Flood risk in Italy and in Emilia Romagna

Italy is notoriously prone to natural hazards and disaster risk. Among the 28 EU Member States (MSs), Italy has experienced the largest economic damage from natural hazards over the period 1980-2013, according to a recent analysis of the European Environmental Agency (EEA). The damage to tangible physical assets topped €112 billion (in 2013 Euro value), on average ~ €3.3 billion per year. This is about a quarter of the damage registered over the rest of the EU. With about 30% of the recorded damage, floods are second only to earthquakes in terms of damage (Mysiak, 2015).

These estimates capture the physical asset damage over a medium-long period. Low-probability/high-impact events are not fully represented. The simulated expected annual damage (EAD) from floods in Italy has been estimated to around €800 million (Feyen et al., 2012; Rojas et al., 2012a, 2013), or higher if the spatial correlation between the flood risk across the major river basins is taken into account (Jongman et al., 2014). A more recent Pan-European study has positioned the EAD higher (Alfieri et al., 2015). The insurance industry commissioned study estimated annual average fluvial flood loss to residential properties in Italy to €230 million a year (ANIA, 2011). The flood hazard and risk mapping conducted in the context of the Floods Directive (FD) (EC, 2007) revealed that respectively around 4.0%, 8.1% and 10.4% of Italian territory (12.000; 24.000 and 31.500 sq.km) is prone to high (return period/RP 1:20-50 years), medium (RP 1:100-200 years) and low (RP 1:300-500 years) risk (ISPRA, 2015). As a result of climate and socio-economic changes, the EAD from floods is projected to increase by factor 2-5 by the end of the century (Alfieri et al., 2015; Ciscar et al., 2011, 2014; Feyen et al., 2012; Jongman et al., 2014; Rojas et al., 2012a, 2012b, 2013).

Emilia Romagna (RER) is the second most flood-exposed among the 20 Italian administrative regions, after Lombardy. According to our analysis of geo-localised floods, the total registered damage in RER amounted to €7 billion over the past 34 years. The extent of area exposed to high, medium and low hazard amounts to 2.500 sq.km (11%), 10.250 sq.km (46%) and 7.980 sq.km (36%) respectively (ISPRA, 2015). In terms of population living in the exposed areas, RER is second only to Tuscany for the low-probability hazard exposure, while maintaining the infamous primacy for the medium and high flood hazard scenarios. Notably, more than 60% (2,760 million) of the RER residents live in areas prone to medium-level hazard and more than 40% in the areas prone to very low-frequency type of hazards. For comparison, around half of the Italian population that lives in areas exposed to medium-level hazard resides in RER.

Our research examined how impairments to infrastructure designed to drain low-altitude areas in the downstream part of the Po River Basin increases the flood risk and amplifies the ensuing economic damage. The analysis informed the multi-sector partnership (MSP), rooted in an inter-regional civil protection agreement, and negotiated among a multitude of public and private institutions including the river basin authority, the regional and provincial administrations, land reclamation and irrigation boards, civil protection agencies, and the land holders.

We have contributed to (1) better delineating the areas exposed to higher flood risk as a result of inoperable DS; (2) outlining flood-prone areas under different precipitation and DS disruption scenarios; and (3) determining the economic losses caused by the controlled and uncontrolled floods, in terms of capital stock damage and foregone production losses.

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Multi-sectoral partnership

The MSP was formed as a response to the temporary disruption of drainage system (DS) in the low-altitude floodplains at the foot of the Tuscan-Emilian Apennines between the rivers Po, Secchia and Enzo. The DS disruption was caused by earthquakes in May 2012, with epicentres of the two major quakes (5.8 and 5.9 RS respectively) less than 30 km away from the study area. The DS consists of river embankment, drainage channels and pumping stations developed over centuries. The sophisticated system of the gravitational water drainage is complemented by water uplifting plants enabling to discharge the water to Secchia when the high river levels do not permit natural emission. The earthquake damaged the critical nodes of the DS, especially the pumping plants Mondine and San Siro, compromising the flood risk protection. As a consequence, almost 100 sq.km of residential, 85 sq.km of industrial and 840 sq.km of agricultural land turned into flood-prone area in the case study area and elsewhere. The affected area holds several middle-sized urban centres (20–60 thousands residents), pieces of central infrastructure systems (high speed train Milano-Bologna-Rome; highway A1 and A27), and major industrial areas.

Conceived as a provisional arrangement until after the full capacity of the DS has been restored, the MSP consents controlled floods on agricultural and/or scarcely developed rural land, to protect settlements and industrial facilities in areas prone to the exacerbated flood risk. The designated areas are neither equipped for holding flood water nor secured from damage.

The major partners in the MSP include on the emergency response side the Civil Protection Agency/Mechanism (CPA), and on the risk prevention side the Land Reclamation and Irrigation Boards (LRIB), in our case the LRIB Emilia Centrale (LRIB-EC), the LRIB Burana and the LRIB Terre dei Gonzaga in destra Po (LRIB-TG). The LRIBs are public bodies established as consortia of real estate property owners within a delimited hydrological district. They embody water institutions with long history, the predecessors of the LRIB-EC had been established back in the 1870s. The landholders in the areas designated for controlled floods are active partners to the MSP-F. The partnership, promoted and overseen by the Po River Basin Authority (PRBA), was sanctioned as an **inter-regional emergency management plan** (PIE, 2012) signed by the presidents of the regions Lombardy and Emilia Romagna. The regions, the first-level administrative divisions of the state, exercise ample control over the water resource management and vest vital responsibility for disaster risk management. The presidents of the respective regional councils were designated Commissioners Delegate in the sense of the law 225/1992[20]. The emergency plan clarifies the role and tasks of organisations concerned, designates areas for controlled flooding, and establishes an inter-regional crisis intervention unit. The plan determines the roles and tasks of other organisations who are not partners to the MSP-F per se but whose participation is essential during the emergency response. The provisions of the plan are to be transposed to district-level and municipal emergency response plans.

[20] Law of 24 February 1992, n. 225 'Establishing the National Civil Protection service'.

"Although the Po River Basic District is believed to be exposed to relatively low seismic risk, the 2012 earthquake has demonstrated that low does not mean non-existent. "

Photo by Rafael Ben-ari/dreamstime.

Risk-based assessment

Improving and enhancing the risk assessment

Our research comprises hazard and risk model development; simulation and assessment of risk, and wide-ranging policy analysis. By use of the empirically recorded structural damage caused by a recent flood event in the case study area (the Secchia levee break in January 2014), we have revised and extended the model for assessing the damage on residential properties and agricultural land (Amadio et al., 2016).

After our adjustments, the maximum damage values for residential buildings were decreased 4 to 4.5 times and the simulated damage assessment tallied the empirical records. Similarly, the added agricultural damage module that reckons temporal variability in production patterns and crop value resulted in halving the maximum crop-yield loss per hectare compared with one of the benchmark models. Besides tangible physical assets, we have analysed the production (output or flow) losses arising from the floods. By gross value added (GVA) information available for detailed spatial units, we have compared the damage inflicted on tangible physical assets with economic losses that arise as a result of foregone production. The latter may either be a consequence of productive capital impairment, and hence a counterpart of physical damage, or a result of business interruption. In either case the output losses are better estimates of fiscal repercussions than the structural damage alone.

In Koks et al. (2015) we have analysed the effects of various modelling tools, notably the **Input-Output (IO)** and **Computable General Equilibrium (CGE)** models, on the estimated output losses as well as their spill-over effects on other regions in Italy. To this end we have replicated the 1951 Polesine flood disaster in Veneto under present-day socio-economic circumstances. In addition to the reconstructed event, we have simulated the levee break on the opposite side and subsequent flood in the Ferrara province in the Emilia Romagna region. Both flooding scenarios yield comparable structural asset damage (around €2 billion each), but the share of industrial damage is much higher in RER (35%) than in Veneto (15%). This has important implication for the ensuing output losses at national level that are under all model experiments almost double as high for the RER flood scenario compared to the flood scenario in Veneto.

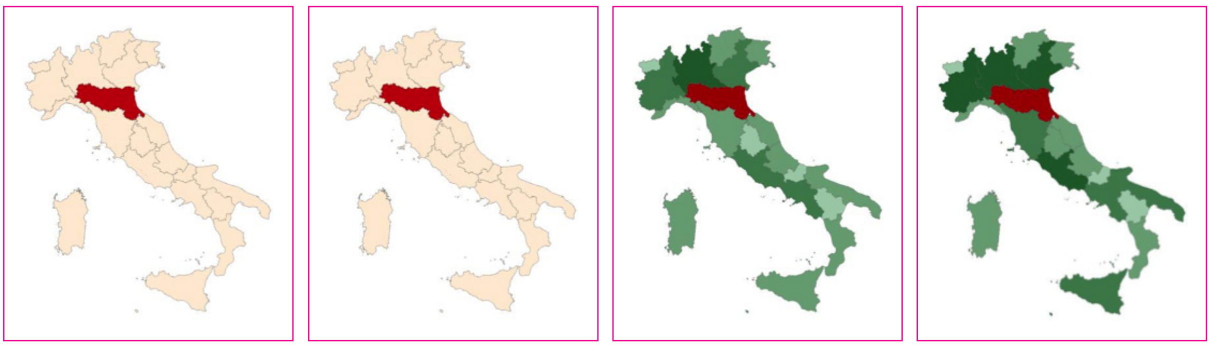
The replicated and simulated flood events were analysed subsequently using **two models built upon the IO approach** and the **regionalised CGE model**. The model comparison for the same events are valuable both from methodological and practical point of view. Firstly, the comparison is useful for identifying model features that determine the entity of loss, its distributions across regions, and the total impact at national level. Secondly, the model results produce a range of possible impacts on the primary affected regions as well as on the other regions that are not affected by the flood scenario itself but by the economic and trade relations. In line with our expectations, the CGE model yielded lower output losses compared to the two hybrid IO models. At regional level, the models yielded less diverging results. Notably, the two IO models yielded different distributions of losses across regions that are at least to some extent reproduced by the different set-up of the CGE model.

In Carrera et al. (2015) we have analysed the **output losses caused by floods across all Italian regions**, including the RER region. This analysis is based on the flood inundation data obtained from the Joint Research Centre (JRC, Rojas et al., 2013). The flood-prone areas are based on LISFLOOD (Van Der Knijff et al. 2010) model simulations forced by 12 different regional climate simulations (Van der Linden and Mitchell, 2009) for the SRES A1B scenario. Production losses are modelled using a vulnerability function that associates the simulated flood depth to the length of the disrupted production. The impacts calculated for each climate simulation have been used as input to the regional general equilibrium model (R-CGE). The R-CGE model estimates the output losses (or gains) separately for each region, flood probability and future time period. The results show that the expected annual output loss (EAOL) under the current climate totals to €191 million for Italy and around €14 million for Emilia Romagna (ranking 7th most affected). The distribution of EAOL losses is highly uneven, with the most economically developed regions in the North suffering from the largest production shortfalls. Interestingly, because of the low flood protection standards, Sicily tops all other regions, followed by Lombardy and Veneto. By the end of the century, the EAOL is expected to increase threefold to €620 million for Italy and €36 million for RER.

Furthermore, we have analysed the **fluvial and coastal flood risk in RER** (**Figure 14.1**) under current and future climates in a similar way as in the previous paper (Carrera et al., 2015) but under different configuration (Mysiak et al., under preparation). We used both the older and the newest flood simulation from JRC and the R-CGE model to assess the economic output losses. A better distribution of wealth and production activities (see also further down) was instrumental to a better appreciation of economic risk from floods. The estimated EAL under the current climate in this work is double as high (€26 million) for RER as in our previous work. This difference is attributable to improved distribution of gross added value (GVA) on the basis of detailed economic accounting (below the NUTS3 level) and on dasymetric mapping of socio-economic variables. The most recent flood hazard simulations lead to higher EAL (€80 million for RER). The economic losses due to climate risk range between 50% and above 100% of the economic damage, depending on the model set-up. By the 2040s, the human induced climate change may amplify the damage and losses caused by extreme weather and climate events with 20-40%. Climate variability and change has sizeable spill-over and distributional effects. Flexible economy may double the costs to the directly affected region. These costs arise from temporary transfers of capital and labour to other, non-affected regions. The gains of the latter regions equate the amplified losses of the directly affected region.

Figure 14.1.

Fluvial and coastal flood risk in Emilia Romagna Region (RER) under current and future climates, using different economic modelling setups (inflexible/ flexible).



(A) Inflexible R-CGE set-up according to 1980s climate

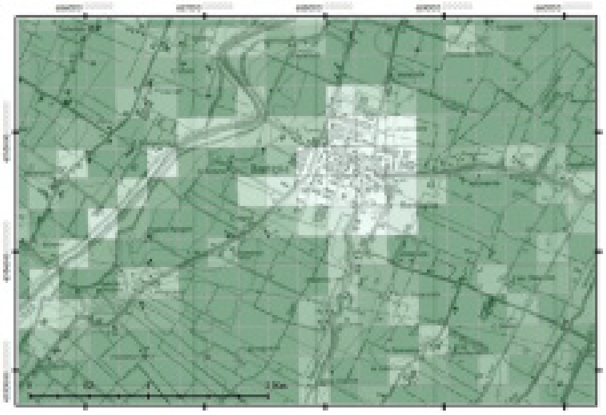
(B) inflexible R-CGE set-up according to 2040s climate

(C) Flexible R-CGE set-up according to 1980s climate

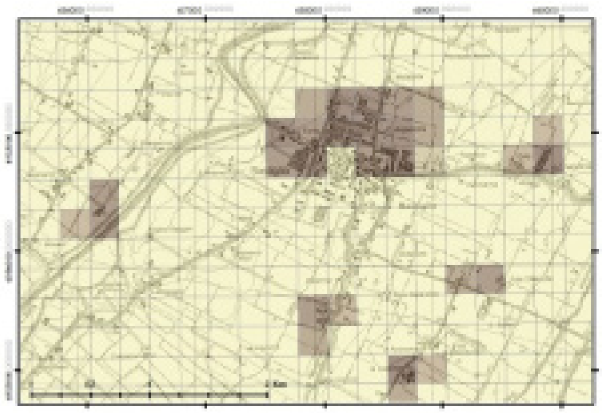
(D) Flexible R-CGE set-up according to 2040s climate

We have also analysed the coastal flood risk in RER (Figure 14.1). Around 20% (€360 million or 0.25% of GRP) of the GVA generated in the 1km wide coastal zones of RER and exposed to medium (p=0,01) risk is below 1m altitude. Some 45% (840 million or 0.65% GRP) of GVA are below 1.5m altitude. Three quarters of the exposed value is generated by services. In the absence of detailed coastal flood simulation, the GVA loss is a good proxy of the GRP losses under inflexible model set-up. Around 30% (€660 million) and almost 60% (€1,3 billion) of the coastal zone-generated GVA located in the areas prone to coastal flood risk with probability of exceedance 0.4% are below 1m and 1.5m altitude. We estimate EAL of the 1km wide coastal zone to at least €10-15 million under current climate. Climate change will lead to permanent loss of land and critical assets.

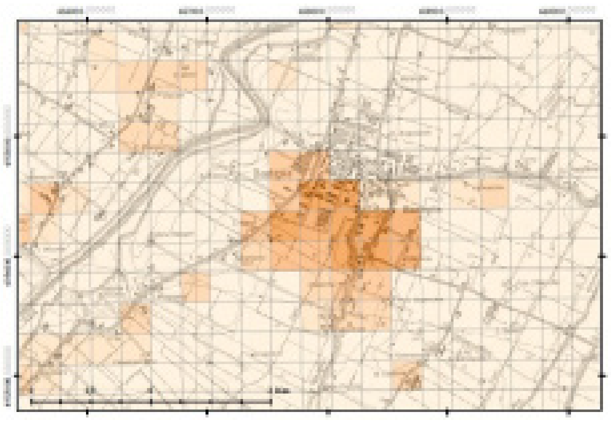
The risk and vulnerability analyses conducted for the scope of the above research benefit hugely from spatially distributed economic and social variables. In Amadio and Mysiak (under preparation) we have used **dasymetric mapping** for deriving a rectangular (grid) representation of population and gross added value (GVA) over the entire RER with high resolution (250m×250m) (see Figure 14.2). Population grids are recently widely available, but most of them do not have the requisites to be reliably employed in small-scale assessments (Figure 14.3). For the purpose of country-wide or global studies, grid datasets with small-scale resolution (from 1 to 5 km) are available: GeoStat (EFGS, 2011), LandScan (Bhaduri et al., 2002) or GWP (Balk and Yetman, 2004). These are adequate at a larger scale, but less suitable to represent local and sub-regional scales. A more accurate depiction can be obtained using a dasymetric mapping approach, starting from census records and disaggregating them to a finer units using ancillary data, such as land use and buildings. The precision of population grids influences the derived datasets that employ population density as a proxy. Dasymetric mapping seeks to improve the assumptions made for areal weighting, by establishing a relationship between the underlying statistical surface and the different classes contained within the area-class map (Mennis and Hultgren, 2006). In recent years this approach has gained interest to estimate populations for small areas (Eicher and Brewer, 2001). In fact, dasymetric mapping can provide more accurate small-area population estimates than many areal interpolation techniques (Mrozinski and Cromley, 1999; Wu et al., 2005).



(A) Agricultural GVA



(B) Industrial GVA



(C) Services related GVA

Figure 14.2.

A gridded sectorial gross added value (GVA) (250m×250m) for a small area within the case study (around the town Bomporto) in Emilia Romagna.

Figure 14.3.

Gridded population (left) and total GVA (right) of the Emilia Romagna region. Our analysis shows high (r= 0.88) correlation between GVA-S (services) and GVA-T (total) and relativelly high correlation between GVA-I (industrial) and GVA-T (r= 0.6). There is a low (but statistically significant) negative correlation btewene GVA-T and GVA-A (agricultur) (-.12). Similar correlations are observed for gridded population which is highly correlated with GVA-T and GVA-S (.86 and .97), but low with GVA-I (.15) and low and negative with GVA-A (-.10).