On the implementation of the French methodology for flood damage assessment to economic activities

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Abstract. Flood damage assessment to economic activities is affected by a general paucity of data to both describe the strong diversity that characterises this sector and validate existing flood damage models. This study aims to assess the applicability, the validity, and the transferability of the methodology for the estimation of flood damage to economic activities developed in France by the working group GT AMC, led by the Ministry of Environment. The method was tested in two case studies: the flood that affected the Île-de-France Region in 2016 and the 2002 flood in the city of Lodi, Italy. Flood damage estimates were compared to observed losses in order to appraise their uncertainty range, to define a methodology of application that reduces such an error, and to supply an evaluation of the methodology transferability.

1 Introduction

To answer the request of performing cost-benefit analysis for flood risk management projects, France is equipped with a multi-criteria analysis methodology and national damage functions to assess damage for different flood exposed items including economic activities. Tools for the evaluation of flood damage to economic activities are valuable because they are less numerous compared to models to evaluate damage to other sectors (as residential or public infrastructures) and because enterprises are among the most affected items in case of flood, and then among the fundamental actors for the development and resilience of communities (Pesaro et al., 2018). Two main obstacles prevent the development and implementation of flood damage models for enterprises: the great variety and quantity of data required to describe the strong diversity that characterises enterprises and their vulnerability to floods, and the lack of data on losses due to past events that limits the possibility to transfer and validate existing tools to different countries. This study aims to assess the applicability, the validity and the transferability of the French damage functions for the estimation of flood damage to economic activities. Firstly, the functions were tested and validated in a French case study: the flood that affected the Île-de-France

Region in 2016 due to the overflow of the Seine River. Then, their transferability was verified in a foreign case study: the 2002 flood in the city of Lodi, Lombardia Region, Italy. In both case studies, obtained flood damage estimates were compared to observed losses. The validation exercise in the French case study tried to give a solution to the problem of working with few information about the identity of the activities, developing a method to localise and assess the damage. The test of transferability in the Italian case study revealed which types of data (and with which degree of accuracy) for damage assessment could be available in another country. To conclude, the comparison with observed data, in both case studies, supplied the evaluation of the uncertainty range of the damage estimates.

2 Case studies

2.1 French case study

Intense rainfall affected the northern half of France from May, 25th to June, 6th 2016, causing many rivers overflows, particularly in the Loire and the Seine catchments. In the Île-de-France Region, several urban areas were affected. Estimated insured damage according to the CCR - Caisse Centrale de Réassurance was around €1.2 billion in total

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(CCR, 2016). This case study was chosen thanks to the collaboration with the association MRN – Mission Risques Naturels. MRN was born from the willingness of two French insurance trade associations (FFSA and GEMA), with the aim of giving them support, knowledge and expertise on natural risk management, with particular attention to climatic damaging events. For this case study, MRN collected 737 compensation payments concerning economic activities in the Île-de-France Region from different insurance companies. In order to maintain the confidentiality of data, only the information about the address of the enterprise was provided. To each compensation is associated the total direct damage, the sum of damage to the structure and to contents. The hydraulic reconstruction of the 2016 event was provided by the Public Territorial Basin Establishment Seine Grands Lacs.

2.2. Italian case study

On 26-27 November 2002, the city of Lodi (Northern Italy) was struck by a flood event caused by the overflow of the Adda River, as a result of two weeks of heavy rainfalls. Severe damage occurred to houses, commercial activities, farms and factories. Damage data comes from claims presented by private citizens to the municipal authority to ask for public compensation. In particular, regarding economic activities, the claims report a total damage (including both structure and contents) equals to 3.35 million €. The hydraulic simulation of the event was performed by a team of researchers of Politecnico di Milano (Scorzini et al., 2018).

3 Method

French damage functions were developed by the working group GT AMC - Groupe de Travail Analyse Multicritères -, led by the Ministry of Environment, through a synthetic approach and the use of the software floodam, which generates relative damage functions, subsequently converted in loss damage functions with the use of the national database ESANE to estimate, which provides estimates of the value of stock and equipment for several categories of activities (Grelot and Richert, 2019, Bremond et al., 2018). In fact, the functions developed by the French Ministry of Environment are of three types, each being a function of water depth and flood duration, for each NACE category: one computes damage to equipment and stock in €/number of employees, the second computes damage to the structure in €/m² occupied by the activity, and the third one supplies total damage, still in €/number of employees; this last function can be used in case the surface of the enterprise is unknown. So, to calculate the total damage, two kinds of data are required: the number of employees, the NACE code of the activity; additionally, information on the surface of the buildings occupied by the activities is optional but recommended.

3.1 French case study

In France, it is possible to easily implement the functions for the total damage and the equipment damage thanks to the database Sirene, which is a national and updated daily by the French National Institute for Statistics and Economic Studies.

In particular, for each activity, it supplies information about the NACE code and the number of employees. The information about the surface of the activities is not present. The estimation of this variable depends on an independent process of activities localisation

However, the validation process was not so easy to implement; the main obstacle was the identification of the activities affected by the 2016 flood event. In this case study, the only available information about the enterprises affected was their postal address. This information is not sufficient to identify the affected activities, because, for a unique address, it is possible to find several commercial and industrial establishments in the Sirene database. So, we decided to adopt the cadastral parcel as the unit of analysis, instead of the single activity. Cadastral parcels are defined as portions of land belonging to the same owner, or to the same joint ownership, and constituting an independent land unit. Each address was then linked to a parcel that can contain one or several Sirene establishments. In order to give a more specific localisation than the parcel, as e.g., the building, the BD Topo, a national topographic database including all French buildings geometry and maintained by the National Institute of Geographic and Forest Information, was analysed. In this database, three types of buildings are distinguished: undifferentiated (i.e. not having a particular function, as residential buildings or offices), remarkable (like administrative or religious buildings) and industrial (i.e., buildings with industrial, commercial or agricultural character). Unfortunately, this information was not enough to localise the single activities because, in a parcel, it is possible to have a mismatch between the number of establishments in Sirene and the number of industrial buildings indicated by the BD TOPO. The doubts about how to localise an activity remained unsolved; How to choose the right building where the activity is localised? How many and which floors are occupied by an activity? And which is the distribution of the employees in the building floors? Only specific and detailed field surveys can really answer these questions, but they are too much time consuming and costly in big areas like the one under investigation. Therefore, the damage simulation was performed considering different conditions and assumptions. In detail, two scenarios were considered, depending on whether or not the number of affected activities is known. In the first scenario, the number of affected activities in a parcel is unknown, as in the case of ex-ante analysis or in absence of observed data, and damage is evaluated as the sum of damage to all the activities in the parcel. We distinguished among 4 sub-cases (DAM 0, DAM 1, DAM 2, DAM 3) according to different assumptions about the number of employees and the number of buildings to consider in the damage simulation.

- DAM 0: Damage is estimated only with the total damage functions, neglecting the information about the surface of the buildings.
- DAM 1: It is assumed that the activities in the parcels occupy all the buildings and that the total number of employees is at ground floor. The surface of buildings is considered in damage estimation.
- DAM 2: We assigned to the type of activities the most probable type of building between undifferentiated or industrial and we selected only the corresponding types. For the undifferentiated buildings, the maximum number

of employees per floor was computed by considering the legal minimum area of a workstation equal to 10 m² per person. For industrial building, the total number of employees is assumed at ground floor.

- DAM 3: The assumptions are the same as DAM 2, except for the number of employees that was computed by dividing the total number of employees by the number of floors of the buildings.

In the second scenario, we considered the number of compensations associated to the same address (N) as the number of activities actually affected by the flood in the same parcel, and we used this information to differentiate among three sub-cases:

- DAM_MAX: damage was computed as the sum of damage of the N activities, among all the activities present in the parcel, associated with the highest level of damage.
- DAM_MIN: damage was computed as the sum of damage of the N activities, among all the activities present in the parcel, associated with the lowest level of damage.
- DAM_AVER: damage was computed by considering the average of the activities' damage in the parcel multiplied by N.

To compare the insurance data and the simulated damage, a specific library was developed in R, to compute the total damage, the deviations between the two sets of data, and the average of the deviations. The library guarantees the data confidentiality and aims to require the minimum effort by the supplier of empirical data.

3.2 Italian case study

In order to investigate the transferability of the damage evaluation method to Italy, it was necessary to verify the presence of similar and coherent databases than those adopted in France. As highlighted in section 3.1, in order to implement the French methodology, it is necessary to know the NACE code, the number of employees and optional to know the surface of the building, of all the investigated enterprises. Most of such data are supplied in France by the Sirene database; unfortunately, Italy does not have a similar database, but different databases (that are regional, municipal or maintained by private institutions), which are not always open and do not usually include updated and comprehensive descriptions of the enterprises. This is a big limitation to the implementation of the methodology ex-ante. In this case study, in fact, the information about the NACE code and the address of the affected activities were obtained from the refund request forms. With this information, it was possible to identify buildings owning to the activities, and assigning to them a surface. This was done by implementing the regional topographic database (which supplies information on all regional buildings geometry) and the support of Google Street View, coupled with a survey on the field. In case more activities were in the same buildings, the surface of the building was divided by the number of activities.

The number of employees was instead derived from national census data that supply the number of employees and local units for NACE code, but at the census block level. Moreover,

the French damage curves were calibrated using the Italian value of equipment supplied by the Italian National Statistical Institute (ISTAT) as the net capital stock, that is “the sum of the written-down values of all the fixed assets still in use; it can also be described as the difference between gross capital stock and consumption of fixed capital” (ISTAT). This value is available for NACE categories, at first or second level, at the census block level.

Like in the French case study, damage assessment was performed considering and not considering the information about the surface. In the case “no surface”, water level was evaluated in a point (the activity position), total damage and equipment damage were computed with the corresponding damage functions, while building damage was evaluated as the difference between total damage and equipment damage. In the case “with surface”, water depth was evaluated by averaging the water level values of the cells occupied the building, building and equipment damage were evaluated with corresponding damage functions, and the total damage corresponds to their sum.

4 Results

For the French case study, starting from the address of the MRN compensations, we identified 318 parcels that contain 1953 Sirene establishments and 437 MRN compensations in total. Only 148 parcels (where 179 compensations are localised) were inside the flooded area. **Table 2** shows the observed and the simulated damage by the French damage curves for the economic activities in the parcels in the inundated area.

	Total damage 10 ⁶ €	Mean damage 10 ³ €	Mean relative deviation
Observed	5.2	34.8	
DAM 0	24.5	143.7	9.4
DAM 1	25.5	172.3	10.8
DAM 2	24.8	167.4	10.6
DAM 3	21.3	143.8	7.8
D MAX	15.7	106.3	6.2
D MIN	5.4	36.5	1.7
D AVER	9.0	61.1	2.7

Table 1. Comparison between simulated and observed damage data in French case study.

In the Italian case study, the Municipality of Lodi collected claims related to 119 activities, but we had all the necessary information for damage assessment only for 83 of them: NACE code, observed damage, and localisation in a building. The observed and simulated damage for the economic activities in the flood event of Lodi is shown in **Table 2**. The Italian claims have the advantage to distinguish between damage to building structure, and damage to equipment and stock, so it was possible to compare both the total damage and its components.

	Total 10 ⁶ €	Equip+stock 10 ⁶ €	Building 10 ⁶ €	Equip+stock/Total
Observed	3.3	2.6	0.6	80%
Simulations no surface	10.4	7.2	3.2	70%
Simulations with surface	10.4	8.3	2.1	80%

Table 2. Comparison of observed and simulated damage for the Italian case study.

Figure 1. Comparison of observed and simulated damage for the Italian case study.

5 Conclusion and discussion

Table 1 shows that simulations tend, in general, to overestimate damage. The simulation with the minor mean deviation is DAM_MIN, that uses the N minimum damage estimates of the activities in the parcel. The consideration of all the activities in a parcel (Cases DAM 0, 1, 2, 3) entails an overestimation of 4/5 times. This result is important because it gives us a range of estimation error, in the case the parcels exposed to flood are known, but it is unknown which activities, located in the parcel, actually risk being inundated. The comparison between DAM 0 and DAM 1 supplies another important information: the consideration of building surface does not significantly improve the total damage estimation. This assertion is valid also for the Italian case study that shows, in **Table 2**, that the total damage estimate is close to 10.4 M€, considering or not the surface. On the other hand, the Italian case study shows that damage to single components (equipment and building) changes when the surface is considered or not. The simulated damage to equipment and building is different in the two cases but remains in the same order of magnitude. In conclusion, we can then state that there is a mismatch between the influence of data about surface on the total damage estimation, and the effort to collect this information. Moreover, **Table 2** shows that damage to equipment and stock is the main portion of the total damage. All these considerations highlight the important role, in this methodology, of the information about the number of employees exposed to flood risk.

Regarding the transferability of the damage model, literature shows that the performance of foreign models can be affected by high levels of error, with overestimation from two to eleven times (Molinari et al., 2020, Scorzini and Frank, 2017). So, for the Italian case study, the overestimation of 3.15 times is not unacceptable. This error can be attributed to two main reasons: the difference of the geographical and economic context and the inaccuracy of input data (as the

number of employees or the value of the equipment). In fact, the application to the Italian case study showed that the French methodology is strongly related to the type of data that are available in France, but that it is possible to find similar data for its implementation, although with some approximation. Both case studies highlight another important element that characterises damage models validation. The number of usable data, compared to the initial data set, is inevitably reduced, due to the different purpose for which the validation data were originally collected (Molinari et al., 2019), i.e. usually compensation. This element suggests that challenges about the availability and the accuracy of past flood data for flood damage assessment remain open.

Further tests of the methodology are still required: to investigate if the overestimation tendency is confirmed, to define a method to assign the number of employees by storey (according to this test, we will choose the minimum number), and to verify if the R library to compare insurance damage data and simulations could be reused. The method implemented in the R library to compute damage and compare observed and simulated data in the French case study respects the request of privacy by private companies, and, therefore, could be re-proposed in future collaborations between researcher/public authorities and the insurance sector. In fact, in France, the insurance sector has a key role in disaster risk reduction and flood damage compensation, and collaborations between this sector and public and research actors are necessary and desirable. In particular, it is the insurance sector that owns data about the affected enterprises and the losses that are necessary to validate damage functions. Still these data are characterized by a high level of confidentiality; consequently, data available to researchers could be deprived by very important information for the validation process and in particular the geo-localisation of affected activities, like the name of the enterprises or other protected data.

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