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By **Fabio Farinosi**, Fondazione Eni Enrico Mattei, Euro-Mediterranean Center for Climate Change, “Ca’ Foscari” University, Italy

Lorenzo Carrera, Fondazione Eni Enrico Mattei, “Ca’ Foscari” University, Italy

Alexandros Maziotis, Jaroslav Mysiak

Fabio Eboli, Gabriele Standardi, Fondazione Eni Enrico Mattei, Euro-Mediterranean Center for Climate Change, Italy

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Fabio Eboli, Fondazione Eni Enrico Mattei, Euro-Mediterranean Center for Climate Change, Italy
Gabriele Standardi, Fondazione Eni Enrico Mattei, Euro-Mediterranean Center for Climate Change, Italy

Summary

This paper estimates the direct and indirect socio-economic impacts of the 2000 flood that took place in the Po river basin (Italy) using a combination of Computable General Equilibrium (CGE) model and Spatial and Multi-Criteria Analysis. A risk map for the whole basin is generated as a function of hazard, exposure and vulnerability. The indirect economic losses are assessed using the CGE model, whereas the direct social and economic impacts are estimated with spatial analysis tools combined with Multi-Criteria Analysis. The social impact is expressed as a function of physical characteristics of the extreme event, social vulnerability and adaptive capacity. The results indicate that the highest risk areas are located in the mountainous and in the most populated portions of the basin, which are consistent with the high values of hazard and vulnerability. Considerably economic damages occurred to the critical infrastructure of all the sectors with the industry/commercial sector having the biggest impact. A negative variation in the country and industry Gross Domestic Product (GDP) was also reported. Our study is of great interest to those who are interested in estimating the economic impact of flood events. It can also assist decision makers in pinpointing factors that threaten the sustainability and stability of a risk-prone area and more specifically, to help them understand how to reduce social vulnerability to flood events.

Keywords: Risk Assessment, Flood, Economic Impacts, Social Impact, Impact Assessment

JEL Classification: Q2, Q25

Address for correspondence:

Fabio Farinosi
Fondazione Eni Enrico Mattei
Isola di San Giorgio Maggiore
30124 Venice
Italy
E-mail: fabio.farinosi@feem.it

Policy-relevant assessment method of socio-economic impacts of floods: an Italian case study.

Fabio FARINOSI[1,2,3], Lorenzo CARRERA[1,3], Alexandros MAZIOTIS[1,2], Jaroslav MYSIAK[1,2], Fabio EBOLI[1,2], Gabriele STANDARDI[1,2]

[1] Fondazione Eni Enrico Mattei, San Giorgio Island, Venice, Italy

[2] Euro-Mediterranean Center for Climate Change, San Giorgio Island, Venice, Italy

[3] "Ca' Foscari" University, Venice, Italy

Abstract

This paper estimates the direct and indirect socio-economic impacts of the 2000 flood that took place in the Po river basin (Italy) using a combination of Computable General Equilibrium (CGE) model and Spatial and Multi-Criteria Analysis. A risk map for the whole basin is generated as a function of hazard, exposure and vulnerability. The indirect economic losses are assessed using the CGE model, whereas the direct social and economic impacts are estimated with spatial analysis tools combined with Multi-Criteria Analysis. The social impact is expressed as a function of physical characteristics of the extreme event, social vulnerability and adaptive capacity. The results indicate that the highest risk areas are located in the mountainous and in the most populated portions of the basin, which are consistent with the high values of hazard and vulnerability. Considerably economic damages occurred to the critical infrastructure of all the sectors with the industry/commercial sector having the biggest impact. A negative variation in the country and industry Gross Domestic Product (GDP) was also reported. Our study is of great interest to those who are interested in estimating the economic impact of flood events. It can also assist decision makers in pinpointing factors that threaten the sustainability and stability of a risk-prone area and more specifically, to help them understand how to reduce social vulnerability to flood events.

Keywords: risk assessment, flood, economic impacts, social impact, impact assessment.

1. Introduction

Since 1950, a significant number of flood events occurred in Italy. The Hydrological and Inland Waters Service of the Italian Agency for Environmental Protection and Technical Services (APAT) - renamed today as Advanced Institute for Research and Environmental Protection (ISPRA) has collected data from fifty-five events that occurred in Italy from 1951-2003. For each flood event, time, number of casualties, and estimated economic total damage (both in Euros and in percentage with respect to GDP) have been collected and reported. The information is regularly updated including additional data on hydrological phenomena such as the total duration of precipitation, the maximum total rainfall value in 24 hours, and the hydrographic basins affected by floods (Lastoria et al. 2006). The authors pointed out that overall, the flood events recorded between 1951-2003 caused 1394 casualties, half of which occurred during the time period from 1951-1970.

The data confirm the significant impact of these flood events to society and to economy at national level. Therefore, in this paper we will focus on a major flood event that occurred in October 2000 in the Po river basin (especially in Piedmont and Valle d'Aosta Regions). This basin was chosen as our study area because it is recognized as a highly economically developed area, for instance, 40 per cent of the national GDP is produced in the Po river basin by more than one third of the country's industries. Moreover, 5 per cent of Po's total surface is at risk of floods, a significant number of habitants and municipalities are located at risk prone areas. During the 13th and 16th of October 2000, a series of extreme precipitation events hit the Northwest of Italy leading to numerous floods and landslides. The communities of Piedmont, Valle d'Aosta and Liguria regions were significantly affected, but floods were also registered in Lombardy, Emilia Romagna and Veneto. This event is among the most significant floods that have occurred in the Po river basin over the past years, causing around 30 casualties (Camera dei deputati, 2000) and substantial total economic damages in all economic sectors. More than 40,000 people were evacuated and at least 3000 lost their houses (Guzzetti and Tonelli, 2004).

The flood event affected more than 700 municipalities and almost all main cities including Turin, the capital of the Piedmont region. All economic sectors were severely impacted, either directly through structural damage or indirectly through business interruptions. Moreover, as several chemical plants and industrial waste treatment plants are located in this area, there was a high risk of industrial accidents (ANPA, 2001; ANPA, 2002; ARPA Piemonte 2003). The flood caused direct impacts to transport infrastructures and urbanized areas. It led to lifelines interruptions in the affected regions, interrupting major highways, together with regional and provincial roads. The disaster influenced the economic system of the affected areas for days, provoking disruptions to several Local Labour Systems (LLS) in the major Italian economic area. In addition to this, highly productive agriculture land was flooded causing significant damages to their productivity.

Figure 1. Po River Basin, administrative borders.

The purpose of this paper is to estimate the direct and indirect socio-economic impacts of the flood that took place in the Po river basin in 2000. In order to accomplish this, a risk map, as a function of vulnerability, exposure and hazard, is produced. Furthermore, a combination of Geographical Information System (GIS) using spatial data, Computable General Equilibrium (CGE) models and multi-criteria analysis are employed. Firstly, the direct economic costs are estimated by employing GIS techniques with spatial information data. The CORINE (Coordination of information on the environment) Land Cover 2006 (ISPRA, 2006) is used to create land cover maps for the flooded areas. This is combined with the use of flood damage functions related to water depth and economic losses to assess direct impacts of floods in Europe (HKV Consultants, 2007). Secondly, the indirect economic impact of flood is estimated through the analysis of the disruptions to the socio-economic system in terms of flooded land areas divided by productive sectors and labour force affected by the flood, using CGE model. Finally, the social impact of the flood is estimated using tools derived from the multi-criteria analysis, based on the methodology by Coninx and Bachus (2008). The social impact is expressed as a function of exposure to flood, social vulnerability and adaptive capacity.

The importance of this paper is twofold. Firstly, to the best of our knowledge, this is the first study that quantifies the social and economic impact of flood in the Po river basin, a highly economically developed and populated area with industries, municipalities and habitants located in flood risk prone regions. Secondly, and most importantly, it attempts to propose an assessment method to fill knowledge gaps, in particular those concerning indirect and intangible losses of floods in the Po river basin. Finally, our study should be of great importance for those who are interested in improving the efficiency in the evaluation of hydro-meteorological risk and promoting the sustainable development within the European Flood Risk Management Directive implementation.

This paper unfolds as follows. Section 2 briefly reviews the existing literature, while Section 3 provides a comprehensive discussion of the methodology and a description of the sample data and variables definitions. In Section 4 we present and discuss our empirical results, while Section 5 concludes the paper.

2. Literature review

This section will examine the literature regarding the assessment studies focused on the concepts of risk and vulnerability. It will first examine the methodologies for vulnerability and risk assessment, and then it will move to the examination of past risk and impact assessment studies in Italy.

2.1 risk and vulnerability assessment methodologies

The modern approach towards natural disasters has shifted from being hazard-oriented to a risk-based approach (Lastoria et al. 2006). Flood research and flood protection policy have been dominated by a technical world view, focusing on the technical and financial aspects and ignoring the impact and significance of the socio-economic drives and social science techniques. However, in recent decades, social and socio-economic aspects gained more importance with a shift from flood protection to flood risk analysis (Messner and Meyer, 2005).

Three factors are defined to set the framework of risk analysis: exposure, vulnerability and hazard. According to UN/IDSR (2009) definition, risk to natural hazards is defined as the anticipated probability of harmful consequences or losses resulting from interactions between natural or anthropogenic hazards and vulnerable conditions and its (human) exposure. The concept of risk can be represented alternatively at equation (1).

$$R = f(H, E, V) \qquad (1)$$

Where *R* denotes risk and is a function of hazard, *H*, Exposure, *E,* and Vulnerability, *V*.

Hazard is the probability of occurrence within a specified period of time in a given area, of a potentially damaging event so it implies to consider the frequency and the magnitude of the threatening event (Lastoria et al. 2006). Exposure refers to the situation where people and economic assets become concentrated in areas exposed to severe hazards through processes such as population growth, migration, urbanization and economic development (UN/IDSR, 2009). In this sense, exposure is more or less a geographical attribute (ENSURE, 2009). Vulnerability refers to a propensity or susceptibility to suffer loss and is associated with a range of physical, social, political, economic, cultural and institutional characteristics. For example, unsafe, poorly built housing, schools, hospitals and lifeline infrastructure are characteristics of physical vulnerability (UN/IDSR, 2009). Therefore, the concept of vulnerability can be represented alternatively at equation (2):

$$V = f(SU, AC) \qquad (2)$$

Where SU is defined as susceptibility to suffer losses and AC as adaptive capacity, which is the capacity of people and economies to absorb losses from hazards and recover. Kienberger (2012) states that vulnerability can exist everywhere at any place, but it depends on its degree, whereby in certain areas it may be close to zero, and in other areas may have a higher degree. The final risk is therefore defined by the spatial overlay (and mathematically defined through a 'function') with a hazard, which can be delineated spatially (e.g. the extent of a flood).

The IPCC Third Assessment Report (TAR) (2001) also provides two definitions of vulnerability (Brooks, 2003). The first one defines vulnerability as the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Therefore, vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity. The above definition may be compared with that given in Chapter 18 of the TAR, cited from Smit *et al*. (1999), in which vulnerability is described as the degree to which a system is susceptible to injury, damage, or harm (one part - the problematic or detrimental part - of sensitivity). Sensitivity is in turn described as the degree to which a system is affected by or responsive to climate stimuli (IPCC, 2001). The two IPCC definitions above are very different and somewhat contradictory, and are not consistent. The first definition of IPCC views the vulnerability of a system as a function of its sensitivity, whereas the second definition views vulnerability as a subset of sensitivity (Brooks, 2003). According to Brooks, if the first definition is seen as a definition of biophysical vulnerability and the second definition as a definition of social vulnerability, then the contradiction is resolved.

The aspects of biophysical and social vulnerability were integrated by the development of the Hazards of Place (HOP) model of vulnerability by Cutter (1996). The HOP model shows how risk and mitigation interact in order to produce hazard potential, which is filtered through (1) social fabric to create social vulnerability and (2) geographic context to produce biophysical vulnerability (Cutter and Morath, 2012). Cutter et al. (2000) employed the Hazards of Place (HOP) model to carry out a local-scale, empirical assessment of all-hazards vulnerability for the coastal county of Georgetown, South Carolina. A geographical information system was employed to set up areas of vulnerability based on twelve environmental factors such as flood pains, surge inundation zones, seismic zones and historical hazard frequency. Social vulnerability was defined based on eight socio economic indicators such as total population and structure, differential access to resources/greater susceptibility to hazards due to physical weakness, wealth or poverty, level of physical or structural vulnerability. The results indicated that the most biophysical vulnerable places do not always spatially intersect with the most vulnerable populations (Cutter et al. 2000). The authors concluded that a methodology for downscaling place vulnerability needed to be further developed. This concern provided the stimulus for developing a place based, scale dependent, inductive approach for measuring social vulnerability, the Social Vulnerability Index (SoVI) (Cutter et al. 2003). Based on the 1990 data from the United States, the authors collected 250 socio-economic and environmental variables. Then after using statistical methods (Principal Components Analysis) 42 independent country level variables were finally used to construct the social vulnerability index for the entire United States. Therefore, SoVI is a comparative assessment of the relative levels of vulnerability between places. High positive values indicate counties with elevated social vulnerability, while high negative values indicate lower social vulnerability (Cutter and Morath, 2012). Also, Cutter et al (2003) mapped the overall SoVI score based on standard deviations allowing them therefore to illustrate the degree to which some places are more vulnerable than others, highlighting counties at the tails of the distribution (i.e. high and low social vulnerability) (Cutter and Morath, 2012).

2.5 Risk and impact assessment studies in Italy

In Italy, Lastoria et al. (2006) reported economic losses for the flood events that occurred in the country during the years 1951-2003 based on funds necessary for the restoration after the flood. These economic losses were based on the data collected by the Hydrological and Inland Waters Service of the Italian Agency for Environmental Protection and Technical Services (APAT) - named today as ISPRA. The authors emphasized that the economic losses were calculated based on the partial or total destruction of buildings, infrastructures and engineering works, interruption of economic activities and public services. The reported economic losses ranged from 15.49 million Euro as a result from the flood event in 1951 to 2.8 billion Euro in 1994, or equivalently 0.27 per cent and 0.33 per cent of GDP, respectively. As far as the number of casualties is concerned, the results indicate that almost 50 per cent of the analyzed floods caused more than 5 casualties and almost 10 per cent more than 100 over the years. The importance and usefulness of the information included in this dataset is highly acknowledged, however, the lack of homogeneity of data among the different flood events does not allow a meaningful comparative estimation. Although there is an overall decreasing trend in the number of casualties and damages over the years, the socio-economic impact of flood cannot be meaningfully estimated and compared among the flooded areas as the flood events did not hit the same areas and with the same intensity.

A recent study by De Marchi et al. (2007) assessed the risk destruction and social vulnerability in an Italian Alpine region which was affected by flash floods and debris flows between the 2000 and 2002. The study area included five communities in the Trentino-Alto Adige Region, which nearly corresponds to the upper Adige river catchments, except for some small areas along its borders and the South-Eastern part of the Trento province, belonging to the Sarca river catchments. The purpose of this study was to promote preparedness, increase resilience and reduce vulnerability at the community level. Therefore, the authors explored the main strengths and weaknesses of communities exposed to flood risk, focusing on socio-psychological, cultural, economic and organizational aspects. Provincial services and agencies in charge of civil protection, risk prevention, water resources, and hydrology were interviewed in order to gather information on local communities' capability to respond to and recover from flood events (flood risk management). The experts' technical views were then complemented with views of local residents who were aware of their social and economic aspects such as mayors and other elected officials, persons in charge of technical, planning, and environmental departments. The main conclusions from this case study can be summarized as follows. Increase in risk awareness such as knowledge of hydro-geological risk and their unpredictability, frequency of the events and its consequences and information about the role of protection works were considered to be great importance for reducing vulnerability to floods. The efficiency risk management agencies can encourage people to enact self-protection behaviours. Risk maps need to be constantly updated to provide with valuable information regarding the risk-prone flooded areas. Finally, the designation of an area as a risky one might lead to a decrease in property values; and as a result residents who lived there are deprived twice, as they live in an unsafe area and are not able to sell their property.

Moreover, Guzzetti and Tonelli (2004) underlined that in Italy, 382 municipalities (5.9 per cent) have a 0.90 or larger probability of experiencing at least one damaging flood or landslide, and 1319 municipalities have a 0.50 or larger probability of experiencing at least one flood or landslide for a 10 years period. These numbers can increase to 1319 (20.5 per cent) and 3835 (59.6 per cent) municipalities for a 25-years period, and to o 2621 (40.7 per cent) and 4783 (74.4 per cent) municipalities for a 50-years period, respectively. The authors reported the results based on the use of data from hydrological and geomorphological catastrophes in Italy. It is emphasized that the societal and economic impact of flooding and slope failures is high in Italy, with just in the 20th century, the toll of disaster impacts amount to 10,000 deaths, missing persons and injured people, more than 700,000 homeless people, and thousands of houses and bridges and hundreds of kilometres of roads and rails destroyed or damaged. Therefore, Guzzetti and Tonelli (2004) recommend a combination of geographical data to report the flood risk areas and demographic variables to assess the socio-economic impact.

The next section discusses the methodology adopted in this study and provides a useful tool to decision makers to estimate the economic damage caused by flood events. It also provides instruments to better understand how decision makers can reduce social vulnerability to flood events. The interest is focused on both the direct and indirect impact of floods. Direct impacts cover all varieties of harm to humans, property and the environment such as damage to buildings, economic goods and dykes, loss of life, whereas the indirect is associated with disruption in economic and social activities (Messner et al. 2007).

3. Methodology

This section will analyse the methodology and the data employed for the production of the risk map of the Po river basin, followed by a discussion for assessing the economic and social impacts.

3.1 Risk mapping

The Risk is calculated as function of hazard *H*, exposure *E* and vulnerability *V* equally weighted.

$$R = 0.33H + 0.33E + 0.33V \qquad (3)$$

3.1.1 Hazard

The Po River Basin Authority through the Hydrological Management Plan provides a dataset of potential hazards related to the hydrogeological risk. The Plan analyses the territorial hydrogeological characteristics and system of interventions. In order to improve the basin's security level against hydrogeological risk, the plan defines structural (hydraulic works) and non-structural (rules) actions for soil and water uses. The Plan aims to design a functioning framework of the basin with the clear objective of preventing the risk:

- defines and quantifies critical exposure, actual and potential, investigating relevant causes;
- identifies required actions to deal with specific issues related to the gravity and extent of damages;
- formulates safeguards rules that enable the effective and positive actions to protect soil and water.

The Plan considers two types of areas: the territories where the emergency status has been declared and that could be high level of risk for people safety, infrastructure and cultural and environmental heritage security. Also, the plan identifies potential hydrological risk for inundating and flood prone areas, with three grade of inundation gravity (very high risk, high risk, medium risk), including also river buffer areas prone to rare flood risk (500 years return period), frequent flood risk (100-200 years return period) and common flood risk (20-50 years return period). Finally, the Plan provides geo-referenced information about active, stable and stabilized landslides. Figure 2 represents the exposed areas to hydrogeological risk in the Po river basin.

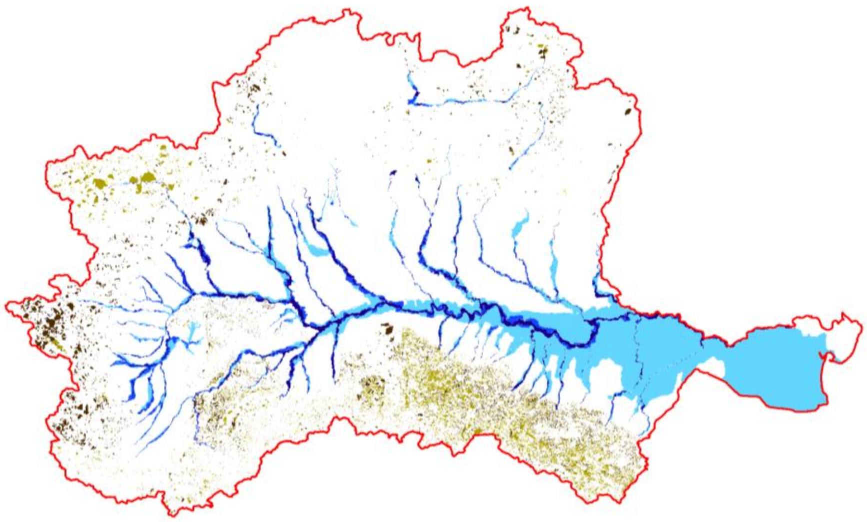

Figure 2. Hydrological Management Plan, flood and landslide prone areas of the Po river basin. Blue: flood and inundating prone areas. Brown: landslide prone areas. Source: Authors' own elaboration on Po River Basin Authority dataset.

In this study, the information provided by the Hydrological Plan has been used to produce a hazard map of the basin at municipal level.

3.1.2 Exposure

For the purpose of this study a simplified definition of exposure has been adopted. The exposure in the Po River Basin was defined as the degree of soil used for human activity in the municipality area. The total area and the percentage of area employed for construction was calculated for each of the municipalities of the basin. Constructed area is represented by civil, industrial and commercial areas.

3.1.3 Vulnerability

Vulnerability of people is measured by the social flood vulnerability index (Ernst et al. 2010). Due to the restriction of data because of privacy at the individual level, data at the level of the municipalities of the flooded area have been used. The selected indicators in the social flood vulnerability index are proxies of the vulnerable social groups (Cutter et al. 2003, Tapsell et al. 2002).

Vulnerability to flood, *V*, has been calculated as follows:

$$V_j = \sum_{i=1}^{K} W_i X_{ij} \qquad \text{with } W_i > 0 \text{ for } i = 1,\ldots,K \qquad (4)$$

Where V_j represents the vulnerability to flood for each municipality j, X_{ij} the set of the i indicators of vulnerability for each municipality j, and W_i the weight for each indicator i, where i=1,…, K with K being the total number of indicators. The variables X_{ij} have been chosen following the methodology developed by Cutter et al. (2003). The variable chosen as indicators of the socio-economic vulnerability are nine, divided in two groups:

- Indicators contributing to the increase of vulnerability: population density; percentage of the underage (under 18 years old) population; percentage of elder (over 65 years old) population; percentage of population not reaching the basic education (mandated by Italian law); percentage of foreign population; percentage of everyday commuting population; percentage of car possession.
- Indicators contributing to the decrease in vulnerability: percentage of population reaching a high level of education (high school or more); employment rate.

Data regarding the mentioned indicators have been obtained from the official database of the Italian National Bureau of Statistics (ISTAT) – Census 2001 (ISTAT, 2001), with the only exception of the car possession rate, which was obtained from the official statistics of the Automobile Club d'Italia (ACI) referred to the year 2001. The database of the ACI is organised at regional level, whereas the ISTAT at municipal level.

Normalisation and weighting

The data referring to each of the indicators are different in unit and scale. In this work, it has been chosen to follow the same methodology used in UNDP's Human Development Index (HDI) (UNDP, 2006) to normalise them: Min-Max normalisation. The methodology adopted allows to standardize the values of the indicators and to obtain a final result ranging between 0 and 1 (ICRISAT).

The Indicators contributing to increase vulnerability have been normalised as follows:

$$x_{ij} = \frac{X_{ij} - \min_i \{X_{ij}\}}{\max_i \{X_{ij}\} - \min_i \{X_{ij}\}} \qquad (5)$$

Moreover, the indicators contributing to the decrease of the vulnerability have been normalised as follows:

$$x_{ij} = \frac{\max_i \{X_{ij}\} - X_{ij}}{\max_i \{X_{ij}\} - \min_i \{X_{ij}\}} \qquad (6)$$

The population density, originally expressed as people over squared kilometre, has been normalised using the logarithm of the values in order to reduce a wide range to a more manageable size. After normalising the indicators, a method of aggregation in which the vulnerability index score represents the summation of the equally weighted average sub-index scores, was chosen. The weights (W_i) have been equally distributed among the different indicators. The choice is motivated by the inability to concretely proof differences in the contribution of the single indicators in the overall determination of the Vulnerability Index (Cutter, 2010).

3.2 Economic Impact

3.2.1 Direct economic impact

The direct economic impacts of 2000 flood were estimated on land cover maps which were elaborated using CORINE (Coordination of information on the environment) Land Cover 2006 (ISPRA, 2006). CORINE is a program of the European Commission, which aims to compile information on the state of the environment with regard to certain topics. Within the project CORINE-Land Cover section elaborates maps on European land uses. The project covers an area of 2.3 million km^2, having as smallest mapping unit of 25 hectares, scale 1:100,000 and three levels of land cover nomenclature. Its principal sources of information are ground truth surveys, earth satellite observations and aerial photographs. CORINE provides maps with 4 principal levels, namely artificial surfaces, agricultural areas, forest and semi-natural areas, wetlands. The highest level (i.e. three) includes 44 land cover sub-types.

In order to estimate a local direct impact of the flood event occurred in 2000, CORINE land cover map is overlaid with actual flood extent. The maximum extension of the flood is developed through the aggregation of several layers of information. The main sources used for this studied are: Piedmont Region, Valle d'Aosta Region and Regional Agency for Environmental Protection in the Emilia-Romagna Region (ARPA Emilia Romagna). Piedmont and Valle d'Aosta areas were most affected by the event. Indeed, both regions produced comprehensive integrated assessments maps. Flooded areas for the rest of the basin are estimated through information obtained from the ARPA Emilia Romagna. ARPA confirmed that the flood affected both river buffer areas A and B, 50 years and 200 years flood return period, respectively. Flood layer is then intersected with CORINE-Land Cover, which corresponds to the land use that has actually been flooded. Thus, flooded areas are divided into five categories: urban continuous, urban discontinuous, transport infrastructures, industry and commercial, and agriculture. An example of the result obtained is shown in the inset of Figure 3.

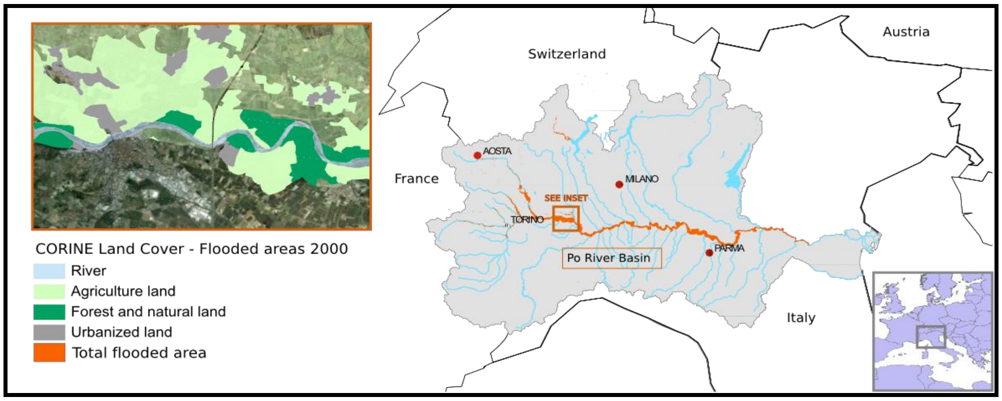

Figure 3. Flooded areas 2000 intersected with COVER Land Cover to define direct impacts of flood.

In order to estimate the direct cost of the event, flood damage functions have been used. Damage functions were obtained from an unpublished report "Flood damage functions for EU member states" from HKV consultants. The report aims to produce flood damage functions relating water depth and economic losses to assess direct impacts of floods in Europe (HKV Consultants, 2007). The study covers impacts related to humans, environmental and properties. The economic value obtained is therefore a function of the level of damage (based on water depth) and the specific use of the land flooded. The study covers 27 EU members in addition to Norway, Switzerland, Croatia and Turkey. Even if the study has not yet been published, its results are used for methodology definition purposes. The first part of the report addresses a general assessment of the impacts of the 2000 flood that occurred in the Po river basin. The section discusses a spatially-explicit vulnerability analysis, including territorial and critical infrastructure vulnerability assessment, with consideration of protected areas. It offers a review of the main conceptual background related to vulnerability and resilience assessment. Critical infrastructure is also defined and analyzed. A large integrated vulnerability assessment of the Po river basin reports the work that the river basin authority is conducting in order to respect the dictates of the European Flood Directive. In order to define direct impacts, a spatial-based methodology has been carried out. CORINE-Land Cover map is overlaid with actual flood extent and using damage functions, which are defined as damage cost for each meter square of specific land use, comprehensive direct damage estimation is employed. Then, the direct economic impact of flood is calculated by multiplying each damage value to the categories of land identified through CORINE-Land Cover. In order to quantify different land uses, the following assumptions were considered:

- Since CORINE-Land Cover does not distinguish between industry and commercial, the average of the respective values was applied.

- Discontinuous urban areas consider 50 per cent only of continuous urban damage values, because of their lower density, which could be estimated as half of continuous developments.

- 70 per cent only of road's damage values are considered for transport surfaces, including airports and railways.

3.2.2 Indirect economic impact

Indirect economic damage is estimated through the analysis of the disruptions to the socio-economic system in terms of flooded land areas divided by productive sectors and labour force affected by the flood, using computable general equilibrium (CGE) model developed by the GTAP Global Trade Analysis Project since the early 1990s. The standard GTAP Model is a multiregional, multisectoral, computable general equilibrium model, under the assumptions of perfect competition and constant returns to scale. The flood impact has been assessed using the last version of the GTAP model, version 6.2 (developed from: Global Trade Analysis: Modeling and Applications, T.W. Hertel (ed.), published in 1997 by Cambridge University Press). The benchmark referring scenario has been modelled using the database available for the year 2001 (Dimaranan B.V., Editor (2006); Global Trade, Assistance, and Production: The GTAP 6 Data Base, Centre for Global Trade Analysis, Purdue University).

The different methodologies used for the estimation of the indirect losses from extreme natural events have been reviewed by Cochrane (2004). The authors concluded that the GCE models are affected by different limitations. Among these, the most evident are represented by the assumption of functioning markets and by the inability of the model of capturing non-market values (Pauw et al. 2011). On the other hand, CGE models are able to capture all the economic flows using a consistent accounting methodology. This could avoid the unpleasant problems of 'double-counting', often affecting the evaluation conducted through the application of partial equilibrium approaches (Pauw et al. 2011). GCE models also offer the possibility to conduct counterfactual analyses, comparison between what happened and what would have happened in the absence of the catastrophic event. For all these reasons CGE models are still the preferred methodology for estimating losses (Rose, 2004).

Our analysis is affected by different limitations mainly given by the small geographic scale of the event under consideration in comparison with the global scale in which the model operates and the availability of an appropriate detail of the data. This exercise does not aim to give a concrete quantification of the indirect costs caused by the 2000 flood event, but rather to propose a possible methodology useful in this kind of assessments. Data availability gave different restrictions in the possibility to give highly detailed input to the model: the abstraction of a complex event like a flood, with its different variables, required the introduction of different assumptions.

The inputs for the simulation have been designed in the following way:

- Using a spatial analysis, the percentage of land used for agriculture impacted by the flood in comparison with the total surface used for agriculture has been assessed.
- Impacted surface has been used as a proxy to quantify the percentage of capital lost in the industrial, commercial, infrastructural and urban sectors.
- The temporal extension of the flood event has been reasonably quantified in 2.5 months.
- The impact on the labour has been estimated assuming a general suspension of the working activities for 2 days in the area of the Po river Basin Impacted by the flood.

3.3 Social impact

The assessment of the social impact has been conducted only for the most impacted part of the area affected by the 2000 flood event. As mentioned above, the event affected more than 700 municipalities. This assessment has been implemented taking into account 239 municipalities due to data availability.

The social impact of flood is estimated following the methodology developed by Coninx and Bachus (2008) and recently applied by Ernst et al (2010) for the evaluation of inundation hazard, exposure and flood risk for a case study along river Ourthe in the Meuse Basin (Belgium). The social risk evaluation is a function of three variables, exposure to flood characteristics, social vulnerability and adaptive capacity.

Thus, following the approach of Coninx and Bachus (2008) which was employed by Ernst et al (2010) the social impact index, SI, is defined as follows:

$$SI = 0.5F + 0.25V + 0.25AC \qquad (7)$$

Where F is defined as the physical characteristics of the flood, V and AC denote the social vulnerability of people to floods and adaptive capacity, respectively. Coninx and Bachus (2008) stated that social flood impact experiences are very diverse among the affected people as there are people that can recover from floods easily and others that can be affected for months or years. Thus, the authors suggested that the way people experience social flood impacts is determined by three driving forces: flood characteristics, the exposure of people and vulnerability (as adopted by Hilhorst (2004), Peduzzi et al. 2002, Granger 2003 and Schneiderbauer and Ehrlich 2004).

The exposure to flood characteristics, F is calculated as follows:

$$F = 0.45WD + 0.22WR + 0.22VE + 0.11D \qquad (8)$$

Where *WD* denotes water depth score, *WR* is defined as water rise score, whereas *VE* and *D* denote as velocity and duration score, respectively. In Coninx and Bachus (2008), each of these scores in equation (8) is represented with a binary value (0 and 1) after taking into account a threshold value based on Ernst et al (2010) and (Penning-Rowsell et al. 2003) approach. In this study, it has been decided to use actual data collected by the Environmental Agencies within the Po river basin. The flood characteristics have been studied for each of the rivers involved in the 2000 extreme event. As a proxy for the *WD*, the maximum hydrological height reached by the rivers during the event was used. Regarding the variable *VE,* the maximum flow, expressed in cubic metres per second, registered for the rivers was employed. As a proxy for the *WR*, it has been decided to use the variation of the hydrologic height of the river in a 24 hours period. Finally, for the variable *D*, the duration of the flood event, lasting for 4 days, was considered.

The discussion will be now focused on the measurement of the other two components of the social risk index, the social vulnerability, *V* and adaptive capacity, *AC*. The calculation of the social vulnerability index is already discussed above. It takes a value which ranges from 0 to 1 and indicates that the higher the score of this index, the larger is the proportion of vulnerable people to floods. Moreover, the adaptive capacity is analyzed by an analytical framework, developed and applied based on literature reviewing, policy documents and stakeholders consultations. Both physical characteristics of the flood and adaptive capacity were normalised using the same methodology as for vulnerability. Finally, the social impacts were classified as very low (20^{th} percentile), low (40^{th} percentile), medium (60^{th} percentile), high (80^{th} percentile) or very high (100^{th} percentile) for the calculated values of *SI*.

4. Results

4.1 Risk map

As mentioned above, the hazard map (Figure 4) has been produced on the base of the information provided by the Hydrological Plan of the basin. The elaboration conducted is aimed to combine the different typologies of hazard (landslides, floods, inundation) threatening the basin, in order to obtain a hazard value at municipality level. The final output classifies the municipalities into four categories: low, medium, high and very high hazard. The most hazardous areas appear to be the mountainous regions of the basin. This could be explained by the large presence of small rivers and torrents that, in case of extreme rainfall events, are suddenly subject to flash floods with catastrophic consequences. Moreover, the mountainous regions of the basin are characterised by the presence of multiple active or stabilised landslides that constitute a serious problem in case of a consistent increase of the humidity rate of the soil. It could appear controversial that the alluvial plain created in the geological eras by the main river of the basin is characterised by a low hazard. This is mainly due to the fact that several engineering and infrastructural interventions have been implemented in the last three centuries to contain floods with a return period lower than 500 years.

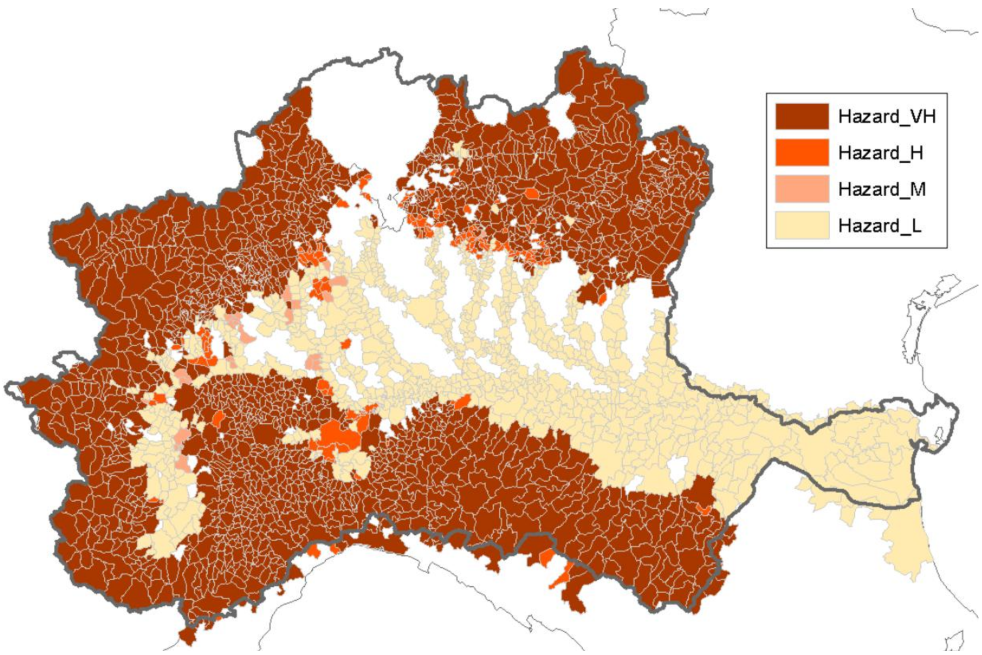

Figure 4. Hazard map of the municipalities in the Po river basin. Source: Authors' own elaboration based on AdBPo Data. The map presents 4 classes of hazard: low, medium, high and very high.

Regarding the exposure (Figure 5), the percentage of the constructed area over the total area of the municipality has been chosen as a proxy of the value exposed to the hazard. The final exposure map classifies the municipalities into five categories: 0 to 2 per cent, 3 to 5 per cent, 6 to 10 per cent, 11 to 20 per cent, 21 to 100 per cent of the area used for construction. The five classes of exposure were chosen considering the 20th, 40th, 60th, 80th and 100th percentile of the calculated values of exposure in the basin. As expected, the highest values are reached in the areas where the main cities are located. The highest exposure is registered in the areas of Milan (mainly), Turin, Reggio Emilia and Modena. The lowest values are registered in the mountainous areas of the basin.

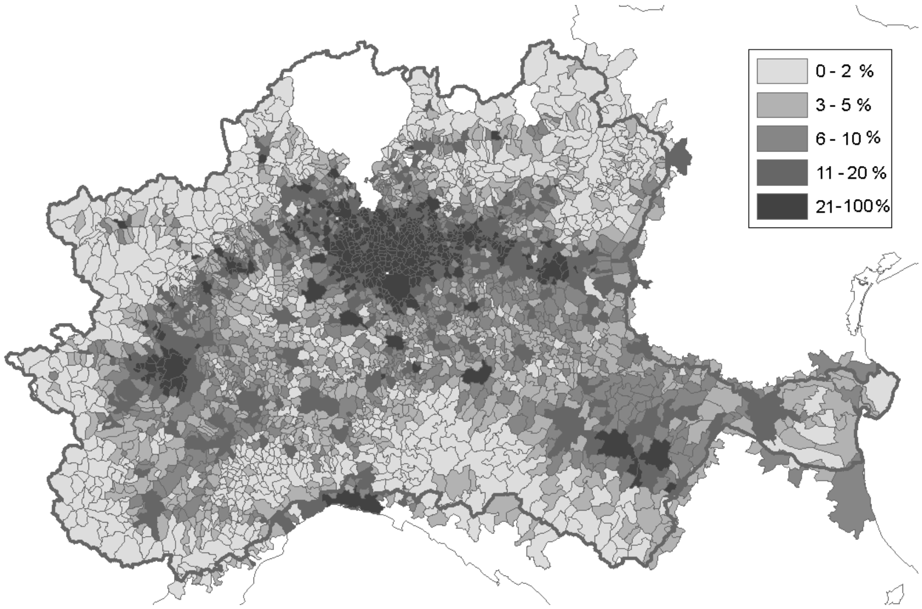

Figure 5. Exposure map of the municipalities in the Po river basin. Source: Authors' own elaboration based on CORINE Land Cover (2006).

As far as the vulnerability (Figure 6) is concerned, the index above defined gives a good representation of the most vulnerable areas. The final output classifies the municipalities into four categories obtained considering the quartiles of the results. The areas characterised by the lower level of vulnerability (ranging from 0.268 to 0.393) are located in the most remote and less populated areas, such as the alpine regions of Piedmont (west part of the basin) and Lombardy (north part of the basin) and the Appennine region of Emilia Romagna (south part of the basin) where the landscape is characterised by the presence of forests, national parks and natural ecosystems. The situation is very different in Valle d'Aosta, where the level of vulnerability reaches the highest values. This is explained by the fact that even if the density of the population could suggest a low level of vulnerability, its composition (age, education, presence of foreigners) leads to be classified as one of the highest vulnerable areas (ranging from 0.428 to 0.539). Other high vulnerable areas are located in the central of the basin, where the highest population density is reached.

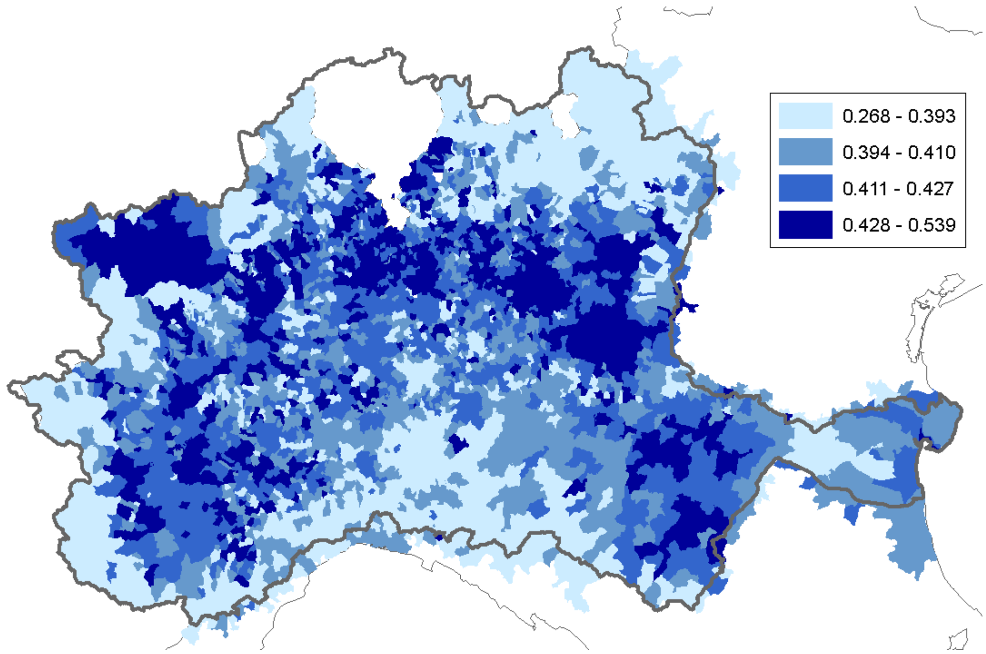

Figure 6. Vulnerability map of the municipalities in the Po river basin. Source: Authors' own elaboration based on ISTAT and ACI Data.

Moreover, the discussion is now focused on the risk map (Figure 7) obtained by the combination of the hazard, exposure and vulnerability. The final risk map classifies the municipalities into five categories: very low, low, medium, high and very high. The five classes of risk were chosen considering the 20th, 40th, 60th, 80th and 100th percentiles of the calculated values of risk in the basin. The results from the risk map are consistent with the results of the hazard, exposure and vulnerability maps. The highest risk areas are located in the mountainous and in the most populated portions of the basin. Almost the entire Valle d'Aosta region is characterised by the highest risk which is consistent with the high values of hazard and vulnerability for the specific area. The same is apparent for the metropolitan areas of Milan, Turin, Parma, Reggio Emilia and Modena. On the other hand, low and very low levels of risk were registered in the central part of the basin, mainly driven by the low hazard.

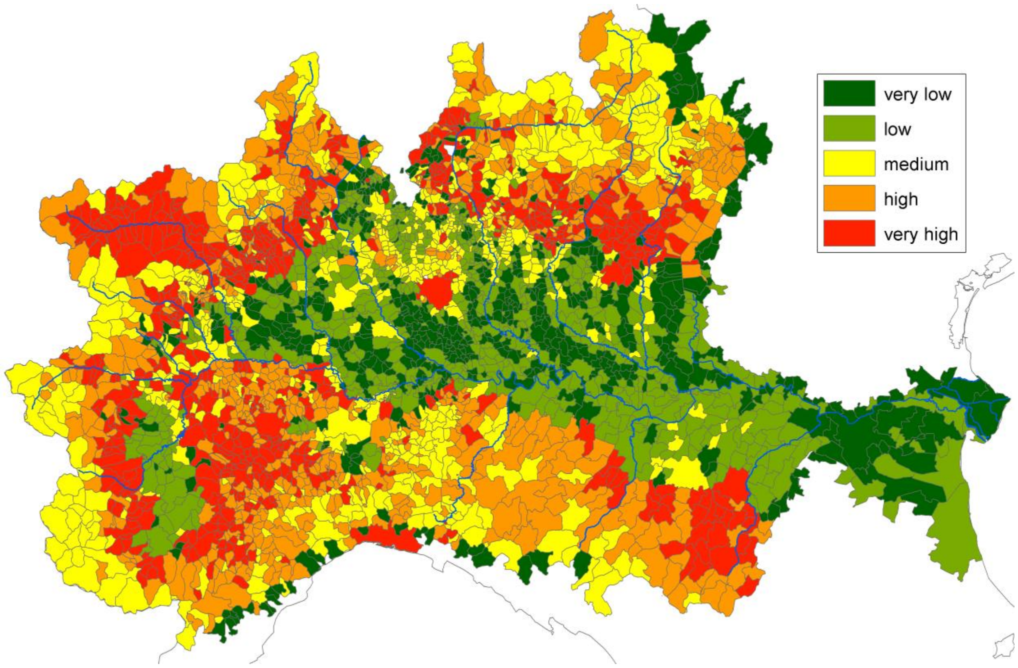

Figure 7. Risk map of the municipalities in the Po river basin. Source: Authors' own elaboration.

4.1 Direct economic impact

The first step to estimate the direct economic impact of floods requires the use of damage functions. These were obtained from HKV Consultants' report (2007) and are depicted in Table 1. HKV consultants calculated damage functions and specific maximum damage per damage category, based on replacement and productivity costs for Netherlands. Replacement costs are used for the evaluation of physical damage to buildings, inventories, terrain and infrastructure and accounts for the flood damage to be fully repaired or replaced. Productivity costs are used for business interruption inside and outside the flooded area (Wagemaker et al. 2007). As a result, HKV consultants applied the same valuation methods on behalf of the Joint Research Centre of the European Union, and harmonized the damage functions and country specific maximum damage per damage category for all EU-27 countries on the basis of replacement costs and productivity costs, relating them to the Gross National Products of the various member states (Huizinga, 2007).

	Residential building	Commerce	Industry	Road	Agriculture
EU27	575	476	409	18	0.59
Italy	618	511	440	20	0.63
Luxembourg	1443	1195	1028	46	1.28
Germany	666	551	474	21	0.68
Netherlands	747	619	532	24	0.77
France	646	535	460	21	0.66
Bulgaria	191	158	136	6	0.2

Table 1. Maximum damage values (euro/m^2) per damage category for selected EU countries (HKV Consultants 2007).

The results indicate that on average among the EU27, residential buildings are estimated to have the highest damage from floods, at the level of 575 Euro/ m^2, or equivalently the highest share of total damages, 39 per cent. Commerce and industry sectors also suffer from significant damages due to floods, 476 and 409 Euro/ m^2, respectively or equivalently 32 per cent and 27 per cent share of total damages, respectively. The damages to the other sectors such as roads and agriculture amounted to 18 and 0.59 Euro/ m^2. As far as Italy is concerned, it is estimated that damages to residential buildings from floods have the highest damage among the other categories, reaching the level of 618 Euro/ m^2, or equivalently the highest share of total damages, around 42 per cent. The damages to commerce and industry sectors due to floods were estimated to be at the level of 511 and 440 Euro/ m^2 or equivalently 35 per cent and 30 per cent share of total damages, respectively. The damages to the other sectors such as roads and agriculture amounted to 20 and 0.63 Euro/ m^2, respectively. Considerable damages from floods were estimated for Netherlands, Germany and France which were above the average level of EU27. Finally, Luxembourg had the highest maximum damages values as expressed per Euro/ m^2 and Bulgaria showed the lowest values among the EU27.

Based on the damage values estimated on the HKV consultants report (2007), we were able to calculate the direct economic impact of flood by multiplying each damage value to the categories of land identified through CORINE-Land Cover. Table 2 summarises the direct economic impact the flood occurred in Northern Italy in October 2000.

	Urban	Urban discontinuous	Industry/Commercial	Agriculture	Roads/Rail/Airports
Area [m2]	614,385	19,869,805	5,715,726	631,062,817	387,697
Damage [euro/m2]	618	309	475.5	0.63	14
Damage [euro]	379,689,930	6,139,769,745	2,717,827,713	397,569,575	5,427,758
Total damage [euro]	9,640,284,721				

Table 2. Economic direct impact from the 2000 flood event (expressed in 2007 terms)

The 2000 flood event caused significantly economic damages to the critical infrastructure of urban, urban discontinuous, ie areas outside the cities characterized by low density, industry/commercial, agriculture and transport sectors, which included either destruction or disruption of the infrastructure of these sectors. It was estimated that the total damage to critical infrastructure from the 2000 flood event reached the level of almost 9.6 billion Euros in 2007 terms, with urban discontinuous area and industry/commercial having the biggest impact among the sectors. The total direct damage to the infrastructure of urban and discontinuous urban areas was at the level of 380 million and 6 billion Euros respectively, whereas the level of damage for the infrastructure of industry/commercial and agriculture was at the level of 2.7 billion and 400 million Euros, respectively. The infrastructure of roads, railways and airports was also damaged, with almost 2 million Euros of estimated damage. The EM-DAT International Disasters Database indicates 25 casualties, population of 43,000 affected by the floods and overall damage amounting to US$ 8 Billions in 2000 dollar value (EM-DAT, 2009). By analysing the available reports we conclude that even if the damage is grossly underestimated, because it refers to direct cost only, the estimation obtained by the combination of CORINE-Land Cover and damage values has similar degree of magnitude to other studies.

The estimated direct economic impact for the above sectors is confirmed by the empirical evidence. As mentioned before, there is a high number of municipalities located in the Po river basin area, whereas the population amounts to 17 million inhabitants. In total, 43 per cent of the municipalities and 39 per cent of the population were severely affected by the 2000 flood event. For instance, in the area of Piedmont and Valle d'Aosta from the total 1280 municipalities, a large portion was flooded, with 357 of those reported as damaged. The same applies for the total number of residents, where almost 2 million people were recorded as being affected by the flood (PREEMPT, 2011a).

Moreover, in the Po river basin area, there is a significant number of industrial plants such as sewerage treatment, chemical and nuclear plants. The 2000 flood area caused severe accidents for most of the plants leading to damages to the plants themselves, 79 per cent of the sector in the Po river basin was damaged due to the flood (PREEMPT, 2011b), resulting in serious threats for the environment and human health. For instance, the invasion of water in waste dump areas in Turin moved away wastes, polluting the environment and posing risks for human health. Additionally, flooded chemical plants caused serious threats in the environment such as in the case of invaded water that came in contact with polluted land stored in the chemical plants in the area of Verbano-Cusio-Ossola, or the existence of pollutants in the surface water and underground aquifers in the area of Alessandria. Significant damages in infrastructure of natural gas plants were also reported in the area Verbano-Cusio-Ossola (PREEMPT, 2011b).

Furthermore, the flood event caused lifeline interruptions in the flooded areas. For instance, highways between Milan and Turin, Turin and Aosta were severely damaged. Several bridges were destroyed, such as in Noasca, Robassomero, Salassa, Feletto, resulting in temporal isolations of small and medium sized towns (SMS - Redazione Nimbus, 2000). The restoration of the railway between Turin and Aosta lasted for more than 2 years (PREEMPT, 2011b). There were significant interruptions in the electricity network, telecommunication and drinking water supply for several areas. For instance, Turin, Moncalieri and 30 small villages experienced interruptions of water supply for almost a week (SMS -Redazione Nimbus, 2000). However, immediate measures were taken by local administrations and regional institutions in order to repair the interruptions in the services' sector. For instance, in Valle d'Aosta Region 35.7 per cent of the total repairing costs was related to the water system, 25.5 per cent to the restoration of the road system and 38.8 per cent to the removal of landslips from railways and roads (PREEMPT, 2011b). Except for the industry and services sector, the 2000 flood event caused serious damages to the agriculture in terms of livestock and crops (PREEMPT, 2011b). For instance, in the area of Piedmont and Valle d'Aosta the damage to all the economic sectors amounted to 83,565 million Euros (PREEMPT, 2011c).

Except for the direct economic impacts of flood, for instance harm to humans, property and the environment such as damage to buildings, economic goods, loss of life, it is of great importance to estimate the indirect impacts, which is related to the disruption in economic and social activities and consequently, the effect in national production and economy as a whole.

4.2 Indirect economic impact

The first step to estimate the indirect economic impact of floods requires the estimation of capital, labour and land losses due to the extreme event under consideration. As underlined in the methodology section, the inputs for the estimation of the indirect economic losses have been calculated using a spatial analysis. The spatial analysis uses CORINE (Coordination of information on the environment) Land Cover 2006 (ISPRA, 2006) overlaid with actual flood extent, developed through the aggregation of several layers of information, to quantify land and capital lost during the event. The percentage of agricultural surface impacted by the flood event has been assessed, and the impacted surfaces of industrial, commercial, infrastructural and urban areas have been used as a proxy for capital lost.

Scale	Sector	Name	Area [m2]	% of Sector	Impact [months]	% Sector over 1 year
Italy	All	Total Surface IT	301,283,000,000			
Italy	Agriculture	Agriculture	157,274,427,413	100		
Italy	Industrial	Industry/Commercial	2,502,034,179	100		
Italy	Transport	Road/Rail/Airport	348,761,068	100		
Italy	Urban	Urban	10,992,336,579	100		
2000 Flooded Area	Agriculture	Agriculture	646,651,193	0.411	2.5	0.086
2000 Flooded Area	Industrial	Industry/Commercial	5,715,726	0.228	2.5	0.048
2000 Flooded Area	Transport	Road/Rail/Airport	387,697	0.111	2.5	0.023
2000 Flooded Area	Urban	Urban	20,484,190	0.186	2.5	0.039

Table 3. Surface area impacted by the 2000 flood event. Source: Authors' own elaboration based on CORINE Land Cover (2006) and Flood propagation data (Piedmont Region, Valle d'Aosta Region and ARPA ER).

As highlighted at Table 3, the 2000 flood event impacted the 0.411 per cent of the total Italian agricultural area. The extreme event under consideration affected also the 0.228 per cent of the industrial and commercial areas; the 0.111 per cent of the transport infrastructures; and the 0.186 per cent of the urban areas. The temporal extension of the flood has been estimated within a period of 2.5 months. Therefore, the percentages of land impacted by the 2000 flood event have been reduced taking into account this temporal horizon. The final inputs for the GCE model have been reported as follow:

- Agricultural land losses: 0.086 per cent of the total national agricultural area;
- Industrial and commercial capital losses: 0.048 per cent of the total national industrial and commercial capital;
- Transport infrastructural capital losses: 0.023 per cent of the total national transport infrastructural capital;
- Urban capital losses: 0.039 per cent of the total national urban capital.

The labour losses have been estimated considering a reasonable two working days stop for the entire workforce in the impacted Local Labour Systems. The Local Labour System (LLS) is a statistical unit devised by the National Bureau of Statistics (ISTAT) in order to describe areas of 'auto- reference' that is areas able to offer enough job opportunities and services for the population to live and work within the same statistical boundaries. The estimation has been conducted as follows.

Scale	Sector	Workers	% of Sector	Impact [days]	% Sector over 1 year
Italy	Agriculture	1,110,202			
Italy	Industrial	6,828,797			
Italy	Service	15,441,795			
Italy	All	23,380,794			
2000 Flooded Area	Agriculture	73,935.00	6.66	2	0.0365
2000 Flooded Area	Industrial	714,852.00	10.47	2	0.0574
2000 Flooded Area	Service	1,367,643.00	8.86	2	0.0485
2000 Flooded Area	All	2,156,430.00	9.22	2	0.0505

Table 4. Labour force impacted by the 2000 flood event. Source: Authors' own elaboration based on ISTAT data.

The 2000 flood event affected 6.66 per cent of the Italian population employed in the agricultural sector; 10.47 per cent of the population employed in the industrial sector; and the 8.86 per cent of the population employed in the services. The assumed temporal horizon of two days brings these percentages on a yearly scale as follows:

- Agricultural sector: 0.0365 of the total national agricultural workforce;
- Industrial sector: 0.0574 of the total national industrial workforce;
- Services sector: 0.0485 of the total national workforce employed in the services;
- All the economic sectors: 0.0505 of the national workforce.

Table 5 reports the results from this simulation. These results should be interpreted as the hypothetical application of the extreme event registered in October 2000 in the economic dynamics of the year 2001. The General Equilibrium Model GTAP has been set up referring to the world economy of the year 2001, chosen as baseline scenario. Therefore, the results at Table 5 give an order of magnitude of the shock on the national economy, variation in the country, sectoral GDP, prices and exports, caused by the flood registered in the Po river basin in October 2000, in comparison with the baseline scenario.

Country GDP Variation (%)	All Sectors	-0.0804
Sectoral GDP variation (%)		
	Agriculture	-0.0741
	Industry	-0.0958
	Transport	-0.0796
	Services	-0.0768
Sectoral Prices variation (%)		
	Agriculture	0.0149
	Industrial	0.0143
	Transport	0.0187
	Services	0.0213
Sectoral Exports variation (%)		
	Agriculture	-0.0717
	Industry	-0.1068
	Transport	-0.0729
	Services	-0.0833

Table 5. Results of the GTAP simulation for the 2000 flood event.

The estimated results showed a negative variation in the national Gross Domestic Product (GDP) of 0.0804 per cent, having all the sectors of the national economy been impacted by the shock. For instance, the agricultural sector is estimated to decrease its GDP by 0.0741 per cent, whereas the industrial sector showed the highest impact among the sectors with a decrease by 0.0958 per cent. The transport and services sectors are estimated to decrease by 0.0796 and 0.0768 per cent in GDP, respectively. Moreover, the estimated results reported a slight increase in the prices with respect to the baseline scenario. For example, the prices in the agricultural sector are estimated to increase by 0.0149 per cent, in the industrial sector by 0.0143 per cent, whereas in the transport and services sector the prices were estimated to increase by 0.0187 and 0.0213 per cent, respectively. Finally, the estimated results also showed a general decrease in the exports with respect to the baseline scenario. The biggest impact among the sectors was related to the exports in the industrial sector, by 0.1068 per cent, whereas the impact in the exports of the agricultural, transport and services showed lower impact, by 0.0717 per cent, 0.0729 and 0.0833 per cent.

4.4 Social Impact

The social impact map (Figure 8) was elaborated focusing on the most affected part of the flooded area during the 2000 extreme event (239 municipalities). The final SI map classifies the municipalities into five categories: very low, low, medium, high and very high. The five classes of social impact were chosen considering the 20th, 40th, 60th, 80th and 100th percentiles of the calculated values of SI in the assessed area. The results indicate that the most socially impacted areas are located along the Dora Baltea river (north west of the basin, passing through Valle d'Aosta region) and at the conjunction of it with the Po river (in Turin and downstream). This result is mainly attributed to the physical characteristics of these rivers and the high vulnerability of the area. Moreover, medium social impact was registered in the area of the Verbano-Cusio-Ossola province (north part of the basin), where the Toce river strongly affected the population. Finally, the lower value of social impact was presented by the area along the Dora Riparia river (western part of the assessed area). This is consistent with the lower level of vulnerability and physical characteristics of the river, during the extreme event, in comparison with the rest of the assessed area.

The obtained results are consistent with the empirical evidence of the 2000 flood event. It was reported that the event, jointly with the large number of landslips, strongly affected the local communities in the mountainous area of the North-West of Italy (PREEMPT, 2012). The disaster impacted residents both in urban and rural areas, and in some cases it is possible to empirically highlight particular differences for age, socio-economic conditions and job categories. The 2000 flood event strongly impacted young and old people, lower social classes and inhabitants of rural areas. For instance, the first human losses officially registered on October 16th had the following characteristics: a child at the age of 7 years living in a poor gipsy village near Turin; a 15 years old boy in Piedmont; an old man living in a small rural village in Valle d'Aosta who got trapped in the underground floor of his house; a three persons family and a mother with her child died when swept away by a landslip in the mountainous area; a homeless person was swept away by the water flow in Turin (PREEMPT, 2012).

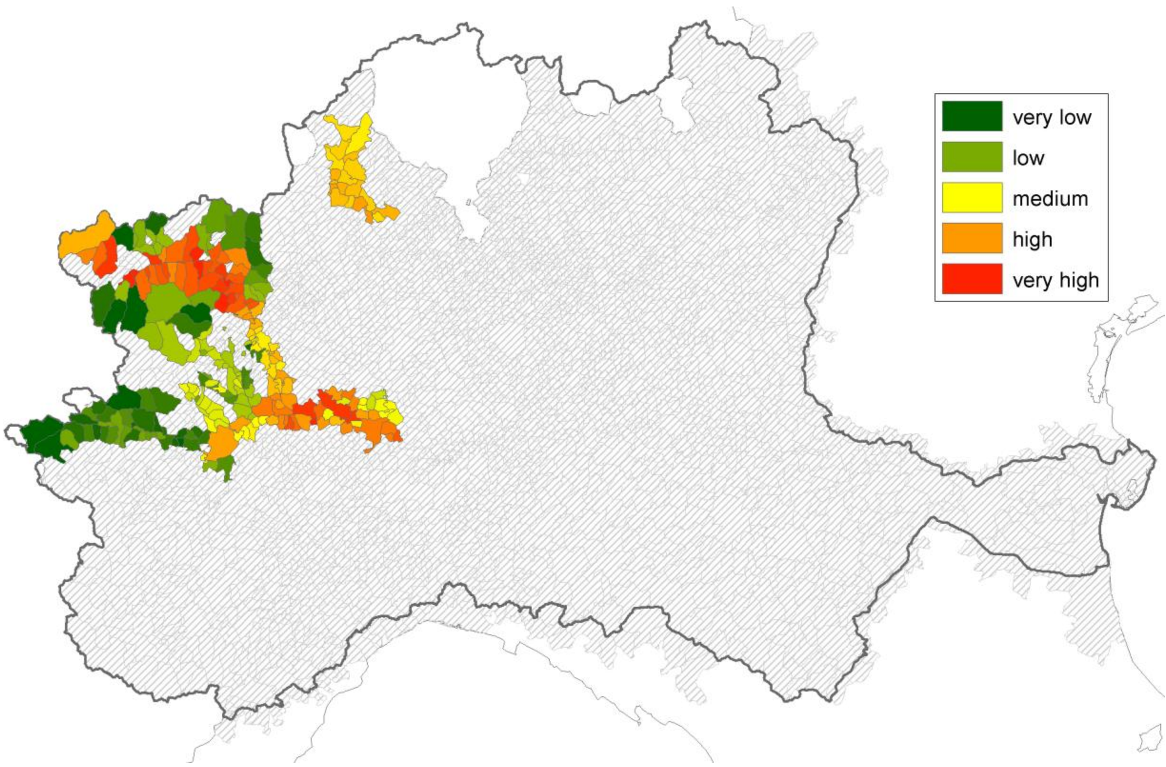

Figure 8. Social Impact. Source: Authors' own elaboration.

5. Conclusions

This paper estimated the direct and indirect socio-economic impact of flood that took place in the Po river basin (Italy) in 2000. It firstly provided a risk map for the whole basin which is generated as a function of hazard, exposure and vulnerability. Then, it estimated the direct economic costs by employing GIS techniques with spatial information data. Moreover, the indirect economic impact of flood is estimated through the analysis of the disruptions to the socio-economic system. Finally, the social impact of flood focusing on the most affected part of the flooded area is estimated using tools derived from the multi-criteria analysis and is expressed as a function of physical characteristics of the extreme event, social vulnerability and adaptive capacity.

Delving more deeply into our results suggests that the highest risk areas are located in the mountainous and in the most populated portions of the basin. Almost the entire Valle d'Aosta region (north-west part of the basin) is characterised by the highest risk which is consistent with the high values of hazard and vulnerability for the specific area. The same is apparent for the metropolitan areas of Milan, Turin, Parma, Reggio Emilia and Modena. On the other hand, low and very low levels of risk were registered in the central part of the basin, mainly driven by the low hazard.

Focusing on the direct economic impacts of the flood event, the study concludes that significantly economic damages occurred to the critical infrastructure of urban, urban discontinuous, areas outside the cities with low density, industry/commercial, agriculture and transport sectors. It was estimated that the total damage to critical infrastructure from the 2000 flood event reached the level of almost 9.6 billion Euros in 2007 terms, with urban discontinuous area and industry/commercial having the biggest impact among the sectors. As far as the indirect economic impact is concerned, the estimated results reported a negative variation in the national Gross Domestic Product (GDP), having all the sectors of the national economy been impacted by the shock. The highest impact in terms of GDP, prices and exports was reported for the industrial sector. Regarding the results from the social impact, it is concluded that the most socially impacted areas are located along the Dora Baltea river (Valle d'Aosta region) and at the conjunction of it with the Po river (in Turin and downstream). This is mainly attributed to the physical characteristics of these rivers and the high vulnerability of the area. On the other hand, the lower value of social impact was reported at the area along the Dora Riparia river (western part of the area of study). This is consistent with the lower level of vulnerability and physical characteristics of the river during the extreme event in comparison with the rest of the assessed area.

It should be finally noted that this is the first study that quantifies the social and economic impact of flood in the Po river basin, a highly economically developed and populated area with industries, municipalities and habitants located to flood risk prone regions. It provides a useful tool to those who are interested in estimating the economic damage caused by flood events. It can also assist decision makers in pinpointing those factors that threaten the sustainability and stability of a risk-prone area. More specifically, this study could help to better understand how social vulnerability to flood events can be reduced. It has to be finally underlined that this study should be of great importance for those who are interested in improving the efficiency in the evaluation of hydro-meteorological risk and promoting the sustainable development within the European Flood Risk Management Directive implementation.

Acknowledgments

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REFERENCES

ANPA (2001). Emergenza alluvione Ottobre 2000. Rapporti 7_2001, Agenzia Nazionale per la Protezione dell'Ambiente.

ANPA (2002). L'alluvione in Piemonte del 13-16 ottobre 2000 - Gli effetti su alcuni siti a significativo impatto ambientale. Rapporti 14_2002, Agenzia Nazionale per la Protezione dell'Ambiente.

ARPA Piemonte (2003). Eventi alluvionali in Piemonte. 13-16 ottobre 2000. Torino, Agenzia Regionale per la Protezione Ambientale Piemonte.

Badri Narayanan G. and Terrie L. Walmsley (2008). Global Trade, Assistance, and Production: The GTAP 7 Data Base, Centre for Global Trade Analysis, Purdue University.

Brooks, N. (2003). Vulnerability, risk and adaptation: a conceptual framework. Working Paper 38, Tyndall Centre for Climate Change Research, University of East Anglia, Norwich. Available at: www.tyndall.ac.uk.

Camera dei deputati (2000). Eventi alluvionali verificatisi nell'Italia settentrionale nel mese di ottobre 2000. Commissione Parlamentare VIII. Indagini conoscitive e documentazioni legislative n. 38. Atti Parlamentari XIII Legislatura.

Cochrane, H. (2004). Economic loss: myth and measurement, Disaster Prevention and Management, 13(4): 290-296.

Coninx, I., and Bachus, K. (2008). Social flood risk assessment - Methodological paper for the ADAPT project. KUL, 25.

Cutter, S.L. and Morath D.P. (2012). The evolution of the Social Vulnerability Index. Forthcoming, J. Birkmann (ed.), Measuring Vulnerability to Natural Hazards (2nd Edition), United Nations University Press.

Cutter, S. L., (1996). Vulnerability to environmental hazards, Progress in Human Geography, 20: 529-539.

Cutter, S. L., B. J. Boruff and W. L. Shirley, (2003). Social vulnerability to environmental hazards, Social Science Quarterly, 84 (2): 242-261.

Cutter, S. L., J. T. Mitchell and M. S. Scott, (2000). Revealing the vulnerability of people and places: a case study of Georgetown County, South Carolina, Annals of the Association of American Geographers, 90 (4): 713-737.

Cutter, S. L., Burton, C. G., Emrich, C. T., (2010). Disaster Resilience Indicators for Benchmarking Baseline Conditions. Journal of Homeland Security and Emergency Management. 7 (1)

De Marchi B., Scolobig A., Delli Zotti G., Del Zotto M. (2007). Risk construction and social vulnerability in an Italian Alpine Region, Floodsite, Integrated Flood Risk Analysis and Management Methodologies.

EM-DAT (2009). The OFDA/CRED International Disaster Database – www.emdat.be, Université Catholique de Louvain, Brussels (Belgium)

ENSURE (2009). Del. 2.1.2: Relation between systemic and physical vulnerability and relation between systemic, social, economic, institutional and territorial vulnerability. Enhancing resilience of communities and territories facing natural and natech hazards.

Ernst J., Dewals B.J., Detrembleur S., Archambeau P., Erpicum S., Pirotton M. (2010). Micro-scale flood risk analysis based on detailed 2D hydraulic modelling and high resolution geographic data, Natural Hazards, 55: 181-209

Granger K. (2003). Quantifying storm tide risk in Cairns. Natural Hazards. 30: 165-185.

Guzzetti, F. and Tonelli, G. (2004). SICI: an information system on historical landslides and floods in Italy. Natural Hazards Earth System Science, 4: 213–232

Hertel T.W. (1997). Global Trade Analysis: Modeling and Applications, Cambridge University Press

Hilhorst D. 2004. Wageningen course Natural Hazards and Disaster. Universiteit Wageningen. Wageningen (16 maart 2004)

HKV Consultants (2007). Flood damage functions for EU member states. Unpublished Report.

Huizinga, H.J., 2007. Flood damage functions for EU member states. HKV Lijn in water, Lelystad, the Netherlands.

ICRISAT. Vulnerability Analysis Manual.

IPCC (2001). Climate change 2001: Impacts, Adaptation and Vulnerability, Summary for Policymakers, WMO.

ISPRA (2006). Corine Land Cover 2006, Istituto Superiore per la Protezione e la Ricerca Ambientale.

Kienberger S. (2012). Mapping Vulnerability- Integration of GIScience and participatory approaches at the local and district levels. Forthcoming, J. Birkmann (ed.), Measuring Vulnerability to Natural Hazards (2nd Edition), United Nations University Press.

Lastoria, B. M. R., Simonetti, M. Casaioli, S. Mariani, and G. Monacelli (2006). Socio-economic impacts of major floods in Italy from 1951 to 2003, Advances in Geosciences, 7. 223–229

Mercalli, L., Cat Berro, D., (2000). "L'evento alluvionale del 13-17 Ottobre 2000 nel bacino del Po: analisi pluviometrica." Nimbus Nimbus 21-22 – Speciale alluvione Ottobre 2000

Messner, F. and Meyer, V. (2005). Flood damage, vulnerability and risk perception – challenges for flood damage research, UFZ Leipzip-Halle, UFZ-Diskussionspapiere.

Messner, F., Penning-Rowsell, E., Green, C., Meyer, V., Tunstall, S. and Veen, A. (2007), Evaluating flood damages: guidance and recommendations on principles and methods, Integrated Flood Risk Analysis and Management Methodologies, Floodsite, UK.

Peduzzi P., Dao H., Herold C. (2002). Global risk and vulnerability index trends per year. Phase II. Development, analysis and results. Scientific report. UNDP/BCPR, Geneva.

Pauw, K., Thurlow J., Bachu, M., and Van Seventer D.E. (2011). The economic costs of extreme weather events: A hydro-meteorological CGE analysis for Malawi, Environment and Development Economics, 16 (2): 177-198

Penning-Rowsell, E. C., Johnson, C., Tunstall, S. M., Tapsell, S. M., Morris, J., Chatterton, J. B., Coker, A., and Green, C. (2003). The Benefits of Flood and Coastal Defence: Techniques and Data for 2003. Flood Hazard Research Centre, Middlesex University.

PREEMPT (2011a). B.1 Report on data and risk assessment methods used in reference river basins, policy requirements and potential for improvement, Policy-relevant assessment of socio-economic effects of droughts and floods.

PREEMPT (2011b). C.1 Database of Losses Inflicted, Policy-relevant assessment of socio-economic effects of droughts and floods.

PREEMPT (2011c). D.1 Comprehensive impact assessment report, Policy-relevant assessment of socio-economic effects of droughts and floods.

PREEMPT (2012). D.2 Vulnerability and resilience report. Analysis of drivers amplifying/attenuating the effects of disasters.

Rose, A. (2004a). Defining and measuring resilience to disasters, Disaster Prevention and Management 13(4): 307-314.

Schneiderbauer S. and Ehrlich D. (2005). Risk, hazard and people's vulnerability to natural hazards. A review of definitions, concepts and data. Joint Research Centre, European Commission.

Smit, B., Burton, I., Klein, R. J. T. and Street, R. (1999). The science of adaptation: a framework for assessment, Mitigation and Adaptation Strategies for Global Change, 4: 199-213.

Tapsell, S. M., Penning-Rowsell, E. C., Tunstall, S. M., and Wilson, T. L. (2002). Vulnerability to flooding: health and social dimensions. Philosophical Transactions of the Royal Society, A: 1511-1525.

United Nations Development Programme - UNDP (2006). Human development report, United Nations Development Program.

United Nations International Strategy for Disaster Reduction - UNISDR (2009). Global Assessment Report on Risk Reduction.

Wagemaker, J., Leenders, J. and Huinzinga, J. (2007). Economic valuation of flood damage for decision makers in the Netherlands and the Lower Mekong River Basin. HKV consultants, Leystad, the Netherlands.

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