2.1 Steps of damage assessment

Flood damage assessment, which (as previously discussed) is carried out separately for each category and sub-category of exposed assets, can be divided into four consecutive phases:

i. Identification of input data; available databases for the definition of the hazard and the exposure scenario are identified, as well as those allowing for the identification of the spatial distribution of the vulnerability parameters within the flooded areas. Flood hazard maps included in the last update of the Flood Risk Management Plan (FRMP) of the Po River District are the main reference for hazard data, especially regarding the flood extent and the distribution of the water depth within the flood perimeter. The databases for the evaluation of exposure and vulnerability vary instead with the typology of assets; still all of them owns the following characteristics, which allow to compare different areas within the whole District: data are available at the national level, or at least at the district one, and are of institutional nature (if possible).
ii. Definition of the scale for both the analysis and the representation of results; the scale of the analysis depends on the one hand on the level of detail of available input data; on the other hand, on the scale of implementation of models available for the damage evaluation. In particular, depending on the type of asset under consideration, the analysis can be performed at the level of the individual exposed element (i.e., microscale) or at more aggregated scales, such as the census blocks of Italian National Institute of Statistics or cadastral units (i.e., mesoscale). The scale of representation of results is defined on the basis of the objective of the assessment. Within the scope of the MOVIDA procedure and for the purposes of FRMPs development, damage outcomes are returned at the census block level, according to a District point of view.
iii. Exposure assessment – The exposure scenario, which represents the maximum (potential) damage in case of flood, is defined in physical and, if possible, in monetary terms, by intersecting the hazard scenario and the data concerning the spatial distribution, the amount and the value of exposed elements.
iv. Damage assessment – Flood damage is evaluated by means of models that have been calibrated and validated in the Italian context. As previously mentioned, according to the category of exposed assets, these models provide a quantitative (and monetary, if possible) or qualitative estimate of the expected (or potential) damage in case of flood. Some of the most important references to the models implemented within the MOVIDA project are listed in the bibliography.

3. RESULTS

The MOVIDA procedure was implemented in all areas of potential significant flood risk (APSFRs) in the Po District, by means of the ISYDE tool. The results of the analysis can be found in the reports prepared for each APSFR, as annexes of the updated FRMP of the Po River District (https://pianoalluvioni.adbpo.it/piano-gestione-rischio-alluvioni-2021). Each report shows the results of the flood damage assessment in the area, to the different categories of exposed assets, by means of tables, charts, and maps. Especially, two types of

outcomes are provided: (i) the overall expected damage, at the APSFR level, in addition to the total value of the main exposure and vulnerability variables, for all the three hazard scenarios indicated by the Floods Directive, (ii) the spatial distribution of the damage within the study area only for the most significant hazard scenario or, in the absence of this, the scenario with a medium probability of occurrence (typically corresponding to the reference scenario in the design of mitigation measures). The spatial distribution of the outputs for all scenarios is available in the database of the project.

As an example, the results of the damage assessment for the residential sector in the APSFR of the Panaro River are shown hereinafter. Specifically, Table 2 summarizes the monetary value of exposure and damage for residential buildings in the potential flooded area, for all the hazard scenarios; the map in Figure 2 shows the spatial distribution of the expected damage to residential buildings per unit of flooded area (EUR/km^2), at the census block scale, for the medium probability scenario (Return Period = 200 years).

Table 2. Exposure and damage for the residential buildings in flooded area, for the three hazard scenarios.

EXPOSURE	**High probability scenario - H (RP = 20 years)**	**Medium probability scenario - M (RP = 200 years)**	**Low probability scenario - L (RP = 500 years)**
Total number of buildings in flooded area [nr.]	58	18 924	20 445
Total surface of buildings in flooded area [m^2]	28 924	3 458 207	3 763 206
Monetary value of exposed buildings [millions of EUR]	38	4 419	4 812
Average monetary value per building [EUR]	451 378	331 522	341 448
DAMAGE	**High probability scenario - H (RP = 20 years)**	**Medium probability scenario - M (RP = 200 years)**	**Low probability scenario - L (RP = 500 years)**
Monetary damage [millions of EUR]	2	457	513
Average monetary damage per building [EUR]	32 300	26 540	29 900

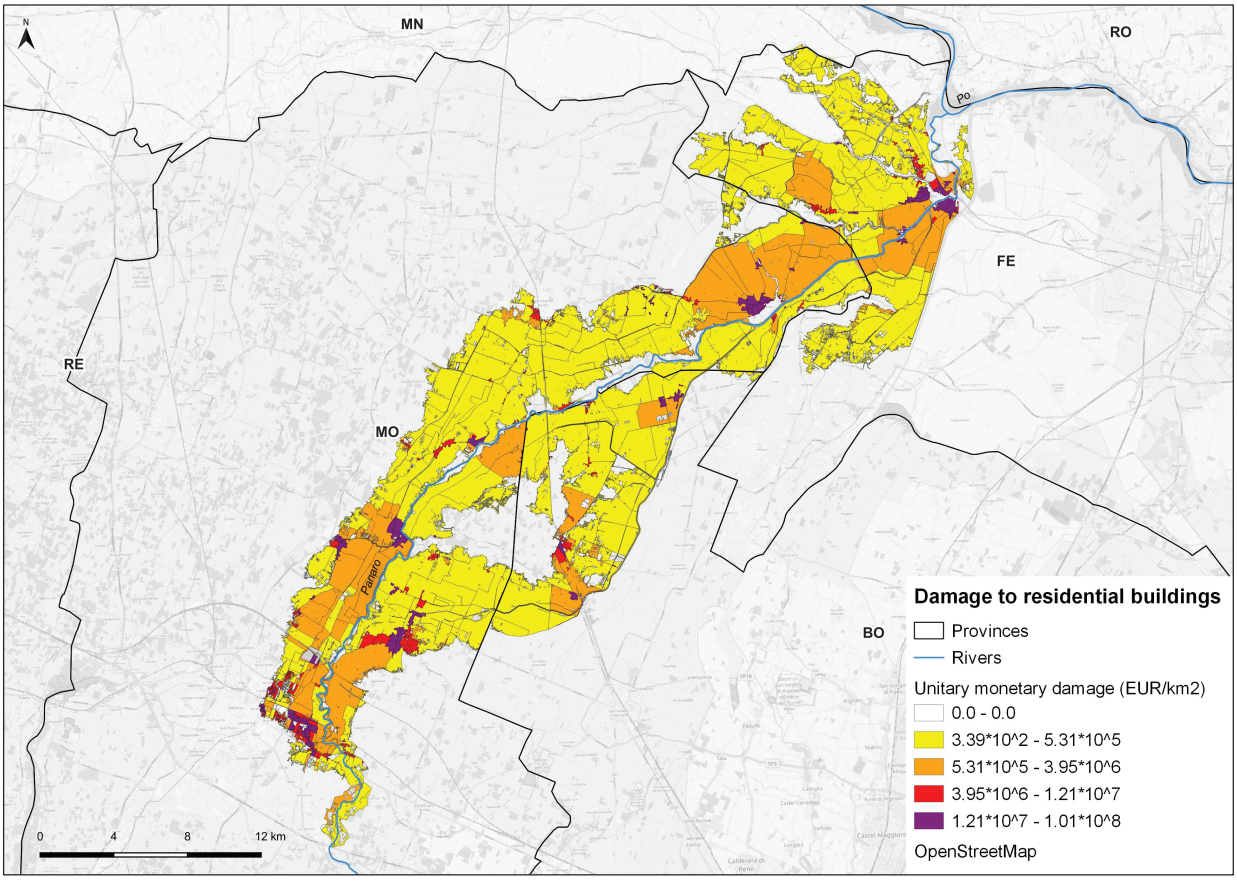

Figure 2. Monetary damage to the residential buildings (per km^2 of flooded area), at the census block scale, for the medium probability scenario (RP = 200 years), in the APSFR of the Panaro River.

4. DISCUSSION AND CONCLUSIONS

Results obtained from the implementation of the MOVIDA procedure represent a significant improvement with respect to presently available damage maps, both in terms of assets considered and information supplied. In detail, differently than current qualitative maps, damage estimation supplied by MOVIDA supports the cost-benefit or the multi-criteria analysis of risk mitigation actions to be defined in Flood Risk Management Plans. Indeed, the analysis of damage assessment outcomes enables the identification and localization of any possible spatial and typological hotspot in a specific APSFR, and the comparison among different intervention scenarios. On the other hand, further methodological developments are still required to obtained more robust and comprehensive flood damage assessment, including all kinds of assets and types of damage. With respect to this the experience carried out in the MOVIDA project allows to identify more urgent research needs and to carry out related research with specific application to a few APSFRs in the Po District. In particular, research activities are ongoing on the (quantitative) estimation of flood mortality, indirect damage to people, direct and indirect damage to economic activities, damage to cultural and environmental assets, and damage to infrastructures, also with specific reference to coastal areas. Implementing results of such activities will be the objective of the next revision of flood risk maps.

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