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Estimating flood damage to crops and implications for flood risk assessment

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Introduction

Damage models are a key element for quantitative (i.e., economic) flood risk assessments, as they relate information on flood hazard and vulnerability features of exposed items to express expected losses (Merz et al. 2010). While more advanced modelling tools exist for estimating direct damage to residential properties, only recently the agricultural sector has started to receive increasing attention from researchers. In this context, Molinari et al. (2019) developed AGRIDE-c, a synthetic, expert-based model relying on a coupled approach considering the physical damage to crops (i.e., yield reduction as a function of hazard and vulnerability features) and its economic effects in terms of loss of revenue and variation in production costs for farmers. The model, after adaptation to the context of implementation ("regional model", as shown in Scorzini et al. 2021), allows estimating, for each crop type, the economic damage caused by a flood event of certain hazard characteristics. Differently from other sectors, crop damage depends on many hazards parameters beyond traditional variables reported in flood hazard maps, as water depth and flow velocity; indeed, other important influencing factors include inundation duration, water salinity, yield of sediments and/or contaminants, as well as the month of flood occurrence, due to the seasonality of crop production and changing plant vulnerability over the different phenological phases. In particular, the last factor would imply a shift from the traditional representation of inundation scenarios based on annual probability (i.e., return period), as requested for instance by the Floods Directive ("very rare/rare/frequent flood scenario"), to monthly-based risk estimations.

By means of an example of application for the system of Panaro and Reno river basins in northern Italy, this study aims at showing the usefulness of a model like AGRIDE-c for supporting informed decisions on flood risk management.

Materials and methods

Agricultural flood risk assessment with the regional analytical model of AGRIDE-c for cereal crops (maize, wheat, barley, grassland), developed in the framework of the MOVIDA project (https://sites.google.com/view/movida-project), requires the combination of hazard data with information on exposure in flood affected areas. In this study, the available inundation maps produced by the Po River Basin Authority for three synthetic flood events with return period of 25, 100 and 500 years were the main hazard input data; these consisted of raster files depicting inundation features in terms of water depth and flow velocity, at a resolution of 10 m and 5 m for the Reno and Panaro River, respectively. For the sake of conciseness, inundation duration was assumed to be fixed and shorter than 5 days, as typical for the region. The four considered crop types, which extended over an area of about 286 km^2 for the 100-year flood, were identified by using the agricultural parcel dataset of the Emilia Romagna Region.

With the total losses obtained with the application of AGRIDE-c for each flood scenario, it was possible to determine the expected annual agricultural damage (EAD), as follows:

$$EAD = \sum_{j=1}^{N} \Delta P_j \cdot D_j \quad (1)$$

where ΔP_j and D_j are respectively the exceedance probability increment and average damage of two events with exceedance probabilities (P_j) and (P_{j+1}). However, the seasonal varying susceptibility of agricultural crops

would affect the estimation of flood damage D_j. To evaluate the influence of accounting for this variability on an ex-ante flood risk assessment, the EAD was calculated in two different ways: the first considering D_j as the weighted average of possible losses occurring in the different months of the year (D_{ave}), with weights given by the probability of flooding in each specific month, and the second simply assuming for D_j the maximum value of the monthly expected losses (D_{max}). In the first case, monthly maximum flow timeseries available for river gauges in the areas were considered for deriving monthly flood probabilities. The implications of the method selected for calculating D_j on the results of decisional processes for the identification of risk reduction measures are here exemplified by considering a possible scenario concerning the calculation of the maximum cost for economically efficient structural mitigation measures in the area (under the assumption of totally avoiding agricultural damages). The benefit-cost ratio (BCR), defined as the ratio between discounted benefits (i.e., avoided damages) and costs over the lifetime of the intervention, is considered as an indicator for evaluating the cost-effectiveness.

Results and concluding remarks

The results of monthly damage calculations are reported in Figure 1 (left panel), which indicates the largest losses to be expected for an event occurring between May and July, with D_{max} ranging from about 1.7 M€ for the 25-y flood (July) to 29.4 (April-May) and 40.5 M€ (July) for the 100-y and 500-y flood, respectively. However, the combination of monthly losses with the related flooding probability would lead to a weighted average annual damage (D_{ave}) for the Panaro-Reno river system of about 1.2, 17.8 and 23.5 M€ for the 25-y, 100-y and 500-y event, respectively. These differences have clearly an impact on the calculation of the EAD and, consequently, on the results of the cost-benefit analysis (right panel of Figure 1), which would indicate economically feasible mitigation measures with costs lower than 7-12 M€ or 13-20 M€ (depending on the discount rate, t) when using D_{ave} or D_{max} for the assessment.

Overall, these results indicate the advantages of flood damage models, like AGRIDE-c, considering the effect of seasonal varying susceptibility of the exposed asset for a more informed flood risk management.

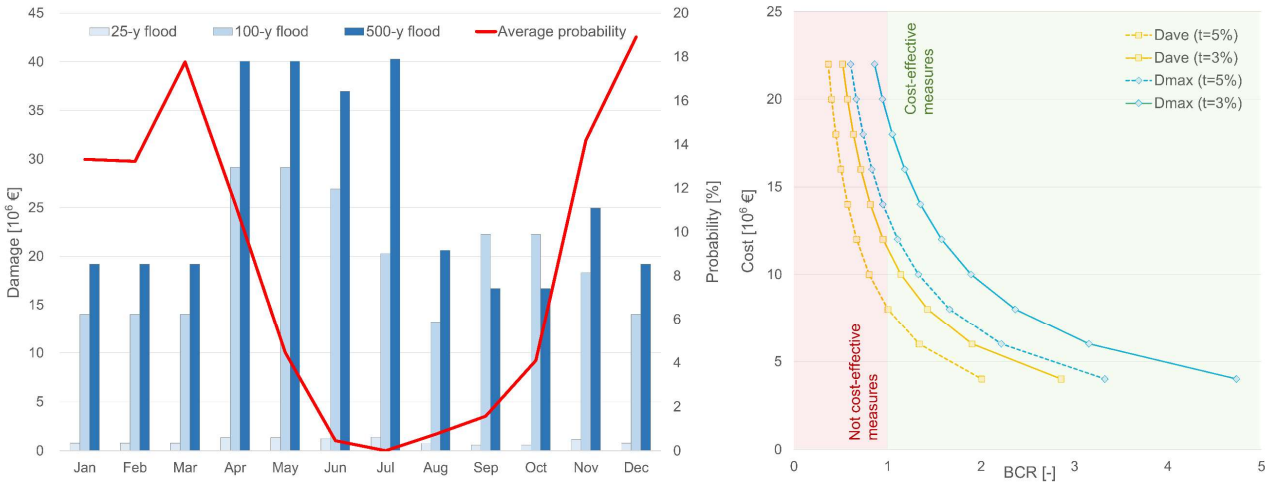


Figure 1. Left: monthly flood probability for the Panaro and Reno river and expected losses for the considered synthetic flood scenarios. Right: influence of the method for damage calculation on the results of the cost-benefit analysis.

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