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# FLOOD DYNAMICS, SOCIAL VULNERABILITY AND RISK PERCEPTION: CHALLENGES FOR FLOOD RISK MANAGEMENT

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# DINAMICHE DI PIENA, VULNERABILITÀ SOCIALE E PERCEZIONE DEL RISCHIO: OPPORTUNITÀ PER LA GESTIONE DEL RISCHIO ALLUVIONALE

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*Dedicated to all flood-prone communities worldwide*

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# SUMMARY

The 2015 was a remarkable year in the global policy with the publication of three milestones: The Sendai Framework for Disaster Risk Reduction, the Sustainable Development Goals and the Paris Agreement for Climate Change. The global significance of such documents raised interest in the understanding of the interaction between humans, the Earth and the climate, and the past and current development of disasters. Anthropogenic landscapes are one of the most sensitive environments to hydrological extremes, fluctuations and changes. Here, hydrogeological disasters such as floods are considered one of the major threat of our time, bringing negative consequences to the whole societal system. However, while climate change and socio-economic development are important drivers of flood impacts, human behaviours can alter the potential effects of a flood by undertaking protective behaviours. In this regard, risk perceptions are potential drivers of behaviour. Thus, exploring individuals' concern about natural hazards provide essential information about people willingness to take precautionary measures and can, therefore, identify the major reasons behind the unsatisfactory performance level of current disaster management practices. This suggests that advancing our understanding of the hazard perceptions by investigating personal, social and cultural influences can help in determining people preparedness. Limitations of personal action in front of the risk might come from social vulnerabilities, those factors that increase the fragility of individuals toward a particular threat. In light of this, there is the need to create people-oriented management strategies, with governments focused on vulnerable groups, able to recognise local capacities, foster communication and create awareness campaigns to empower the citizens and mitigate the undesirable effects of such events.

For this reason, this thesis proposes an analysis of flood and human interactions using historical and land use change data, participatory approaches and analysis of social vulnerability. Furthermore, this thesis would suggest possible flood risk management actions and policies in

different anthropogenic communities. Different study areas have been chosen in order to tackle site-specific flood dynamics and capture how the socio-political and unique cultural background of each community might affect individuals conceptualisation of risk.

# SOMMARIO

Il 2015 è stato un anno chiave nella politica globale con la pubblicazione di tre documenti fondamentali: il Quadro di Sendai per la Riduzione dei Rischi Naturali, gli Obiettivi di Sviluppo Sostenibile e l'Accordo di Parigi sui cambiamenti climatici. Il significato globale di tali documenti ha suscitato interesse riguardo l'interazione tra uomo, Terra e clima simultaneamente alla frequenza dei disastri. I paesaggi antropici sono uno degli ambienti più sensibili agli eventi climatici estremi, alle loro fluttuazioni e mutamenti. Qui, i disastri idrogeologici, come le alluvioni, sono considerati una delle maggiori minacce del nostro tempo con conseguenze negative sull'intero apparato sociale. Tuttavia, mentre i cambiamenti climatici e lo sviluppo socio-economico sono fattori chiave che incidono sull'impatto delle inondazioni, i comportamenti umani possono anch'essi alterare e talvolta esasperare le conseguenze di tali eventi. A tal riguardo, la percezione del rischio di un individuo costituisce un elemento strategico per la definizione delle politiche di gestione poiché influenza la capacità del singolo di adottare misure precauzionali. Questa conoscenza permette di identificare le motivazioni che spingono le popolazioni ad agire (o non agire) in protezione da questi eventi. Si esaminano così le componenti personali, ma anche la struttura sociale, culturale e politica della comunità, che influenza tutto il processo cognitivo relazionato alle alluvioni. Tra i caratteri personali, ci possono essere degli elementi che amplificano la vulnerabilità verso tali eventi, rendendo l'individuo più esposto al pericolo e limitando la capacità di reazione. Tutti questi elementi sottolineano la necessità di una gestione integrata del rischio alluvionale, atto a riconoscere le capacità locali, aumentando la comunicazione, sensibilizzando la popolazione ad una cultura del rischio affinché possa prepararsi e mitigare gli effetti di tali eventi. Per questa ragione, questa tesi mira a proporre un approccio integrato alla gestione del rischio, proponendo analisi di dinamiche di piena e di cambiamento di uso del suolo, valutando il comportamento dell'uomo in relazione a tali eventi, attraverso analisi storiche, di vulnerabilità sociale e anche

attraverso l'uso di approcci partecipativi. Inoltre, questa tesi suggerisce possibili azioni e politiche di gestione del rischio alluvionale in diversi territori antropizzati. Le aree di studio analizzate si differenziano tra loro al fine di comprendere come il contesto socio-politico e culturale unico di ogni comunità possa influenzare la comprensione del rischio e come si sono evolute le dinamiche di piena.

CHAPTER 1

# INTRODUCTION

Among all observed disasters, hydro-meteorological hazards are unquestionably the most frequent and damaging ones worldwide (UNISDR and CRED 2015). In particular, floods represent one of the most hazardous environmental risks of our time (Dottori et al. 2018), posing severe impediments to human security and development (IDMC 2016). Between 1995 and 2005, 3,062 floods have been registered worldwide (CRED EM-DAT 2017). This burden is not shared equally among the countries, in fact, Asia seemed to be the most affected continent by floods and storms, with 44% of all disaster events, 58% of total deaths and 70% of total people affected (CRED EM-DAT 2017). A recent publication investigating changes in extreme floods worldwide, excluding the Southern Asian continent, highlighted that in the 30 year period from 1980 to 2009, there had been an increase in extreme floods with the most influential trends in Europe and the United States with weaker frequency in the lower hemisphere (Berghuijs et al. 2017). Floods have produced more than 539,000 fatalities and affected nearly 3 million people in the same period (Doocy et al. 2013). Between 1998 and 2005, Europe experienced a high concentration of floods, involving north-western Romania, south-eastern France, central and southern Germany, northern Italy, and eastern England (EEA 2018).

Apart from the dramatic direct damages and fatalities, floods also cause broader and long-term adverse economic consequences (Koks and Thissen 2016). These consequences are exacerbated by land- cover changes responsible for controlling the rainfall-runoff relations, with an impact on flood risk (Kundzewicz et al. 2010). In former floodplains, near rivers and coastal areas, urbanisation is steadily increasing (Adikari and Yoshitani 2009; Anguillari 2013) contributing to a rise of impervious areas and a reduction of the time-to-peak. Land-use change, the intensification of agriculture, and the engineering of landscapes have been amplifying the flood hazard as found by Van der Ploeg et al. (2002) in Germany. In Italy, Sofia et al. (2014) argued that land use management and the new agricultural practices had decreased the network storage capacity resulting in a long delay in the watershed response. Many dysfunctionalities of the reclamation systems do not derive only by anthropic pressure and unsustainable land management but also by worsened climatic conditions (Pijl et al. 2018). The climate change is observed by an increase in air temperatures of 1.5 °C - 2 °C (King et al. 2018) and by changes in the spatial and temporal characterisation of precipitations that burden the global hydrological cycle (Yao et al. 2015). Precipitation has generally increased over the land, and since the 20$^{th}$ century, the magnitude is about 2% (Dore 2005). However, this increase is not uniform within the globe and varies with the latitudes. The climatic regime is therefore altered affecting the intensity of such precipitations (Kunkel and Frankson 2015; Alexander 2016; Donat et al. 2016) with consequences on the risk of flooding. Even if individual extreme events cannot be used to deduce a trend, some recent rainfall events have exceeded all-time records (Van der Ploeg et al. 2002). The effects of meteorological extremes and human activities on flood dynamics have not sufficiently studied because the interaction among these factors is quite rapid and complex (Di Baldassarre et al. 2013a). Moreover, the precise magnitude of the anthropogenic contribution remains uncertain (Pall et al. 2011), and data usually are limited. Long-time series are essential for planning flood protection systems (Kundzewicz et al. 2010), that should consider hydrological data but also human dynamics at different spatial scales (Di Baldassarre et al. 2013a). Although advanced efforts have been made to protect people from floods, the number of people vulnerable to them worldwide is expected to thrive to two billion by 2050 (Bogardi 2004). The lesson learnt from past floods are costly but valuable (Mysiak et al. 2013). These lessons need to be understood and translated into effective planning actions with more community-centred policies. These goals are at the top of the global political agenda for the next 15 years and have been widely discussed in the Sendai Framework for Disaster Risk Reduction (2015-2030). The guidelines deriving from this global summit expressed the need to reduce the impacts of risks and disasters with the engagement of all stakeholders (UNISDR 2015). Taking into account the experiences gained from the Hyogo Framework for Action (2005-2015) four priorities areas have been fostered: (1) Understanding disaster risk (2)

Strengthening disaster risk governance to manage the risk (3) Investing in disaster risk reduction for resilience and (4) Enhancing disaster preparedness for effective response and to 'Build Back Better' in recovery, rehabilitation and reconstruction. At the European level, the requirement for a complete flood risk management approach at a watershed level has been documented by the European natural disaster management policy with the Flood Directive 2007/60/EC (European Union 2007). This directive of the European Parliament and the Council of European Union establishes a framework for "Community action in the field of water policy" that requires river basin management plans that will contribute to mitigating the effects of floods focusing on prevention, protection and preparedness.

## 1.1 State of knowledge

Risk is an important concept in any fields of research. While risk is a term used daily, its more conventional meaning is used to refer to "a combination of the probability, or frequency, of occurrence of a defined hazard, and the magnitude of the consequences of the occurrence" (Harding 1998). When this term is sorted to the disaster context, it implies much more. Disaster risk is the potential loss expressed in lives, welfare, assets and services, deriving from the combination of hazard, exposure and vulnerability (Cardona et al. 2012). These three elements are interconnected, underlying that the adverse consequences of disasters are not only a result of the hazard per se.

In the ordinary sense, the hazard is anything that causes fear of loss or potential harm to humans and their possessions (Dahal 2008). In the human-ecological perspective, Burton and Kates (1964) defined natural hazards as those elements in the physical environment harmful to humans and caused by forces extraneous to them. However, this implies that only those events that threaten the human safety are called natural hazards. Alcántara-Ayala (2002) highlighted how several disciplines define differently such term, concluding that natural hazards are "threatening events capable of producing damage to the physical and the social space" not only when they strike but also in some time after their occurrence. There are several type of natural hazards and, for that, there are several aspects to take in consideration for their categorization: (i) the triggering event; (ii) the areas where hazards are likely to initiate; (iii) the areas where they would spread; (iv) the expected intensity and (v) its associated frequency or probability of occurrence (ISDR 2004). Natural hazards are related to the geomorphology, e.g. Earth's surface dynamics, that interact with the human resources (exposed elements). The second component of risk is, in fact, exposure. It refers to the inventory of elements present in an area in which hazard events may occur (ISDR 2004; UNISDR 2009). Hence, if population and economic resources are not located in (exposed to) a potentially dangerous environment, no disaster risk would exist. However, the literature and common usage often incorrectly merge the two factors that are distinct by definition. Exposure is necessary, but not a sufficient determinant of risk. The increase in population growth that requires a continuous search for building up areas is translating into a progressive decrease in land availability and an inclination to build in unsafe locations (Lavell 2003). Thus, land use and spatial planning are critical factors for reducing the risks posed by these threats and reduce the negative effect on communities. Where the land use planning cannot reduce the exposure to hazards, a combination of structural or non-structural methods is necessary for managing the risks (United Nations 2009a).

Another term often associated with exposure is vulnerability, the third component of the risk equation. It is possible to be exposed but not vulnerable, i.e. for example by living in a floodplain but having sufficient resources to be able to reduce the possible losses. However, to be vulnerable to an extreme event, it is necessary also to be exposed. Vulnerability is the susceptibility to environmental threats, determined by exposure and sensitivity to disturbance, and the capacity to adapt (Smit and Wandel 2006). More specifically vulnerability refers to the characteristics of the elements exposed (Crichton 1999) and the social relations among groups in a given society (Cutter et al. 2003; Smit and Wandel 2006; Mechanic and Tanner 2007). In fact, according to Hewitt (1997), the social geography and the political interactions influence the vulnerability of risk-prone communities and their capacity to react. The vulnerability can be defined as 'biophysical' when the causes of people fragility involve the environmental system, whereas it is 'social' when the human component is the subject of such sensitivity (Brooks 2003). In other words, social vulnerability identifies those demographic characteristics or social groups that are more or less susceptible to threats being a function of social, economic, historical and political processes that are root causes of the current vulnerability (Hill and Cutter 2001). This concept is described in the Pressure and Release (PAR) model (Figure 1.1) that defines the vulnerability as a progression of social forces rooted in the society, dynamic pressures and activities that translate into temporally and spatially unsafe conditions (Wisner et al. 2004). For this reason, the measurement of social vulnerability is complicated (O'Brien et al. 2004) because of the dynamic relationship between the physical and human processes over time.

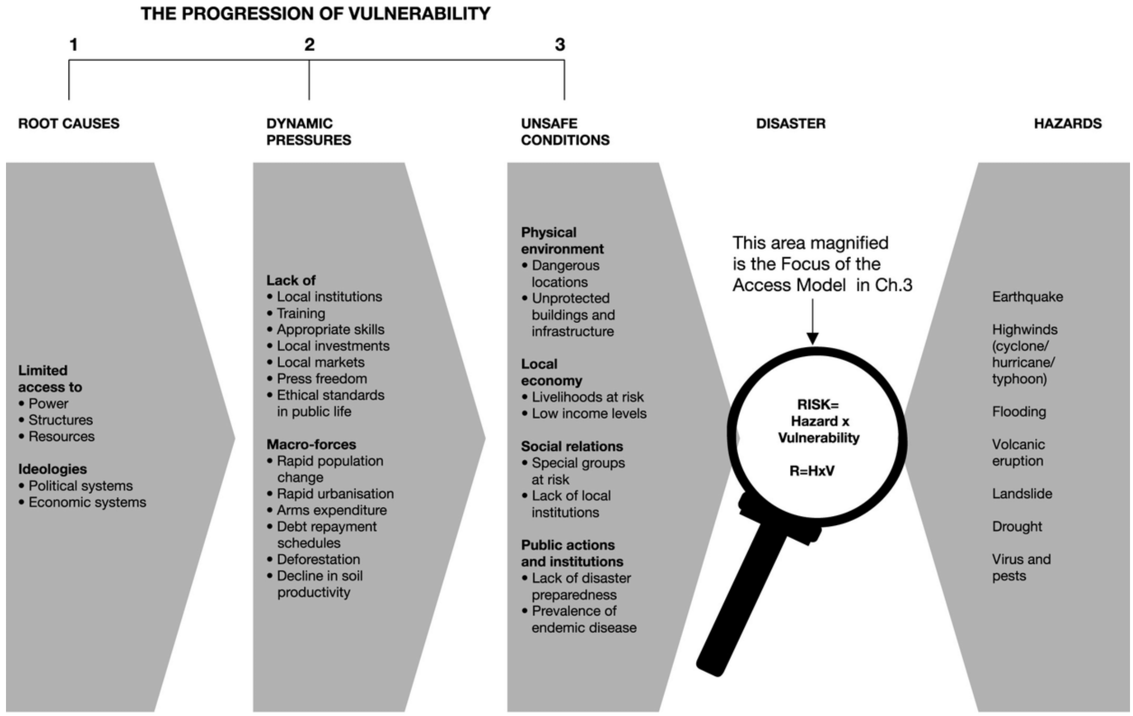


Figure 1.1 Pressure and Release (PAR) model: the progression of vulnerability. Source: Wisner et al. (2004).

The inclusion of social vulnerability within the disaster context was introduced in the 1970s when researchers had recognised that vulnerability also involved socio-economic factors able to affect community preparation, adaptation and resilience (Juntunen 2006). Those factors are a function of power relations, i.e. class, age, gender, ethnicity, among others that are operative in every society and that affect people differently in the globe. Disasters can exacerbate already-existing inequalities within communities (Thomas et al. 2013) transforming the old concept of being ‘at risk’ as a mere function of being in a specific place or in a specific time (Bankoff 2006). Social vulnerable indicators interplay with cognitive and psychological factors that influence the way people conceptualise the risk and co-exist with such events by getting prepared. The decisions that people make in front of a possible natural hazard event depend on their interpretation of risk. The perception of risk involves the process of collecting, selecting and interpreting signals about the uncertain impacts of events, activities or technologies (Slovic 1987; Scholz 2011). Such studies in the disaster context attempt to comprehend how individuals evaluate the danger (Fromm 2005; Bradford et al. 2012) and which are the activities they would implement if resources are available (Botzen et al. 2009a; Hufschmidt 2011). The criteria adopted at the individual level to evaluate different risks vary depending on personal conditions and local situations (Salvati et al. 2014). Individual's socio-economic characteristics are important predictors of this cognitive process (i.e. Lai and Tao 2003; Barberi et al. 2008; Lindell and Hwang 2008; Paton et al. 2008; Kellens et al. 2013; Ainuddin et al. 2014), however, there are some factors (i.e. gender and ethnicity) that are often ignored in the disaster management and also underreported in research. Gender disparities exert a powerful influence on societies worldwide, as demonstrated by the Gender Equality Index reported by the Social watch organisation (2012). The same disparities have been recently found to influence personal perceptions of disaster because of differentiated roles and responsibilities, skills and capabilities, vulnerabilities, power relations, institutional structures, and long-standing traditions and attitudes (Obcarskaite 2014).

Similarly, ethnicity has the same influence on disaster awareness and preparedness. In fact, during the 70s, researchers found a divergence between white people and African Americans concerning environmental issues (Macias 2015). This unbalance is grounded in different social pressures and political forces that led minorities to set environmental issues as the lowest priority (Mohai and Bryant 1998). As a consequence, members of socially powerful groups see threats to self and the community as less risky and more manageable than do members of non-dominant groups (Finucane et al. 2000; Solberg et al. 2010) implying that there are ethnic/racial differences in risk-taking. Among ethnic groups worldwide, indigenous people are more than 370 million in 90 countries being today the most disadvantaged and vulnerable group in the world (United Nations 2009b). Their identity and livelihood are related to the environment and the way natural resources are managed, but they have been violated many times. Indigenous people have learnt how to view and interact with the environment, have special knowledge (called as 'traditional knowledge'), maintain lessons from past disasters and invest in the place where they live (Baumwoll 2008).

While socio-economic factors are important, individuals' psychological characteristics and emotional responses to disasters influence the individual conceptualisation of risk (Kitzinger 1999; Eiser et al. 2012; Gotham et al. 2018). Trust, in this regard, plays a crucial role in the perception of natural risks, especially when the knowledge or understanding of a specific risk is limited (Wachinger and Renn 2011). Building public trust can help people tolerating uncertainties derived from disaster events, reducing the complexity of such situations (Siegrist and Cvetkovich 2000). Also, individuals' network and the neighbourhood relations might influence the perceptions or misperceptions of a particular situation. The theory of 'place attachment' in this framework can explain the relationships an individual has with the surrounding environment (Low and Altman 1992). It is likely that such bonds would affect disaster preparedness and evacuation, as registered by Mishra et al. (2010) in a study conducted in India. The more the social networks are robust and rooted, the more people act in synergy against the negative occurrences. The remainder of previous flood experience (Kitzinger 1999; Eiser et al. 2012) and the proximity to rivers (Mishra et al. 2010) are other important factors influencing the perception and protection to floods.

The term 'protection' encompasses two different measures regarding the strategies to mitigate disaster risks: structural and non-structural actions. Structural measures include engineered solutions that offer security at high costs, but until the economic lifetime of the construction (Baan and Klijn 2004). Non-structural measures, e.g. building codes, land-use planning laws, public awareness programmes, monitoring, early warning systems and emergency, are on particular advantage respect the others because they are sustainable over the long run with minimal costs for operation, maintenance, and replacement. Natural hazards insurances are non-structural measures aimed to assist the contractor to dampen the costs of damages, but without eliminating the current risk nor preventing a future one.

In 2017 there have been registered fewer catastrophes than in 2016, however, the damage they inflicted was double the 2016 total (USD 337 billion vs USD 180 billion) (Swiss Re 2018). Thus, the rapid increase in global economic losses and the steady parallel increase in the number of properties (Kousky and Kunreuther 2018) have fostered discussions among private insurers, governments, and international organisations about the role of insurance in addressing the risks (Surminski 2014). Insurances are "zero- and low-carbon adaptation strategies" (Wamsler and Lawson 2011) working in the ex-ante, able to lessen the economic burden to the homeowner (Ghesquiere and Mahul 2007; Melecky and Raddatz 2011; von Peter et al. 2012), being more effective than that ex-post disaster aid (Ranger and Surminski 2011). This because they provide a rapid alternative for early recovery to potential losses, reducing the heavy reliance on government aid (Abbas et al. 2015). Risk transfer is a mechanism able to decrease the burden of anxiety and stress derived from risks and simultaneously consolation in case of loss (Michel-Kerjan and Kunreuther 2011).

There is a variety of measures of risk financing (Wamsler and Lawson 2011), from free private market solutions to compulsory insurance pools (European Commission 2017). Apart from compulsory solutions, people are freely exposed to the insurance market deciding whether or not to purchase insurance. In fact, there are those unaware of the consequences of natural hazards, neglecting the probability of occurrence and loss, and those that invest in their protection by paying an annual premium to an insurance company. The firsts are individuals that do not justify the expense, feeling to be not rewarded in the long run and becoming less attracted toward these products (Bubeck et al. 2013; Poussin et al. 2014). The second group of people are much concerned about the consequences of extreme events, not necessarily based on previous experiences, and decide to invest in their protection. Understanding people willingness to invest in their protection is fundamental especially in those countries where there is not a consolidated insurance system in place in order to plan strategic policies of disaster risk financing.

## 1.2 Research questions and objectives

In line with an interdisciplinary approach, this thesis aims to understand the interaction of human, landscape and climate in relation to flood dynamics, analysing people perceptions and vulnerabilities in different anthropogenic communities. In light of the results obtained, this thesis suggests possible flood risk management plans, identifying strategies of actions and recognising the potentialities of vulnerable people worldwide.

Six papers (four published and two submitted) have been written and included in this thesis, whose format is described in details in Chapter 1.3. This thesis relies on the following research questions, specific objectives and related outcomes:

1. What are the factors that burden the responsibility of flood dynamics in anthropogenic landscapes?
    1.1. Understanding flood dynamics in relation to human, climate and landscape interactions.
        1.1.1. Sofia, G., **Roder, G.**, Dalla Fontana, G., Tarolli, P. (2017) Flood dynamics in urbanized landscapes: 100 years of climate and humans' interactions. *Scientific Reports*, 7,1-12(40527).
        1.1.2. Viero, D.P., **Roder, G.**, Matticchio, B., Defina, A., Tarolli, P. (2019) Floods, landscape modifications and population dynamics in the Polesine (North-East of Italy). *Science of the Total Environment*, 651(1), 1435-1450.

2. Is it possible to track social vulnerabilities?
    2.1. Develop a GIS-based framework for the identification of potentially vulnerable people.
        2.1.1. **Roder, G.**, Sofia, G., Wu, Z., Tarolli P. (2017) Assessment of social vulnerability to floods in the floodplain of Northern Italy. *Weather, Climate, and Society*, (9), 717-737.

3. How people judge and react to flood risk? What are the determinants affecting individual's risk perception and flood preparedness? What are the strategies people have adopted (or not) to mitigate the effects of floods?
    3.1. Investigating flood risk perception, and preparedness and examine the willingness to pay for flood insurance schemes (if applicable).
        3.1.1. **Roder, G.**, Ruljigaljig, T., Lin, C-W., Tarolli, P. (2016) Natural hazards knowledge and risk perception of Wujie indigenous community in Taiwan. *Natural Hazards*, 81(1),641-662.
        3.1.2. Cvetković, V.M., **Roder, G.**, Öcal, A., Tarolli, P., Dragićević, S. (2018) The role of gender in preparedness and response behaviors towards flood risk in Serbia (*submitted to International Journal of Environmental Research and Public Health*).
        3.1.3. **Roder, G.**, Hudson, P., Tarolli P. (2018) Flood risk perceptions and the willingness to pay for flood insurance in the Vento region of Italy (*submitted to International Journal of Disaster Risk Reduction*).

## 1.3 Thesis organisation

This thesis consists of six papers coming from my PhD activity (Chapters from 2 to 7).
The first paper (Chapter 2) has been published in *Scientific Reports* (IF: 4.122) in 2017. It presents a regional screening of land-use, rainfall regime and flood dynamics in north-eastern Italy, covering the timeframe 1900–2010. It proposes a new index called flood aggressiveness index, indicating the contribution of short duration floods respect to the increase in the percentage of the flooded locations. From the analysis undertaken, it can be seen that while

climate highly impacts the flood trends, but with constant influences, many drivers connected to land use are also prominent, and they change during the years.

The second paper (Chapter 3) published in *Science of the Total Environment* journal (IF: 4.420) takes the Polesine region (Norther-East of Italy) as a significant case study to determine the impact that anthropogenic landscape modification has on flood dynamics. The analysis makes use of flood inundation numerical modelling and is then enriched considering population and socio-economic changes. The modelling showed increased water levels and depths in large areas, and substantially different spatial distribution of water arrival time. People and assets exposure to flooding varied within the same period.

The third paper (Chapter 4) has been published in *Weather Climate and Society* journal (IF: 2.033) in 2017. It proposes a GIS-based framework for the identification of potentially vulnerable people in one of the largest floodplains in Europe. It proposes a revised version of the Social Vulnerability Index adapted to the socio-cultural and –political context of the floodplain of Northern Italy. This index has been transferred into a GIS platform, allowing a mapping representation and a full translation of the concepts of social vulnerability into research and practice.

The fourth paper (Chapter 5) has been published in *Natural Hazards* journal (IF: 1.901) in 2016. It aims to investigate the natural hazards knowledge and risk perception of Wujie indigenous community, which belongs to one of the largest groups in Taiwan. This community faced a long colonising period that modified their environment, currently prone to frequent natural hazard events, especially floods and landslides. Wujie people have been seen to be highly knowledgeable about these events but not prepared to overcome these negative occurrences. The reason is ascribable to an inefficient communication strategy due to multiple transmitters information has to pass through.

The fifth paper (Chapter 6) has been submitted to *International Journal of Environmental Research and Public Health* (IF: 2.145) and investigates flood risk perception and preparedness in a gendered perspective in Serbia in light of the gender unbalanced consequences of the 2014 flood event. Men have seen to be risk-takers because of their confidence in managing emergencies gained during the period spent in the army. Women have been seen to be more sensitive and knowledgeable but limited in their coping capacities due to limited gender-specific roles in the community.

The sixth paper (Chapter 7) has been submitted to *International Journal of Disaster Risk Reduction* journal (IF: 1.968), and it explores the flood risk perception in Veneto region evaluating the risk salience towards a set of other natural hazards. It evaluates for the first time in Italy the acceptance of an insurance product and the desire to pay for it. Results showed that trust plays a fundamental role in the willingness to adopt private mitigation measures and there is an urgent need to create openings for a financing instrument able to assist individuals in reducing the burdens of floods.

At the end of each chapter, the authors' contribution of the paper is shown.

The thesis concludes with Final remarks (Chapter 8) and References (Chapter 9).

### *1.3.1 Glossary*

In this thesis, we used the term 'flood' and 'inundation' as synonyms for all events where water covers land not normally covered by water (Directive 2007/60/EC, European Union 2007). We excluded, 'flash floods' and 'debris-flows' from the definition because of different physical characteristics, triggering factors, the speed of onset and propagation compared to floods.

CHAPTER 2

# FLOOD DYNAMICS IN URBANIZED LANDSCAPES: 100 YEARS OF CLIMATE AND HUMANS' INTERACTIONS[1]

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## 2.1 Abstract

Raising interest in the interaction between humans and climate drivers to understand the past and current development of floods in urbanised landscapes is of great importance. This study presents a regional screening of land-use, rainfall regime and flood dynamics in north-eastern Italy, covering the timeframe 1900–2010. This analysis suggests that, statistically, both climate and land-use have been contributing to a significant increase of the contribution of short duration floods to the increase in the number of flooded locations. The analysis also suggests that interaction arises, determining land-use dynamics to couple with climatic changes influencing the flood aggressiveness simultaneously. Given that it is not possible to control the climatic trend, an effective disaster management clearly needs an integrated approach to land planning and supervision. This research shows that land management and planning should include the investigation of the location of the past and future social and economic drivers for development, as well as past and current climatic trends.

## 2.2 Introduction

The year 2015 was a remarkable year in global policy with the publication of three milestone UN agreements regarding the Disaster Risk Reduction, Sustainable Development Goals and Climate Change (Aitsi-Selmi et al. 2016). The coincidence of three such treaties is an opportunity of global significance, also to raise interest in the interaction between humans, landscape and climate, to understand the past and current development of disasters in complex landscapes. Urbanized landscapes are one of the most sensitive systems to hydrological extremes, fluctuations and changes (Hapuarachchi et al. 2011; Lewin 2013; Tarolli and Sofia 2016). Here, hydrogeological disasters such as floods represent one of the most dangerous environmental risks of the current time (Miceli et al. 2008), with a broad range of impacts on society and the environment. While more evidence is needed to recognise the part played by the climate in this trend (Visser et al. 2014), growing human activity in hazard-prone areas has been shown to be a major factor (IPCC 2014; Tarolli 2016). Specifically, during history, an enormous, capillary and highly evident system of mechanical devices for channelling and controlling water (Earle and Doyle 2008) shaped urbanised landscapes. Over the centuries numerous changes in land use (Camorani et al. 2005; Brath et al. 2006; O’Connell et al. 2007; Wheater and Evans 2009; Di Baldassarre et al. 2009; Sofia et al. 2014) caused a profound metamorphosis of the natural system (Macklin et al. 2010). Such alterations have enormous consequences on the flood regime, whose sensitivity to changes tends to increase as the recurrence interval of the rainfall event decreases (Camorani et al. 2005; Brath et al. 2006; Sofia et al. 2014; Lewin 2014; Pistocchi et al. 2015). Other influencing factors burdening the responsibility of the high frequency of flood events are changes in people's wealth, increasing population density and vulnerability (IPCC 2014), and also, higher rates of urbanisation as a consequence of the economic growth.

While the global process of urbanisation continues, world's climate changes result in more frequent and more intense flooding (Feyen et al. 2012). Such increasing trends in flood risk may have severe direct humanitarian and economic impacts and lasting long-term adverse effect in economic growth (Jongman et al. 2014). Especially river floods in Europe could directly affect more than half a million people a year by 2050 and nearly one million by 2080, as compared to the 200 thousand influenced currently (Alfieri et al. 2015). The predicted steep increase in river flood could mean that related annual damages climb from the current 5.3 billion EUR to up to 40 billion EUR in 2050 and reach 100 billion EUR by 2080, due to the combined effect of climatic change and socio-economic growth (Alfieri et al. 2015). As all these issues are becoming increasingly frequent, the current planning system seems to be inadequate to tackle the landscape vulnerabilities (Anguillari 2013). In this context it is, therefore, timely relevant to analyse impacts and relatively subtle changes in weather and land-use related risks when quantifying present-day flood regimes, to provide essential information to understand the future of flood risk (Winsemius et al. 2016). Achieving this requires a relatively detailed information on topography and asset distribution, as well as information about the climatic settings (Alfieri et al. 2015). In this work, we present a local screening of a long-term analysis to understand the relationship of human land use drivers with the climate dimensions of urban flood dynamics. For the human drivers, we focussed on changes in the built-up areas (or changes in imperviousness, $Imp_{Ch}$) (see Chapter Methods: Observatory data). An index of rainfall concentration (Martin-Vide 2004) –or aggressiveness- ($Cl_a$) describes the input given by short but intense rainfall to the total rainfall amount, to investigate the climate dimension. Finally, flood dynamics are studied using an index of flood concentration ($Fl_a$) indicating the contribution of short duration floods respect to the increase in the percentage of the flooded locations (see Chapter Methods: Rainfall and flood concentration).

The analysis focuses on the Veneto region (north-eastern Italy) (Figure 2.1), a paradigmatic example of human-landscape interaction. The region presents a subcontinental climate [average annual temperatures between 10 and 14.4 °C], affecting the whole range of floodplains and the pre-Alpine valleys. The floodplain presents rainfalls equally distributed during the year, with an average yearly value between 600 and 1100 mm, with drier winters and thunderstorms in summer. The pre-Alpine areas present average yearly rainfall of 1100–1600 mm, mostly in autumn and winter. The mountain regions, excluding the pre- Alpine valleys, are located mainly within the cool/cold temperate climate [average annual temperatures between 6 and 9.9 °C for the cool areas, and between 3–5.9 °C for the cold ones], with the highest ranges of the Alps influenced by cold climate [mean annual temperatures below 3 °C]. These zones present average yearly rainfalls of 1600 mm, mostly in late spring and autumn (ARPAV 2016).

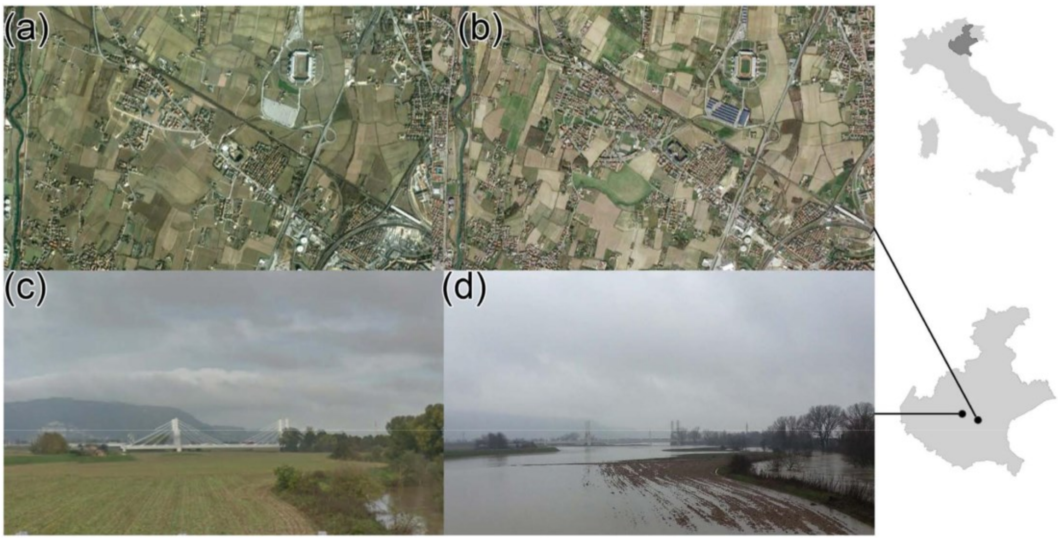


Figure 2.1 Urban sprawling and examples of a typical flood in the Veneto floodplain. Same area as seen in 2000 [Image© 2016 DigitalGlobe] (a) and 2015 [Image© 2016 DigitalGlobe] (b). An example of a frequent flood: area as seen in normal condition [Map Data: 2016 Google©] (c) and after a few days of rain in 2014 (ph. G. Sofia) (d). The map was created with ArcGIS version 10.4 (https://www.arcgis.com/).

Like many other highly developed nations, highly governed landscapes such as the reclaimed areas of Veneto, are landscapes that have been subject to even greater degrees of human manipulation than normal cultural landscapes (Bertollo 2001; ISPRA 2015a). Due to the dispersed character of its urbanisation [diffused city -*Citta diffusa* (Besussi et al. 1998), Figure 2.1a,b], the impact of floods in the region is manifesting with increasingly social effects (Salvati et al. 2010), especially after rather frequent, short and intense rainfall events (Figure 2.1c,d).

The proposed analysis applies to any region facing similar issues, for the assessment of flood, climate and land-use interactions at a regional scale.

## 2.3 Methods

The analysis focuses on the years 1910 to 2010, excluding 2010. This, to investigate dynamics antecedent to the year of the *All Saints* flood (2010), that caused the largest up to date economic and social impact in the region. This timeframe has been divided four intervals (1910–1930, 1930–1950, 1950–1970, 1970–1990, 1990–2010) considering that 20 years could be long enough for meaningful assessments of climate change (WMO 2013), and to capture permanent changes to the built-up system. The availability of information constrained the choice of the time periods for the analyses in terms of time and spatial scale.

### *2.3.1 Observatory data*

To investigate the changes in floods, a complete database of floods and landslide events is available[41], with location and dates, that covers systematically the period 1917 to 2000, and non-systematically the periods 1900 to 1916 and 2001 to 2002. The database was updated to the year 2009 by obtaining other records containing information on inundations: bibliographical and reference information, press communications, Veneto Region and the National Civil Protection technical reports, and personal communication with local authorities in charge of the management of rivers. The database reports, aside from the date, the location and the municipality where each event happened.

For the change in land use, the analysis focused on the variations in the built-up areas (or changes in imperviousness). This because changes in artificial coverage have a dual effect on floods: i) a direct hydrologic effect increasing runoff, and ii) an increase in the exposed number of goods. Furthermore, changes in the built-up areas can imply a modification to the drainage system, with changes to the drainage network and conversion to urban drainage system (Fabian 2012; Lewin 2014). The built-up area analysis comprises three reference years (1970, 1990, 2009) and the changes among them. The map of imperviousness for the year 1970 is based on maps produced between 1956 and 1968 by the National Research Council using cadastral datasets at a geographic scale of 1:200,000. The 1990 and the 2009 datasets were derived from the Corine (‘coordination of information on the environment’) Land Cover project (recently taken over by the European Environment Agency, EEA) at a scale of 1: 100,000. For these two maps, the analysis focussed on the artificial surfaces excluding those classified as artificial non -agricultural vegetated areas (class 1.4). The three dataset were aggregated at the municipality scale, providing a map of the percentage of imperviousness respect the municipality area. To create a distributed map of the imperviousness for a more quantitative analysis, a kernel-density estimation, hereafter referred to as KDE (Silverman 1988), was applied. This technique allows, starting from a point location (in this case the centroid of each municipality), to generate a consistent and continuous spatial layer of data (Sofia et al. 2016), representing the predicted imperviousness or the imperviousness changes throughout the landscape. This solution enabled the use of the different datasets at different resolutions, and it allowed to analyse simultaneously the land use changes analyses with the flood events reported in the flood database and the climatic trends over the region.

For the rainfall dataset, data related to the number of days of rain, and the related cumulated rainfall, were acquired from the automatic weather station network of the Regional Agency for Environmental Protection and Prevention of Veneto (ARPAV), and from the historical values recorded by the network of the Hydrographic Office of the Venice Water (Ufficio Idrografico del Magistrato alle Acque di Venezia). Specifically, the products used in this study are rain gauge quantitative precipitation estimates in daily accumulation. The ARPAV dataset comprises rainfall values from 1994 to current days. The Hydrographic Office network, instead, covers the XX century, up to 1994, when the management of the rain-gauge network was delegated to the regional environmental protection agencies.

### *2.3.2 Rainfall and flood concentration*

The index of rainfall concentration (Martin-Vide 2004) –or aggressiveness- ($Cl_a$) ranges from 0 to 1, and higher values imply that less days of rain contribute to a notable increase in the accumulated rainfall. The idea of concentration was extended to floods, considering the number of days of flood and the number of flooded sites within the same municipality. Higher values of the flood concentration index ($Fl_a$) imply that less days of flood contribute to a notable increase in the percentage of the flooded locations. For the computation of the indices, the considered variable (rainfall daily cumulative amount or flooded locations within the same municipality) is divided into classes, and it is presented in ascending order. For each class, a midpoint is evaluated, as a sufficiently precise characterization (Martin-Vide 2004). The number of recorded days (of precipitation for the rainfall characterization, or days of flood for the flood characterization) in each class, or absolute frequency ($n_i$), is listed. From these values, the cumulative frequencies are obtained (∑n i) by adding the absolute frequencies of all the classes up to the one under consideration, the last one included. $n_i$ is multiplied, class by class, with the class midpoint, obtaining the total of each class ($P_i$). The cumulative frequencies of $P_i$ (∑Pi) are computed. Finally, $\sum P_i$ and $\sum n_i$ are presented in percentages respect to their total. These results give the graphic representation shown in Figure 2.2, where the cumulative proportion of rainy days is plotted alongside the cumulative percentage of rainfall amounts (Figure 2.2a), and the cumulative percentage of flood days is plotted against the cumulative percentage of flooded locations (Figure 2.2b).

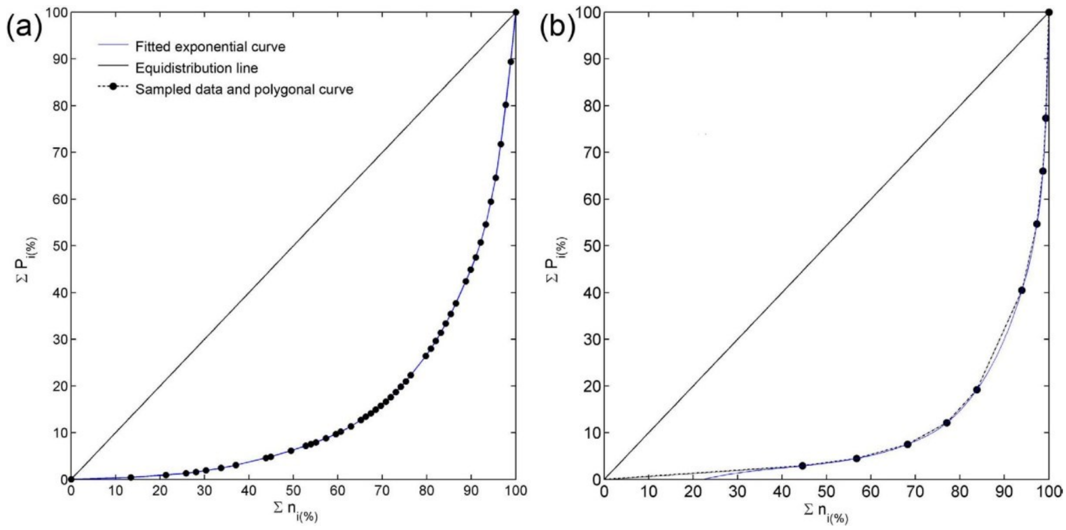


Figure 2.2 Cumulative percentage $\sum n_i$ (%) of rainy days (a) and flood days (b) plotted against the cumulative percentage $\sum P_i$ (%) of rainfall amounts (a) or flooded locations (b). The fitted exponential curve according to Eq.1 is also shown, as well as the equidistribution line.

In both cases, the resulting polygonal line is markedly exponential and can be represented by an exponential curve of the type

$$y = axe^{bx} \quad (1)$$

where $a$ and $b$ can be computed by means of the least-squares method (Martin-Vide 2004).
The bisector of the graphs in Figure 2.2 represents the equidistribution line, an ideal case where the distribution of the variable under consideration is perfect. The area $S$ enclosed by the bisector and the polygonal line provides a measure of concentration because the greater the area, the greater the concentration.

Once both the $a$ and $b$ (Equation 1) constants have been determined, the definite integral of the exponential curve between 0 and 100 is the area A under the curve, following Eq. 2

$$A = \left[\frac{a}{b} e^{bx} \left(x - \frac{1}{b}\right)\right]_0^{100} \tag{2}$$

The area $S$ compressed by the curve, the equidistribution line and X =100 is the difference between 5000 and the value of Equation (2).
From here, the concentration index is given by:

$$Cl_a \; or \; Fl_a = S/5000 \tag{3}$$

Distributed maps were then obtained by interpolating the local values for each rainfall station (for $Cl_a$) or municipality centroid (for $Fl_a$) using two different techniques. For the $Cl_a$, the ordinary kriging interpolator was chosen to make this study comparable to a previously published research showing values of the $Cl_a$ for the region (Consiglio regionale del Veneto 2012). For the $Fl_a$, a simple inverse distance weighting technique was applied: this considering the localised nature of a flood (that is, the farther from the flood break, the lower the damages, generally).

## *2.3.3 Downstream effect*

To evaluate the effect due to land-use changes and climatic concentration down-stream, imperviousness ($Imp_{up}$) and rainfall concentration ($Cl_{up}$) were accumulated downstream, based on the local topography and flow directions (Tarboton and Water 2008). The final accumulated values were standardised according to a min-max normalisation, to have values ranging from 0 to 1 as for the climatic and flood concentration index, where 0, in this case, would imply less climatic concentration or land use changes effects downstream, and 1 the highest contribution. These values should not be taken as absolute values, but rather as an indication of how much changes might have happened upstream, even though there may be no potential for any local impact. In the manuscript, the text will refer to 'local changes in imperviousness' or 'local land use changes' when speaking about $Imp_{ch}$ and 'upstream changes in imperviousness' or 'upstream land use changes' when speaking about $Imp_{up}$. Similarly, 'local climatic concentration' or 'local climatic aggressiveness' will be used for $Cl_a$ in opposition to 'upstream climatic concentration' or 'upstream climatic aggressiveness' for $Cl_{up}$.

### 2.3.4 Statistical analyses

The significance of trend of $Cl_a$, $Fl_a$ and $Imp_{ch}$ during the years was evaluated using a two-tailed Mann–Kendall nonparametric test, with the null hypothesis of a trend absence, against the alternative of a significant trend. The significance threshold level was set (Cortesi et al. 2012) as $p < 0.10$.

The relationship between landuse, climate, and flood aggressiveness relies on the time frames 1970–1990 and 1990–2010, for which there was the availability of all three parameters. The flood concentration was set to be the dependent variable, while imperviousness changes and rainfall concentration were configured to be the explanatory variables. Multiple linear regression models were used to test the ability of each explanatory variable, taken as a single predictor or implying an interaction (the situation in which the simultaneous influence of two variables on a third is not additive) among them, to predict the response variable. To reduce the high variability, the raw flood concentration values were aggregated (binned) into 0.01 intervals, and a mean value for each bin was evaluated. Significant samples for the analysis were therefore obtained by assigning an average value of $Fl_a$, say $Fl_j$, Cl ($Cl_j$) or Imp ($Imp_j$) to all locations found having flood concentration in the range of $Fl_j - 0.01$ – $Fl_j + 0.01$. For discussion purposes, the binned values for each parameter have been classified in four classes named High, Medium-High, Medium-Low and Low according to a Natural Breaks Classification, seeking to minimise each class's average deviation from the class mean, while maximising each class's deviation from the means of the other groups. The significance of each model was given through an analysis of variance (ANOVA). All the assumptions for the regression models were checked and, in the case of non-linearity between explanatory and response variables, the datasets were opportunely transformed. As for the other trends, the significance threshold level for the ANOVA was set to $p < 0.10$.

## 2.4 Results

### 2.4.1 Land use changes

Overall the region witnessed a statistically significant trend in the increase of built-up area (*p-value* 0.0275). The imperviousness in the 70s (Figure 2.3a) was related to the larger cities in the region (e.g. Padova and Venezia). In 1990 and 2009, the whole region appears to be highly impervious. The highest increase in imperviousness is the one from 1970 to 1990 (Figure 2.3d), and it is mostly related to the floodplain area of the region.

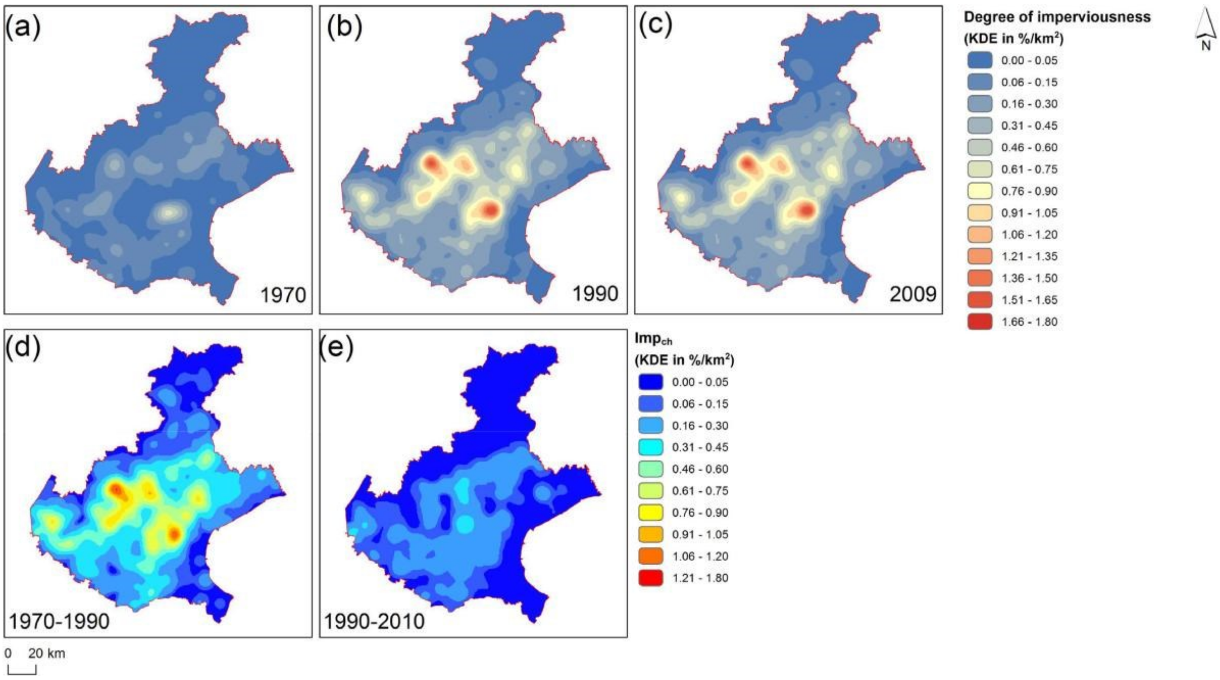


Figure 2.3 Kernel Density Estimate (KDE) of the degree of imperviousness during the years. (a) 1970, (b) 1990, (c) 2009, and KDE of imperviousness changes ($Imp_{ch}$) between (d) 1970–1990 and (e) 1990–2009. The map was created with ArcGIS version 10.4 (https://www.arcgis.com/)

The significant changes in imperviousness can be explained by the economic trend of Veneto during the years. In the 1970s, the Gross Domestic Product (GDP) increased more than 30% per year, resulting in Veneto being the second Italian region for GDP (Consiglio Regionale del Veneto 2015). During the 80s, Italy became one of the main economies of Western Europe, thanks to the northern Italy regions. Amongst them, the Veneto economy became an international example. In the 80s the region of Veneto experienced an economic transformation in parallel with a profound change in politics as well (Barbieri 2012). Since 1982, the region's GDP has kept up a trend of constant growth achieving, from 1993 to 1999, one of the most relevant levels in the whole Europe (Consiglio Regionale del Veneto 2015). In 2000–2007, the GDP grew by 1.3%, showing the greater growing patterns throughout all period analysed except during the crises that penalised the region from 2007 until 2011 (Consiglio Regionale del Veneto 2015). The economic growth caused major changes in families' way of life and local sociability networks. Veneto is characterised by industrial facilities relocation and the diffusion of a manufacturing system based on small firms, whereas small dispersed rural settlements characterise the local social and cultural structure. These interactions resulted, especially in the 1970–1990 timeframe, in dispersed settlements developing within the net-work of large urban centres (Besussi et al. 1998; Fabian 2012), mostly resulting in loss of agricultural landscape. This high level of urbanisation along with agricultural mechanisation and the regulation of watercourses determined a certain tendency to simplification and unification of the landscape (Fabian 2012). Differently, the changes over the 1990–2010 period mostly followed transport infrastructures (Figure 2.4), and resulted in a low-density suburban development in the periphery of cities, as also witnessed in other countries of Europe (European Environment Agency 2006).

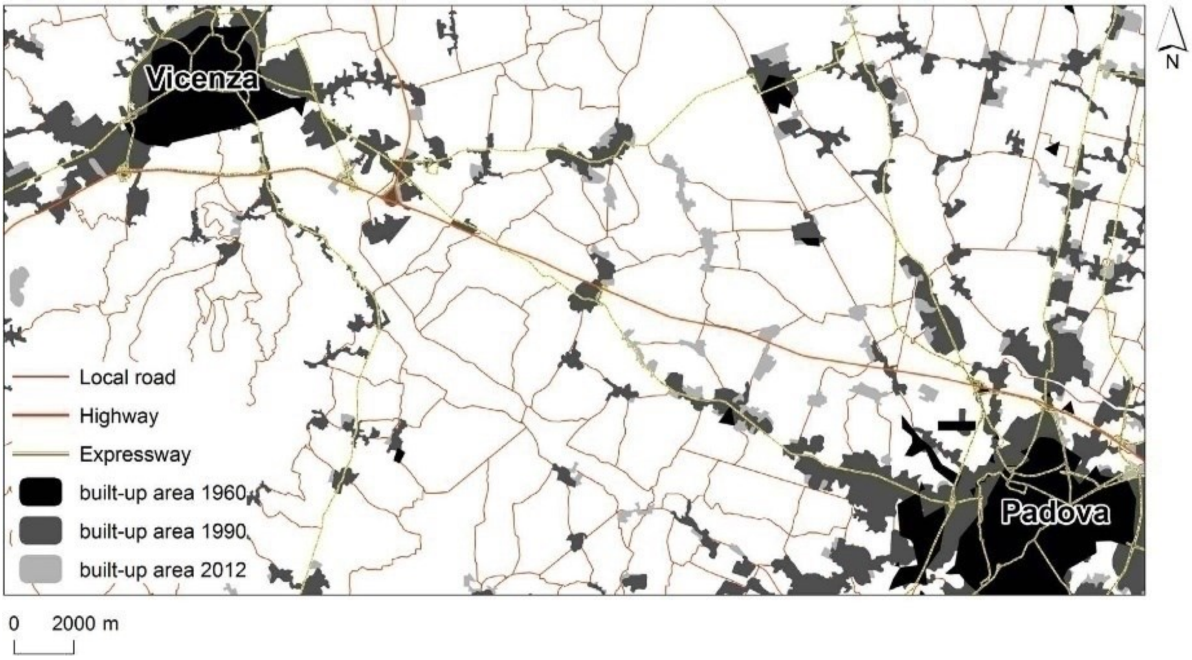


Figure 2.4 Veneto floodplain. Built-up area in 1970, 1990 and 2012. The map was created with ArcGIS version 10.4 (https://www.arcgis.com/).

The analysed urban sprawl and the development of urban land also transformed the properties of soil, reducing its capacity to perform its essential functions. A fully functioning soil for the analysed landscape (Cazorzi et al. 2013) can store water for more than 300 $m^3$/ha. Covering land with impermeable layers reduces the amount of rain that can be absorbed by the soil. The average changes in imperviousness between 1970 and 1990 (~6%) and between 1990 and 2009 (~2%) can roughly imply in a loss of ~30 M $m^3$ and ~10 M $m^3$ of water storage over the whole region. In cities with a high proportion of sealed surfaces this loss of storage, especially during eavy rains, can quickly overwhelm drains, causing sewage systems to overflow (European Union 2013).

### *2.4.2 Flood analysis*

The overall trend between the percentage of flooding days in each year and the number of flooded locations for the whole 1900–2010 timeframe shows the presence of drastic changes in the curve steep-ness (knick points, labelled with Ks in Figure 2.5), implying that during the years fewer days of flood contribute to a notable increase in the percentage of the flooded locations.

The first knickpoint around 1917 ($K_0$ in Figure 2.5) is probably due to the nature of the considered database that covers only non- systematically the periods 1900 to 1916 (Guzzetti and Tonelli 2004). The other knickpoints ($K_1$ to $K_5$) are related to major flood events that affected the region in 1928 ($K_1$ in Figure 2.5) (Guzzetti and Tonelli 2004), 1951 ($K_2$ in Figure 2.5) (von Hardenberg 2013), 1966 ($K_3$ in Figure 2.5) (Guzzetti and Tonelli 2004), 1992 ($K_4$ in Figure 2.5) (Guzzetti and Tonelli 2004), 1998 ($K_5$ in Figure 2.5) (Regione del Veneto 2004).

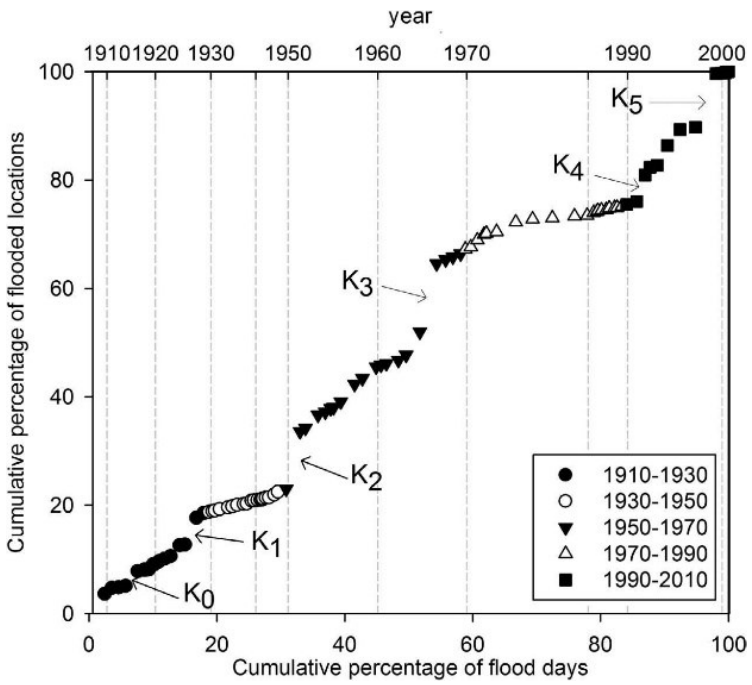


Figure 2.5 Flood analysis and major past floods in Veneto. Accumulated percentages of flooded sites contributed by the cumulative percentage of flooding days in each year for the whole 1900–2010 timeframe. Knickpoints of the curve are labelled with Ks.

It is interesting to notice that 1) the analysis of the days of floods VS flooded locations allows to identify clearly major events; 2) between these major events, the trends between days of flood and the percentage of the flooded locations appear to be constant. Analysing the graph considering the timeframes proposed for the research [1910–1930, 1930–1950, 1950–1970, 1970–1990, 1990–2010], it is possible to define statistically significant relationships (*p-value* always $< 0.01$). In the timeframe 1950–1970, the high slope of the trend is mostly due to the two major events (1951 and 1966). Differently, in the recent decade (1990–2010), the trend seems to be related to a larger number of flood events with a relatively shorter duration (fewer days of floods), which hit a greater number of locations, in addition to the two major floods (1992 and 1998). Thus, suggesting a larger coupling of the land-use and climatic influence for the more recent timeframe.

The average flood concentration (Figure 2.6) shows an increasing trend over the considered timeframes, from a value of 0.7 in the period 1910–1930 to a value of 0.9 for the timeframe 1990–2010. Clearly, the major flood events that hit the region have an influence on the index. However, the trend appears to be similar, and it becomes more regular when removing such events (1928, 1966, 1992, 1998) from the computation. The 1910 to 2010 trend is non-significant, both including and excluding the major flood events. The data in the 1910–1930 timeframe are, however, hindered due to the nature of the considered database, that covers only non-systematically the periods 1900 to 1916 (Guzzetti and Tonelli 2004). Removing the 1910–1930 timeframe makes the trend in $Fl_a$ significant (*p-value* 0.089).

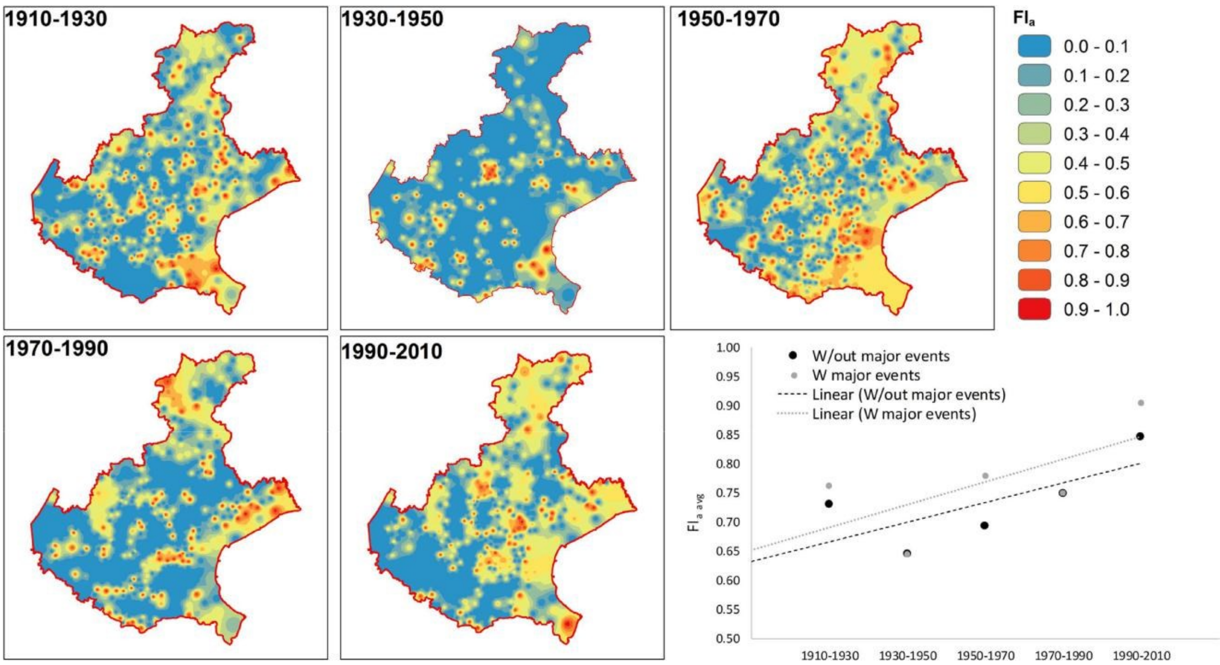


Figure 2.6 Flood concentration ($Fl_a$) over the region and trends during the year, evaluated considering or excluding the major flood events. The map was created with ArcGIS version 10.4 (https://www.arcgis.com/).

### *2.4.3 Land-use, climate and flood interaction*

In both 1970–1990 and 1990–2010, the areas having the larger changes in imperviousness (Figure 2.7a and d) do not necessarily correspond to regions with the higher climatic concentration (Figure 2.7b and e). However, in these areas, the concentration of the floods is high (Figure 2.7c and f).

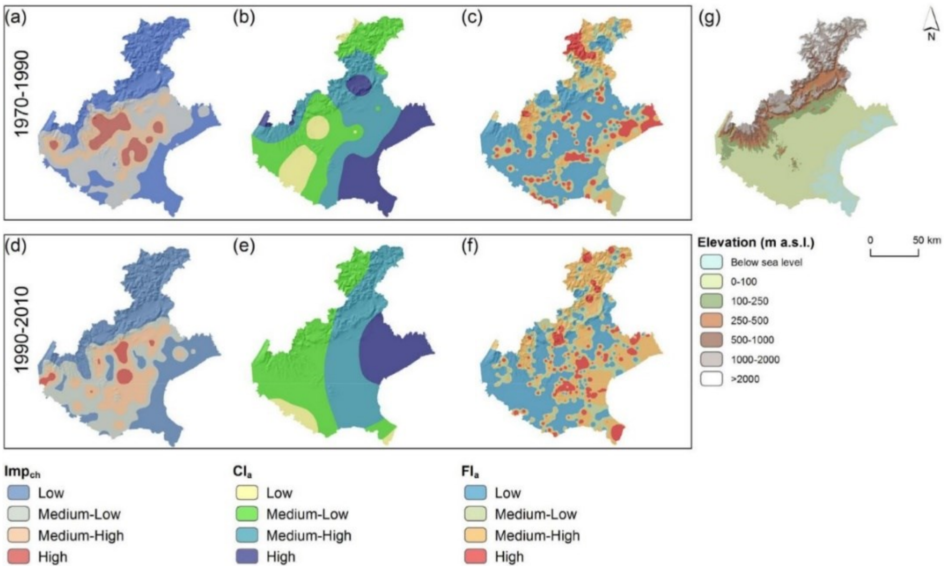


Figure 2.7 Changes in imperviousness ($Imp_{ch}$ in a,d), climatic concentration ($Cl_a$ in b,e), and flood concentration ($Fl_a$ in c,f) for the timeframe 1970–1990 (a,b,c) 1990–2010 (d,e,f). The values are classified into Low, Medium-Low, Medium-High and High based on a Natural Breaks approach. A map showing the overall elevation of the region is also shown (g). The map was created with ArcGIS version 10.4 (https://www.arcgis. com/).

In both timeframes, there is a significant relationship between the flood concentration and the rainfall concentration (Table 2.1). Individually, Impch and $Cl_a$ have a significant effect on Fla. The statistical significance and the changes in order of magnitude ($O_m$ changes in Table 2.1) highlight that despite the overall decrease in the yearly rainfall registered during the years36, the increased concentration of the rainfall events (more rain in fewer days) might have resulted in increased concentration of floods, whereas more localities are flooded in fewer days of floods. As well, despite being lower in amount, the changes in imperviousness are still significantly impacting the flood concentration index. In 1990–2010, in addition to the large-scale event of 1998 ($K_5$ in Figure 2.6), the higher significance was also connected to the influence of climate and urbanisation on local flooding attached to the failure of the urban or periurban drainage system (Camorani et al. 2005; Brath et al. 2006; Fabian 2012; Sofia et al. 2014).

Table 2.1 ANOVA analysis showing the significance of effects on Fla of rainfall concentration (Cla), changes in imperviousness (Impch), rainfall concentration upstream (Clup), changes in imperviousness upstream (Impup), and their interaction (indicated by the column). The last two columns show the differences in p-value (p) and the changes in the order of magnitude (Om changes) between the two timeframes. For the p column, the negative sign implies a decrease of the significance in the 1990–2010 respect to 1970–1990, positive sign indicates an increase in the statistical significance. *Significant at the 0.10 probability level. ns stands for not significant at the 0.10 probability level.

| | **1970–1990** | **1990–2010** | **p** | **$O_m$ changes** |
|---|---|---|---|---|
| Rainfall Concentration ($Cl_a$) | 2.20E-16* | 2.20E-16* | + | −2 |
| Change in Imperviousness ($Imp_{ch}$) | 3.63E-05* | 7.02E-07* | + | −2 |
| $Cl_a$: $Imp_{ch}$ | 2.94E-05* | 2.20E-16* | + | −2 |
| Rainfall Concentration upstream ($Cl_{up}$) | 2.20E-16* | 2.20E-16* | − | 0 |
| Change in Imperviousness upstream ($Imp_{up}$) | 2.20E-16* | 1.59E-03* | − | 12 |
| $Imp_{ch}$:$Cl_{up}$ | 6.50E-03* | 6.13E-04* | + | −2 |
| $Imp_{ch}$:$Imp_{up}$ | 9.46E-11* | ns | − | 9 |
| $Cl_{up}$: $Imp_{up}$ | 2.02E-05* | 8.42E-03* | − | 2 |
| $Cl_a$: $Imp_{ch}$: $Cl_{up}$ | 5.13E-03* | 8.42E-03* | − | 0 |
| $Cl_a$: $Imp_{ch}$: $Imp_{up}$ | 1.70E-04* | ns | − | 2 |
| $Cl_a$: $Cl_{up}$: $Imp_{up}$ | ns | 5.71E-02* | + | −2 |

Furthermore, one should consider that the eastern part of the Region, along the coastline where the climate is more aggressive (e.g. Figure 2.7b and e), is characterised by lands lying below sea level (Figure 2.7g) that require continuous management of the reclamation networks to stay viable (Cazorzi et al. 2013).

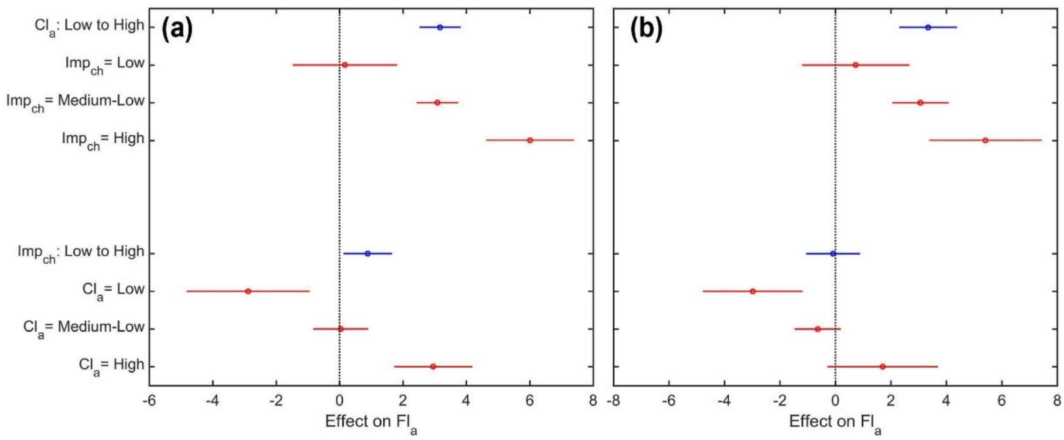


Figure 2.8 Estimated effects on $Fl_a$ of keeping one predictor fixed (Climatic concentration, $Cl_a$ in the top half, and changes in imperviousness, $Imp_{ch}$ in the bottom one) while varying the other for the (a) 1970–1990 and (b) 1990–2010 timeframe. The average effect is shown as a circle, while the horizontal bars are showing the confidence interval for the estimated effect. The blue symbols represent the overall average effect obtained by changing one predictor independently from the other, while the red ones represent the average effect achieved by changing one predictor over different values of the other one.

These areas often witness flooding due to lack of volumes of storage for water within the channels, and the intensity of rainfall events has a significant effect on this (Sofia et al. 2014; Pistocchi et al. 2015). To better exemplify and analyse the interaction among changes in imperviousness and climatic concentration, Figure 2.8 shows the estimated effects on $Fl_a$ of keeping one predictor fixed (Climatic concentration, $Cl_a$ and changes in imperviousness, $Imp_{ch}$) while varying the other. The average effect is shown as a circle, while the horizontal bars are showing the confidence interval for the estimated effect.

For both timeframes, the interaction plots show that the increase in rainfall concentration has a direct (positive) effect on the flood concentration (blue symbol in the top half in Figure 2.8a and b). The changes in land use have a greater effect in 1970–1990 respect 1990–2010 (confirming the ANOVA analysis) (blue symbol in the bottom half in Figure 2.8a and b): this mostly because the amount of changes in that timeframe is higher (Figure 2.8a and b). Overall, the higher the changes in imperviousness, the higher the effect on $Fl_a$ at the increase in rainfall concentration (red symbol in the top half in Figure 2.8a and b). Changes in imperviousness instead have different implications for the flood concentration, depending on the climatic concentration (red symbols in the bottom half in Figure 2.8a and b). For the higher climatic concentration ($Cl_a$=High in Figure 2.8a and b), an increase in imperviousness is correlated directly to an increase in the flood concentration ($Fl_a$ has a positive variation). However, for Medium-Low values of $Cl_a$, changes in imperviousness does not seem to have a great impact on the flood concentration, but still, they imply a slightly positive variation in $Fl_a$, at least in the 1970–1990 timeframe. It is interesting to notice, however, that for the least aggressive climate ($Cl_a$ =Low in Figure 2.8a and b), the increase of imperviousness seems to have a lowering effect on the flood concentration. Different trends in climate and urbanisation depending on the topographic location might explain this latter point (Figure 2.9). In both timeframes, part of the region is characterised by an inverse relationship between changes in imperviousness and elevation: urbanisation increases largely in the floodplains, while changes in imperviousness are low (but still positive) for mountain areas. In this same zone, however, the climatic trend is opposite: the rainfall concentration increases with increasing elevation due to the complex role of topography influencing the characteristics of the daily rainfall frequency (Isotta et al. 2014). The Alpine together with the higher zone of the Pre-alpine territory has an overall low (but increasing at the growth in elevation) level of $Cl_a$ that could explain the adverse effects of the increase in imperviousness on the flood concentration in Figure 2.8a and b.

A second part of the region, instead, differs in the two timeframes. This area comprises among the rest, the coastal part of the area, where the proximity to the sea produce exceptionally high rainfall accumulations (Barbi et al. 2012), and urbanisation is highly prominent. In 1970–1990 this part was characterised by an increase in rainfall concentration and a simultaneous growth in imperviousness (Figure 2.9a). Especially in the time frame 1970–1990 (Figure 2.9a) these contemporary trends result in the highest level of flood concentration. The 1990–2010 period partially differs (Figure 2.9b). While the trend for the areas having the lower rainfall concentration is similar to that of 1970–1990 (changes in imperviousness decreases with elevation, while climatic concentration increases), the area with the higher rainfall concentration has a different land -use dynamic. In the 1990–2010 timeframe, there are few areas where urbanisation happens in a relatively larger area of the lower Pre-Alps in addition to the floodplain.

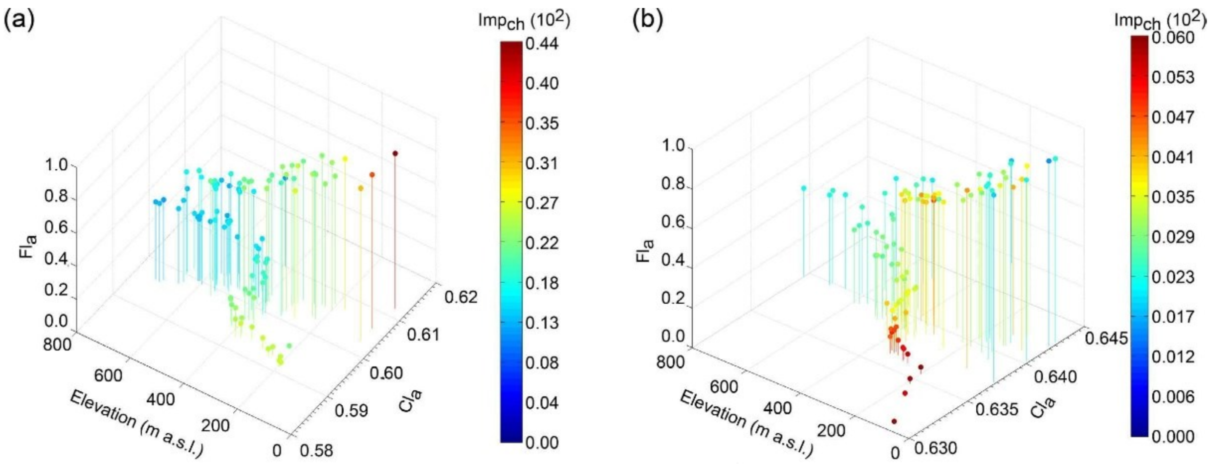


Figure 2.9 Flood concentration ($Fl_a$) for 1970–1990 (**a**) and 1990–2010 (**b**) as related to the landscape topography (elevation m a.s.l.), climatic concentration -$Cl_a$ -, and changes in imperviousness -$Imp_{ch}$ -. The percentage changes in imperviousness are shown as multiples of $10^2$. Elevation was computed considering a Digital Elevation Model with a 50 m cell size. Thus they are an approximation of the actual elevation.

For the rainfall concentration ($Cl_{up}$) and changes in imperviousness ($Imp_{up}$) upstream it is possible to partially draw the same conclusions as described for the local $Cl_a$ and $Imp_{ch}$ (Table 2.1): both parameters, when taken independently, have a significant effect on the flood concentration. However, the significance diminishes in the recent timeframe. The changes in the order of magnitude ($O_m$ changes in Table 2.1) highlight how the changes of imperviousness upstream, despite being still significant, have a lower effect on flood aggressiveness respect to the past (*p-value* increases of 12 orders of magnitude).

The results highlight that in the 1990–2010 timeframe, local changes in imperviousness seem to couple significantly with climate concentration, both considering either the upstream climate alone ($Imp_{ch}$:$Cl_{up}$ in Table 2.1) or combined with local climate concentration ($Cl_a$:$Imp_{ch}$:$Cl_{up}$ in Table 2.1). For this timeframe, the imperviousness changes -either upstream or local- cannot explain the increase of flood concentration independently from the climate input ($Imp_{ch}$:$Imp_{up}$ in Table 2.1), while they interacted in the 1970–1990 timeframe with a direct effect on $Fl_a$. Despite being significant when taken separately, local climate input and upstream climate do not have a significant interaction in either timeframe. In the 1970–1990 timeframe, upstream climate aggressiveness was more significant when coupling with the upstream land use changes with or without coupling with the local climate changes ($Cl_{up}$:$Imp_{up}$ and $Cl_a$:$Cl_{up}$:$Imp_{up}$ in Table 2.1).

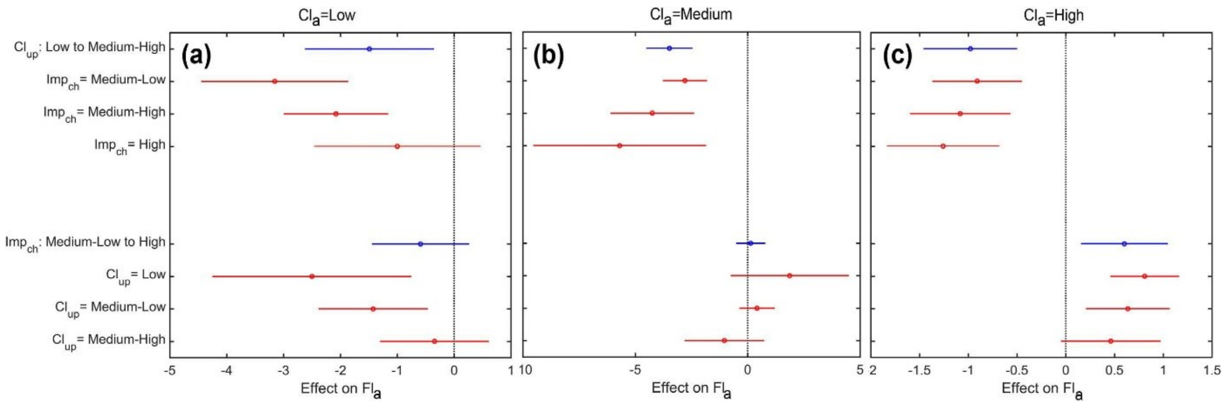


Figure 2.10 Timeframe 1990–2010. Estimated effects on $Fl_a$ of keeping one predictor fixed (Climatic concentration upstream, $Cl_{up}$, in the top half, and local changes in imperviousness, $Imp_{ch}$, in the bottom one) while varying the other for (a) Low local climate concentration ($Cl_a$) (b) Average local climate concentration and (c) High local climate concentration. The average effect is shown as a circle, while the horizontal bars are showing the confidence interval for the estimated effect. The blue symbols represent the overall average effect obtained by changing one predictor independently from the other, while the red ones represent the average effect achieved by changing one predictor over different values of the other one.

In 1990–2010, when local climate concentration is low (Figure 2.10a), the increase of climate concentration upstream ($Cl_{up}$ from Low to Medium-High) has an opposite effect on the local flood concentration. However, when the local imperviousness changes are high ($Imp_{ch}$ =High), the changes in climate upstream lose their effect on $Fl_a$ (top half Figure 2.10a). An increase of the local imperviousness changes ($Imp_{ch}$ from Medium-Low to High in the bottom half Figure 2.10a) has a slightly negative effect on $Fl_a$: this effect, however, gets closer to positive when climate concentration upstream is Medium-High. At the increase of the local climate concentration (Figure 10b), the effects of land use changes become more evident ($Imp_{ch}$ from Medium-Low to High in the bottom half Figure 2.10b) and have the highest effect when the climate upstream is not aggressive ($Cl_{up}$= Low in Figure 2.10b). When local climate is highly concentrated (Figure 2.10c), independently from the local land use changes, the increase in climate concentration upstream has an inverse effect on local $Fl_a$ (top half Figure 2.10c). However, a variation of the local imperviousness changes from Medium-Low to High (bottom half Figure 2.10c) has a direct effect increasing the local flood concentration, and this effect is higher for low climatic concentration upstream. This latter point can be explained by the fact that at the local scale climatic concentration has a direct influence on the local flood aggressiveness (Tab. 2.1). Thus its effect might impact locally, but they might not be transferred downstream.

## 2.5 Discussion

Keeping in mind that the city is the way in which society is spatially organised to meet the requirements of the financial system28, the analysis showed how economic trends and growths during the century could explain the past and current conformation of the impervious area in the region. Concerning the climatic input, despite the negative trend in the overall yearly precipitation (Consiglio regionale del Veneto 2012), the presented results suggest that this trend has been accompanied by an increase in the concentration of the climate, with short daily events contributing to a larger amount of rainfall. In accordance, numerous studies in literature (with different datasets) showed a similar increase in the mean precipitation intensity for the most recent years, mainly due to a strong positive trend in the contribution of the heavy daily precipitation events (Brunetti et al. 2000b; Brunetti et al. 2000a; Brunetti et al. 2001; Cortesi et al. 2012). Concerning flood aggressiveness, the observed statistically significant increase implies that in the recent decades, fewer days of flood contribute to a notable increase in the percentage of the flooded locations.

The proposed analysis allows to understand two major aspects that connect land use, climate and flooding: (i) the location of values and key components of the economy provided and provides the primary reason for developments being placed there, but at the same time created and creates risks for the society in terms of flood-exposed goods and thus loss potential (high flood aggressiveness); (ii) in areas where the economy shifts are less evident (e.g. mountain environments, for the analysed region), the changes in rainfall intensity upstream might assume a greater importance, transferring their consequences downstream, depending on the local rainfall intensity.

From the analysis, it can be seen that while climate highly impact the flood trends, but with constant influences, many drivers connected to land use are also prominent, and they change during the years. The economic development and consequent increase in urban areas historically effected the largest extent in the region (in 1970–1990). For the same timeframe, the climatic trend in the area was highly aggressive towards the coastal areas, and population and hence consumption, but also higher exposure, was biased towards the same area. These two changes coupled locally, resulting in the highest flood concentration. Differently, in 1990–2010, the rainfall status showed similar behaviours, but urbanisation increase mostly in a relatively larger area of the lower Pre-Alps in addition to the floodplain, thus interactions between land use and climate might have been transferred down-stream, increasing the flood concentration in an area where such issue was already evident in the past. This type of interactions can also be foreseen for the future, although as of now they remain relatively unexplored.

This research emphasises the need for an integrated analysis system that can represent the effects of climate, and the interface with socio-economic effects as both drivers and receptors of flood risk (e.g. land use changes increasing the exposed goods locally, and climate whose effect transfers downstream). Given that the climatic trend cannot be controlled, an effective land management clearly needs an integrated approach for catchment planning and supervision. It should cover the analysis of the location of the past and future drivers for development as well as the past and future drivers of climatic inputs.

*Author contributions*: G.S conceived the presented idea. G.S. and G.R. collected the data. G.R. handled the flood database and its updated. G.S. designed the model and the computational framework and analysed the data. G.S and G.R. contributed to interpret the results and drafted the manuscript in consultation with G.d.F. and P.T. P.T. is the coordinator of the project.

CHAPTER 3

# FLOODS, LANDSCAPE MODIFICATIONS AND POPULATION DYNAMICS IN ANTHROPOGENIC COASTAL LOWLANDS: THE POLESINE (NORTHERN ITALY) CASE STUDY[2]

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## 3.1 Abstract

It is widely recognized that the complex relationship between humans, soil, and water has become increasingly complicated due to anthropogenic activities, and is further expected to worsen in the future as a result of population dynamics and climate change. The present study aims at shedding light on the multifaceted links between floods, landscape modifications, and population dynamics in anthropogenic coastal lowlands, using a large flood-prone area (the Polesine region, north-eastern Italy) as a significant case study. Based on the analysis of historical events and the results of hydraulic modeling, it is shown that human interventions on both the landscape and the subsoil have substantially altered the flood dynamics, exacerbating hydraulic hazard. Furthermore, the combined analysis of people and assets exposure to inundation reveals that flood risk is not properly taken into account in land-use planning, nor it is properly understood by people living in areas subject to low-probability, high-impact flooding events.

## 3.2 Introduction

Investigating the complex interactions between human action, climate, and environment is essential to understand and predict the evolution of flood risk. Interdisciplinary studies focusing on the environment- and human-related dynamics are attracting increasing attention from both the scientific community and the international policy (Sivapalan et al. 2012; Di Baldassarre et al. 2013a; Loucks 2015; Sivapalan 2015; Ciullo et al. 2017; Sofia et al. 2017; Pijl et al. 2018). The analysis of dynamic processes that are driven by the growing human impact needs to move beyond the assumption of stationarity. In this context, insights gained from the recent past are the basis for a deeper understanding of the current conditions, for predicting future scenarios, and for orienting strategic decisions as well (Di Baldassarre et al. 2015).

Throughout the history, humans have long concentrated their activities along major rivers to ensure easy access to a wealth of vital resources (e.g. water, food, transport route). Yet, the erratic behavior of rivers, with major floods wrecking settlements and threatening lives, has been a major obstacle to human development (Di Baldassarre et al. 2013b). In the Anthropocene, heavy human interventions such as deforestation, confinement of rivers, intensive agriculture and urbanization, have substantially altered natural floodplains into anthropogenic environments. With economy rather than ecology as the main driver, recent development has seldom relied on a holistic and long-term vision in which environment and human activities are perceived as part of a unique system. One of its disastrous consequences concerns safety from floods, which are one of the major threat of our time (Opperman et al. 2009; Doocy et al. 2013; Blöschl et al. 2017). This especially holds for highly urbanized lowlands and coasts (Douben 2006), for example, according to Syvitski et al. (2009), 85% of the deltas experienced severe flooding in the past decades, resulting in the temporary submergence of 260,000 $km^2$. The issue of hydraulic risk cannot be regarded as a by-product of static environmental characteristics. Indeed, lowlands and coasts are complex and dynamic geomorphological systems, in which climatic forcing interplays with socio-economic conditions (Dawson et al. 2009; Balica et al. 2012; Di Baldassarre et al. 2013a; Anthony et al. 2014; Domeneghetti et al. 2015; Sofia et al. 2017; Minaei et al. 2018; Pijl et al. 2018). Human interventions have often intensified, rather than mitigated, flood risk in these environments (Parker 2000; Di Baldassarre 2012; Di Baldassarre et al. 2013a; Sofia et al. 2017); this was primarily due to the lack of an integrated system approach to flood risk reduction (Merz et al. 2010). Indeed, it is widely recognized that the historical approach adopted to reduce hydraulic risk, which primarily consisted in confining the river by building up higher and higher levees, actually led to overloading the downstream reaches of fluvial systems (Di Baldassarre et al. 2009). Moreover, in the dynamics of coupled human-natural systems such as rivers and the surrounding areas, levees affect the perception of flood likelihood by filtering small floods, thus encouraging human settlement in areas that, far from being protected, are vulnerable to destruction by low-probability, high-impact events (Werner and McNamara 2007; McNamara and Werner 2008; Ludy and Kondolf 2012). Anthropogenic impacts on surface water management have been the subject of several studies, focusing on the effects of climate and land-use changes on frequency and magnitude of floods (Fohrer et al. 2001; Bronstert et al. 2002; Camorani et al. 2005; Tomer and Schilling 2009; Li et al. 2009; Ferrier and Jenkins 2009; Wooldridge 2012; Whitfield 2012; Kundzewicz et al. 2014; Hall et al. 2014; Zope et al. 2016; Huang et al. 2017; Zope et al. 2017; Zhang et al. 2018), on the impacts of engineering works aimed at flood control and navigation (Surian and Rinaldi 2003; Mitkova et al. 2005; Spinewine and Zech 2008; Pattison and Lane 2012; Gai et al. 2017) and on coastal and estuarine dynamics as well (Nicholls and Hoozemans 1996; Simeoni and Corbau 2009; Silvestri et al. 2018). Less attention has been paid to the effect of anthropogenic landscape modifications on flood dynamics, i.e., on the evolution and features of the flooding process, as it is affected by the interaction with the landscape (Onishi et al. 2014; Carisi et al. 2016).

The Po River basin (Northern Italy) perfectly fits with this general picture, as it is one of the most anthropogenic and flood-prone regions in Europe (Parrinello 2017; Roder et al. 2017). Since the Neolithic, this floodplain has been affected by several transformations regarding its topography and hydraulic structure, majorly due to deforestation, population growth, intense industrialization, and climate (Marchetti 2002; Surian and Rinaldi 2003). The river system and landforms of the Po plain have been dramatically altered, and its natural setting of the alluvial plain forest has been lost. Several major levee systems and a large network of artificial channels currently shape the river basin, thus stressing the fragile and undersized hydraulic setting that is more prone to flooding than ever before (Guidoboni 1998; Simeoni and Corbau 2009; Luino et al. 2012).

The Polesine, extending in the downstream part of the Po River basin, is a 1800 $km^2$ flood-prone lowland area that was almost entirely flooded in 1951, when about 8 billion $m^3$ of water outflowed through three, close each other, bank failures of the left embankment of the Po River (Turitto 2004; Amadio et al. 2013a; Masoero et al. 2013). At present, the Polesine is still exposed to substantial residual risk from major floods (AdBPo 2008). Interestingly, significant anthropogenic modifications affected the landscape and the subsoil of the region in the meantime. The ensuing topographic changes, mainly related to land subsidence and to raised embankments, are expected to affect the flood dynamics significantly. For these reasons, in the present study, the Polesine is taken as a significant case study to assess the impact on flood dynamics of anthropogenic modifications to the landscape, here mainly intended as changes to terrain elevation and land features within the region. In a more general view, the study aims at shedding light on the complex relationship between humans, environments, and floods. The analysis makes use of flood inundation numerical modeling. Specifically, two different topographic settings, referring to the 1951 and 2011, are analyzed. The 1951 flooding event is used to validate the hydrodynamic model; the same flooding event is then simulated using the 2011 topography, and the results are compared to highlight the effects of anthropogenic landscape modifications on flood dynamics. The hazard-based comparison is finally enhanced by analyzing population and socio-economic dynamics, which allows estimating the exposure of people and assets, and its variability in time. A flow diagram describing the methodology of the study is shown in Figure 3.1.

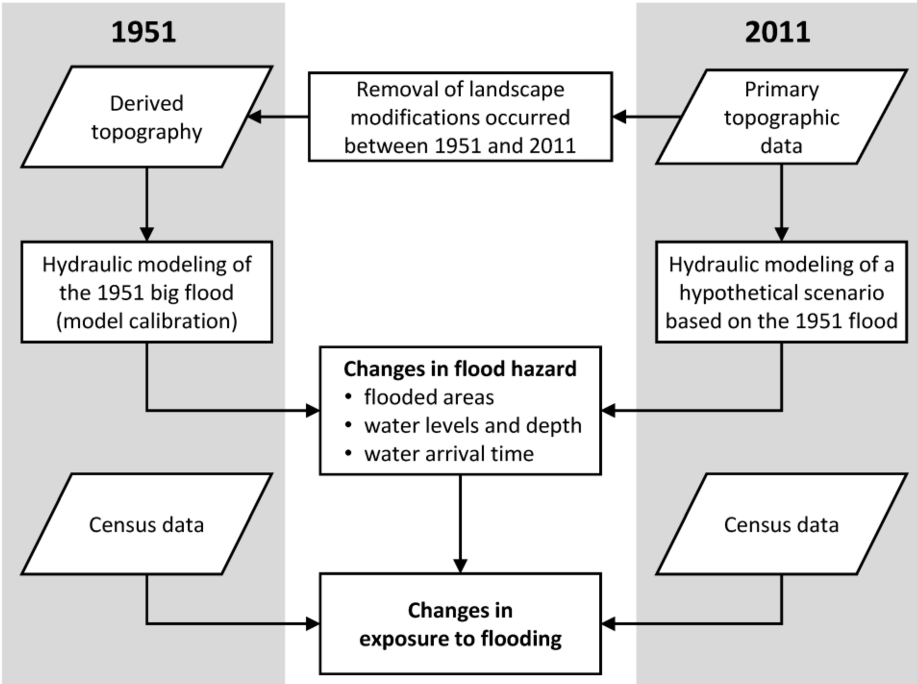


Figure 3.1 Flow diagram describing the methodology of the study.

## 3.3 Materials and methods

### *3.3.1 Study area: the Polesine region*

The Polesine is an 1,800 km$^2$, nearly flat, low-lying and flood-prone area located in the Northern Italy, (Figure 2), fringed by the embankments of the Po River from South and of the Adige River from North, and bounded by the Adriatic Sea on the East side. The mean slope of the region is directed eastward; terrain elevations range from +10 m above the sea level (a.s.l.) in Badia Polesine to -4 m a.s.l. close to the Po River delta and the Adriatic coast. Although being formally part of the Fissero-Tartaro-Canalbianco basin, the Polesine region closely resembles a large polder, with a drainage network of about 2,000 km of irrigation canals and 80 pump stations for land reclamation (Amadio et al. 2013a). The system is firmly stressed during intense precipitation events, and further pressure is due to the sea level rise. Nonetheless, the major source of flood hazard comes from the above main rivers (Figure 3.2b) rather than from the inner drainage network.

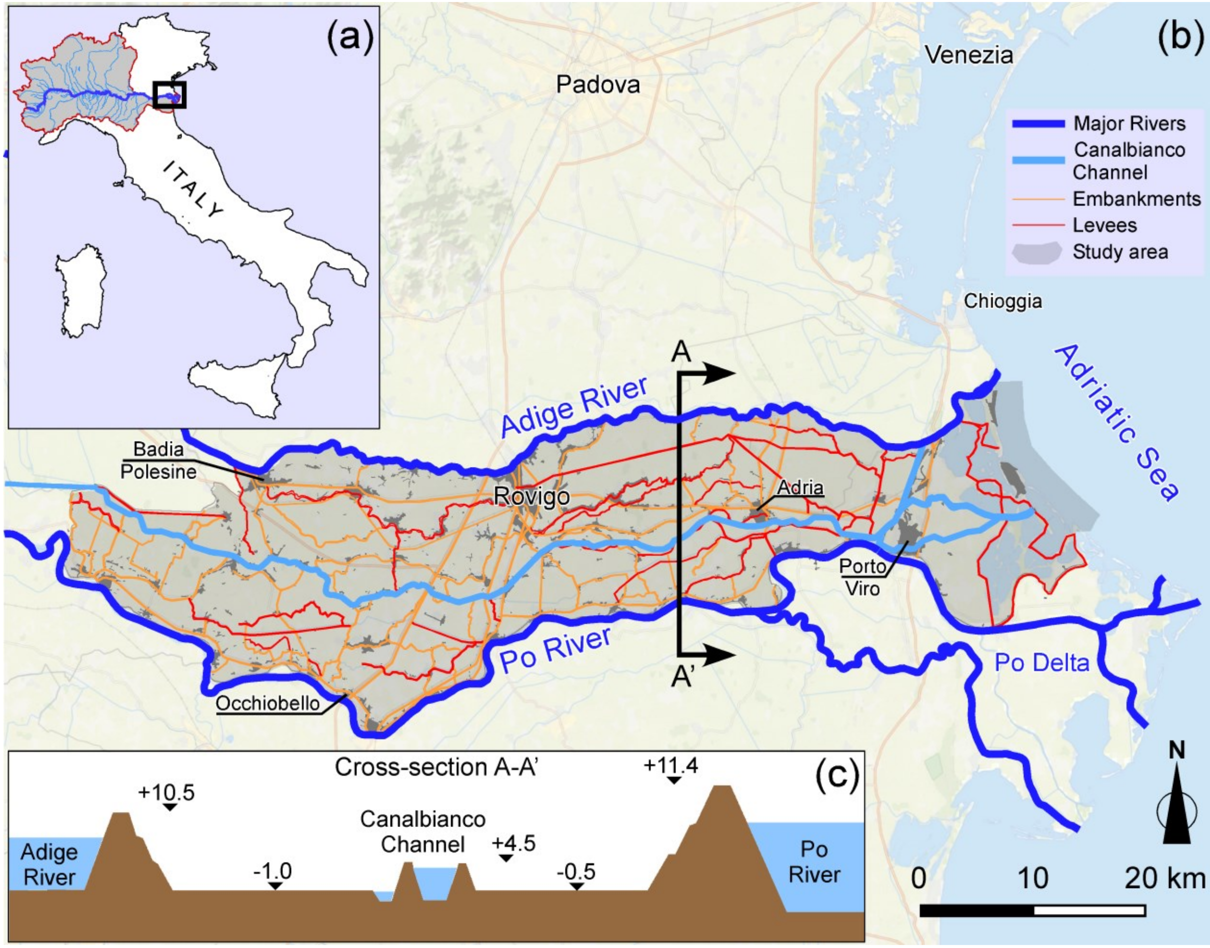


Figure 3.2 a) Geographic location of the study area, with the Po River basin shown in gray. b) The Polesine Region study area (on National Geographic base map), fringed by the levees of the Po River (South) and the Adige River (North). c) Schematic cross-section (not in scale) of the Polesine Region.

The main land features that characterize the topography of the Polesine are the levees of navigable channels such as the Canalbianco Channel and the Po-Brondolo Canal, and of the main drainage network (red lines in Figure 3.2). Many road and railway embankments (orange lines in Figure 3.2) are topographic discontinuities that are expected to affect flood propagation by diverting and blocking floodwaters. Overall, due to the widespread presence of relatively high levees and embankments, distinct sub-basins can be identified which, in case of major flood events, lead to the formation of a sequence of a sort of successive pools.

### *3.3.1.1 Hydraulic hazard and the 1951 flood*

According to the Flood Risk Management Plan drawn up by the Alto Adriatico Water Authority (www.alpiorientali.it) in fulfilment of the 2007/60/CE Flood Directive, the Adige River (Figure 3.2) can convey major flood waves safely along its terminal reach. According to the same plan, only small patches of low probability flood-prone areas are identified within the Fissero-Tartaro-Canalbianco basin. The major source of hydraulic hazard in the Polesine region is related to the Po River, which is the longest and most important river in Italy, having a length of 652 km from the Cottian Alps to the delta protruding in the Adriatic Sea. The discharge ranges between 270 $m^3s^{-1}$ and 13,000 $m^3s^{-1}$, with an average of 1,470 $m^3s^{-1}$ (Montanari 2012). The lands siding the lower reach of the Po River are protected against flooding by a continuous system of embankments, which are as high as 10 m over the surrounding lowlands (Mazzoleni et al. 2014).

In the last century, a series of severe floods affected the downstream part of the Po River (Govi and Maraga 2005). In 1917 and 1926, embankment failures led to severe flooding nearby Piacenza; in 1951, multiple embankment failures at Occhiobello (Rovigo) caused a catastrophic flooding in the Polesine region; more recently, overflowing were about to occur in 1994 and 2000, with discharges recorded just upstream of the terminal reach of more than 11,000 and 10,000 $m^3s^{-1}$, respectively.

The 1951 flood event (Figure 3.3) left a deep mark on the Polesine Region, and on Italy as a whole. According to the Po River Water Authority (AdBPo), this event is taken as a benchmark for both flood risk assessment and flood modeling. For example, peak discharges recorded during the 1951 flood event, increased by 10%, have been used to evaluate potential breaks of the embankments (AdBPo 2007), and the mapping of flood-prone areas in official plans for flood risk management is primarily based on the flooding actually occurred in 1951 (AdBPo 2008; AdBPo 2015). Also, the left levee of the Po River, which bounds the Polesine Region, is still susceptible to overflowing for floods having a return period of 200 years (AdBPo 2007; AdBPo 2008; AdBPo 2014; AdBPo 2015).

The present study is mostly based on the 1951 flood event; accordingly, this event is here described in details. The flood occurred in November 1951 was triggered by intense rainfall all over the whole basin of the Po River. Due to average precipitation of 214 mm in 7 days and to the synchronous formation of severe flood waves in almost all the Alpine and Apennine tributaries, a major flood formed along the main reach of the Po River. All the hydrographic stations downstream of the Ticino confluence, approximately 270 km from the Adriatic Sea, measured water levels higher than ever (Marchi et al. 1995; Govi and Maraga 2005; Amadio et al. 2013a). On November 14, water started overflowing the left embankment near Occhiobello, about 90 km upstream of the Po River mouth at the Adriatic Sea, and three, nearly simultaneous breaches formed at Paviole, Bosco and Malcantone (final width of 220, 204, 312 m, respectively). The dynamics of the flooding event is schematized in Figure 3.3a. During the early stage of the flooding event, the levees of the Polesella and Canalbianco Channels acted as a barrier against the flooding wave, which then was forced to propagate westward; in the first hours of November 15, floodwater began overtopping these levees, and the flood wave expanded eastward towards the cities of Rovigo and Adria. On November 20, the flood wave reached the Adriatic Sea; on November 25, as a result of a controversial political decision, the levees of the Polesella Channel (dashed lines in Figure 3.3) were artificially breached to facilitate the draining of the upstream land and to avoid worse scenarios for the city of Rovigo (Lugaresi 1994; Turitto 2004; Lastoria et al. 2006). An area of about 800 $km^2$ was still flooded on December 25, and 350 $km^2$ were still flooded on February 25, 1952.

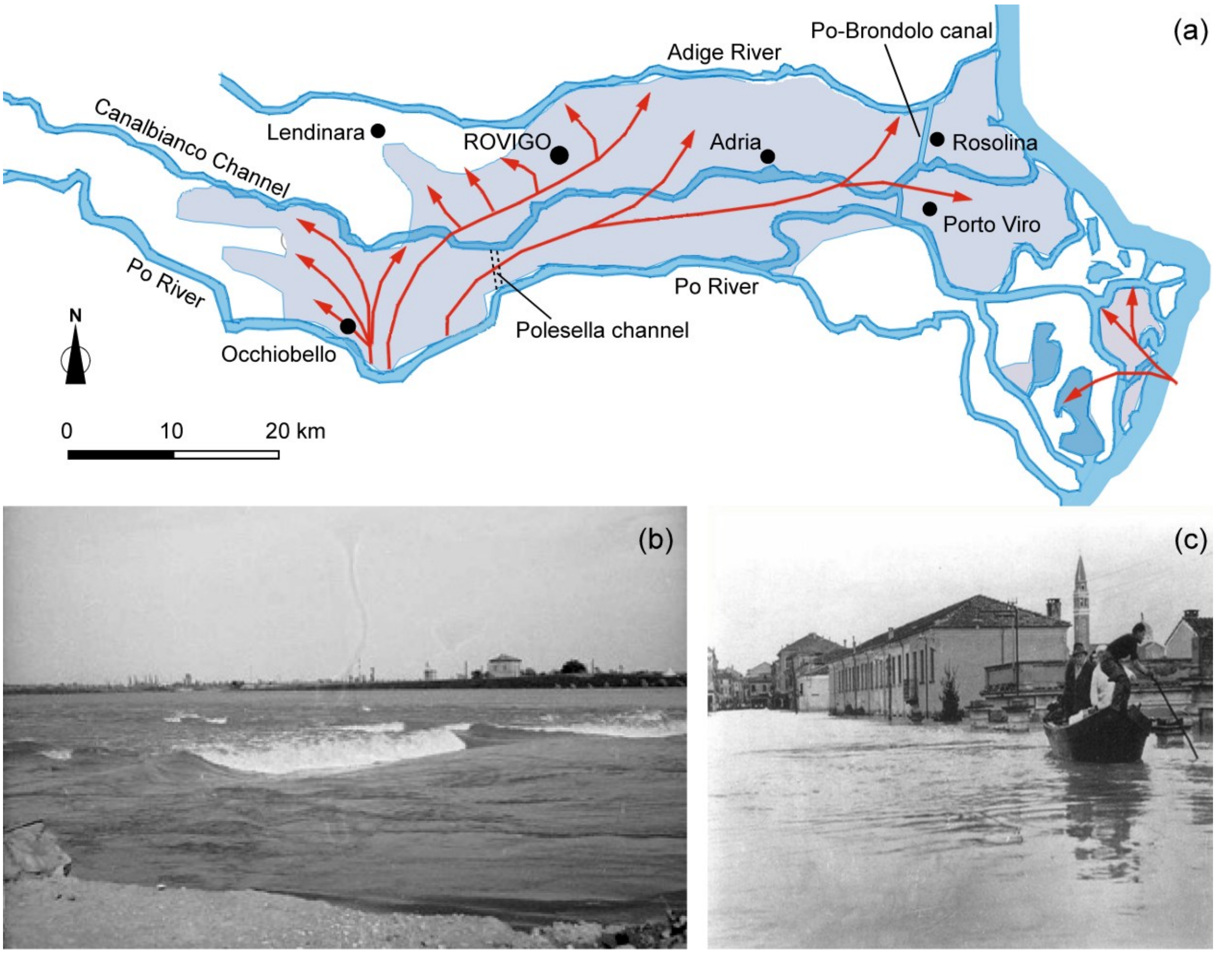


Figure 3.3 a) Sketch of the dynamics of the 1951 flooding event in the Polesine region. Shaded areas denote flooded land, red arrows denote the inundation directions; b) photograph from the *Archivio fotografico dell'Agenzia d'informazione e comunicazione della giunta regionale dell'Emilia-Romagna* and c) photograph from the *Archivio dei Vigili del Fuoco*.

The city of Rovigo and, among the others, the towns of Adria, Cavarzere and Loreo were evacuated because completely flooded.

On the whole, a total outflow of about 8 billion $m^3$ caused the flooding of about 1,000 $km^2$ in 38 municipalities of the Polesine region, with water depths up to 5-6 m ponding the whole area for several months (Rossetti 1957). The flood caused almost one hundred deaths and left 180,000 people homeless (Guzzetti et al. 2005). Nearly 14,000 farms, 5,800 buildings, 26 bridges, 140 km of main roads, and 820 km of smaller roads were severely damaged or destroyed. The estimated total damage was of more than 200 million € (uninflated), equivalent to 7.8 billion of today's dollars, and equal to 3.7% of the 1951 gross domestic product of Italy (Lastoria et al. 2006).

*3.3.1.2 Major anthropogenic changes of the landscape in the period 1951-2011*

The landscape of the Polesine Region has been the subject of several anthropogenic changes in the period between 1951 and 2011. In the present study, we consider three major modifications that play a significant role in flooding due to extreme events such as the failure of Po River levees in 1951. First, the Polesella navigable channel, connecting the Canalbianco River and the Po River before its breakup during the 1951 flood event, was not reconstructed. Note that the Polesella channel, with artificial levees of about 6 m height, acted as a very effective barrier for water flowing eastward toward the sea (Figure 3.3). Second, the elevation of many levees and embankments was significantly lower in 1951 than now, and new ones were built in between. In particular, (i) the banks of the Canalbianco channel are now ~2 m higher than in 1951, as a result of interventions carried out in order to adapt the river to the current waterway functions in the complex navigable system composed by the Fissero, Tartaro, Canalbianco, and Po di Levante channels; (ii) along the Adriatic Coast, the levee for protecting the adjacent lowlands from coastal flooding were raised from 2 to 3 m a.s.l. after the extreme storm surge of November 1966, when the sea level peaked at about 1.80 m a.s.l. (De Zolt et al. 2006; Mel et al. 2014); (iii) as revealed by the analysis of the 1954–1955 aerial images IGMI–GAI (http://idt.regione.veneto.it), several roads were constructed, and most of them involved the creation of new embankments. Third, the eastern part of the Polesine region experienced significant land subsidence. Aimed at exploiting hydrocarbons, exploration of deep structures under the Po Valley started in the 1930s; the extraction of water mixed to methane from the subsoil significantly increased in the 1950s (Pozzi 2010), leading to considerable pollution of irrigation canals and anthropogenic land subsidence. The fast lowering of land elevation due to anthropogenic causes, which reached its maximum rate of 300 mm $yr^{-1}$ in the period 1950–1957 (Caputo et al. 1970; Sestini 1996), stopped as water extraction was forbidden in 1965 (Teatini et al. 2011). Within the next years, land subsidence continued due to geological mechanisms of soil compaction of the shallowest (30–40 m), highly compressible Holocene deposits (Menin et al. 2008; Teatini et al. 2011); the subsidence rate, which is correlated with the age of the deposits, has remained nearly constant in time up to now. Accordingly, current subsidence rate ranges from 1 mm $yr^{-1}$ at the inland part of the delta, up to 12 mm $yr^{-1}$ at the apex, with an average rate of 2.5 mm $yr^{-1}$ in large part of the region (Carminati and Di Donato 1999; Teatini et al. 2011).

The effects of both anthropogenic and natural subsidence are exacerbated due to sea level rising and to reduced aggradation in the delta region, which is the major consequence of sediment trapping in the upstream reservoirs and floodplain engineering (Syvitski et al. 2009). For a land that is already below the mean sea level of about 4 m, this critical situation poses severe problems related to both coastal and riverine flood defense, to coastal management, land reclamation, and salinization of subsoils.

Finally, it has to be remarked that, in the last decades, also the minor channel network forming the complex reclamation system the Polesine Region has undergone substantial modifications (Sofia et al. 2017; Sofia and Tarolli 2017). Due to both industrialization of agriculture and urbanization, the storage capacity of the channel network has dramatically reduced, thus enhancing the hydrological response to local rainfall events (Viero et al. 2014; Sofia et al. 2014; Sofia and Tarolli 2017). Nevertheless, when considering flooding events due to levee failures of a major river, overflow discharges can exceed by (at least) one order of magnitude those conveyed by the minor channel network. For this reason, and analogously to similar studies (Masoero et al. 2013), the role of the minor channel network has not been explicitly considered in the present study.

### *3.3.2 Socio-economic context and dynamics*

The Polesine region has a population of about 250,000, of which 50,000 live in the chief town of Rovigo. The population density, equal to 138 people $km^{-2}$, is low compared to both the regional and the national mean (268 and 201 people $km^{-2}$, respectively; data from the national census database, ISTAT). The significant population decrease between 1951 and 1971 (Figure 3.4) is mainly due to the disaster of 1951, whereas the ensuing negligible population growth trend can be essentially ascribed to unfavorable social conditions and to emigration to large cities in the north of Italy and other European countries; projections suggest that population density will remain stable for the next 40 years, with a significant increase of the average age (Provincia di Rovigo 2005). After the 1951 flood event, 100,000 people left the region; the awareness of insecurity and vulnerability adversely affected the job market, slowing down and even arresting the economic development of the area and forcing new jobseekers to move away (Lugaresi 1994). The primary sector has a major role in this region, whose territory maintained a marked agricultural vocation and was just marginally affected by the fast industrializing process occurred in the northeast Italian area from the 1970–1980s. The mechanized arable land monocultures (maize, cereals and soy) cover most of the agricultural surface (~95%), with little forage and meadow areas supplying the few remaining zoo-technical enterprises. Permanent arboreal cultures are not diffused (~4%) since neighbor provinces are more specialized in vineyards and fruit trees cultivation, thus providing a stiff market competition.

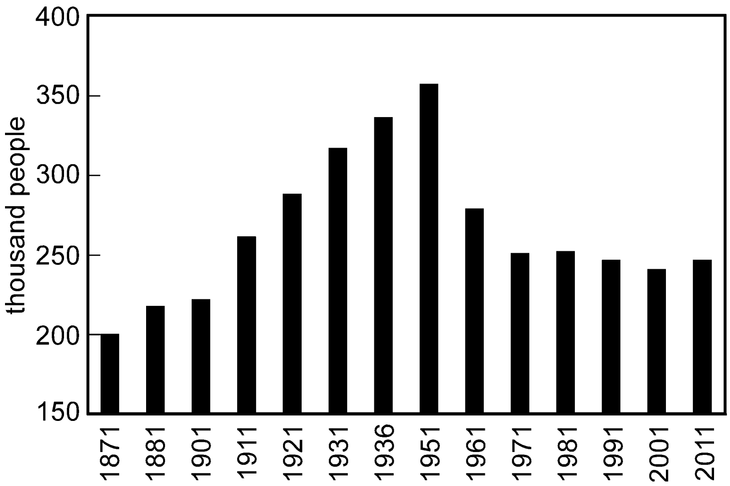

Figure 3.4 Population trend in the Polesine region from the national census database (ISTAT).

On the contrary, fishing and fish farming is a diffused activity on the coastal side of the region, even though the number of fish-farms valleys has significantly reduced since the last century (Unioncamere Movimprese, www.infocamere.it/movimprese). Tourism is increasing business in the region, especially in the coastal area, with almost 2 million visitors every year (mainly during summer), allowing the presence of little to medium size tourism-related enterprises. In conclusion, nowadays the Polesine is a monoculture lowland with few urban areas and reduced natural environments, the latter being mainly located in the eastern part of the delta.

### 3.3.3 Topographic data for hydraulic modelling

To support a quantitative comparison between the 1951 and the current flood dynamics in the Polesine region, two different computational grids are set up. Given the far more considerable amount of geographic data available for the more recent scenario rather than that of 1951, the computational grid of the 2011 scenario is first set-up using primary topographic data; successively, the 1951 grid is derived by 'subtracting' the major landscape modifications that affected the Polesine topography in the 60-years interval in between.

To set-up the 2011 computational domain, we had to use available data from different sources in order to cover the entire region. LiDAR data (~1 m spatial resolution, ~20 cm vertical accuracy), provided by the Ministry of the Environment and 'Po Delta' Reclamation Consortium and referring to years 2008–2011, were available only for the area of the Po River delta; accordingly, terrain elevations in the domain East of Rosolina and Porto Viro (Figure 5a) were assigned based on these LiDAR data. Topography in the remaining part of the Polesine Region is obtained from the digital terrain model (DTM, 5 m spatial resolution, 40 cm vertical accuracy). Levees and embankments were located precisely based on aerial images (50 cm spatial resolution) and Numerical Technical Maps (1:5000) provided by the Veneto Region. The resulting topography is shown in Figure 3.5b. The extent of the model domain, with an indication of the main land features (hydrographic network, main roads and railways, towns etc.) that are expected to affect flood wave propagation significantly, are shown in Figure 3.2. The computational mesh of the 1951 scenario is then constructed from the 2011 scenario by including the main landscape changes occurred from 1951 to 2011. Practically, we started from the 2011 computational domain and 'subtracted' the major landscape modifications occurred between 1951 and 2011. Specifically, the levees of the Fossa Polesella are added to the mesh, the levees of the Canalbianco Channel and the sea levees are lowered by 2 m and 1 m respectively, and the ground elevation is updated to account for the large land subsidence occurred in the Po delta during this period. The change in ground elevation due to subsidence was estimated separately for the periods 1950–1957 (Caputo et al. 1970), 1958–1967 (Caputo et al. 1970; Carbognin et al. 1984), and 1968–2011 (Teatini et al. 2011), and then superposed to obtain the total variation. Overall, land subsidence in the period 1951-2011 caused a lowering of ground elevations of the order of meters over large areas, with elevation loss up to 3 m (Figure 3.5c). The 1951 reconstructed topography is shown in Figure 3.5a.

The derivation of the 1951 topography from that of 2011 is a consequence of the lack of enough topographic data referring to 1951. Furthermore, the procedure here adopted is the best way to assess the effect of the lowland changes occurred in the meantime, as systematical errors associated to topographical reliefs taken to so different years are excluded.

The differential map in Figure 3.5c highlights the major changes occurred in the region from 1951 to 2011. The variation in terrain elevations due to, respectively, land subsidence and raised embankments can be clearly distinguished as the former is rendered in blue tones (lowering), the latter in orange tones (raising, except for the levees of the Polesella channel that were removed).

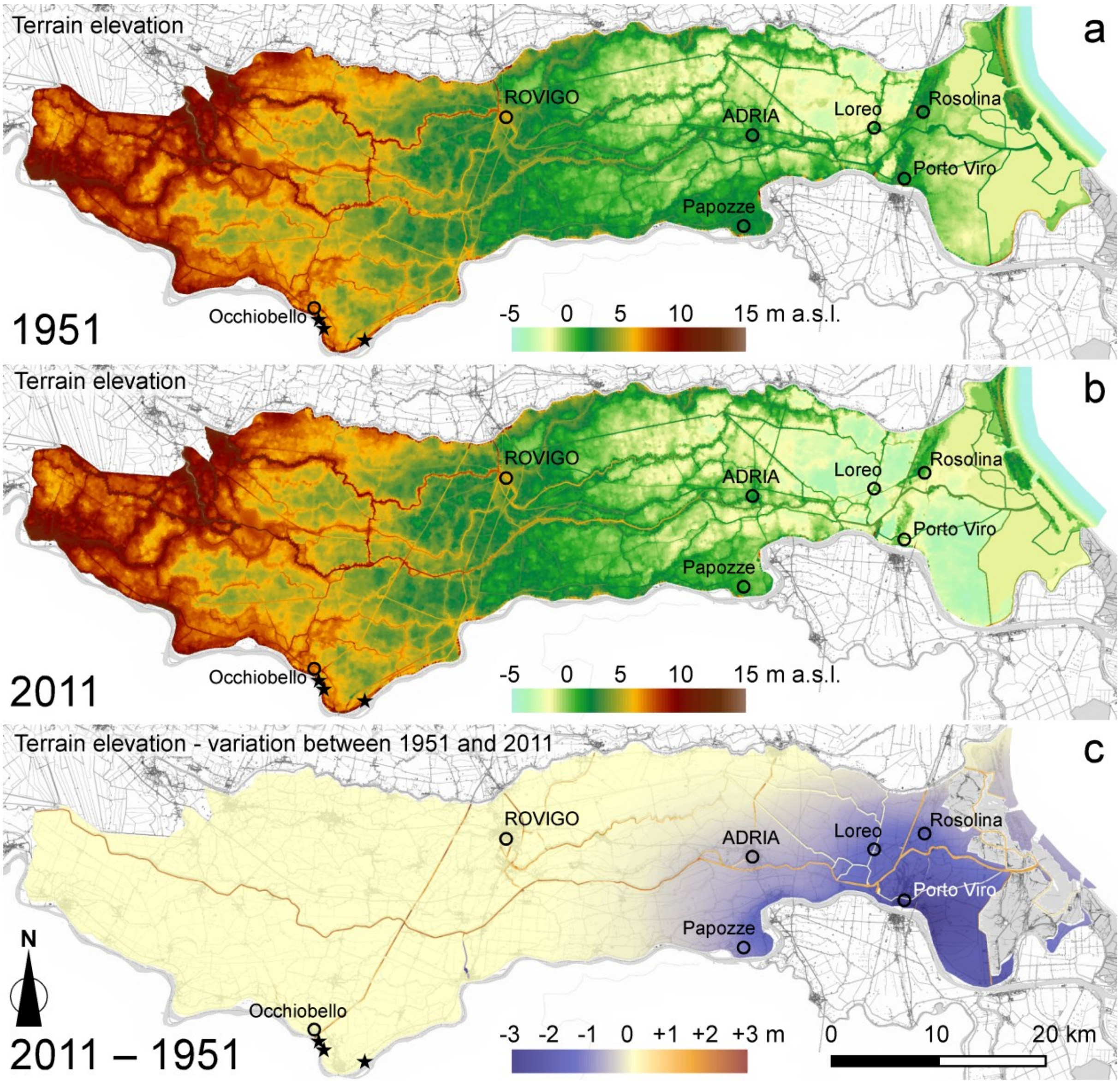


Figure 3.5 Terrain elevation (m a.s.l.) concerning 1951 (a) and 2011 (b), and variation in terrain elevation between the two time frames (c); black stars locate the three levee breaches.

In the present study, the focus is on the dynamics of major flooding events. Accordingly, hydraulic modeling has to be intended given comprehensive, large-scale analysis. Relatively small landscape features such as minor channels and small obstructions, which are known to affect the flow dynamics at a local scale (D'Alpaos et al. 1995; Hailemariam et al. 2014; Viero and Valipour 2017), play a negligible role in major flooding events like those here considered (Masoero et al. 2013), and thus are not included in the computational grid. Similarly, while uncertainties in the modeled topography can undoubtedly affect the reliability of model results, particularly the extent of flooded areas where water depths are very shallow (say <50 cm), the global picture described in the following sections, as well as the main conclusions of the study, are nevertheless robust.

### *3.3.4 The hydraulic model*

A wealth of different models is available for flood risk assessment (e.g., Bates and De Roo 2000; Vacondio et al. 2017; Minaei et al. 2018). In the present study, flood dynamics are investigated using the 2DEF hydrodynamic model, which is an appropriate tool for the purpose of the study given its physics-based and spatially explicit nature. The model solves the full 2D shallow water equations (SWEs) on unstructured triangular meshes. The 2DEF model enforces a statistical subgrid approach for bottom elevations (Defina et al. 1994; Defina 2000), which allows for a physically based, accurate and stable treatment of wetting and drying processes over very irregular topographies (D'Alpaos and Defina 2007; Viero et al. 2013). The SWEs are solved using a semi-implicit staggered finite-element method, based on mixed Eulerian-Lagrangian approach (Defina 2003). The depth-integrated horizontal dispersion stresses are evaluated using the Boussinesq approximation (Stansby 2003), and the eddy viscosity is computed according to Uittenbogaard and van Vossen (2004). The 2DEF model has been improved in the years to account for, e.g., interactions between free-surface flow and saturated flow in the topsoil layer (Viero et al. 2014), transport of pollutants and evaluation of transport time scales (Viero and Defina 2016b; Viero and Defina 2016a), and anisotropy in bottom resistance due to oriented roughness (Viero and Valipour 2017). The model also allows for using 1D channels to model the minor channel networks and 1D-links to model levees, sills, and the operations of hydraulic devices such as gates and flow controls (Martini et al. 2004; D'Alpaos and Defina 2007; Viero et al. 2013; Viero and Defina 2017; Viero and Defina 2018).

The computational mesh covers an area of 1408.6 $km^2$. It is made up of about 34,000 nodes and 67,000 triangular elements, characterized by a cell-side length that ranges between 300 m in flat areas and 25 m close to topographic features such as rail and road embankments. In the model, terrain elevations are defined on an element-by-element basis. In nearly flat areas, the elevation of computational elements is evaluated as the mean of all the LiDAR and/or DTM points that fall within each triangle of the mesh; the maximum elevation is used in place of the mean to characterize the elevation of embankments correctly (Vacondio et al. 2016).

The model results are quantitatively assessed against surveyed flooded areas according to the method proposed by Bates and De Roo (2000) and Aronica et al. (2002). GIS software is used to compute the area that the model correctly predicts as flooded (W1), the area wrongly predicted as flooded (W0), and the flooded area not predicted by the model (D0). A first performance index, P1=W1/ (W1 + W0 + D0), is a non-dimensional measure of the flooded area correctly predicted by the model. P1 is equal to 100% when the predicted and surveyed flooded areas perfectly overlap, and penalizes both over- and under-predictions. A second index, introduced by Hunter et al. (2005) to further penalize the fraction of flooded area wrongly predicted by the model, is P2=(W1 − W0)/ (W1 + W0 + D0).

### *3.3.5 Exposure evaluation*

Exposure is evaluated by identifying people and assets affected by flooding in the two scenarios (1951 and 2011), to ascertain a possible correlation between the two. Demographic and assets data are gathered at a municipality level from the national census database (ISTAT). Then, the percentage increment of the two variables is computed. The zonal statistics of the water depth is calculated for each municipality, extracting the minimum, maximum, and mean values, and the standard deviation for both 1951 and 2011 scenarios. An analysis of variance (ANOVA) is performed to address the implication with the water depth for each municipality and the variations in population dynamics. An equal interval classification is considered for the water depth change, dividing the sample into 0.5 m class breaks based on the value range.

## 3.4 Results

### *3.4.1 The 1951 scenario*

The simulation of the 1951 scenario is used to validate the model, and to shed light on the flooding dynamics that are characteristic of the region. Previous studies (Masoero et al. 2013; D'Oria et al. 2015) showed that free outflow occurred through the Occhiobello breaches. This means that the discharge poured into the Polesine Region does not depend on the water surface elevation outside the Po River levees. The flooding of the Polesine region can thus be modeled independently from the in-channel flow field. Accordingly, a discharge hydrograph is prescribed at the boundary of the mesh where the three breaches occurred (black stars in Figure 3.6). At the eastern open boundary of the mesh, where the sea level is prescribed, water is allowed to leave the computational domain. Two estimates of the outflow through the breaches are available. The former was derived by Eng. Mainardi, former Director of the of the newly established 'Po Delta' Reclamation Consortium, who applied the weir flow relation using measured water levels of the Po River and the estimated width of the breaches as reported in Lugaresi (1994); the latter was derived from the solution of an inverse method based on a 1D hydraulic model (D'Oria et al. 2015; D'Oria et al. 2016). The shape of the two discharge hydrographs is very similar, the main difference being the magnitude of the discharge and hence the flood volume. In a set of preliminary simulations, we tested the two different boundary conditions and varied the model parameters within an acceptable range. The model results led us to force the model with the outflow hydrograph estimated by Mainardi; the Manning roughness coefficient was finally set equal to 0.033 s $m^{-1/3}$.

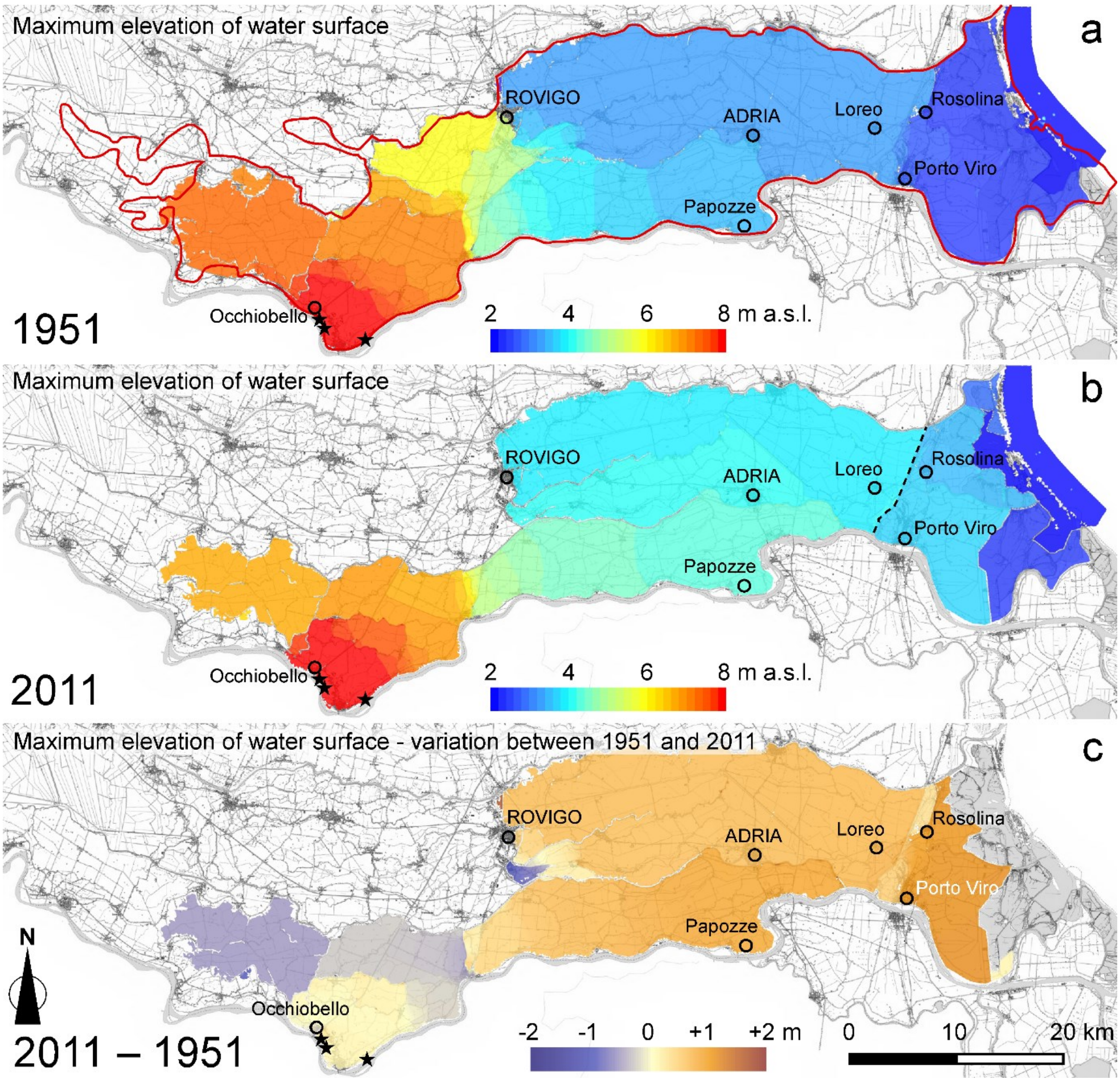


Figure 3.6 Maximum elevation of the water surface for the 1951 (a) and the 2011 (b) scenarios, and difference between the two (c). The red line in panel a bounds the surveyed flooded area in 1951; the dashed line in panel b denotes the Po-Brondolo canal; black stars denote the position of the three levee breaches.

Model simulation is run starting from 0:00 of the 14 November 1951 for 26 days. Model results are shown in Figure 3.6a (maximum elevation of the water surface) and Figure 3.7a (maximum water depth). The model is validated by comparing modeled and surveyed flooded areas (the latter is bounded by a red line in the above Figures). The two performance indexes are equal to P1=88% and P2=86%. The visual comparison shows a satisfactory agreement, except for minor discrepancies that are found in the north-western part of the flooded area, where water depths are shallower (i.e., less than 1 m). Here, the minor channel network (not included in the model) and the topographic uncertainties associated to the vertical accuracy of available data are deemed to play an important part. The timing of flood wave propagation are also checked against available historical data (Lugaresi 1994); this is an essential check considering that the flood wave propagation is controlled by the overtopping of many levees and embankments, which is very sensitive to the water surface elevation. The results of the comparison, reported in Table 3.1, show a very good agreement between collected data and model results, thus confirming the robustness of model results.

Table 3.1 Comparison between real and modeled timing of the flood propagation over the Polesine Region.

| **Chronology of the 1951 flood** | **Recorded timing** | **Modelled timing** |
|---|---|---|
| Overtopping of the levees of the Polesella and Canalbianco Channels | 15 Nov, 5–6 a.m. | 15 Nov, 5:30 a.m. |
| Flood wave up to the city of Rovigo | 15 Nov, 4 p.m. | 15 Nov, 4 p.m. |
| Flooding of Ca’ Emo | 15 Nov, 11 p.m. | 16 Nov, 2 a.m. |
| Flooding of Adria | 16-nov | 16 Nov, 3 p.m. |
| Flooding of Rosolina | 18-nov | 18 Nov, 0 a.m. |
| Sea levees overtopped | 20-nov | 19–20 Nov |

### *3.4.2 The 2011 scenario and comparative analysis*

The 2011 scenario, the flooding dynamics in the Polesine Region reflects the major anthropogenic changes of the landscape. Specifically (see Figure 3.6b,c and Figure 3.7b,c), in the North-West of Occhiobello, water levels are ~70 cm lower, and the flooded area is smaller than in 1951; this occurrence is due to the absence of the banks of the Polesella Channel that significantly hindered the eastward flood propagation in 1951. As a consequence, and also due to the higher elevation of the Canalbianco Channel levees, an area of ~100 km$^2$ West of Rovigo is no longer flooded in the 2011 scenario. On the other hand, the higher elevation of the levees along the Po-Brondolo Canal (dashed line in Figure 3.6b) causes a significant increase in water level (~70 cm) over large areas (more than 300 km$^2$) from the city of Rovigo to the Po-Brondolo Canal. The sea levees, which are more than 1 m higher than in 1951, cause about 1 m higher water levels in the region of Rosolina and Porto Viro, close to the Po delta (Figure 3.6b). Here, the maximum water depths are dramatically higher than in 1951 because of the concurrent effects of higher water levels and lower terrain elevations owing to anthropogenic subsidence occurred in the last half-century (Figure 3.7).

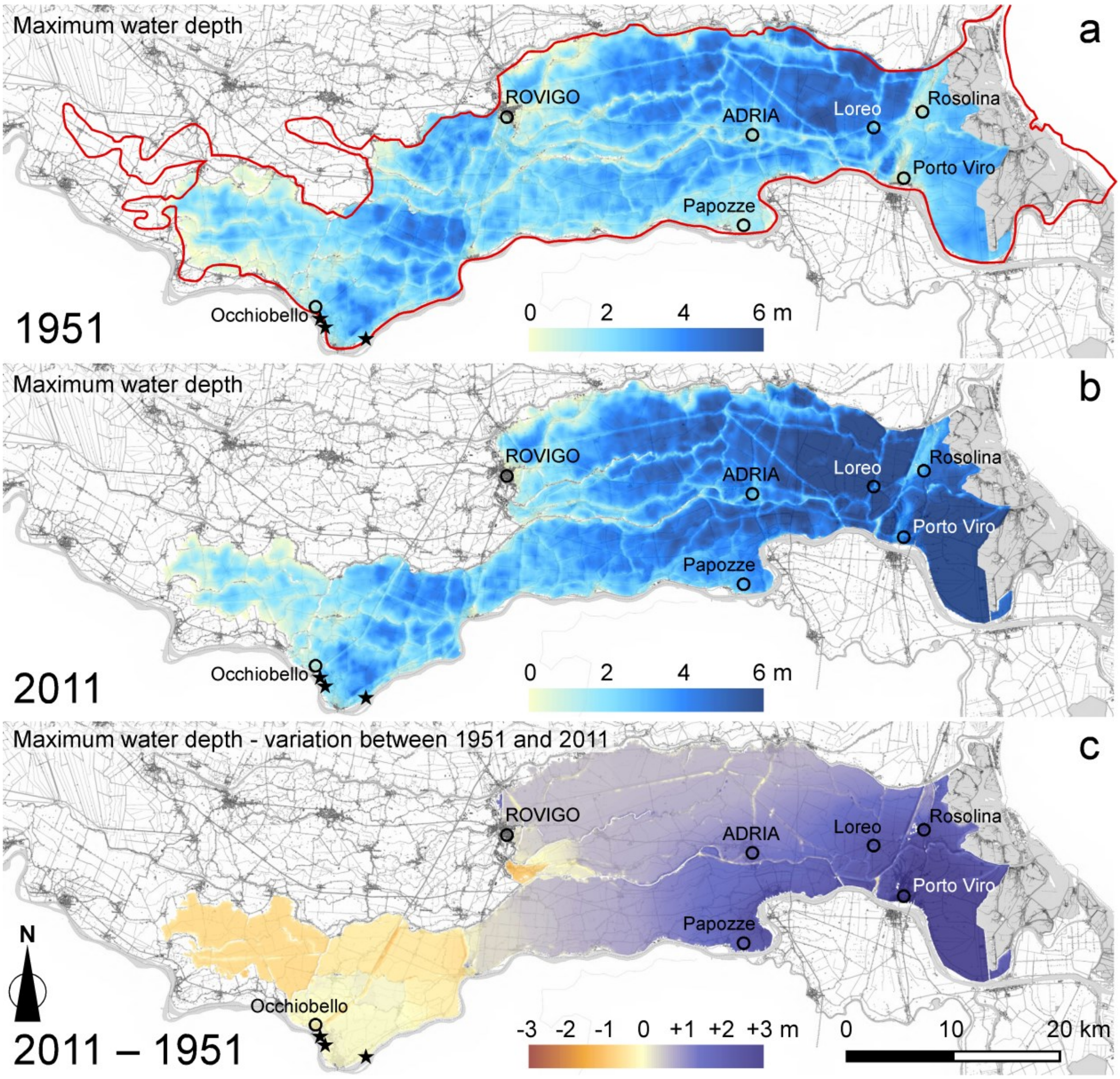


Figure 3.7 Maximum water depth for the 1951 (a) and the 2011 (b) scenarios, and difference between the two (c). The red line in panel a bounds the surveyed flooded area in 1951; black stars denote the position of the three levee breaches.

The effects produced by land subsidence and by modified embankment elevations can be distinguished as the maximum water levels were affected almost solely by the changes in embankment elevation, which can be appreciated in Figure 3.6c. Indeed, the volume of floodwaters outflowed from the Po River was so large that the maximum elevation of the water surface was not affected by the increased storage volume ascribed to land subsidence in the eastern part of the region. Land subsidence essentially led to increased water depths in the Po delta region (dark blue areas in Figure 3.6c). The differential map of Figure 3.7c confirms that, while in the western part of the Polesine Region (North of Occhiobello) water depths are about

1 m shallower in 2011 than in 1951, the flooding scenario progressively worsen moving from the city of Rovigo toward the Adriatic coast. It is worth noting that, with water depth up to more than 7 m nearby Loreo and South of Porto Viro, the hydraulic hazard increased dramatically in this area. For example, during the 1951 flood, water depths of about 1 m were recorded in the city of Adria (20,000 inhabitants); the main square of Adria (located 3.4 m a.s.l. in 1951) was not flooded, thus allowing most of the people to meet there while waiting for helicopters bringing food and drugs and, ultimately, to be rescued. In the 2011 scenario, with water levels up to 4 m a.s.l. (1 m higher than in 1951) and, moreover, ground elevation 70 cm lower than in 1951 due to land subsidence, no dry areas could be found in the city of Adria, and water depths greater than 2 m all over its historical center would prevent people from quickly reaching any safe location before the arrival of the flood water, thus causing severe danger of drowning and complicating rescue efforts (Baan and Klijn 2004; de Bruijn et al. 2015).

When dealing with flood hazard in populated areas, time plays a central role (de Bruijn et al. 2015; Balbi et al. 2016). Water arrival time after a levee failure determines the set of possible countermeasures to be undertaken and, for people, the chances of reaching a safe location. Based on water arrival time, public authorities can develop emergency plans and dispose of evacuation (Molinari et al. 2013). Figure 3.8 shows the spatial distribution of water arrival time (computed from when the three levee breaches occurred) and how (and how much) it changed between 1951 and 2011 (Figure 3.8c). Flood dynamics are significantly different in the two scenarios. Arrival times were more spatially homogeneous in 1951 than in 2011. Indeed, while in 1951 the levees of the Polesella channel forced major overflowing North of the Canalbianco Channel towards Rovigo, in the 2011 scenario floodwater flows eastward without overtopping the Canalbianco levees; later, barrage effects exerted by the higher levees of the Po-Brondolo Canal cause floodwater to overflow the Canalbianco levees northward, and then to return westward towards Rovigo.

In terms of water arrival time, the 2011 scenario is undoubtedly less critical in the main town of Rovigo (+5 days to be reached by floodwater) compared to that of 1951; however, it is significantly worse for the strip of land confined between the Po River and the Canalbianco Channel since, e.g., water arrival time is shorter by 18 h in Papozze (-30%), by 10 h in Adria (-17%), and by up to 20 h (-27%) in its periphery and in Loreo as well (Figure 3.8c).

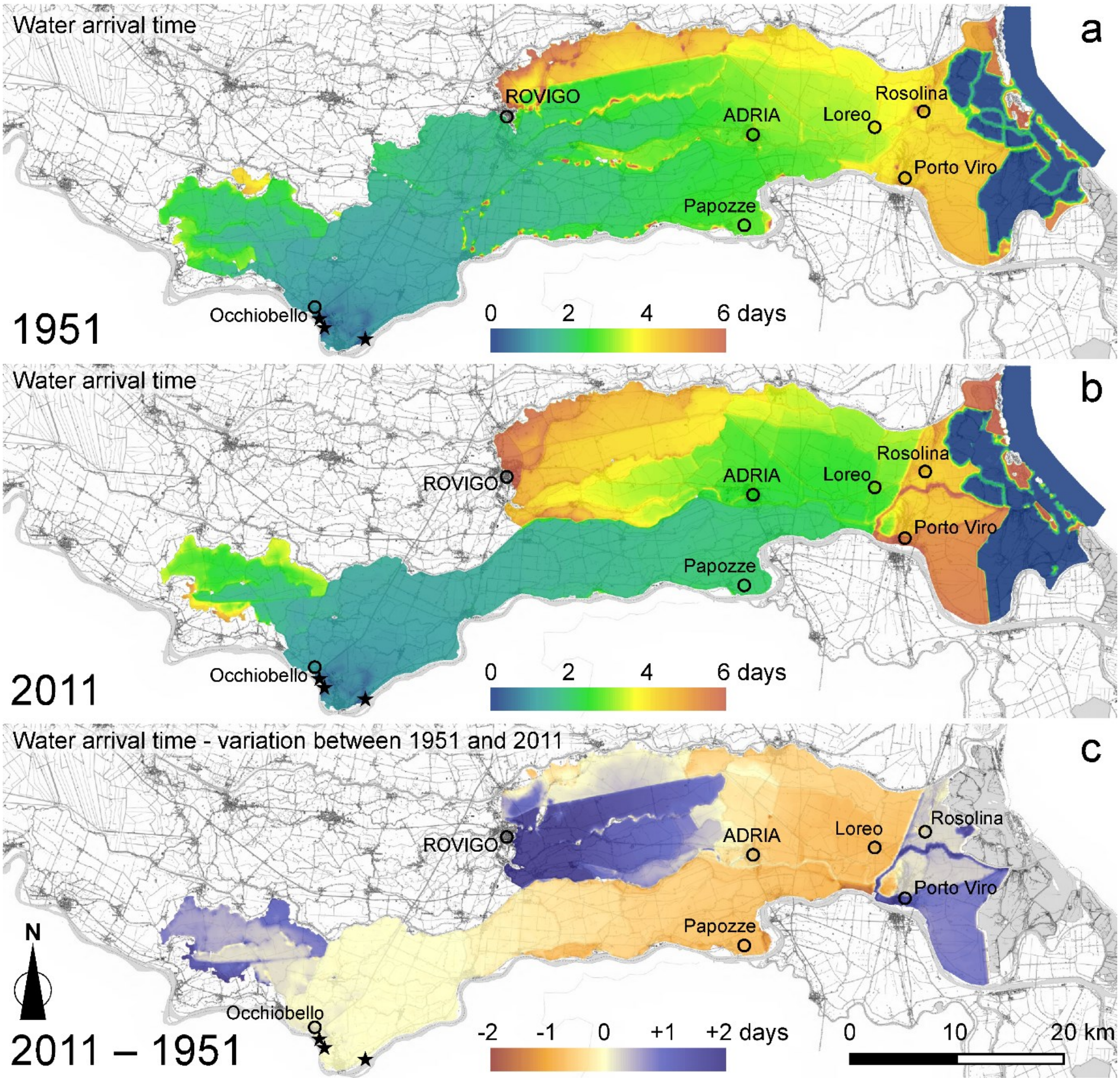


Figure 3.8 Water arrival time (since the breach opening) for the 1951 (a) and the 2011 (b) scenarios, and difference between the two (c). Black stars denote the position of the three levee breaches.

In 1951, the three breaches were closed about one month after they occurred; the time needed to close levee breaches is likely smaller nowadays than in 1951, thus entailing smaller volumes of floodwater poured into the Polesine region. On the other hand, the volume of floodwater to be pumped away to dry up the land lying below the sea level is now 458·106 $m^3$ compared to 205·106 $m^3$ in 1951 (+125%).

### *3.4.3 Exposure and population dynamics*

The analysis of variance shows a moderate statistical association between mean water depth and both population and housing changes over the time period. Firstly, associated with an increase in the mean water depth (see classes 1 and 2, Table 3.2) there was an increase in the number of houses (41.7% in class 1 and 104.2% in class 2).

Table 3.2 Class variations according to the percentage of houses and population between 1951 and 2011. In brackets the fraction percentage of variation per class. Eta-square effect size is also shown.

| Class | Water depth change (m) | House variation (%) | Population variation (%) |
|---|---|---|---|
| 1 | > 0.5 | 41.7 [-5.2] | -41.6 [-7.2] |
| 2 | 0 - 0.5 | 104.2 [10.0] | -9.4 [10.9] |
| 3 | 0 - -0.5 | 24.8 [-4.1] | -43.0 [-3.1] |
| 4 | < - 0.5 | 26.1 [-0.7] | -43.6 [-0.6] |
| | Eta-square ($\eta^2$) | 0.05 | 0.07 |

This means that the increased number of houses is specifically consistent in areas known to be flood-prone, representing a higher consumption and demand of build-up areas since the 1951 (Aubrecht et al. 2011; Koks et al. 2015). The effects of rising urban areas coupling with flood exposure create a challenge for risk financing, at both a household and a national level. Firstly, because the private insurance market in Italy for flood protection is almost absent (Gizzi et al. 2016), and secondly because the Government has not created a protection system in support of the private one. Floods burdens are not only exacerbated by these aspects but also by population dynamics affecting the resulting exposure (Jongman et al. 2014; Tanoue et al. 2016). In accordance with this research, the 1951 massive migration caused a decrease in population, easily traduced into a decreased exposure. However, it has been found that lower levels of depopulation correspond to classes 1 and 2 of water depth change (a depopulation of 41.6% in class 1 and 9.4% in class 2). In simple words, this means that fewer people abandoned the most hazardous areas resulting that those that at the time did not migrate remained exposed to flood risk up to present days. Considering the broader picture, the Polesine region is one of the regions (based on the Northern Italy floodplain) suffering the most from a social vulnerability to floods (Roder et al. 2017). Here, the national census and subsequent statistical analyses evidenced the most substantial burden defined by an economic fragility derived by the lowest rate of employment and by the high pressure on the agriculture sector. The high dependency

individuals have with the environment (Tiraboschi 2014a) put them in higher jeopardy during a flood event.
The situation described so far can depict a strange correlation between the increased number of properties and the reverse trend for the population growth. This might be due to different, interrelated reasons. After the major flood, some rural units have certainly been abandoned and never recovered, seeing more convenient constructing new urban areas. In parallel, the necessity of building new urban areas might be correlated to people's necessity to live closer industrial and urban nuclei, abandoning slowly the farming activities towards new businesses. In fact, according to Bühnemann et al. (1979), in the Rovigo province after 1951 there was an increase in the number of 'unproductive' areas over the whole of the flat country, which is attributable to substantial urbanization. A third explanation might be ground on family size. Now, more than in the '50s, families are smaller, sometimes composed of single individuals (Bianco 2015). This probably has risen the need for more residential units. However, the important point is that the new urban sites have been built-up in the actual higher hazard zones according to the correlations in Table 3.2.
The municipalities highly exposed to flooding are Porto Viro, Papozze, Loreo, Adria and Rosolina, localities emerging even in Figure 3.7.

## 3.5 Discussion

### *3.5.1 Main implications of the study*

Based on the results of the study, a number of interesting issues deserve to be discussed.
First, anthropogenic landscape modifications, such as the construction (or removal) of embankments or land subsidence, can significantly affect flooding dynamics and hydraulic hazard in lowland areas. Therefore, as a general rule, planning the construction of rail or road embankments and levees in the minor channel network should bear in mind possible interactions with major flooding events.
Indeed, the present study confirms that, in nearly flat floodplains and coastal areas, relatively high land features (levees, rail and road embankments) play a critical role in determining the flooding extent. It also suggests that land features aligned with the main course of the river can limit the flooding extent; on the contrary, transverse land features can significantly worsen the flooding scenario in the upstream land for huge distances. Hence, the removal of barriers that

act to hinder the water flowing toward the sea can be an effective measure to limit flooding extent by creating a sort of route-to-the-sea for floodwaters. By looking at the Polesine region, it seems in fact that the severity of flooding is mostly determined by the elevation of the highest transverse land features.

Secondly, a change in protection philosophy is extremely needed to increase both safety and resilience of communities exposed to flooding. The classic concept of 'flood control' must give way to holistic practices of 'flood management'. Examples encompass the adoption of 'room-for-the-river' policy aimed at lowering flood levels by giving more room to the rivers instead of heightening dikes and let the flood levels go up (Baan and Klijn 2004; Opperman et al. 2009; Salazar et al. 2012; Sayers et al. 2015; Dadson et al. 2017), or the purposeful inundation of low-exposed areas in order to protect downstream lowlands from accidental flooding. In this view, Marchi et al. (1995) suggested to reduce the flooding risk in the lower Po reaches and the risk of inundation of the Polesine region by reducing the flood discharge entering the lower Po. This could be achieved with the on-purpose, temporarily flooding of about 400 million $m^3$ in a 100-$km^2$ area immediately upstream of the lower reach of the Po River. With such a measure, the catastrophic flooding of the Polesine in 1951 would have been forestalled by flooding a one-tenth area than that flooded in 1951 with only one-twentieth water volume. This change of perspective has already been observed for example in Great Britain (Dadson et al. 2017) and in the Netherlands (Vis et al. 2003; Ludy and Kondolf 2012), and must undoubtedly be adopted in Italy and worldwide as well. However, the actual implementation of such plans involves distinct economic and social responses (Marchi et al. 1995). Beside proper technical choices, authoritative political decisions are needed (Gober and Wheater 2015).

These points can be particularly relevant for developing countries with a large range of coastal lowlands (Gupta 2007; Sarmah and Das 2018), in which substantial anthropogenic modifications are expected to affect floodplain environments in the near future (Sampson et al. 2016). Indeed, while in developed countries works such as transportation network and structural flood protection measures taken in the past do constrain future choices (Jeuken et al. 2014), planning process benefits from far more freedom in developing countries. This entails plentiful opportunities for reducing flood exposure and for improving urban resilience (Duy et al. 2018). Considering that knowledge transfers from developed to developing countries cannot be direct because of different geographical settings, socio-economic situations, and political situations, governments are encouraged to develop effective and comprehensive flood governance programs (Chan et al. 2018). To avoid or, at least, to minimize detrimental impacts of anthropogenic landscape modifications on flooding events, planning must be guided by good practices of integrated flood management in order to balance flood risk, ecosystem, and livelihood objectives (Juarez Lucas and Kibler 2016).

### *3.5.2 Study limitations and future research directions*

With regards to the limitations of the study, the modeling analysis uses the 1951 flood event as a base to infer the effect of landscape modifications on flooding dynamics. While such an event is undoubtedly representative of what would occur in the case of similar major floods, the effects of landscape modifications on the dynamics lower level of flooding (e.g., Moftakhari et al. 2017; Karegar et al. 2017) has not been investigated. As a second point, census data are available only at municipality level, thus preventing a more detailed analysis concerning the 'intra-municipality' changes in the spatial distribution of the population. Finally, as a consequence of the above point, also the exposure analysis cannot account for 'intra-municipality' variability.

Future directions of research encompass the study of the appropriate morphology of land features (e.g. urban areas, transportation network, farmlands, canals, etc.) in the targeted landscape for reducing flood hazard, or the in depth analysis of the role played by the pattern of transportation network and land features such as canals or farmlands in affecting flood propagation and, in general, hydraulic hazard. This could be done concerning flood events of different magnitude, from moderate flooding to major floods.

### *3.5.3 The challenge of boosting preparedness to floods and resilience*

In case of severe flood events in lowlands such as the Polesine region, the availability of civil protection plans is pivotal. In this view, the results of the hydraulic modeling can provide a wealth of key information. Knowing the spatial distribution of water depths allow determining what must be done before, during, and after a flood to protect people and properties. Also, water arrival time can be compared with the time needed for evacuation or fleeing, which is influenced by several factors such as the population density, road capacity, distance to safe areas, weather conditions, etc. (de Bruijn et al. 2015). Technical information must be spread to the population in suitable form (Feldman et al. 2016; Cheung et al. 2016), and must be completed with direct and widely accessible communication channels, to make inhabitants aware of both the actual and expected situations, and to allow them to take proper countermeasures or eventually to leave the region (Halling-Sorensen et al. 1998; Balbi et al. 2016). Indeed, social perception of risk is of fundamental importance to enhance preparedness and resilience of urban areas (Bodoque et al. 2016); it can be enhanced by involving citizens in both exploratory studies and decision-making processes (Lane et al. 2011; Vávra et al. 2017; Luke et al. 2018). Major flooding events are relatively infrequent in lowlands as in polders (Baan and Klijn 2004). This entails negative consequences, which are substantially different in the short term versus long term. Major flooding events obviously have significant impacts on population dynamics in the few following years (increased awareness, depopulation, etc.). On the contrary, people and public institutions seem to be unaware of flood-related issues in the long-term. Food risk impact on property markets disappears rapidly over time (Rajapaksa et al. 2017). Also, the lack of a long-term memory causes flood risk to lose any role in driving urban planning and in the political agenda. This occurrence is further intensified by the fact that anthropogenic landscape modifications take place in 'periods of calm' so that their effects on flooding dynamics go unnoticed. These detrimental dynamics is not unexpected considering the overall enhancement of human presence close to streams and rivers during the last decades (Ceola et al. 2015). Furthermore, it demonstrates the need for correct and comprehensive information on flooding hazard both to guide land-use planning and to develop effective emergency plans.

People are seldom aware of being exposed to flood hazard. However, it is possible to increase self-consciousness by creating a culture of risk able to improve individual and community preparedness and response during flood events. Information is needed regarding the current and expected flooding dynamics that might reflect into tangible protection actions (Thieken et al. 2007). However, preparedness is found to be difficult to achieve, particularly in places where extreme events do not occur frequently (Molinari et al. 2013; Kreibich et al. 2017), causing a lacking public response to warnings (Parker et al. 2007). A useful enhancement could be achieved by strengthening the involvement of citizens in both exploratory studies and decision-making processes (Lane et al. 2011; Wehn et al. 2015; Vávra et al. 2017; Liu et al. 2018; Laborde et al. 2018). If planners, authorities or academics keep concentrating on the probability of occurrence of these events, people will remain sufferers, whereas if individuals undertake the risk, they will become active agents creating a positive decision-making situation. Of course, this approach to risk is driven by risk attitude, i.e. the decision-makers' inclination for risk-taking that stems from personality and personal cognitive spheres. In this regard, individual's knowledge, perception and action are a successful combination to enhance preparedness and resilience of urban areas (Bodoque et al. 2016). To permit this 'assimilation-engagement', that may be translated an involvement in the decision-making process in the risk mitigation process, people need to receive information. According to Lugeri et al. (2018), information needs to be simple and not simplistic, to permit individuals to create a geoethics [Geoethics is the ethical, social, and cultural implications of Geoscience research, practice, and education, representing a new way of thinking about and practicing Earth Sciences (Peppoloni and Di Capua 2012)] of the environment they live into creating a balanced relationship with their psycho-physical development. Lugeri et al. (2018) argued that "a communicative strategy that informs the public of the characteristics of a territory (understood as a natural and cultural environment) and the relative operative dynamics, just as one should understand the anatomy and physiology of one's own body, when still healthy, in order to manage and protect it in the best possible way". It seems evident the need for an integrated watershed management to reduce the hydraulic hazard being sustainable with the environment (Salazar et al. 2012; Sayers et al. 2015; Dadson et al. 2017).

## 3.6 Conclusions

The effects of anthropogenic landscape modifications on flooding dynamics in lowland areas were analyzed to explore the multifaceted relationship between floods, population dynamics, and human activities such as urbanization, landscape modification, and groundwater exploitation.

The Polesine (North-East of Italy), which is a large lowland area where the residual risk related to major flooding events is far from being negligible, was chosen as a significant case study. Since the last great flood of 1951, the Polesine landscape underwent major anthropogenic changes that significantly affected the flooding dynamics, exacerbating hydraulic hazard in large part of the region. A comparative analysis between 1951 and 2011, based on the results from numerical modeling, showed increased water levels and depths in large areas, and substantially different spatial distribution of water arrival time. People and assets exposure to flooding varied as well within the same period. Population decreased by ~30% in the years following the great flood and remained stable so far; nevertheless, the number of houses is increased by 36% in 50 years. Quite surprisingly, the increase of houses was greater and the reduction of population smaller in areas where the hydraulic hazard has increased, suggesting that population and urban settlements reallocated after the 1951 flood for reasons other than safety from floods.

According to the results of the study, anthropogenic landscape modifications, such as the construction (or removal) of embankments or land subsidence, can significantly affect the flooding dynamics and hydraulic hazard in lowland areas. Therefore, as a general role, planning the construction of road embankments and levees in the minor channel network should bear in mind possible interactions with major flooding events. In this view, the results from hydraulic modeling can provide a wealth of key information. With a look to the future, effective strategies should be pursued (i) to enhance resilience and preparedness to flooding events in lowlands, (ii) to take into account flood-related issues in the long-term land-use planning, (iii) to change the protection philosophy, by replacing the classic concept of ‘flood control’ with holistic practices of ‘flood management’.

Finally, the need of placing flood risk in the centre of the public debate is even more critical shortly due to climate change, which is expected to exacerbate flood risk in these areas (Simeoni and Corbau 2009; Muis et al. 2015; Aich et al. 2016; Hettiarachchi et al. 2017).

*Author contributions*: D.P.V. conceived the presented idea, gathered the topographical data and performed the modelling in consultation with B.M. and A.D. G.R. integrated the manuscript with socio-economic data and performed the exposure and population dynamic analyses in discussion with P.T. D.P.V., G.R., B.M., A.D. and P.T. contributed to interpreted the overall results and D.P.V. and G.R. drafted the manuscript in collaboration with B.M., A.D. and P.T.

CHAPTER 4

# ASSESSMENT OF SOCIAL VULNERABILITY TO FLOODS IN THE FLOODPLAIN OF NORTHERN ITALY[3]

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## 4.1 Abstract

Practices for reducing the impacts of floods are becoming more and more advanced, centered on communities and reaching out to vulnerable populations. Vulnerable individuals are characterized by social and economic attributes and by societal dynamics rooted in each community. These indicators can magnify the negative impacts of disasters together with the capacity of each individual to cope with these events. The Social Vulnerability Index (SoVI) provides an empirical basis to compare social differences in various spatial scenarios and for specific environmental hazards. This research shows the application of the SoVI to the floodplain of northern Italy, based on the use of 15 census variables. The chosen study area is of particular interest for the high occurrence of flood events coupled with a high level of human activity, landscape transformations, and an elevated concentration of assets and people. The analysis identified a positive spatial autocorrelation across the floodplain that translates into the spatial detection of vulnerable groups, those that are likely to suffer the most from floods. In a second stage, the output of the index was superimposed on the flood hazard map of the study area to analyze the resulting risk. The Piemonte and Veneto regions contain the main areas prone to flood 'social' risk, highlighting the need for a cohesive management approach at all levels to recognize local capacities and increase communication, awareness, and preparedness to mitigate the undesirable effects of such events.

## 4.2 Introduction

Among natural and anthropogenic hazards, water-related disasters represent one of the main environmental risks of our time causing the major obstacles to human security and development (Adikari and Yoshitani 2009). Floods affect on average about 70 million people each year (UNDP 2004; United Nations 2011), and the severity of such events sees to increase in the future (Swiss Re 2012). These data have intensified the attention of public authorities and researchers in understanding the factors contributing to such risks (IPCC 2012).

In a general sense, risk derives from the combination of hazard, vulnerability and exposure of the elements present in a community that may translate into possible adverse effects (Cardona et al. 2012). The vulnerability is the fragility of the human-environment system to disturbances and losses (Smit and Wandel 2006) related to the social, economic and environmental conditions of the community (ISDR 2004; Kasperson et al. 2005). In this framework, the social vulnerability can be defined as the vulnerability of the human environment (Brooks 2003), and can be related not only to some individual's characteristics such as gender, age, education, economic welfare, race among others, but even to complex community dynamics and support systems, that may influence certain individuals in their ability to respond to particular threats (Cutter et al. 2003; Mechanic and Tanner 2007). Beside social and economic inequalities, as expressed by several authors, the social vulnerability may include house characteristics (Mechanic and Tanner 2007; Armaş 2008; Flanagan et al. 2011; Ludy and Kondolf 2012) and critical infrastructures (Cannon et al. 2003; Adger et al. 2004; Fekete 2009; Flanagan et al. 2011). The interaction among these factors across space may help in the definition of the so-called vulnerable groups (Cutter et al. 2013). However, labelling all the people as vulnerable according to one or more general characteristics has been seen to be quite problematic (De Marchi and Scolobig 2012). In fact, measuring the vulnerability of a society implies the identification of the social, economic and political context behind people susceptibility into a defined spatial and temporal setting (Borden et al. 2007). Spatiotemporal parameters may influence the presence or the absence of some variables used for the overall computation of the social vulnerability. For example, as shown by Zhou et al. (2014) there is not a unique temporal set of variables for the assessment of vulnerability. And similarly not all the variables explain the vulnerability for all hazard settings. As commented by Weichselgartner (2001) concentrating attention to a single hazard may produce accurate and in-depth analysis surrounding it because of the unique physical process characteristics. This means that there are factors related to vulnerability at a broad-spectrum (e.g., Chakraborty et al. 2005; Masozera et al. 2007; Cutter and Finch 2008; Siagian et al. 2014; Zhou et al. 2014; Guillard-gonçalves et al. 2015) and some others that are more hazard-dependant (Schneiderbauuer and Ehrlich 2006), [For example for tropical cyclones (Andeson-Berry 2003) hurricanes (Cutter and Emrich 2006; Rygel and Yarnal 2006; Myers et al. 2008), earthquakes (Schmidtlein et al. 2011; Noriega and Ludwig 2012), landslides (Santha and Sreedharan 2012; Eidsvig et al. 2014), drought (Iglesias et al. 2009), volcanic hazards (Chester et al. 1999; Hicks and Few 2015), and floods (Pelling 1997; Tapsell et al. 2002; Fekete 2009; De Marchi and Scolobig 2012; Zhang and You 2014; Koks et al. 2015; Rufat et al. 2015)]. Analyses of social vulnerability to floods are justified by the intrinsic characteristic of these natural phenomena: the likelihood of occurrence, the speed of onset, the potential damage and the society's capacity to be prepared and cope with these events (Rufat et al. 2015).

The spatial identification and the inclusion of vulnerable people into the risk management planning process have been widely discussed and fostered in the Sendai Framework for Disaster Risk Reduction (March 2015) (Aitsi-Selmi et al. 2016). It emerged that it could enhance effective mitigation plans aimed at increasing social capacities (Dunning and Durden 2011) serving as a communicating tool amongst all the actors involved in the disaster management framework, from those involved in the academics to those in the political, governmental and humanitarian agencies (Eakin and Luers 2006). Having a prior recognition of community's needs (Morrow 1999; Fernandez et al. 2016), and a mapped representation of the people that require much consideration prior, during and after a flood, might help the monitoring, the forecasting and the assistance phases (Flanagan et al. 2011). As argued by Morrow (1999), maps are considered as 'low-tech' technologies that can communicate the same message to different stakeholders, and that can be enriched with useful information (like shelter places) being readily available to the population. The geographic information system (GIS), as a tool map for illustrating the spatial vulnerability to floods, have the advantage to monitor the results through time and space (Fedeski and Gwilliam 2007; Hebb and Mortsch 2007; Van Westen 2013). This advanced monitoring could be achieved by updating the vulnerable human indicators, supplementing updated hazard-related data, economic losses, and urban infrastructures among others. In this way, politicians and public authorities could prioritise those areas that require specific management actions.

## 4.3 The study area physical environment and flood risk

The trend of floods within the European continent shows increasing numbers since the 1980s, mainly due to the constant rise of meteorological events (Munich RE 2012). Twenty-six major flood disasters were recorded between 2003 and 2009, mostly affecting Romania, United Kingdom and Italy (CRED EM-DAT 2015). Italy has been hit by several flood events since the late 7th century, where the oldest event for which the number of casualties is recorded to be around 1000, occurred in 671 in the Lombardia region (Northern Italy) (Salvati et al. 2010). As reported by the authors in a systematic review from 671 to 2008, 2770 flood events have been recorded, with a total of 41265 victims (encompassing deaths, missing and injured people). In the period 2009-2014, there have been registered 99 fatalities and more than 37000 people displaced (IRPI-CNR 2014). In particular, the floodplain of Northern Italy is an area where the high level of human activity, the on-going concentration and sensitiveness of assets and the increase of unequal exposed people (Alfieri et al. 2016) have magnified the damages caused by floods. Since the early 1860s, the floodplain of Northern Italy has stood out by being the leading area in agricultural productivity. This has led to a need for a large labor force, generating the first significant immigration fluxes in the floodplain (Bonifazi and Heins 2011). After that, its landscape and environment have seen numerous transformations making it in recent times the most extensive populated area in Italy (Menichini 2005). Due to its geomorphic and topographic settings, and the complex drainage system articulation, this floodplain presents numerous areas prone to flooding (Sofia et al. 2014). Among the latest notable flood events, there is the 2000 inundation occurred in Piemonte (October 13-16) causing more than 40000 homeless, 5 missing people, and 3 deaths (Figure 4.1a).


Figure 4.1 Floods have recurred in the floodplain of northern Italy: (a) 2000 flood in Piemonte region in the Po River basin (Angelini 2014), (b) Cresole Municipality (Province of Vicenza) hit by the All Saints flood in 2010 (Ribichini 2011), (c) 2014 Baganza flood in Parma (Olivetti 2014), and (d) 2014 Secchia flood in the Modena floodplain in the locality of Bastiglia (Solignani 2014).

The Veneto region was involved in a large event in 2010 when 540 mm of rainfall in 24 hours fell during the All Saints days. This flood caused 200000 dead animals, 500000 displaced people, 140 $km^2$ of inundated surface, and over a billion of euros of damages (Figure 4.1b). In June 2011, the Province of Parma (Emilia-Romagna region) was hit by a dramatic flood causing more than 7.5 M of euros of damages (private, public and industrial properties accounted for), with more than 185 families displaced (Figure 4.1c). Recently, in 2014, a flood in the Province of Modena covered lands for 75 $km^2$ of water, causing 1000 evacuations and one victim (Figure 4.1d). According to its physical environment and the high flood risk exposure, there is a need to develop a GIS-based multicriteria evaluation framework for the identification of potential vulnerable. In accordance, this work proposes a social vulnerability analysis at a municipality level by the use of the Social Vulnerability Index (SoVI). This methodology has been adapted to this study case according to the societal and historical construction of the area. In a second stage, it offers a spatial identification of the areas that might be highly exposed to flood risk by a combination analysis of the SoVI scores and recent flood hazard data. The chosen area could seem relatively small. However, the municipalities included represents the 34% of all the municipalities in Italy. In general, a larger scale would have hidden details regarding local differences that are important in tracking the vulnerability of people. According to the way the SoVI responds to some social constraints, it is easier to address the needs of people for the management of floods. The results and lessons offered by this case study could be compared to countries with the same social, cultural, geomorphological and environmental settings, giving the basis for practical management guidelines.

## 4.4 Materials and method

The area considered for the study is bounded on the north by the Alpine mountain range, on the south by the Po River and by the Upper Apennine range, and on the east by the Adriatic Sea to which it declines gradually. It covers an extent of approximately 67700 $km^2$, accounting 2772 municipalities, distributed in 38 provinces and 6 regions (Figure 4.2). Similar to the Great Hungarian Plain (Carpathian Basin), and the Rhine-Meuse Delta (Netherlands), it represents one of the largest alluvial environments of Europe (Fontana 2012).

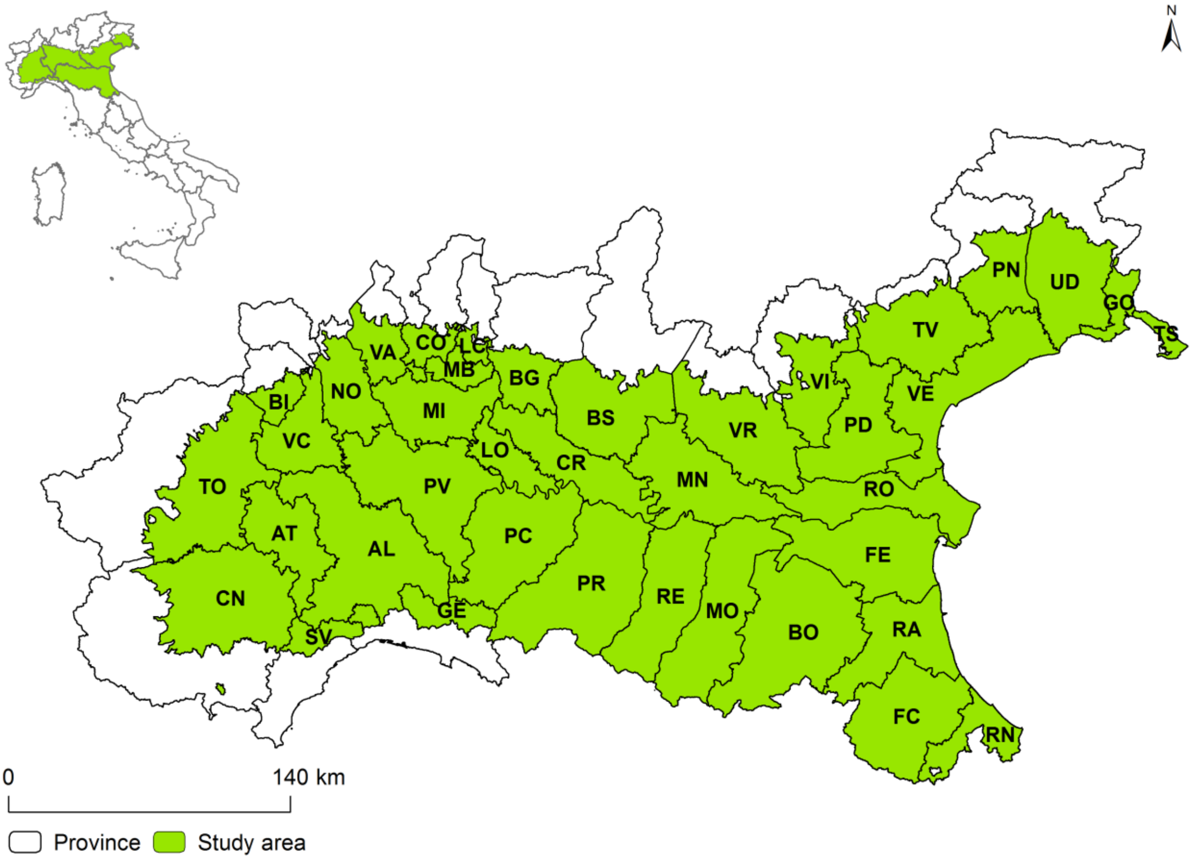


Figure 4.2 Map of the study area and abbreviation of the provinces (regions of which each province is composed are shown in italics): *Piemonte*, CN (Cuneo), TO (Torino), BI (Biella), VC (Vercelli), AT (Asti), AL (Alessandria), and NO (Novara); *Liguria*, SV (Savona), GE (Genova); *Lombardia*, PV (Pavia), MI (Milano), VA (Varese), CO (Como), LC (Lecco), MB (Monza-Brianza), LO (Lodi), CR (Cremona), Bergamo (BG), and Brescia (BS); *Emilia-Romagna*, PC (Piacenza), PR (Parma), RE (Reggio nell'Emilia), MO (Modena), BO (Bologna), FE (Ferrara), RA (Ravenna), FC (Forlì-Cesena), and RN (Rimini); *Veneto*, VR (Verona), VI (Vicenza), TV (Treviso), PD (Padova), RO (Rovigo), and VE (Venezia); *Friuli-Venezia Giulia*, PN (Pordenone), UD (Udine), GO (Gorizia), and TS (Trieste). Top left picture shows the regional subdivision of Italy where the study area (green area) is located.

### *4.4.1 Data*

The data used for the assessment of the social vulnerability analysis to floods are census data, while for the risk evaluation we used recent flood hazard data. Census data have been extrapolated from the Italian national census database of ISTAT (National Institute of Statistics), and the income data provided by Ministry of Economy and Finance (*Ministero dell'Economia e della Finanza*) for the 2011 timeframe. As already noted, many indicators are responsible for increasing (or decreasing) the social vulnerability of people. Those selected for this study are based on the work conducted by Cutter et al. (2003), and consequently re-adapted, including and excluding some variables according to data availability and the construction of the northern Italy society. As Burton (2015) argued, it is important to focus on a single dimension of the social vulnerability to highlight a particular context under flood hazard.

Table 4.1 Indicators that may influence the vulnerability of people in the area under study. All the data have been collected at a municipality scale for the year 2011, except the population growth variable that derived from the decade 2001-2011. Total number of municipalities N=2772. Mean (M) and Standard Deviation (SD) are also shown.

| Indicator | Description | Variable name | M | SD |
|---|---|---|---|---|
| Socio-economic status | Percentage of housing units w/o basic sanitation installations | NOBASICSANITATION | 0.7 | 0.8 |
| | Percentage of rent houses at family unit | RENTHOUSE | 13.4 | 5.3 |
| Gender | Percentage of female | FEMALE | 50.6 | 1.8 |
| Ethnicity | Percentage of no native people | NON-NATIVE | 8.1 | 4.0 |
| Age | Percentage of dependent people (< 4 and > 85 years old) | AGEDEPENDENT | 7.8 | 1.3 |
| Education | Percentage of illiterate people | ILLITERATE | 0.5 | 0.4 |
| | Percentage of people with less than 8 years of education | EIGHTYEARSEDU | 13.2 | 2.4 |
| Employment | Percentage of unemployed people | UNEMPLOYED | 3.4 | 1.1 |
| | Percentage of retired people | RETIRED | 27.2 | 6.3 |
| | Percentage of active people involved in the agriculture sector | EMPLOAGRICULTURE | 3.5 | 3.3 |
| Family structure | Percentage of single-parents (both female and male headed) | SINGLEPARENT | 7.8 | 7.1 |
| | Percentage of family with more than 6 members | MORESIXMEMBERS | 1.3 | 0.8 |
| Population consistency | Population growth index | POPGROWTHINDEX | 0.1 | 0.1 |
| Income | Mean annual income per single inhabitant | INCOME | 13054 | 2012 |
| Special needs people | Percentage of people living in assistance institute | NEEDASSISTANCE | 0.8 | 1.9 |

For this reason, we considered only socio-economic and demographic variables excluding housing characteristics, critical infrastructures, awareness, and coping capacities. For the purpose, 15 variables have been selected, as shown in Table 4.1.

Table 4.2 Definition of the Italian flood hazard classification. Flood hazard areas in the floodplain of Northern Italy and the Italian territory are shown in $km^2$. In brackets, the percentage of the flood hazard layers respect the whole study area surface is shown.

| **Flood hazard classification** | **Definition** | **Study area ($km^2$)** | **National level ($km^2$)*** | **%** |
|---|---|---|---|---|
| High (H3) | High floods occurrence. Return period of 20-50 years | 6306 (9.3) | 12218 | 51.6 |
| Moderate (H2) | Moderate floods occurrence. Return period of 100-200 years | 15477 (22.9) | 24411 | 63.4 |
| Low (H1) | Low floods occurrence/extreme floods | 19443 (28.7) | 32150 | 60.5 |

*ISPRA (2015b)

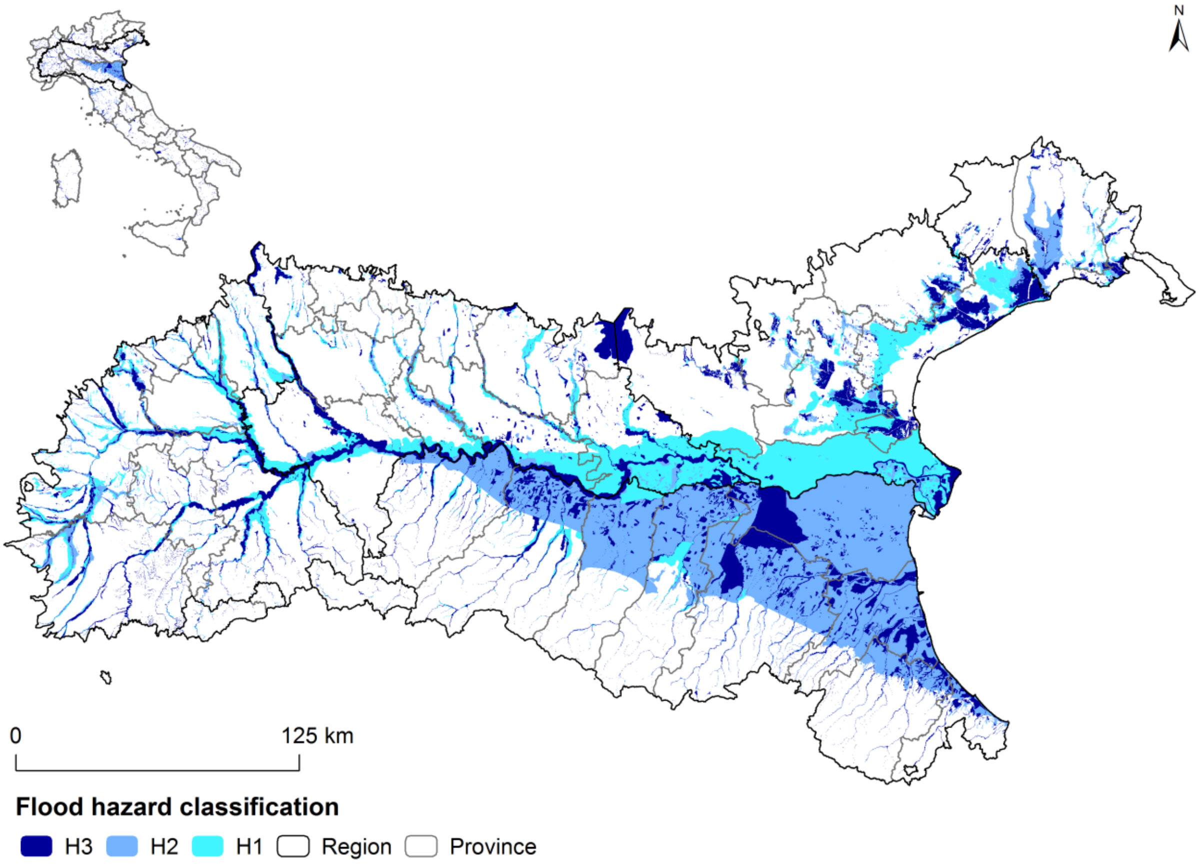


Figure 4.3 Flood hazard map of the study area. H3 stands for high, H2 for moderate, and H1 for low hazard probability. Top left picture shows the flood hazard map for the whole Italian territory. Own elaboration from ISPRA (2015b).

Flood hazard data, updated in May 2015, (Figure 4.3) were provided by ISPRA Institute (*Istituto Superiore per la Protezione e la Ricerca Ambientale*) and given by a three-class flood probability distribution [see the guidelines proposed by Ministero dell'Ambiente e della Tutela del Territorio e del Mare (2013)] (Table 4.2).

### *4.4.2 Methodology*

The social vulnerability was assessed by using the Social Vulnerability Index, developed in 2003 to underline the social vulnerability to environmental hazards amongst U.S. counties (Cutter et al., 2003). This index provides a social vulnerability map by synthesising socio-economic and demographic factors through principal component analysis (PCA) [see Dunteman (1989) for further details]. For assessing the SoVI (Figure 4.4), the variables have been collected and normalised according to a *z*-score normalisation (mean of zero and a standard deviation of one).

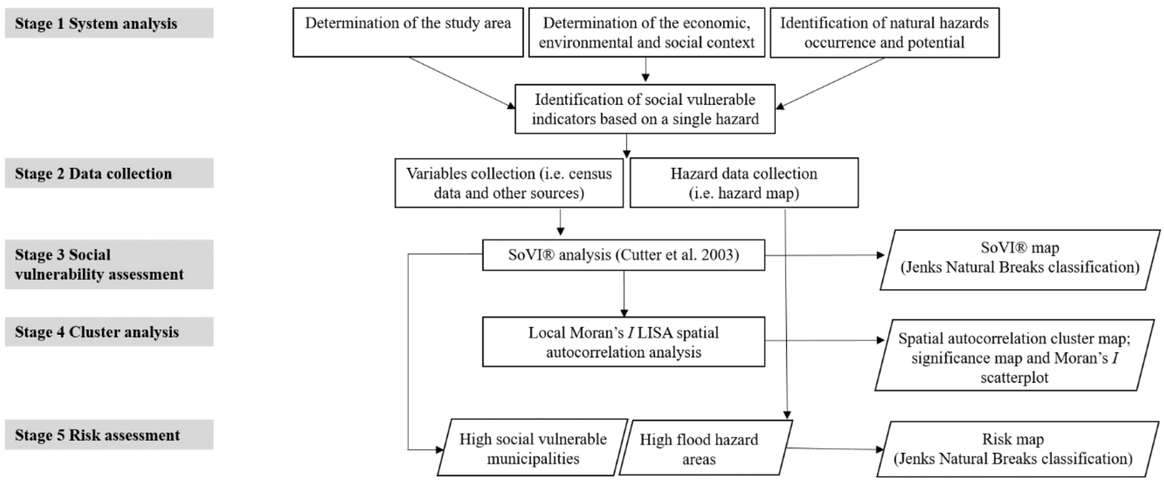


Figure 4.4 Visual representation of the methodology for the assessment of the Social Vulnerability Index, and the Flood Risk Assessment in the floodplain of Northern Italy. Squares represent processes, while outputs are bordered by rhombus.

To avoid interference between the variables, we performed a multicollinearity analysis. After recognising that no variables were predictors of one other, a PCA was conducted with varimax rotation and a Kaiser criterion for component selection (with eigenvalues greater than 1). The resulting Bartlett's sphericity test showed a highly significant value ($p<0.000$), demonstrating that the data were appropriate for further analysis. The selection of the components was determined by looking at the latent variables and at the resulting scree plot (Figure 4.5). The figure displays eigenvalues in descending order (*y*-axis) opposed to the number of the components (*x*-axis) to assess which components explain the most of the variability of the data. According to the SoVI approach, to understand the meaning of the generated components, variables are significant only if they present correlation value higher than 0.5 or lower than −0.5. According to Guillard-gonçalves et al. (2015), these variables are called "drivers of the component".

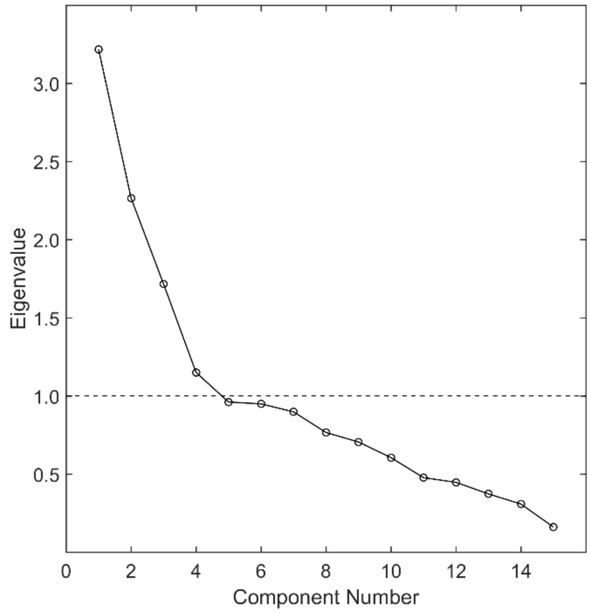


Figure 4.5 Scree plot of the principal component analysis showing the eigenvalues explained by the resulting components. The threshold line set at 1 shows the explanatory components extracted from the PCA.

Before summing the social vulnerability scores, the variables were aligned, implying that positive or negative directionalities were attributed matching the potential positive or negative contribution to the vulnerability. According to the procedure for weighing the factors, the literature encounters a crossroad with different approaches. Authors such as Cutter et al. (2003), Fekete (2009) and Chen et al. (2014) used equal weighting since they assumed that no factor is more important than another. A weighting method based on the contribution of the total variance explained has been undertaken by Schmidtlein et al. (2008) and Wood et al. (2010), for example. The Pareto rankings method orders the cases on multiple criteria but this approach is less common for social vulnerability analysis (e.g. Rygel and Yarnal 2006). Notably there is no appropriate methodology for the calculation of the index; therefore, it remains to the author discretion. Considering the original approach, the output of the PCA and the study area characteristics, we equally weighted the components. The mapped social vulnerability is then divided using Jenks Natural Breaks classes because this optimisation method seeks to reduce the variance within classes, maximising it between them (Jenks 1967). A three-level classification was chosen. First, because it can better detect the differences between the classes in a visual way (without using intermediate levels of medium-low and medium-high),

enhancing a quicker interpretation for non-expert users, and second, for consistency with the flood hazard classification, which is also based on three classes.
To identify the spatial aggregation of the social vulnerability, we performed a Local Spatial Autocorrelation with Moran's *I* with the GeoDa 1.8.14 software. This computes a measure of spatial association for each location, giving an indication of the extent of significant spatial clustering of similar values around that observation (Anselin 1995). A spatial weight file was created to analyse the neighbourhood structure of each location. For this purpose, we applied a rook contiguity method, which provides a more rigid contiguity definition (Anselin 1995) and it is the most used in spatial autocorrelation analysis (Fang et al. 2006; Corrado and Fingleton 2012; Frigerio and De Amicis 2016; Zhou et al. 2016). A map showing locations with significant Local Moran statistics, classified by types of spatial correlation, is defined as a LISA (Local Indicators of Spatial Autocorrelation) cluster map (Anselin 1995). Five scenarios emerge: significant ($p$-value<0.05) concentrations of (1) high values (high–high) or 'hot spots', (2) low values (low–low) or 'cold spots', spatial outliers (3) low–high, and (4) high–low and (5) locations of no significant spatial autocorrelation ($p$-value>0.05). The same setup is easily detected from a Moran's scatterplot that shows observed values ($x$ axis) against the averaged value of their neighbours ($y$ axis). A significant test was performed through the permutation test set to 999, under a random distribution with a significance level threshold of 0.05.

## 4.5 Results

### *4.5.1 The Social Vulnerability Index*

The Social Vulnerability Index has been computed according to 12 variables extrapolated from the PCA explained by four components with adjusted directionality (Table 4.3). Each factor contributed differently to the score of the index, according to the following formula: SoVI=factor 1 – factor 2 + factor 3 + factor 4. Three variables, corresponding to the percentage of low educated people (those with less than eight years of education and those illiterate) and age-dependent individuals, have not been extracted from the rotation matrix, as a result of their low correlation value (<0.5 or >-0.5). The SoVI scores ranged from -23.21 (lowest social vulnerability value) to 24.19 (highest social vulnerability value) with an average of 0.00 and a standard deviation of 3.55 (Figure 4.6). Note 22% of the total municipalities contribute to the high vulnerability of the study area, followed by 25% with a medium contribution, while the remaining 53% are considered as low contributors (Table 4.4). The Piemonte and the Lombardia regions are the highest contributors to the high vulnerability of the study area, with respectively around 62% and 18% of highly vulnerable municipalities over the highest. Following, in decreasing order, there are Veneto (7%), Emilia-Romagna (7%), Liguria (4%), and Friuli-Venezia Giulia (2%). These data do not reflect the variability within each region as expressed in Table 4.4.

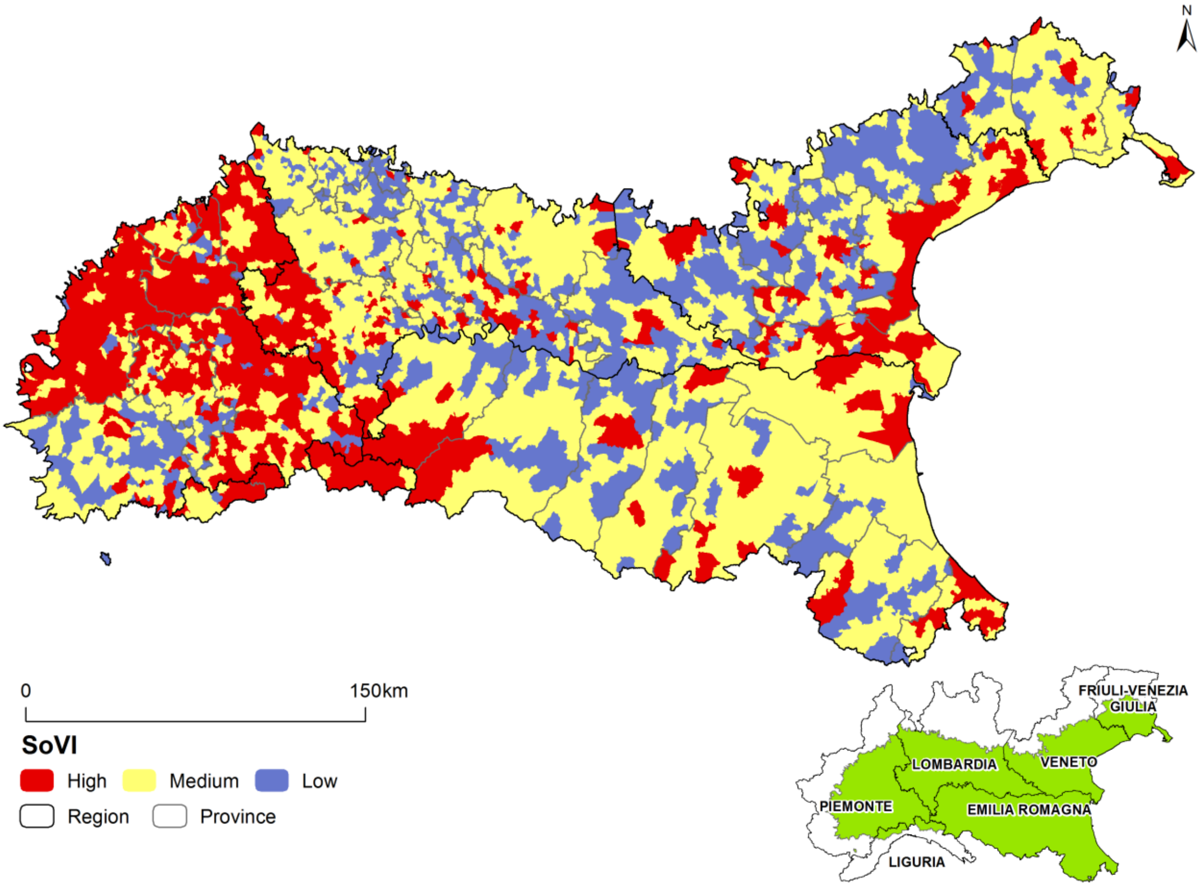


Figure 4.6 Spatial distribution of the Social Vulnerability Index among the municipalities of the Northern Italy floodplain classified into a three Jenks Natural Breaks classification. The right-down picture refers to the regional boundaries of the study area.

Table 4.3 SoVI classification (high, medium and low) within the study area and among the six regions expressed by the number of municipalities; percentages are shown in brackets.

| **SoVI** | **Floodplain Northern Italy** | **Emilia-Romagna** | **Friuli-Venezia Giulia** | **Liguria** | **Lombardia** | **Piemonte** | **Veneto** |
|---|---|---|---|---|---|---|---|
| High | 612 (22.1) | 44 (12.9) | 11 (7.7) | 26 (78.8) | 111 (10.7) | 379 (47.6) | 41 (9.6) |
| Medium | 704 (25.4) | 92 (204) | 47 (33.1) | 5 (15.2) | 281 (27.2) | 184 (23.1) | 95 (22.2) |
| Low | 1456 (52.5) | 204 (60.0) | 84 (59.2) | 2 (6.1) | 642 (62.1) | 233(29.3) | 291 (68.1) |
| Total | 2772 (100) | 340 (100) | 142 (100) | 33 (100) | 1034 (100) | 796 (100) | 427 (100) |

Overall, two regions (Veneto and Liguria) suffer from an underestimation of the SoVI computation that needs to be proper underlined. The Veneto region is ranked only at the third position of the most vulnerable locations. This is mainly due to the exclusion of the low educated people variable from the principal component analysis. This region, in fact, has higher mean values respect the average, considering the whole study area. Similarly, Liguria registers 78.8% of the high vulnerable scores among its area. In fact, it suffers from the exclusion of age-dependent variable. According to SISTAN et al. (2015), Liguria has the highest ageing index with 238 elderly people (aged 65 and over) per 100 young people (persons under 14). The birth rate began to decline in the nineteenth century (Castagnaro and Cagiano de Azevedo 2013); so in the early fifties, the average number of children per woman had fallen to 1.4, well below the national average level of 2.3. Concerning the spatial location of vulnerable areas (Figure 4.7), high-high (HH) municipalities (municipalities with high values of social vulnerability surrounded by similar features) represent the 15.7% of all municipalities (Figure 4.7, Tab. 4.4).

Table 4.4 LISA cluster categories for the SoVI expressed by the number of municipalities and the percentage in accordance. Moran's I spatial statistic is also shown.

| | **N. of municipalities** | **%** |
|---|---|---|
| Significant local spatial clusters and outliers | | |
| High-High | 435 | 15.7 |
| Low-Low | 319 | 11.5 |
| Low-High | 66 | 2.4 |
| High-Low | 58 | 2.1 |
| Not significant spatial clusters | 1894 | 68.3 |
| Total | 2772 | 100 |
| Moran's *I* value | 0.389457 | |

Significance threshold is set at $p$=0.05

The main HH clusters are concentrated in the western part of Po River basin, and in the east nearby its outlet. The Po River basin is characterised by very high indexes of population growth (one-third of the Italian population live in this area) (Mosello 2015) and human activity (Giuliano 1995; Marchina et al. 2015). Similarly, the economic growth, given by the development of the industrial, zootechnical and agricultural sectors, resulted in a gross domestic product of 40% the national income (Marchina et al. 2015). This anthropogenic footprint has dramatically modified the natural and the geological environment of the basin (Carminati and

Martinelli 2002) so that it has been estimated an unyielding increase of exceptional river discharge (Dankers and Feyen 2008).

Conversely, low-low clusters denoting a low social vulnerability (11.5% of all the municipalities), are spotted in all the considered regions, without any particular grouping. Spatial significance outliers of low-high and high-low areas are respectively represented by 66 and 58 municipalities (2.3% and 2.1%) as shown in Tab. 4.4 and Figure 4.7a.

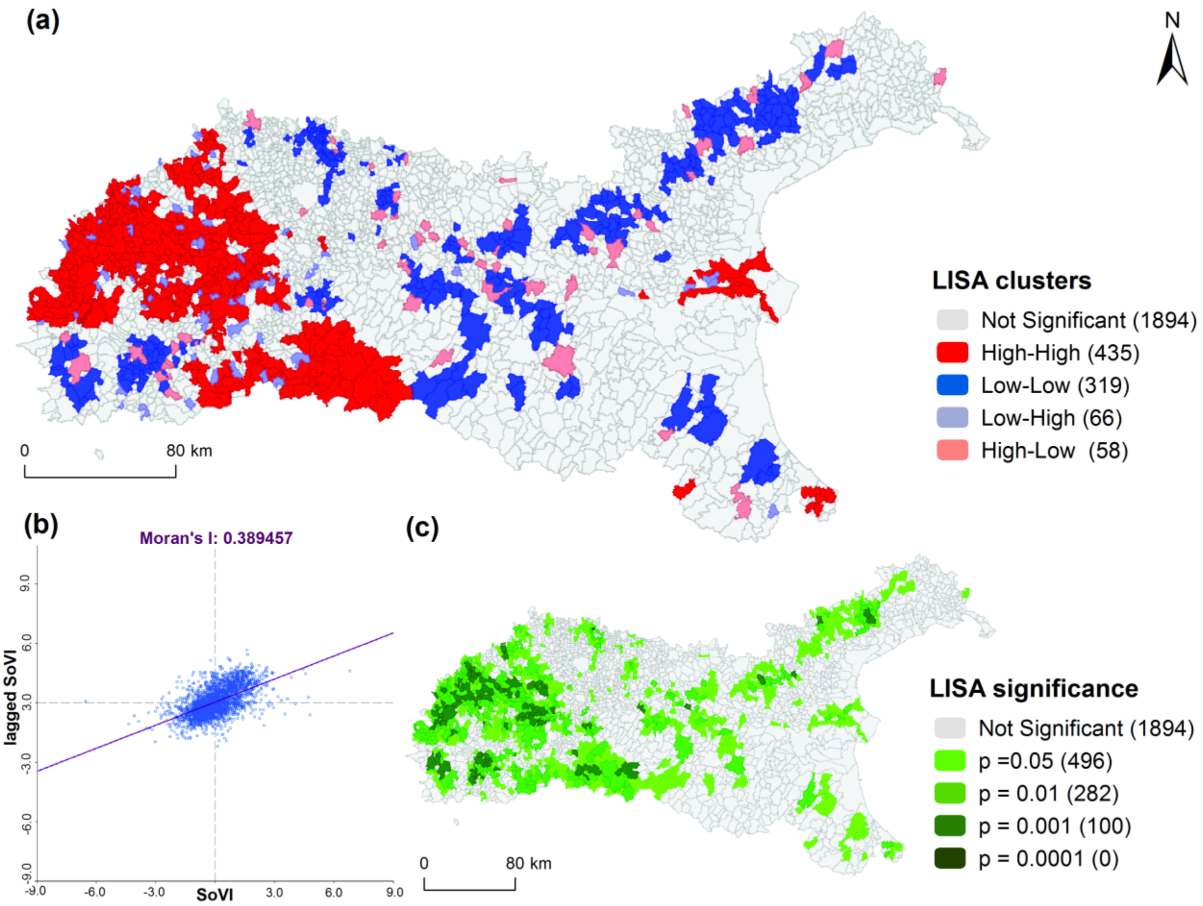


Figure 4.7 Local indicators of spatial autocorrelation cluster map (a) and significance map (c). The Moran's scatterplot (b) shows the standardise values of the variable on the x-axis whereas on vertical-axis shows the standardise spatially lagged variable. The plot is divided into four quadrants in accordance to the four scenarios emerged from the LISA clustering. The slope of the regression line is the Moran's I that identifies a positive spatial correlation.

A Moran scatterplot (Figure 4.7b) illustrates the value of the original variable (% of the index score in the tract) on the horizontal axis (standardise incidence) and the spatial standardise lag of the variable (average % of SoVI scores in the tract's neighbours) on the vertical axis. The graph is divided into four quadrants indicating positive and negative spatial autocorrelations, and the slope of the regression line is approximately 0.39 indicating that the spatial distribution has a positive correlation.

### *4.5.2 The SoVI components and their local geography*

The first component, 'Population consistency', explains three variables with a cumulative variance of 21.5%. A total of 140 municipalities present high social vulnerability, and they cover the 5% of the entire study area. The Piemonte region, with 109 municipalities, is the greater contributor to the high social susceptibility of this component, followed by Liguria region with 45% of its municipalities at risk (Figure 4.8).

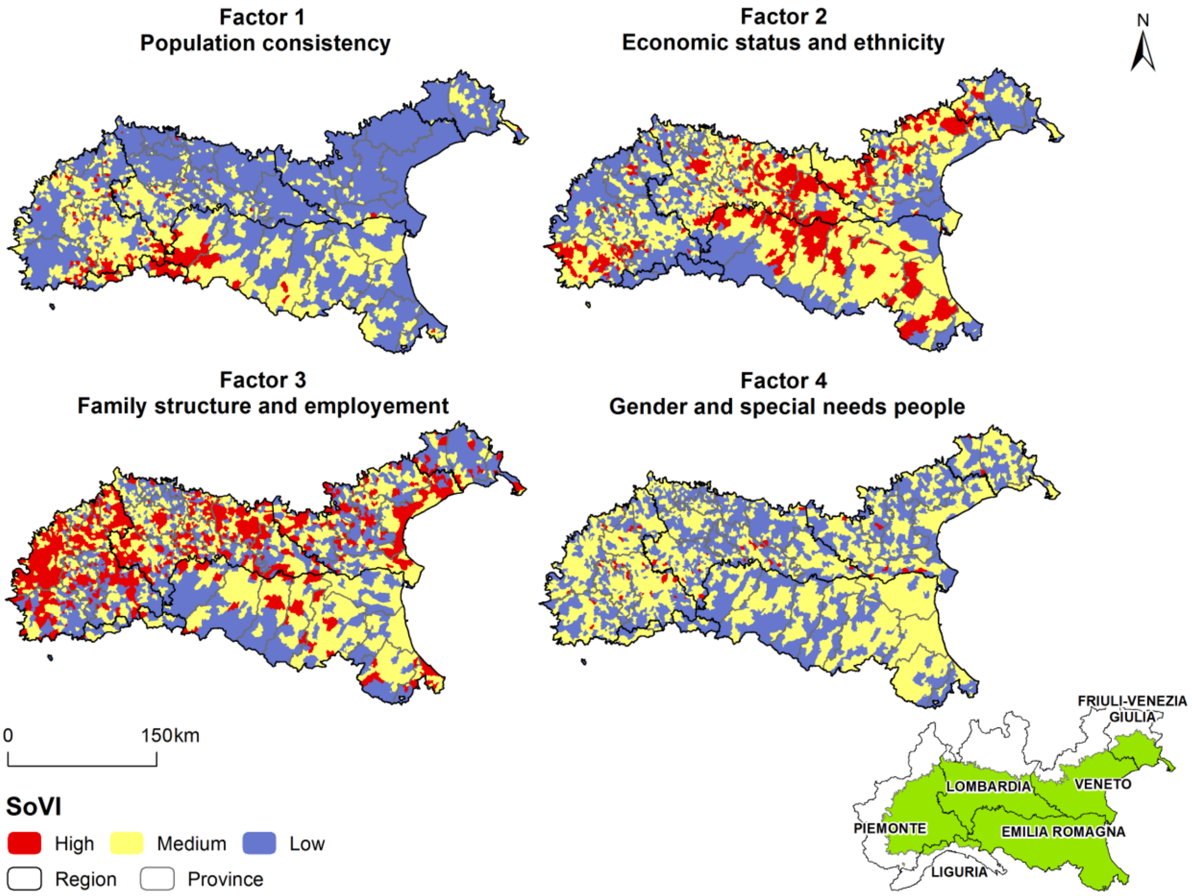


Figure 4.8 SoVI maps of the four factors derived from the PCA analysis across the of Northern Italy floodplain. The bottom right picture refers to the regional boundaries of the study area.

The main drivers considered are the percentage of retired people, households with no basic sanitation facilities and the population growth. In Italy, the progressive increase in the average lifespan implies a higher payment for retired people for a longer time, while contribution revenue has decreased due to the slowdown in the economic growth. Since retired people receive lower income, their financial security puts them at higher risks when facing a possible disaster situation (McKay et al. 1998). The ageing of the population, with the gradual retirement of people expected in the coming years, will result in both a reduction in the workforce and an increase of the labour inactivity. According to Eurostat in 2013, Italy ranked the first according to median age and number of elders (both >65 and >85 years old) within Europe (Morcaldo 2007). Generally speaking, the physiological status is a key factor in the ability of persons in responding to a disaster (IPCC 2012). Elders are likely to be disproportionately vulnerable to floods because they might have different physical and functional limitations, illnesses and imbalances in the sensorial sphere respect than younger people (Lowe et al. 2013). In addition, they might no longer have children at home, and they might be isolated from their relatives, thus seeing, as a consequence, a progressive decline in their networks. Liguria region has a high number of retired people (37.6%) compared to other regions and to the floodplain average (27.2%). A similar finding can be observed for the lack of basic sanitations (3.2% against the average area with 0.7%). Households living without toilet installations, or bath/shower facilities in Italy represent a very small proportion of families (Vitaletti 2010), but they may reflect a poor economic conditions (e.g. Guillard-gonçalves et al. 2015 in Portugal). The related poor sanitation conditions (including lack of safe water and toilet facilities) can increase the risks derived from floods (WHO and FAO 2005). The population growth variable reflects the increase in population from 2001 to 2011 (year of the latest census). It is agreed that population growth, composition and distribution are among the main factors of increasing risks from floods, since they translate into a demand for built-up areas (Marfai et al. 2015) with a massive pressure on sewer systems near rivers (Alfieri et al. 2016) and in urban centres (Walker et al. 2009). This rapid phenomenon in some parts of the world resulted in illegal and squatting constructions (Hung et al. 2007) contributing to present-day flood high occurrence (Sofia et al. 2014; Tarolli 2016; Tarolli and Sofia 2016; Sofia et al. 2017).

The second component, ‘Economic status and ethnicity’, is explained by four variables with a variance of 15.1% (cumulative variance 36.6%). The drivers of the component are income, families with more than six members, non-native people and people working in the agriculture sector. While the highest amount of economic damage is often observed for people owning high-value possessions, the major consequences of floods are generally carried by less wealthy individuals (Hajat et al. 2005; Henry et al. 2015). Zahran et al. (2008) found that income,

especially for unprivileged people, is a significant factor predicting higher physical injuries from flooding, and the psychological and emotional distress (Biswas et al. 2010). On the opposite, wealthier people are more disposed to invest for their protection and their economic stability can ensure proper recovery/reconstruction phases (Kousky 2011).
Veneto region stands out for having the lowest average annual income per inhabitant (with a mean value of 11909 euros, compared to an average value of 13054 euros for the whole floodplain). This trend could be ascribed to the presence of people who are not economically independent. Education is linked to the socio-economic status since a higher educational status often results in greater lifetime earnings and more highly skilled job (Braun and Aßheuer 2011). Ethnic minorities, most of the time, live in unfavourable living conditions with lower income (Fullin and Reyneri 2011), poorer education, and fewer employment opportunities (Fothergill 1999; Gencer 2013). Thus, it is reasonable that people living in their non-native place are prone to a higher danger. The lack of language proficiency, in some cases, poses people at some disadvantage when they looking for risk information (Morrow 1999), or early warning signals. The combination of these attributes may lead to difficulties even in the relief phase of the disaster when applying economic aid or insurance (Donner and Rodríguez 2008). The U.S. is the leading country in devoting importance in ethnic/race differences in the disaster context since its high presence. However, second, only to Spain, Italy is the European country that has seen the most considerable immigration fluxes in the past fifteen years (Fullin and Reyneri 2011) with a particular focus in the Northern Italy. According to the trends registered in the Italian peninsula by ISTAT census track, the share of foreign citizens on total residents has seen a continuous increase since the early '70s. From the XXI century the fluxes growth exponentially from 1.3 M in 2000 to 4.2 M in 2010 unevenly distributed within the country: the higher percentage lived in the North and Centre (9.9% north-west, 10.3% north-east and 9.6% centre), and just 3.1% in the South and 2.7% in the Islands. Among them, women may burden the largest effect of disasters. Those coming for family reunification might have intensified their vulnerability regarding economic dependency on the husband's income. In fact, it has been registered that they suffered from a high difficulty in finding a job, seeing them at higher unemployment rate respect the male counterparts (Reyneri 2007). Women moving for a job found more often positions as in-home nurse or elderlies' housekeepers. They, consequently, might face some obstacles in case of flood evacuation or management due to linguistic barriers. Similarly, families with a large number of members, might found the same impediments.

Despite a significant decrease in the number of big families in Italy, from 3.35% to 2.40% in 2011, a big family might reflect greater strains on the distribution of household resources for the ex-post flood event (De Silva and Jayathilaka 2014). Lombardia region stands out even for number of non-native people that according to the latest census are on the magnitude of 23.5% respecting the national level. According to (Blangiardo 2014), projection of foreign residents in Lombardia region might increase of 0.9% for 2020 and 3.3% in 2035.

The category of people that suffer the most after the consequence of flood events is that having a high dependency on the environment (Tiraboschi 2014b). Farmers are generally the poorest category (Saldaña-Zorrilla 2008) since any flood event might reduce the future farm productivity altering the chemical structure of the soil (Israel and Briones 2013). According to Coldiretti (2014), the agricultural production of many farmers in the Italian territory is estimated to be in the magnitude of 22 billion of euros in the last 20 years. Thus the potential damage caused by flood events is dramatic, especially for Piemonte region, that accounts the highest number of farms in Italy (ISTAT 2011). This could be the reason for the high vulnerability of this component in this area (36% of high vulnerable municipalities among the highest). Also, it is proper to add that in some recent alluvial events occurred in the Northern Italy the agricultural fields have been deliberated flooded to protect houses and buildings.

The third variable, ‘Family structure and unemployed’, reflects 11.4% of the variance with a cumulative variance of 48%. The drivers are single parent household, unemployed people and rent tenure of the house. Single-parent families might suffer a greater stressful pressure than two parents’ units in the wake of flood events (Flax et al. 2002). Probably, this could be ascribable to their economic and social responsibilities limited support (López Marrero 2008). According to Nyakundi et al. (2010), for the Nyando District of Southern Kenya, female-headed households generally perceived to be more vulnerable to floods as compared to households with both spouses. This could be explained by the fact that two individuals’ households are better placed both financially and psychologically, thus they might be able to respond to flood risks in a better mental and emotional state. In Italy, the structure of families has undergone several changes, by shifting the traditional big families into the so-called single individual units. From 1971 the number of these households passed from 12.9% to 31.2%, around 1/3 of the families at the national level (ISTAT 2011). This is the consequence of social and demographic dynamics occurred during the recent decades: the gradual increases of the ageing index, the increase in legal separation and divorces and the number of foreign citizens that at the very first periods live alone.

Unemployed people are vulnerable to floods because of inadequate financial resources to overcome the economic losses after a disaster (Jacinto et al. 2015). Unemployment could also be seen as a consequence of such events. A higher rate of unemployment in a society may translate in a significant ex-post economic aid from the Government that need to move vast quantities of resources to help the poorest. In 2011 in the North-East of Italy, the unemployment rate had been registered to be 37% respect the national level, seeing Friuli-Venezia Giulia be one of the regions recording the highest quotes (48%) followed by Veneto region (Porcellato 2011). These data justify the high vulnerability of these two regions expressed in figure 4.8. The unemployment could be the result of the severe labour market distress starting in 2009 (De Belvis et al. 2012) that showed a dramatic fall of Gross Domestic Product. The subjects that majorly have been hit are young people (especially females) and the low skilled ones (Fullin and Reyneri 2011).

People with a lower economic welfare are more likely to rent the house, thus increasing the threat from natural hazards (Fernandez et al. 2016). Fekete (2009) suggests that a lower income may translate in difficulty in accessing to financial aid in the recovery process. Tenants housing might face some impediments in taking direct actions to protect their property ascribed to the terms of their contracts (Tapsell et al. 2002). Friuli-Venezia Giulia, Lombardia and Piemonte regions (with 20% of the total municipalities) displayed higher values of tenant's household respect the study area average (Figure 4.8).

The last factor, 'Gender and special needs people', contributes 7.7% to the overall variance explained. The drivers included gender and special needs people. People living in assistance or care institutes encounter some impediments in the access and the use of those resources necessary in pre- and post-disaster stages (McGuire et al. 2007). People with physical or medical dependency might encounter higher injury and mortality (Smith and Notaro 2009; UNISDR 2014), difficulty in evacuating (Uscher-Pines et al. 2009), and difficulty in finding special equipped shelters in the provision of their needs (Risoe et al. 2013). Furthermore, failing to include in risk planning the needs of people with medical dependencies might increase their lack of preparedness putting them in higher jeopardy (Risoe et al. 2013). The gender contributor exerts a powerful influence within the disaster context, and an extensive literature is present in this respect [see Fothergill (1996) for further details]. Even though women are raising power in the community with larger independence and personal capacities (De Marchi and Scolobig 2012), they might face some impediments during and after emergency situations. In Italy, in the last forty years, the role of women in the employment sector has been dramatically changed. The country has been characterised by a large amount of women involved in house works from early 1964, with female housekeepers representing double the number respect to other type of workers (e.g. in the industry, agriculture and in the tertiary sectors) (Novelli 1996). Although housekeeping has gradually been abandoned, the actual situation demonstrates that women have the lowest workforce participation in the labour market compared to other developed countries (Bernardi 2004). One of the main reasons is the low coverage of protection for maternity leave, and the related consequences that this lack of social support can lead (Sargeant 2014). As estimated by (Enarson 2000) women are employed mostly in jobs belongings to the informal economy such as domestic, micro-enterprise, and other forms of precarious engagement, putting them at a higher risk of losing both the house and the economic activity at the same time. In addition, their low perceived preparedness respects their male counterparts, as underlined in several research papers in Northern Italy (De Marchi et al. 2007; Miceli et al. 2008; Scolobig et al. 2012), justified the presence of women as a variable contributing to the social vulnerability of the study area. This factor has 2% of high vulnerable municipalities, observing the region of Piemonte and Lombardia with respectively 33 and 22 high vulnerable municipalities (Figure 4.8).

### *4.5.3 A combination of social vulnerability and flood hazard*

One of the main outcomes deriving from social vulnerability maps might be the assessment of 'social' risk, as an interaction of the highest hazard scenario with the high vulnerability of the human environment. The combination of these types of visual assessment could be a further step to enable authorities to target risk reduction initiatives in a more focused way. For this reason, the highest social vulnerable areas (red municipalities of Figure 4.6) have been clipped with the high flood hazard layer (defined as H3 of Figure 4.3) showing the flood risk resulting (yellow areas of Figure 4.9a). Clearly, the flood hazard area is not in perfect overlap with the area of the municipality, thus the risk resulting might not affect the entire municipality, but only a variable amount. For this reason, the flood risk area was evaluated as the percentage of the municipality overlapped by flood hazard surface (Figure 4.9b). Within the floodplain, there are only 22 municipalities in a high-risk area (ranging from 39.5% to 89.7%) (Table 4.5).

Table 4.5 Jenks Natural Breaks classification of risk for each region and the total study area. The numbers correspond to the absolute number of municipalities included in each class (where 1 correspond to the lower percentage of risk and 5 the highest); the percentage values are shown within brackets. Total values displayed in the last column consider each single region, whereas the total displayed in the row considers the contribution of each class to the floodplain.

| | **Jenks Natural Breaks classification of risk** | | | | | |
|---|---|---|---|---|---|---|
| | **Class 1 (0.0-4.3)** | **Class 2 (4.4 - 11.7)** | **Class 3 (11.8-22.8)** | **Class 4 (22.9 - 39.4)** | **Class 5 (39.5 - 89.7)** | **Total** |
| Emilia-Romagna | 30 (73.2) | 9 (22.0) | 2 (4.9) | 0 (0.0) | 0 (0.0) | 41 (100) |
| Friuli-Venezia Giulia | 4 (44.4) | 4 (44.4) | 0 (0.0) | 1 (11.1) | 0 (0.0) | 9 (100) |
| Liguria | 23 (88.5) | 1 (3.8) | 0 (0.0) | 2 (7.7) | 0 (0.0) | 26 (100) |
| Lombardia | 35 (43.8) | 12 (15.0) | 14 (17.5) | 9 (11.3) | 10 (12.5) | 80 (100) |
| Piemonte | 133 (40.5) | 95 (29.0) | 67 (20.4) | 24 (7.3) | 9 (2.7) | 328 (100) |
| Veneto | 7 (25.0) | 4 (14.3) | 9 (32.1) | 5 (17.9) | 3 (10.7) | 28 (100) |
| Total | 232 (45.3) | 125 (24.4) | 92 (18.0) | 41 (8.0) | 22 (4.3) | 512 (100) |

These municipalities are located in three main regions: Lombardia (10; 12.5%), Piemonte (9; 2.7%) and Veneto (3; 10.7%).

These regions are the most economically competitive regions within the North of Italy, where the elevated levels of human-landscape interactions have affected the equilibrium of its drainage network. The province of Alessandria, Venice and Padova (respectively AL, VE and PD of Figure 4. 2) emerge to be the riskiest provinces.

The lowest part of the Po River basin, corresponding to the Polesine region, presented very low scoring of flood risk attributed to low scores of the index. However, this area is well known for being a lowland constant prone to land modifications and submergence caused by rivers flooding (Amadio et al. 2013). For this reason, a deeper social vulnerability analysis would be suitable at smaller scale (for example in high flood exposed areas) since the Social Vulnerability Index changes according to the scale extension. In accordance, specific areas, provinces or basins can be used as macro-scale analysis with a municipality-scale subdivision to see in details the societal characteristics of the community and their locations. This would benefit practitioners and managers to produce rapid flood emergency evaluations and focused land plans. To this point, one must note that in Italy, the responsibility for flood control is quite complicated, and the decentralisation of the authorities in charge may find some obstacles in achieving effective flood management.

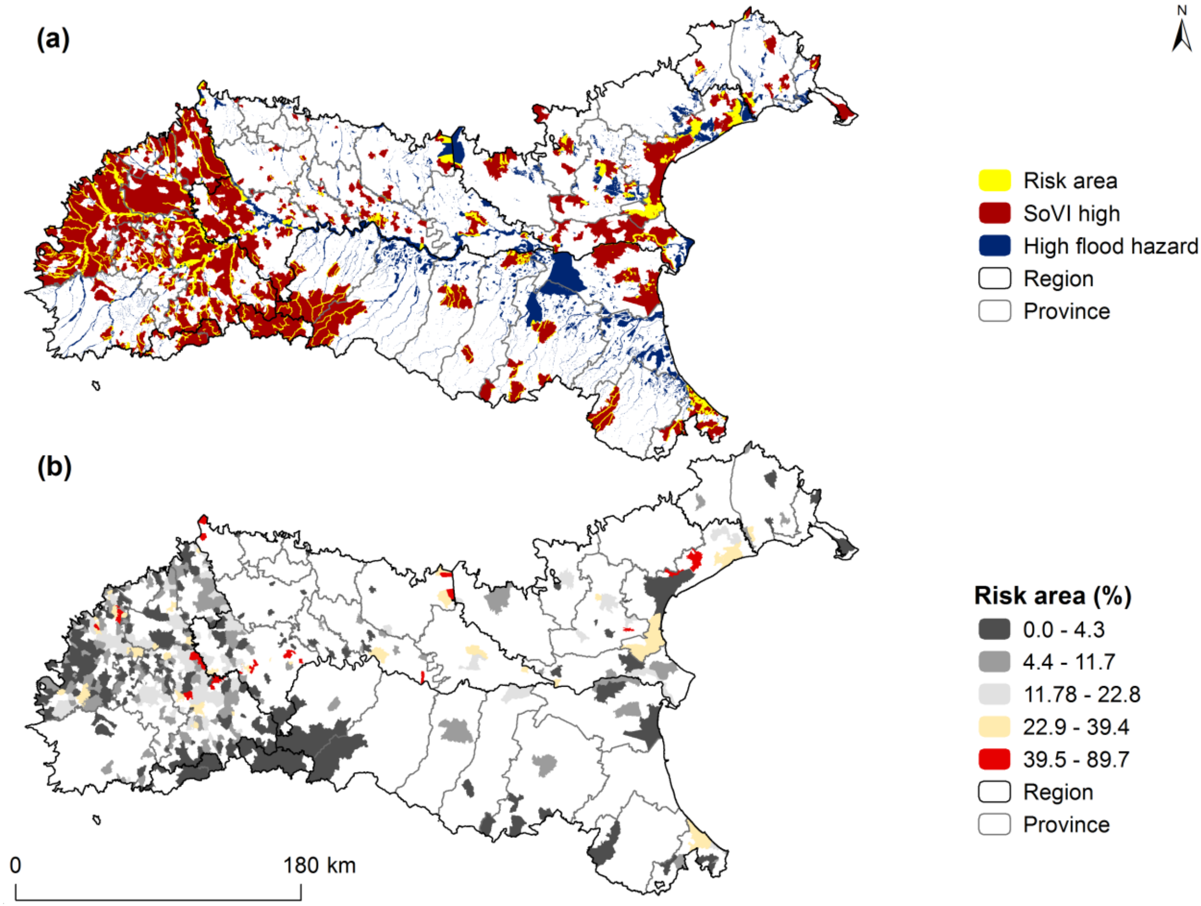


Figure 4.9 (a) Risk map (yellow area) derived by clipping the high socially vulnerable municipalities and the high hazard (H3) flood layer. (b) Risk map expressing the percentage of risk for each municipality represented using a five Jenks Natural Breaks classification. The bottom right picture refers to the regional boundaries of the study area.

Disaster risk governance consists on an inter-correlation of "[…] norms, organisational and institutional actors, and practices that are designed to reduce the impacts and losses associated with disasters" (Tierney 2012). In other words, it includes all the actors (civil society, public and private sector) and the actions that influence the risk management (Holley et al. 2012). In Italy, there are several actors involved in the flood risk management (Cirillo and Albrecht 2015), such as:

1. the Regional Authority, in charge of drafting flood management plans in coordination with other regional authorities and the National Department of Civil Protection (DCP);

2. the DCP that coordinates the functional multi-hazard centres and promotes risk culture, prevention and preparedness and coordinates and assists relief actions in case of disaster events;
3. the Reclamation Consortia management bodies (sub-regional level), that have the role of implementing structural works, urgent measures and controlling and repairing pre-existing hydraulic structures for flood prevention;
4. the Civil Engineering Department (province level) that works for the maintenance of flood safety of the main hydrographic network through surveillance, monitoring and maintenance activities. Also, it verifies the hydraulic compatibility on new urban constructions or changed land use;
5. Provinces and Municipalities are responsible for the building and the maintenance of water installations adopting all safeguarding measures listed in the flood plans;
6. The River Basin District Authority (river basin level) in charge of developing flood risk management plans.

This multi-actor setting of flood risk management is rather complex when responsibilities and duties overlap, reflecting a difficult engagement of the community in the decision-making process. Public participation is an essential way to achieve a successful emergency response. According to Hanfling et al. (2012), a bottom-up approach to the disaster management can be obtained by a two-way communication: "informing community members of sensitive policy decisions and receiving community input on difficult matters".

## 4.6 Discussion

The indicators of socially vulnerable groups are based on the most common individuals' characteristics and can be easily monitored through time since being based on census data (King and MacGregor 2000). However, it is plausible that there could be room for subjectivity when choosing the variables and weighing them when scoring the index. For this reason, it is important to have a broad understanding of the societal construction of the area under study, and of its cultural, economic and political dynamics. From an ethical perspective, it is not in doubt that the people or groups targeted as vulnerable are all vulnerable. For example, in some countries of the world, women, children, seniors and farmers have developed unique skills to overcome the impacts of natural disasters. According to the guide for relief agencies during emergencies published by UNICEF (2007) during the 2004 Indian tsunami, children saved their peers whose have been divided from their parents. On the other side, a report recently published by the World Bank group (Kiyota et al. 2015) underlined how recognising the social capacities of elders has led to the whole community's ability to overcome the shocks caused by natural hazards by creating flexible support mechanisms. Similarly, in some parts of the world, women have developed unique skills to cope with natural hazards. They demonstrated to be very knowledgeable of the territory where they live, being stronger than their male counterparts, increasing rational decision-making when situations call for participation (Morrow Hearn and Enarson 1996; Anderson 2002). Midwives and women's health care providers have a long history of assessing and addressing public health issues, thus they can be a crucial resource in providing expertise relevant to in disaster planning and response (Keeney 2004). Farmers, developed means to manage the lands and overcome the hydraulic pressures in their areas (Pivot and Martin 2002). All these groups have demonstrated to have the skills to overcome the negative consequences of disasters. In fact, there is urgent need to include focused management actions from the main institutional bodies by going beyond gender, age, income, profession stereotypes by creating openings for personal and institutional renovation.

In addition, with institutional and financial supports (public or private), it seems easier to encourage people to take an active role in flood risk management. The general household economic instability, underlined by numerous attributes in this research, support the need for a stronger market for flood insurance schemes. At the present time, the Italian insurance market is poor of products (Gizzi et al. 2016) resulting in low penetration rates. In 2001, only the 0.4% of all Italians subscribed an extension for household flood protection (Ania et al. 2011) Insurances are instruments that can reduce anxiety and stress and simultaneously provide consolation in the case of loss (Michel-Kerjan and Kunreuther 2011). Thus, flood insurance schemes can be negative contributors in the assessment of vulnerability meaning that they can reduce the burdens of individual's fragility. In accordance, the increased role given to risk financing measures in recent years modifies the standard 'vulnerability' factor for the risk appraisal into 'vulnerability-coping capacity' (Wamsler and Lawson 2011). The need for a national regulation for flood compensation is much more relevant in those countries where the population and the related properties are foreseen to increase. In line, recent projections show that the Italian peninsula will register a growth of 2.16% in 2020 62.5 M people (OECD 2016).

The United Nations (2007) explicated that Italy's population in 2050 would be made up of post-1995 immigrants or their descendants (29% and 39% respectively), being more than ten times the proportion of the foreign-born population in 1995. Members of socially dominant groups see threats (to self and the community) as less risky and more manageable than do members of non-dominant groups (Solberg et al. 2010). Thus, it is important to raise natural hazards awareness and preparedness to the new members of the community [for ex. specific multi-language activities (Frigerio and De Amicis 2016)] because people judge, react and recover differently according to their cultural norms, religion and beliefs (Croson and Gneezy 2009). It means that racial/ethnic diversity should be considered when studying population vulnerabilities and perceptions, to address policy makers on sensitive risk management towards minorities groups.

Educational and institutional support systems aimed at identifying and fostering local capacities of less powerful people are the key to an efficient disaster management planning (Agrawal 2011). In this context, an increase communication between all the stakeholders acting in a possible environmental hazard situation can lighten the fragility of exposed individuals (Lazrus et al. 2012; Roder et al. 2016). These actions are possible and could be effective if there is grounded mutual trust among interested parties. As found in a study conducted in Sri Lanka and the USA, the mistrust of people in the government's management capacities and caring attitudes appears to had an influence on their willingness to take action in front of a disaster (Duggan et al. 2010). However, when trust in public authorities is consolidated, people are more disposed to adopt protection measures (Motoyoshi 2006).

## 4.7 Conclusions and step forward

This article provides a social vulnerability assessment to floods in the floodplain of northern Italy using the SoVI approach adapted to the societal and historical construction of the area, according to the real vulnerability that individuals might face in the actual century and the structural conformation of the Italian society and the economic and the political background. The major dimensions of the social vulnerability of the study area are clustered into specific locations, emerging in the Piemonte, Lombardia, and Veneto regions within the floodplain. At a general consideration, economic welfare and the population growth, age, and ethnicity are the major social attributes affecting the residents in the northern Italy floodplain. These characteristics coupled with the potential flood hazard can magnify the adversity of such events. Risk maps derived from the combination of the high social vulnerable municipalities and the high flood hazard zones emphasize the hotspots within this anthropogenic landscape. These data mark the importance of having visual and intuitive maps that could orient decision makers on where risk reduction practices are needed the most.

The adverse consequences of floods on risk-prone communities may be exacerbated in the future, and the costs to those vulnerable people might increase dis- proportionally. Undeniably, social vulnerability and risk maps are only a part of the efforts needed to reduce the risk posed by environmental hazards. In fact, there is a need for multi-stakeholder participation at all levels, from managers to politicians, to plan, finance, and finalize those actions aiming at reducing the vulnerability of people living in natural hazard-prone regions. To achieve this, there is the need first to explore public concerns to be able to address specific management measures in front of vulnerable groups. Risk perception appraisals could be a catalyst for the success of community-based management actions for mitigating the effects of flood events in the region. Qualitative research on peoples' perceptions and beliefs in high- risk areas is a necessary contribution to a quantitative work, and this is the primary focus documented by the Flood Directive 2007/60/EC. This directive of the European Parliament and the Council of European Union established a framework for ‘‘community action in the field of water policy'' that requires river basin management plans for the mitigation of floods adverse effects and the ecological restoration of the rivers (see https://www.eea.europa.eu/policy-documents/directive-2007-60-ec-of).

*Author contributions*: G.R. designed and directed the project, collected the data and in consultation with G.S. performed the statistical analyses and the mapping techniques. G.R. and G.S. contributed to interpret the results and drafted the manuscript in consultation with Z.W. and P.T. P.T is the PI of the project.

CHAPTER 5

# NATURAL HAZARDS KNOWLEDGE AND RISK PERCEPTION OF WUJIE INDIGENOUS COMMUNITY IN TAIWAN[4]

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## 5.1 Abstract

The purpose of this work was to investigate the natural hazards knowledge and risk perception of Wujie indigenous community, located in Fazhi village in the Central Mountain Range of Taiwan. Natural hazards (e.g. floods, landslides and debris flows) are one of the most critical issues for the Taiwanese government and for the people living in mountainous areas. During the last centuries, the native people experienced economic competition and military conflicts with a series of colonial periods that have led to a progressive loss of their original cultural identity. The motivation of selecting the case study of Wujie community is because (1) it has experienced, more than others, generations of devastating colonial oppression by foreign governments; (2) several landslides and debris flows occurred during the last decades; and (3) the area was subject of land exploitation and several hydroelectric projects. Two questions appear spontaneously: How are those indigenous people nowadays living with natural hazards? Have land use change and the anthropic pressure affected their knowledge and perception of natural hazards and related risk? This research, one of the first carried out in Taiwan involving an indigenous community, can offer a unique opportunity to answer these questions. The investigation utilized a variety of participatory methods by the use of face-to-face interviews. Results revealed that residents felt a high worry about landslide and flood risks. However, they felt a slight preparedness to face them. The most considerable differences were found between the personal evaluations respect to the overall community. The discrepancy in the attitude–behavioural link may derive from an unsatisfactory level of communication and information probably ground in the absence of community participation in the decision-making process. Results revealed also the complexity of residents' perspectives about the causes of the increase of natural hazards occurrence. To this point, the community has ascribed this phenomenon to several uncontrolled human actions during colonial period that have affected the environment and their living. In addition, gender, age education and experience of natural hazards were found to be significant predictors in this study. Paying attention to the indigenous perception of a hazard and risk can increase the effectiveness of projects implemented by practitioners who might need to communicate risks in the future. It also helps governments in their possible need to order evacuations, and future researchers to conduct similar projects.

## 5.2 Introduction

Despite technological and scientific advance, we have seen a serious increase in both mortality and economic losses from disasters since the twentieth century, particularly in the developing world (Oliver-Smith 2006). A greater number of people are more vulnerable to natural and other hazards than ever, arising from the increase in population that live in high-risk locations (Huppert and Sparks 2006). Human activities are also a critical issue in exacerbating vulnerability to natural hazards, ranging from anthropogenic climate change at one extreme (Mitchell et al. 2006) to local deforestation and changes in land use at the other (Wheater 2006). Beside the financial resources aimed at minimizing the negative impacts of natural hazards, there has been an increasing recognition of the value of risk perception studies. Such studies attempt to comprehend the choices made by an individual, or a group of individuals, to judge, evaluate, tolerate and react to risk (Fromm 2005) in order to help local authorities in the development of community-based hazard management strategies. The criteria adopted by individuals to evaluate different risks, and to decide to accept (or not to accept) them, vary depending on multiple, general and local conditions and situations (Salvati et al. 2014). Socio-economic and demographic characteristics (age, gender, education level and income) of those at risk are significant predictors of these issues (Lai and Tao 2003; Barberi et al. 2008; Lindell and Hwang 2008; Paton et al. 2008; Kellens et al. 2013; Ainuddin et al. 2014). Similarly, personal experience can be very important in perception of the level of risk, and reminders of particular risks in the media can also have an effect (Kitzinger 1999; Eiser et al. 2012). Simultaneously, trust plays a crucial role in the perception of natural risks, and chiefly when the knowledge or understanding of an individual of a specific risk is (Wachinger and Renn 2011). Building public trust can help people to tolerate uncertainties derived by disaster events reducing the complexity of such situations (Siegrist and Cvetkovich 2000).

Exploring individual knowledge about natural hazards may provide important information about people’s willingness to take precautionary measures (Botzen et al. 2009a) and can therefore identify the major reasons behind the unsatisfactory performance levels of current disaster management practices (Pathirage et al. 2012). To better understand and address hazard risks in its entirety, it is necessary to explore the reasons behind such events looking at the vulnerability of the built environment (Burton 2015) and how such causes are perceived indeed. Knowledge and experience seem to work in parallel, both driven by the emotional reaction that people face in front of disasters. To this point, Slovic and colleagues proposed the affect heuristic theory (Slovic et al. 2002; Slovic et al. 2004a), suggesting that strong emotional experiences with hazards may be important for perceived risks and for motivating preventive behaviours. Moreover, individuals are more likely to perceive an event as more probable if they are able to imagine or recall such events easily (Eiser et al. 2012). Perception and knowledge of risk are one of the fundamental elements that condition the behaviour of local residents (Tulloch and Lupton 2003). Investigating the decisions that people take before, during and after emergency situations is important for the minimization of the social costs of disasters. Thus, it is relevant to explore the personal, social and cultural influences on how people be prepared under the conditions of uncertainty that surround infrequent natural hazards (Eiser et al. 2015). However, several studies have consistently found that providing people information on hazards and how they can manage their consequences appears do not positively influence personal preparedness (Dow and Cutter 2000; Lindell and Whitney 2000; Paton et al. 2008; Lindell et al. 2009). Effective communication, or the absence of it, may have a major bearing on how well people are prepared for a disaster (Basic 2009). For this reason, risk communication should aim for a bidirectional exchange of information (Kellens et al. 2013); in this way, people are facilitated to judge their own risk situation and to make informed decisions according to preparedness and personal safety measures (Hagemeier-Klose and Wagner 2009). Nowadays, more attention has been devoted to understand the efficiency of risk information and how communication is perceived during hazard situations, in order to highlight both strengths and weaknesses of the existing emergency management situations.

While risk perception studies have largely focused on citizens, less attention has been given to indigenous' perception of the risk posed by disasters. In a world facing increased uncertainty and risk from hazards, indigenous peoples are among the most vulnerable groups (FAO 2007; Watson 2010). They are vital and active part of the ecosystems, and any complex challenge is threatening the environment on which their livelihood and culture depend. Indigenous knowledge constitutes a precious national resource in dealing with disasters as a blend of scientific and traditional approaches and methods that open avenues towards better disaster prevention, preparedness, response and mitigation (Kamara 2008). Thus, it is important to learn how they view and interact with the environment and whether or not they have knowledge that helps, monitor, interpret and respond to dynamic changes in the ecosystem, resources and services (World Bank 1998). Many indigenous communities understand their local environment and care for it, maintain lessons from past disasters and invest in the place where they live

(Baumwoll 2008). Failure to recognize the signals and the cause of ecosystem changes will critically impede a community's capacity to adapt and can lead to social and economic collapse (Bronen 2010). It is intuitive to achieve that natural disasters lead to more migration since households want to stay away from the source of risk or they should make a living elsewhere if their livelihoods are wiped out (Tse 2012). Focusing the attention on new generations can help governments in organizing strategic policies in regard to natural disasters, increasing people consciousness and avoiding massive migrations.

The purpose of this paper is to investigate the natural hazards knowledge and risk perception of Wujie indigenous community, which belongs to one of the largest groups in Taiwan. Taiwan has encountered many different types of natural hazards that have increased, especially after Chi-Chi earthquake (Moh and Yao 2005). In the period ranging from 1900 to 2013, there have been recorded more than 90 disastrous events that have affected 3,945,022 people with a total damage of 21,303,712 (91000) US$ (CRED EM-DAT 2015). Because of that, natural hazards (e.g. floods, landslides and debris flows) are one of the most critical issues for the government and for the people living in mountainous areas. These areas are mainly populated by indigenous people (2% of the whole Taiwan's population) that are concentrated in villages, in some cases along alluvial plains. During last centuries, these native people experienced resources exploitation and military conflicts as a consequence of several colonial periods that have caused a progressive loss of their environment and original cultural identity. Wujie community has experienced, more than others, generations of devastating colonial oppression by foreign governments and landscape changes with the development of some hydroelectric projects. Moreover, several documented landslides and debris flows have occurred in the same region during the last decades. The questions are: How are these people nowadays living with natural hazards? Did land use change and the anthropic colonial pressure affect their knowledge on natural hazards and their perception of risk?

This project, one of the first conducted in Taiwan involving an indigenous community, can offer a unique opportunity to answer these questions through the help of a series of onsite interviews followed by a statistical analysis. Attention to this issue can help government in its management policies in those mountain regions, and future researcher planning aimed to increase people's resilience.

## 5.3 Study area

This research was conducted in Fazhi village, located in a floodplain in the centre of Nantou County (Taiwan) (Figure 5.1).

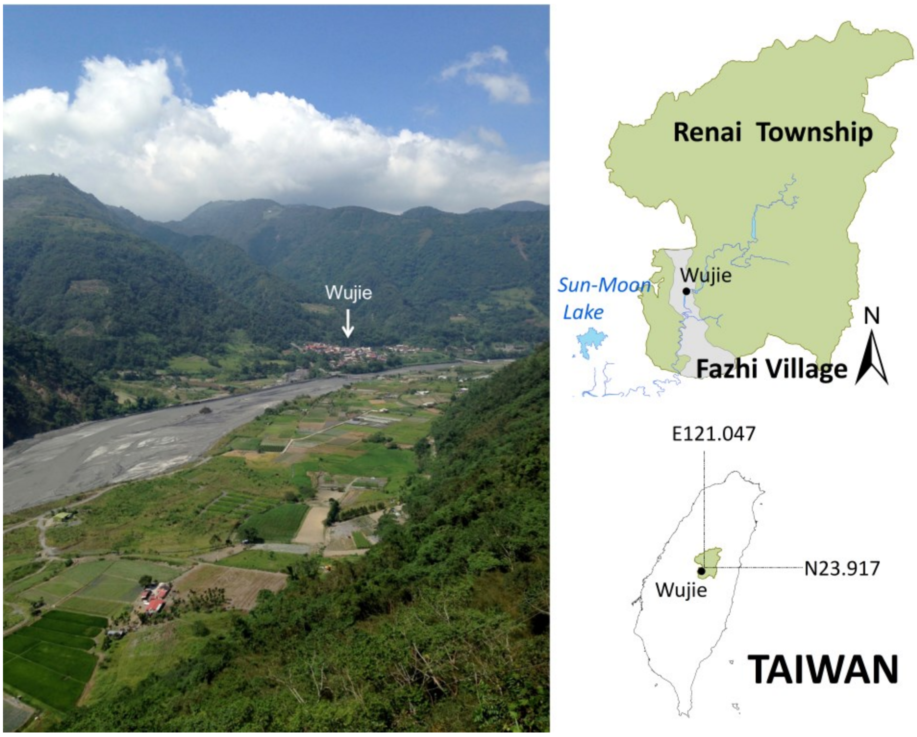


Figure 5.1 Location of Wujie community in Fazhi village, Nantou County, Taiwan

The region is populated by the Bunun tribe, the fourth largest group among Taiwan indigenous. The size of their living area is second only to that of the Atayal, which similarly shows a great ability of expansion (Digital Museum of Taiwan Indigenous People 2008). The Bunun population is distributed in the south of the Central Mountain Range, from the upper stream of the Jhuoshuei River in the north to the upper and middle parts of the Gaoping and Bainan rivers in the south. Wujie community covers an area of 17.172 km$^2$, with an elevation that varies from 720 to 740 meters above sea level at 23.917 of latitude and 121.047 of longitude. Human settlements (2.3%) and agricultural lands (13.9%) can be found around the village (Figure 5.2). Subtropical evergreen forests (62.9%) are characterized by broadleaved species: subtropical and temperate hardwoods grow at lower levels, and conifers at higher elevations. The low elevation plains areas support monsoon evergreen broadleaved forests (Carpenter 2014). The presence of planted forests (9.9%) is related to the end of Kuomintang (KMT) Government

(1996), who started to pay more attention to the increasing number of landslide and debris flow events in the area. The real first steps in this direction have been undertaken after the devastating typhoon Herb with a National Reforestation Campaign, lasted until 2004 (Xin 2015).

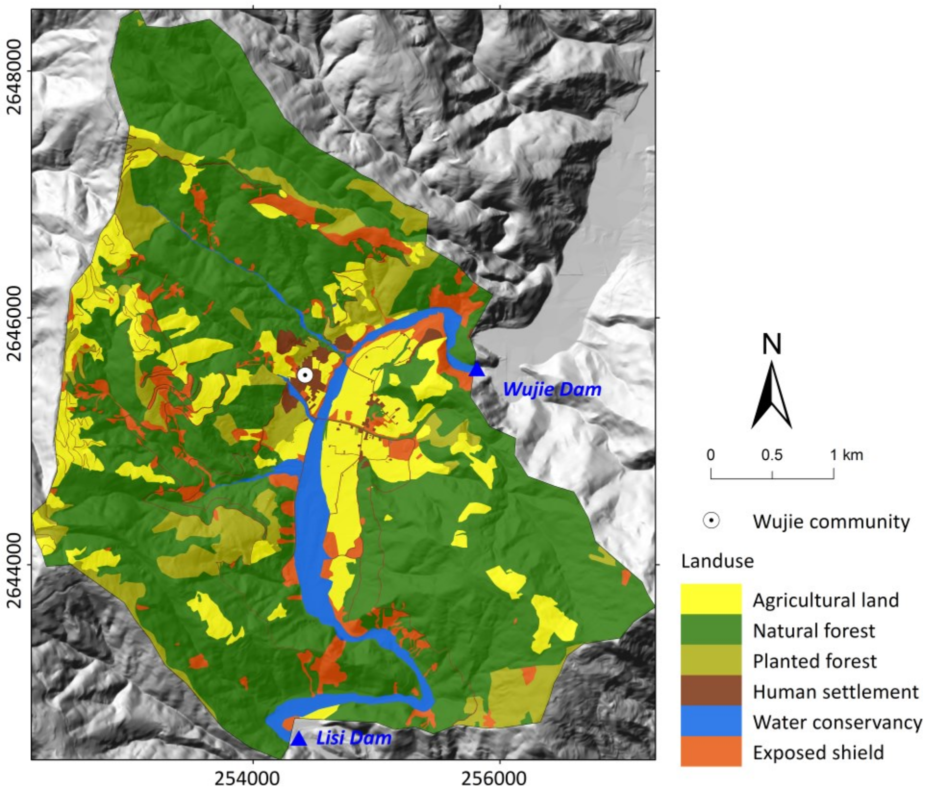


Figure 5.2 Land use cover map of Wujie community (NLSC 2004)

### *5.3.1 Wujie community history*

Similar to many indigenous communities in Taiwan, Bunun people have experienced generation of devastating colonial oppression by foreign governments, with a strong impact in the mountain areas they used to live in. The interest in the natural resources started from the Dutch period, especially for camphor and timber materials, and continued during the Qing Dynasty (Blundell 2000). Afterwards, the colonial rule of Japan exploited all possible resources from the mountains for the war effort, humans as well as materials (Chiang 1997) and constructed several additional trails to facilitate its control on the indigenous tribes. Between 1922 and 1925, it organized a massive relocation of indigenous people from the highest mountain to the floodplains (IWRI 2014). This policy shifted their lifestyle from traditional hunting and gathering to agriculture production, destructing the traditional and tribal cohesion (Chung 2002). In that years, the rising need of electricity justified the government's decision to construct a concrete gravity dam in 1932 on Jhuoshuei River in the nearness of Wujie floodplain (Wulang 2014, personal communication). It has been realized in two stages for divert water from the river to a storage reservoir at Sun Moon Lake and secondly to associate it with the hydroelectric projects of Mingtan Pumped Storage Hydro Power Plant and Minhu Pumped Storage Hydro Power Station (Taiwan Water Resources Agency 2013) that moved a lot of water and sediments to the valley modifying the path of the river. In 1945, KMT Government replaced the Japanese period and after 19 years undertook a deforestation plan, starting to exploit consistently the natural resources (Blundell 2000). After that, it enacted the Hunting Ban in 1948 (which was later repealed and replaced by the Wildlife Protection Law only in 1989) and the National Park Law in 1972 to restrict indigenous peoples from using natural resources (Blundell 2000). Hunting was not just a way for them to access material resources from the mountains, but they had tradition of hunting ceremonies, which were a means of communicating with the spirits of ancestors (IWRI 2014). Consequently, these bans and laws prohibited indigenous peoples to connect with their spiritual world.

### *5.3.2 Documented natural hazards occurred in the last decades*

From 1958 to 1982, during deforestation programme, a series of intense precipitation during typhoon events have triggered floods, landslides and debris flows, as given in Table 5.1. In 1969, a heavy rainstorm caused severe damages to the village with an impacting debris flow devastating all the croplands (Wulang 2014, personal communication). After 1983, KMT government took action in front of these events by allowing deforestation only for land use change towards new farmlands. Despite this, five typhoons events triggered multiple landslides and debris flows in Fazhi village (Table 5.2). During 1999, Chi–Chi earthquake caused deposited landslide masses of critically stable conditions that became the source materials for debris flows during and after intensive precipitation (Moh and Yao 2005).

Table 5.1 List of natural disasters occurred from 1958 to 1983 that have caused damages in the village (Shen 2008). * Total precipitation recorded at Sun Moon Lake Weather Station (Central Weather Bureau of Taiwan 2014)

| **Year** | **Event*** |
|---|---|
| 1959 | 87 Flood (523 mm) |
| 1960 | Typhoon Shirley (721.7 mm) |
| 1963 | Typhoon Gloria (568 mm) |
| 1969 | Heavy rainstorm (n.a.) |

Table 5.2 List of natural disasters occurred from 1983 to 2009 that have caused damages in the village (MOEA 2008). * Total precipitation recorded at Sun Moon Lake Weather Station (Central Weather Bureau of Taiwan 2014)

| Year | Event* |
|---|---|
| 1986 | Typhoon Wayne (270.2 mm) |
| 1994 | Typhoon Doug (551.9 mm) |
| 1996 | Typhoon Herb (652.9) |
| 1999 | Chi-Chi earthquake |
| 2001 | Typhoon Toraji (338.9 mm) |
| 2004 | Typhoon Mindulle (447.8 mm) |

## 5.4 Methodology

A series of face-to-face interviews has been conducted in Wujie community during summer 2014 using different types of questions: qualitative (open, multiple-choice, closed- ended questions) and quantitative (five-point Likert scale, where 1 represented the mini- mum value and 5 the maximum one). The questionnaire was composed by a first part related to a general socio-demographic description of the households (e.g. age, gender, education level and occupation, in order to relate the results to the cultural context in which they are developed), following by six sections exploring the community risk perception face natural hazards:

1. The first section investigates residents' risk perception and awareness, the recognition that a particular natural hazard has the potential to impact upon people and private properties.
2. Risk knowledge and the causes behind Wujie community vulnerability to disasters are investigated in second section. The need of exploring the latter is justified by the long history of colonial authorities and governments.
3. The third section investigates personal and community preparedness to these hazards in a present and future perspective, and the related preventive actions aimed at minimizing the negative effects. Moreover, it explores whether people are educated to natural hazards and the sources from which they receive such knowledge.
4. The fourth section examines the existing traditional indigenous knowledge in relation to the community ability to forecast the incoming natural events.
5. Section five considers the early warning sources from which information passes through and questions the participants to evaluate communication with local authority when hazards occur.

6. Last questions explore the community's willingness to migrate and/or relocate in regard to a future perspective.

The interviews were conducted individually for 40 people of the community, and the remaining 25 were interviewed in five focus groups (total, n=65). The participants were selected randomly inside the community, respecting their free time and the willingness to share their feelings, memories and traditional knowledge. The interview process has been made with the help of one of the authors that belongs to another indigenous community in the country that permitted a very close contact with Wujie participants. For the purpose, face-to-face interviews have been chosen with the organization of focus groups and were found to create a more relaxing environment where the participants were in the majority surrounded by their peers (Smith et al. 2015). Moreover, they are powerful tools to explore people's experiences and perceptions because they can maximize the interaction between the participants (Kitzinger 1999) in calling to mind memories and oral passed down traditions. This technique was suitable to perceive our objectives as they acted as a good compromise between completely uncontrollable participant observation and easily con- trolled interview sessions as found by Morgan (1997)
The interviewees, 35 men and 30 women, were categorized based on their age group: young (18–30 years), adult (31–50 years) and old (51 years). From the household questionnaire, it appears that the education level is quite high. Senior high school educated people (n=31) and university-graduated ones (n=3) represent more than half of the entire sample interviewed. Results indicate that the education level is closely associated with the age of the participants. Highly educated people are relative young, while older got the primary school degree or are illiterate. The recruitment period for military service during Japanese period forced many people to interrupt their studies. 20 of the participants work in the agriculture sector, 13 are labours in private enterprises, 9 cover the public sector, and the remainder covers no remunerative professions (e.g. students, housekeeper, unemployed and retired). Only age, gender and education variables have been related to the results of the present work. Table 5.3 summarizes the basic demographic and social characteristics of the people involved in the interviews.

Table 5.3 Basic demographic and social characteristics of the sample households (n=65)

| | **Number** | **Percentage (%)** |
|---|---|---|
| *Gender* | | |
| Female | 30 | 46.2 |
| Male | 35 | 53.8 |
| *Age class* | | |
| Young (18-30) | 22 | 33.8 |
| Adult (31-50) | 23 | 35.4 |
| Old (>51) | 20 | 30.8 |
| *Education level* | | |
| Illiterate | 2 | 3.1 |
| Primary school | 14 | 21.5 |
| Junior high school | 15 | 23.1 |
| Senior high school | 31 | 47.7 |
| University | 3 | 4.6 |
| *Occupation* | | |
| Farmer | 20 | 30.8 |
| Employees | 9 | 13.8 |
| Labour | 13 | 20 |
| Student | 7 | 10.8 |
| Housekeeper | 9 | 13.8 |
| Unemployed/Retired | 4 | 6.2 |
| Others | 3 | 4.6 |

# 5.5 Results and discussion

## *5.5.1 Perception and awareness*

The first questions were conducted in order to explore the respondents' awareness of landslide and flood risks. On a scale ranging from 1 to 5, people showed a consistent feeling of danger towards landslide risk with a mean value of 3.78 when thinking about their personal safety but higher values when considering the possible threat to the community and one's house (4.15 and 4, respectively). There is a difference between the evaluation of danger at individual and community level, with a tendency to underestimate the former, as found in Scolobig et al. (2012). For what concerns floods, it emerges that there is a similar trend for both the community and individual level (3.86 and 3.91, respectively) with a mean value of 3.77 for one's home. A less frequency of flood events registered in the area can justify a general lower-risk perception, respecting landslides risk concern. The discrepancy in the evaluation of flood risk may derive by the location of the houses inside the village. Private properties are quite far from the river, hence the lower feeling of danger when thinking about a possible flood event. Farm activities are located in the closeness of the main water source, consequently respondent's higher evaluations of danger for the community (possible loss of commercial activities and resources) and themselves working all day in the fields.

At a national scale, risk perception studies carried out among Taiwan citizens showed a higher concern for flood events rather than for landslide hazards (Lin et al. 2008; Ho et al. 2008). The high awareness expressed for both hazards is probably ground on the high frequency of occurrence to one side and the effort of Taiwanese Government to take action in front of such events to the other.

The percentage of the respondents and the related Likert scale value assessed for each item is summed in Figure 5.3. This graph evidences the trend emerged so far related to both flood and landslide risk perceptions. Generally, respondents highlight a greater level of concern for themselves respecting to the community and their houses.

The results described so far can be related to some independent variables (Tables 5.4, 5.5) found to influence differently the residents' evaluations of danger of landslide and flood risks.

More precisely, there is a strong correlation between age and education with the feeling of danger expressed for both hazards. Risk perception decreases while increasing the education level. People with a lower level of education are more likely to overestimate these hazards and, as a consequence, to be strongly worried to (mean value 4.40 for landslide/debris and 4.15 for flood evaluation of risk, on 46.1% of the respondents), similarly found at a national scale (Lin et al. 2008; Kung and Chen 2012). On the other hand, senior high school and university-graduated people are hardly aware about this type of events (mean value 3.58 for landslide/debris and 3.56 for flood evaluation of risk on 53.9% of the respondents). As youngest direct experience is restricted, their risk perception is lower than elders (mean value 2.89 and 4.80, respectively, for landslide/debris and 2.65 and 4.92, respectively, for flood evaluation of risk).

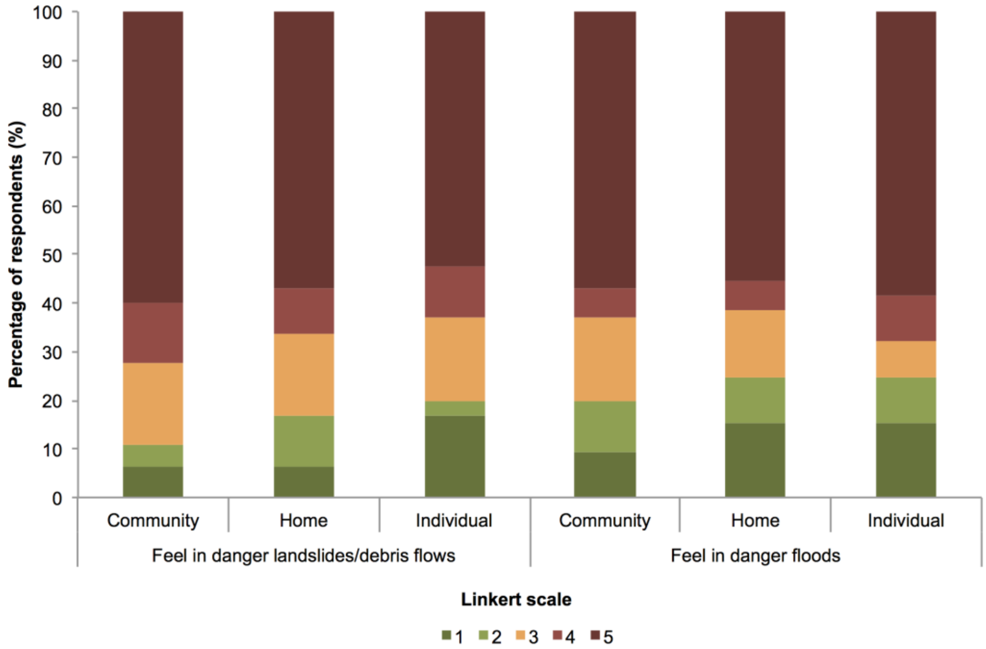


Figure 5.3 Percentage of respondents and related Likert scale value given for each item. Lower values correspond to lower feeling of danger

Gender variable has been found not statistically significant in both correlations, resulting that men and women feel the danger at the same level.

Table 5.4 Results of the cross-tabulation between danger evaluations of landslides and debris flows, and a set of independent variables related to the socio-demographic background. *Significant correlation

| | Danger for Wujie | Danger for one's home | Danger for one's personal safety |
|---|---|---|---|
| Gender | (.01) | (.02) | (.01) |
| Age | (.41)* | (.22)* | (.45)* |
| Education level | (.13)* | (.16)* | (.17)* |

Table 5.5 Results of the cross-tabulation between danger evaluations of floods and a set of independent variables related to the socio-demographic background. *Significant correlation

| | Danger for Wujie | Danger for one's home | Danger for one's personal safety |
|---|---|---|---|
| Gender | (.00) | (.01) | (.02) |
| Age | (.41)* | (.35)* | (.38)* |
| Education level | (.18)* | (.15)* | (.14)* |

### *5.5.2 Risk knowledge and perceived vulnerability*

A visualization and estimation of risk is a function not only of magnitude and frequency of the hazard, but also of previous personal experience and individual's personality traits (Gavilanes-Ruiz et al. 2009). According to this, we were interested in knowing whether the community awareness was associated with a deep knowledge of natural hazards, therefore whether the participants expected that kind of disasters in the past and whether they think they might happen again the future. Almost all of the respondents appear to show a high- risk awareness both for previous expected events (95.4%) and for future ones (93.8%). The main drive force of this concern can be ground in the shared hazard experience expressed by the 98.5% of the respondents.

Individual's knowledge can be made up to the way people conceptualize the environment and the attachment they have with their place (Solberg et al. 2010). For this reason, we asked people to explore their personal direct or indirect (oral transmission from ancestors) knowledge about the environment the community used to live in ancient time. In detail, they were asked to call in mind specifically the relocation policy, the huge deforestation programme and the construction of the dam during colonial period in relation with the actual occurrence of natural hazards. After that, we cross-connected their evaluation of danger with their personal feeling about the above-mentioned events. The results of the analysis, as given in Table 5.6, indicate that each of the variable considered has influenced the residents' evaluations of danger.

Table 5.6 Results of the cross-tabulation between danger evaluations of landslide and flood risks related to the perceived feeling about the imposed relocation, deforestation and the construction of the dam during the colonial periods. *Significant correlation.

| | **Landslides/Debris flows** | | | **Floods** | | |
|---|---|---|---|---|---|---|
| | **Wujie** | **Home** | **Individual** | **Wujie** | **Home** | **Individual** |
| Relocation | (.31)* | (.25)* | (.03)* | (.20)* | (.21)* | (.17)* |
| Deforestation | (.35)* | (.24)* | (.08)* | - | - | - |
| Dam | - | - | - | (.00) | (.00) | (.11)* |

More precisely, the 24.6% of the respondents affirm to be safer before relocation policy since they never experienced neither floods nor landslides when living in the highest mountains. As a consequence, their feeling of danger is high and higher than the rest of the community.

What is more, according to Wujie community, the imposed deforestation and the depletion of the resources during the colonial periods have increased the frequency of natural disasters (confirmed by almost 94% of the respondents). Therefore, they have a great concern about the occurrence of these hazards. Logging activity and major road construction, associated with extreme climate (typhoons) and geologic (earthquakes) events, are able to produce short-term acceleration of landslide incidence (Chang and Slaymaker 2002). In general, there is a growing concern about the impacts of deforestation in decreasing communities' resilience. Research and experience have shown that forest ecosystems play an important role in reducing the vulnerability of people to disasters, in terms of both reducing their physical exposure to natural hazards and providing them with the livelihood resources to withstand and recover from crises (Hammill et al. 2005).

Going ahead, there is a strong significant correlation between the presence of the dam and the feeling of personal risk. 78.5% of the interviewees strongly disagree about the benefits of the dam, lamenting a high amount of sediments, mud and clay that have increased the level of the river with a consequent ease of inundation. These sediments are present due to the inefficient function of the structure in retaining any kind of material; thus, they can easily move and settle in the farmer's land, polluting crops and reducing biodiversity. Almost all of the farmer's lands are close to the river, thus the worry for themselves when working in their properties. Moreover, they sustain that they should have received at least economic incentives, or discounts in the electricity fees. The results described so far show that residents are aware of the current environmental issues in their community and that they would be exacerbated by land use change to one side and human control with relocation policy in minor part. There is a common ideology shared among residents in Wujie that they are so integrated with natural processes that it is impossible for them to separate from the environment because their livelihoods depended on it. Similar findings have been found in a preliminary work regarding risk perception among Italians participants conducted by Salvati et al. (2014). The authors have investigated the factors that people considered important in controlling or conditioning landslide and flood risks. It has emerged that the most representative factors influencing the occurrence of the considered hazards have been the inappropriate management of land and abusive constructions. The same beliefs emerged in the work conducted by (De Marchi et al. 2007) where respondents' personal safety was conditioned by land use and uncontrolled urbanization. Nevertheless, there is still a serious lack of analysis that link personal perceived causes of vulnerability and the major global processes.

### *5.5.3 Perceived preparedness*

As for risk awareness, it was interesting an evaluation of one's personal preparedness and perceived Wujie readiness towards natural hazards, employing a five-point Likert scale. We found the same results between the evaluations at individual and community level with a mean value 2.06. Despite equal average values, slight differences have been detected in the percentage of respondents as shown in Figure 5.4. It seems that respondents underestimate their actual capacity to face a crisis while giving more trust in the overall preparedness of the community.

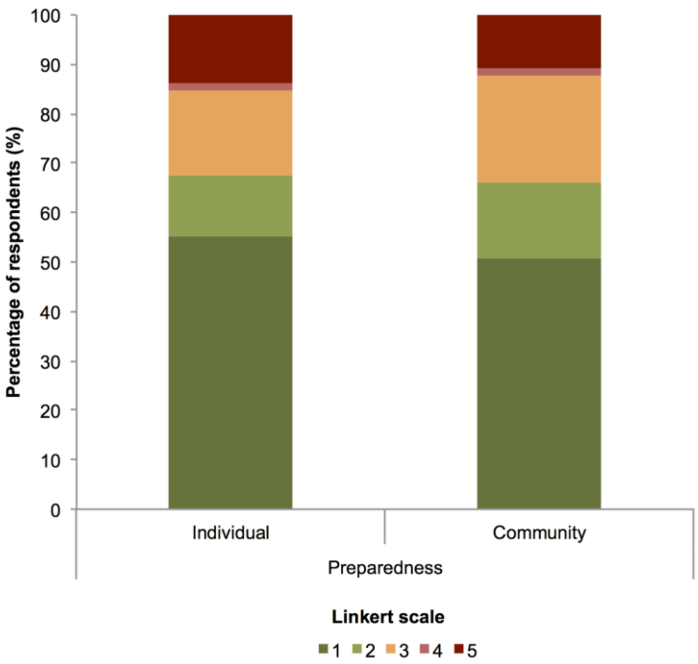


Figure 5.4 Percentage of respondents related to their personal and community preparedness using the five point Likert scale. Lower values correspond to a lower degree of readiness.

Variations can be found according to some independent variables, as given in Table 5.7. In the case of community preparedness, marginal variations can be found with regard to gender: women feel more prepared than men (2.3 vs. 1.8, respectively). This evidence is quite far from the existing literature of gender and natural disasters that relate preparedness to be a male trait (Barberi et al. 2008; Miceli et al. 2008; Armaş 2008; Bubeck et al. 2012; De Silva and Jayathilaka 2014). Cross-tabulation shows significant relationship also with age. Youngest and elders have a lower preparedness (respectively, 1.9, 1.4 individually and 1.64, 1.65 at the community level), while adults have a moderated one (2.78 and 2.83).

Table 5.7 Cross-tabulation between personal and community preparedness and some independent variables. *Significant correlation

| | **Personal preparedness** | **Community preparedness** |
|---|---|---|
| Gender | (.00) | (.03)* |
| Age | (.16)* | (.18)* |
| Educational qualification | (.05)* | (.04)* |
| Education to these events | (.01) | (.03)* |
| Trust in local authorities | (.10)* | (.10)* |

Even if young people have a higher education level, they feel not prepared to these hazards. On the other hand, elders have experienced all their life these disasters but they still do not feel prepared to, probably due to a lack of education. As in other studies, preparedness increases with age (Sattler et al. 2000; Mishra and Suar 2005), but the very old are less likely to engage in preparation (Heller et al. 2005).

Education should play a key factor in increasing people preparedness to overcome the consequences of a crisis. The term 'education' encompasses formal and informal transmission of knowledge and engagement of groups of people in identifying hazards and feasible actions to mitigate them and to prepare for the risk that cannot be reduced (Komac et al. 2010). In this work, 51 of the respondents affirm to be educated about the occurrence of natural hazards from public and private training courses, community-based councils, school and booklets provided by the government. For them, the most powerful channel of natural hazard education is school that represents 44.9% followed by Fire Department courses (24.4%) and councils involving the entire village (17.9%) (Figure 5.5).

What emerges is that knowledge and education of natural hazards are not sufficient to prevent or limit the impact of the negative occurrences. In the community, it was found that the higher is the level of trust in local authority, the more positive are the evaluations of both personal and community preparedness. In detail, higher evaluations of trust in local authority (4 and 5 values in the Likert scale) are associated with mean values of 2.26 and 2.02 of preparedness at individual and community level, respectively, against 1.87 and 1.90 for lower values of trust. This positive assessment may translate into a total delegation of responsibility, overestimating their actual capacity. A low level of preparedness turns in a lower confidence.

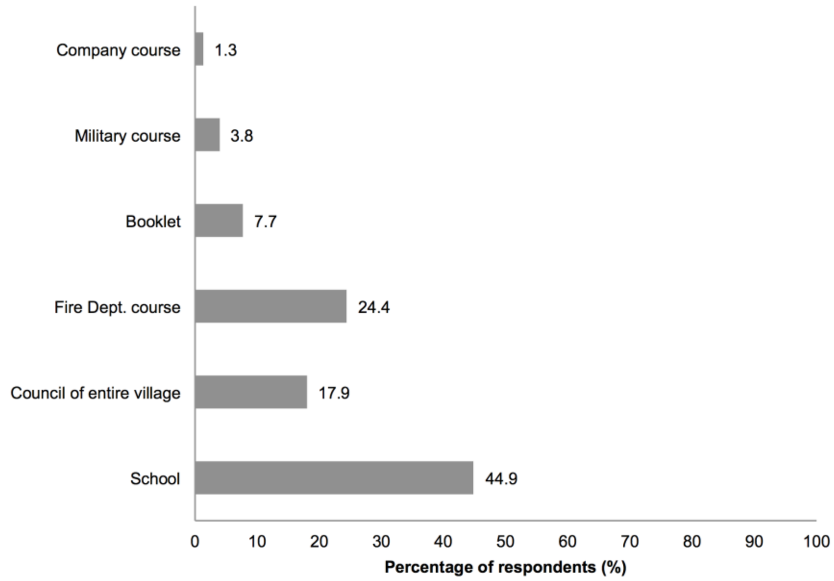


Figure 5.5 Natural hazards education sources provided by each of the respondents.

In order to evaluate respondent's capacity on preparing for a hazard, there has been developed a question inquiring about the adoption of different behaviours to reduce the negative impacts of hazards. People were invited to think about a possible future hazard, and they were asked to indicate their behaviours in order to understand how they have managed these events in the course of time. The most common acts aimed to increase self- protection were stocking food and water (n=43) and arrange emergency kits (n=14) along with lights and batteries (n=30). Youngest do not know what to do (n3) or they affirm that there is no need to cope (n=11). Only 12 respondents protect their farms and one his house (Table 5.8).

Table 5.8 Preventive mitigation strategies adopted by local people in Fazhi village

| **Items** | **Percentage (%)** |
|---|---|
| Stock food and water | 33.6 |
| Stock lights/batteries | 23.4 |
| Arrange emergency kits | 10.9 |
| Move to a safer place | 10.9 |
| Protection measures to the farm | 9.4 |
| Protection measures to the house | 0.8 |
| No need to take action | 8.6 |
| Uncertainty of what to do | 2.3 |

Generally speaking, people in Wujie are not interested in being prepared to these negative events. The main justification provided by this lack of adoption of preparatory measures may derive by the thinking that should be government's task. People expect that public authority should provide protection measures to the whole village and the farms, making some long-term projects. According to Lin et al. (2008), Taiwanese people show a similar low willingness to adopt private mitigation measures, but it is justified by a high sense of powerless in face of hazardous events.

### *5.5.4 Traditional knowledge*

Traditional knowledge has proven to be useful in local cultural and socio-economic con- texts, maintaining traditional principles able to develop a higher resilience (Takeuchi and Shaw 2008). For this purpose, we were interested in exploring the community's ability to anticipate natural hazards for disaster risk reduction. Unfortunately, due to cumulative changes in the long colonial period, the community has never been adapted to these environmental threats and so inefficient to cope with. Nevertheless, respondents, especially elders, remember few strategies in anticipating typhoons or heavy rain events (Table 5.9). The 8% of the interviewees do not know anything about traditional knowledge useful to forecast, and going deeply, they belong to the youngest group of the respondents. These results are in line with those that appeared until now, underlying a general detachment of young towards these issues.

Table 5.9 Indigenous weather-monitoring signals used by Wujie community

| **Indicator** | **Sign** | **Outcome** |
|---|---|---|
| Cloud | Red coloured | Typhoon |
| Plant | Number of bands of palm grass leaves | Typhoon |
| Plant | Longan tree fruit production | Typhoon |
| Moon | Visibility of rings | Heavy rain |
| Animal | Ants, earthworms, snails moving in groups | Heavy rain |
| Animal | Swallows leaving the nest | Heavy rain |
| Animal | Chinese Bamboo-Partridge presence | Heavy rain |
| Animal | Bees nest behaviour | Typhoons |
| Animal | Gadflies and dragonflies flying in groups | Heavy rain |
| Witch | Witches predictions with domestic rats | Typhoon |

Traditionally, residents in Wujie use a number of indicators to predict weather, which are based on environmental and cultural beliefs. The most common indicators, that locals remember, are plant and animal behaviours. When a local bird known as Chinese bamboo partridge (*Bambusicola thoracica sonorivox*) is seen flying within the household environs, it is indicative of incoming rain. Increased occurrence of gadflies and dragonflies in the sky is a normal signal of heavy rain. The same attitude is visible for ground animals such as ants, earthworms and snails that gather in groups. Further, another indicator of heavy rain coming is the nest behaviour of birds and insects, respectively, when swallows leave their nest and when bees create their hideaway in higher and bigger branches. The high production of fruits of Longan tree (*Dimocarpus longan*) is normally associated with a high frequency of typhoons. Moreover, to anticipate the number of expected typhoons, they traditionally see the behaviour of Palm grass (*Setaria palmifolia*) leaves. The number of bounds it presents reflects the number of typhoons expected in the season. Respondents affirm that they rarely use these types of predictors in their actual lives. With the emergence of technology (e.g. television and internet), they have substituted their traditional knowledge with more accurate techniques of forecasting. Elders often use their personal ecological knowledge since they are not used to these sources of information. It seems that the strong anthropic pressure has led to a progressive loss of their cultural heritage; nevertheless, when asking whether traditional knowledge was still important for them, the answers were other than negative. Results highlighted a great importance of traditional knowledge with mean value of 3.95 on a five-point Likert scale. Going deeply, it appears that between men and women there were no consistent differences (3.8 vs. 4.1) and elders, with a mean value of 4.45, gave greater significance respecting young (mean value of 3.23). Once more, we can identify a gap between these two generations. Unfortunately, oral tradition is losing its expression among teenagers even if it plays a crucial part in keeping culture alive.

### *5.5.5 Effectiveness of risk information and communication*

To this point, results reveal that people demonstrate a certain awareness and education about the occurrence of natural hazards, but at the same time they feel to be not prepared to overwhelm these occurrences. The gap could be found in the effectiveness of communication when disasters occur. Some questions were designed to assess the sources from which Wujie community usually receives information regarding hazard situations in order to see whether there were some weaknesses in the communication process.

As we can notice from Table 5.10, the community's headman is valued as the most powerful channel of information. The percentage is not so encouraging (30.2%) since she is the local authority charged to do it. From these results, it emerges an important consideration about the effectiveness of communication illustrated as the social amplification of risk theory, where a message can be altered depending on how many transmitters it passes through (Renn 1991).

Table 5.10 Primary sources of early warning information during disasters

| Items | Percentage (%) |
|---|---|
| Community's headman | 30.2 |
| Emergency drill present in the village | 22.3 |
| TV, broadcast, radio, newspaper, etc. | 21.2 |
| Church | 8.4 |
| Acquaintance | 6.7 |
| Self-experience | 6.2 |
| Internet | 4.5 |
| School | 0.6 |

When government has to inform local people, communication passes firstly through the township administration representative then to the community's chief that organize, if necessary, a volunteer patrol team. At last, after this long succession, civil society is informed. If at all possible, direct communication from the source to the receiver with clear and simple information is the best mean for communication as it reduces message distortion and misunderstandings (Olczyk 2004). This evidence comes out also by respondents, who underlined their need to communicate directly with government without intermediaries. In addition, many respondents (84.6%) expressed certain displeasure about decisions that are often made without consulting local community and questioned the effectiveness of decisions made without local input. People cited various examples such as the lack of long-term projects or the ephemeral solutions implemented to reduce the impact due to landslides and floods (e.g. the relocation of sediments in the river instead of a total removal, not working monitoring stations because of the end of the project, the construction of new road instead of repairing the old ones, the abandonment of river banks protection measures, etc.). Decision makers cannot intuitively know what local residents require and what they do or do not understand without speaking to them (Olczyk 2004). Additionally, it is evident that authorities and local residents have different perceptions and awareness about the environment and the hazards that frequently occur. This causes different ideas regarding making decisions and management plans, because each of the two actors has different knowledge and beliefs that may not necessarily coincide. The community need to be engaged in the decision-making process to enhance its preparedness to a disaster event.

### *5.5.6 Future perspectives: migration and relocation*

Last questions were addressed to know whether Wujie participants have ever thought about migration to escape from the source of danger made by hazards. This study finds out that households exposed to natural disasters absolutely do not want to move. Results show that 59 interviewees (90.8%) have never thought about migrating outside their native place, while only six interviewees (9.2%) affirmed the contrary. Attachment to place is the dominant referent in definitions of indigenous peoples and is central in their culture and social organization (Hibbard et al. 2008). Land and sense of place remain the essence of native identity and sovereignty (Lewis 1995). Cross-tabulation (Table 5.11) connects the will of migration and some independent variables.

Table 5.11 Cross-tabulation between the willingness of migration and some independent variables. *Significant value

| | **Migration** |
|---|---|
| Age | (.00)* |
| Gender | (.29) |
| Hazard experience | (.00)* |
| Risk perception | (.00)* |
| Preparedness | (.87) |
| Trust in local authority | (.25) |
| Education | (.18) |

What emerges from the results is that only young want to migrate outside the village, but it does not seem to be related to safety reasons since their risk perception is very low. Given that Wujie's people do not take into consideration migration as a consequence of natural disasters impacts in the village, it was interesting to know whether or not they would relocate their house in a safer place in Fazhi village. Results, again, confirm that the population do not want to move in a safer place even inside the village. The reasons are different and are grouped in Table 5.12.

Table 5.12 Motivations behind the unwillingness of respondents to move in a safer place in the village

| **Motivation** | **Number** | **Percentage (%)** |
|---|---|---|
| Economic reason | 9 | 13.7 |
| Political reason | 1 | 1.5 |
| Security reason | 23 | 35.4 |
| Social reason | 23 | 35.4 |

Based on the respondents provided, it appears that the social component plays an important role in the unwillingness to move in a safer place. The community is strongly related to the lands that the ancestors gave them even though they would live in unsafe conditions. Moreover, it appears that they feel safe in their houses (13.9%) or think that there is not a safer place in

Wujie where to move (21.5%). These notable comments split the respondents in two categories about risk perception: those that have a higher feel of danger have a greater willingness to move outside and, vice versa, those with a lower-risk perception who do not care about moving in the village and even outside (Table 5.13).

Another finding of this research is that the 13.8% of the respondents do not take into consideration the idea to relocate their houses since they have no economic resources. At last, only one person affirms his wish to relocate his house in the highest mountain, considered a safer place, but the permission has been denied (bureaucratic reason).

Table 5.13 Cross-tabulation between the willingness of relocation and some independent variables. *Significant value.

| | **Relocation** |
|---|---|
| Age | (.16) |
| Gender | (.91) |
| Hazard experience | (.08) |
| Risk perception | (.03)* |
| Education | (.69) |

## 5.6 Conclusions

In this study, it has been examined the knowledge of natural hazards and risk perception of Wujie indigenous community, located in Fazhi village in the Central Mountain Range of Taiwan. The area of their living, among others in the island, was affected by several natural hazards in the last decades with the consequences that now many native people are at risk. The analysis on the perceived risk shows that individuals generally expect landslide and flood events, and for this reason, they feel worried to. Different responses were noted for individuals with different age and education level. Moreover, the community perceives that the anthropic pressure during their colonial period is something not natural that has triggered more disaster than those that would happen in the village. However, despite the great knowledge and awareness demonstrated, people in Wujie showed a low level of preparedness. Neither being educated to such events was catalyst for action. Some of them have increased their response capacity; however, few have implemented protective measures. The tendency to delegate the responsibility for safety to the agencies in charge results in a low personal and community preparedness.

Indigenous people are a resource for Taiwan, because of their cohesion with the environment and the strong memory of past disasters let them knowledgeable to overcome them if guided.

For the purpose, policy makers have to involve the community when developing projects in indigenous area, considering them the utmost priority since their living and survival are at risk. Moreover, every project needs full community participation where people could understand the benefits and the possible negative impacts of the planned activities. Improving communication and cancelling the gap between the public and civil society would lead to more prepared people for future natural hazard events and consequently increasing their resilience and reducing the stress created by uncertainty. Technical communication and findings must be disseminated thought local newspaper, radio and TV channels since the entire sampled population use them as a big source of information.

This work has brought to attention a number of issues, which have been found in other regions in the world, but not fully investigated within indigenous populations. With modernization, indigenous people lifestyle is probably not as traditional as before; however, something should be done to preserve their living, with special attention of young that appeared to be spiritually far from their ancestors. The results presented here must be thought of as a first glimpse of the potential outcomes. Increasing the data, and conducting a widespread study within all indigenous communities in the island, would help Taiwan government in addressing special efforts for the mitigation of the risks in mountain regions, reducing vulnerability and decreasing human and economic losses when natural hazards occur. The impacting consequences of natural disasters, resulting from climate change and the rapid urbanization, demand societies to a change. Change requires advancing in social research aimed at studying risk perceptions of marginalized and disempowered people living in risk-prone communities. Special attention needs to be focused on those socio- economic factors (e.g. gender, age, race and income) that influence people's ability to judge, tolerate and react to natural hazards, in order to help local authorities to develop widely comprehended preventive practices and sensitive management plans.

*Author contributions*: G.R., T.R., C-W.L. and P.T., designed and directed the project. G.R. and T.R. collected the data and in consultation with P.T performed the statistical analyses and interpreted the results. G.R. in consultation with T.R., C-W.L. and P.T. contributed to writing the manuscript.

CHAPTER 6

# THE ROLE OF GENDER IN PREPAREDNESS AND RESPONSE BEHAVIORS TOWARDS FLOOD RISK IN SERBIA[5]

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## 6.1 Abstract

Adverse outcomes from 2014 flooding in Serbia indicated problematic response phase management accentuated by a gender imbalance. For this reason, we investigated the risk perceptions and preparedness of women and men regarding these types of events in Serbia. Face-to-face interviews, administered to 2500 participants, were conducted across 19 of 191 municipalities. In light of the current findings, men seemed to be more confident in their abilities to cope with flooding, perceiving greater individual and household preparedness. By contrast, women displayed a deeper understanding about these events. Perhaps owing to a deeper level of understanding, women demonstrated more household-caring attitudes and behaviors and were more prone to report a willingness to help flood victims at reception centers. Emergency management agencies and land planners should account for these differences in gender awareness and preparedness. Based on these findings, doing so may increase citizen participation and shared responsibility under flood hazard scenarios.

## 6.2 Introduction

Gender disparities exert powerful differences within societies worldwide, even in the field of disasters. Women and men are not merely at risk because of their location in time and place (Bankoff 2006) but because of a complex mix of influential factors that include "differentiated roles and responsibilities, skills and capabilities, vulnerabilities, social relations, institutional structures, and long-standing traditions and attitudes" (Obcarskaite 2014). These social forces are thought to shape different behavioral tendencies, including those related to the ability to anticipate, prepare for, respond to, and recover from disasters (Wisner et al. 2003). The interest and recognition of different attitudes and behaviors among men and women in the wake of environmental problems have origins in the 1990s (Gutteling and Wiegman 1993; Greenberg and Schneider 1995; Riechard and Peterson 1998; Fordham 1999). However, the assessment of gender differences at all levels of the disaster cycle has historically been less than satisfactory. The social research on disasters has often been approached from a mostly gender-blind perspective, mindful of some basic findings reported in the literature for years (e.g., women are more at risk for psychosocial reactions (Norris et al. 2001). According to the gender glossary, gender blindness is "the failure to recognize that gender is an essential determinant of social outcomes impacting on projects and policies". This social–cognitive bias can influence disaster management actions in place, affecting both physical actions and psychosocial preparedness and response (Overton 2014).

As stated above, increased interest in gender inclusion in the disaster context occurred during the International Decade for Natural Disaster Reduction (1990–1999); however gender-specific guidelines were missing. In 2000, the special session of the UN General Assembly, “Gender equality, development and peace for the twenty-first century” highlighted the inefficiencies and inadequacies of existing approaches in responding to disasters (APWLD 2006). Thus, the need for explicitly incorporating considerations on gender into disaster prevention, mitigation, and recovery strategies has been increasingly emphasized. The latest Sendai Framework for Disaster Risk Reduction signed off by 187 Member States on 18 March 2015 in Japan, and lead-up discussions and platforms discussed this topic more assiduously, which included a request to increase the empowerment and participation of women (and youth) (UNISDR 2015). The rising importance of gender-sensitive research was underlined by the United Nations Office for Disaster Risk Reduction, defined as one of the objectives for the period 2015–2020.

As a consequence, one can conclude that during the last century, progressive change regarding this issue increasingly became a current concern for the disaster management community. One emphasis is the effort devoted to understanding social power relations regarding disaster and emergency management. In particular, as promoted through UN processes, mainstreaming the role of gender includes an increased focus on integrating women in disaster policy, practice, and research.

In countries like Serbia, the context for the current study, analyzing gender differences is of particular importance. For example, during a major 2014 flood event, women were found to be particularly affected as they were weakly represented in the flood-planning response and overall decision-making processes (Baćanović 2014). For example, women argued that information did not reach them adequately, thus exposing gaps in risk communication. Many women’s organizations responded immediately and offered assistance in the most vulnerable areas. However, the public perception and media promulgated the idea that men were the first to react. In a policy context, the importance of protection and rescue from floods from a gender perspective has also been recognized by the Council for Gender Equality Government of the Republic of Serbia. In fact, on 29 May 2014, the council held an extraordinary meeting dedicated to this specific issue, concluding that developing more gender-sensitive statistics, indicators of vulnerability, reconstruction, and recovery was a necessary initial step. Thus, for both research- and policy-driven reasons, we conducted extensive interviews to explore and underline the differences in risk perception, preparedness, and response behaviors of both women and men in the wake of flood events in Serbia to foster increasingly targeted solutions for disaster planning and management.

### *6.2.1 Literature review*

Research into risk perception aims to understand the cognitive and emotional processes and behavioral choices of individuals or groups in risk-related contexts (Fromm 2005). Behaviors that people enact before, during, and after disasters are the first and most critical support for the management of emergency circumstances and can contribute to the minimization of adverse effects. According to Slovic et al. (2004b) and Griffin et al. (2008), risk encompasses an affective component responsible for two different perceptions:, risk as a feeling and as a rational conception. Thus, risk is not only a combination of perceived probability but also and the feeling of worry related to it (Neill et al. 2016). According to Cutter et al. (1992), "as men and women view the world differently, it follows that they also perceive risks differently". Gender differences may be linked to different cultural and societal contexts and dynamics. In this regard, being able to spend time watching TV or fraternizing in community centers to access hazard information (Paradise 2005) as well as work in the tobacco fields in Indonesia (Lavigne et al. 2008) gave men a greater awareness to promote responsive behavior. Female counterparts, confined to child-care and housekeeping responsibilities as well as watching less television and therefore receiving less knowledge of such events as a result of less interaction outside the domestic sphere, were put in jeopardy at the onset of a hazard occurrence (Paradise 2005; Lavigne et al. 2008; De Silva and Jayathilaka 2014). By contrast, during Hurricane Andrew (that struck the Bahamas, Florina and Louisiana in August 1992), women were largely responsible for preparing family members and expressed a higher knowledge of stocking provisions and getting the household ready for the hurricane (Morrow Hearn and Enarson 1996). Similar findings have been highlighted by De Marchi et al. (2007). Such findings point to emergency management messaging that understands more localized contexts and can capitalize on household tendencies, leveraging the respective gender-specific tendencies to be able to complement each other more effectively. The form of concern expressed so far can be related to the perceived likelihood of occurrence with personal consequences (Gregg et al. 2004), which could affect female their psychological balance (Armaş and Avram 2009).

Accordingly, in recent work on Icelandic volcanic hazards regarding air travel (Eiser et al. 2015), the perceptions of the necessity of restrictions were positively associated with the perceived risk of an accident and were lower for those who were more concerned about the consequences of false alarms or who had personally experienced travel disruption; they were also higher for women than men. Neill et al. (2016) found females to be more worried about potential flooding, and regarding perceived exposure to flood risk, gender was not found to be statistically significant.

Before a disaster, research shows that many individuals perceive their own risk as sufficiently low, reflecting an 'it will not happen to me' set of beliefs. As a result, people do not feel the need to invest voluntarily in protective measures such as strengthening their house or buying insurance (Kunreuther 2006). Risk perceptions differently drive the willingness to protect and take action before a disaster occurs. Risk awareness is not merely a perception of hazard occurrence or the feeling of threat at the individual or household level, but also a 'behavioral tendency'. Thus, it is related to the interest and intentions to manage more or less intensively a hazard situation. Several researchers have reported men's higher confidence in their proactive behaviors during an emergency, rating their level of self-preparedness as significantly high (Barberi et al. 2008; Miceli et al. 2008; Armaş 2008; Armaş and Avram 2009). This behavior may at least in part be driven by the social role that men usually play within the family context. By contrast, among the Wujie indigenous people interviewed in Taiwan, it was statistically determined that women felt more prepared than men when thinking about possible future hazards (Roder et al. 2016). Similarly, women undertook more hazard adjustments than men in a US study (Lindell and Whitney 2000). Among these actions, there is a range of essential amenities and supplies that are helpful for the first period in a post-disaster phase. Baker (2011) found that being prepared meant having additional items in the house that were essential, particularly in the response and early recovery process. According to the results obtained by Able and Nelson (Able and Nelson 1990), men may see themselves as responsible for some of the necessary supplies that are needed to survive in the wake of disasters. However, in the USA, less than half of the individuals reported having a household emergency plan, including household instructions for safer locations in the case of an emergency (FEMA 2009).

Regarding one aspect of planning, the few studies determining gender differences have found that women are more likely to evacuate than men, perhaps because of socially constructed gender roles and dynamics (Bateman and Edwards 2002). Enarson (2006) found that mothers rarely resisted evacuation orders, treating them more seriously than men, who may be more likely to disregard such orders. Delegating trust to local authorities and their preventive actions could magnify or shrink the response of a community by displaying a high willingness to adopt protection measures (Motoyoshi 2006) in the first case, or demonstrating dramatically low preparedness in the second (Terpstra 2011; Scolobig et al. 2012; Roder et al. 2016).

Official rescue attempts are made by emergency rescue services and, inevitably, those contained within relevant government authorities, supplemented by volunteer organizations (Mileti 1999; Helsloot and Ruitenberg 2004). Provision of more informal forms of voluntary assistance depends on the social order, personal characteristics, attitudes, and situational variables (Okun and Michel 2006). Assisting during and after a natural disaster can significantly contribute to reducing the consequences of disasters. Proper assistance, coming from an informed public, can create an environment where the management of a disaster event is more likely to be successful (Olczyk 2004). Every individual has the right to be informed of the potential risks and preparedness measures to enable secure and efficient access to this type of information (Ivanov and Cvetković 2014). Results suggest that providing specific information on how preparedness measures can be realized may increase the confidence of women in their ability to protect their property (Brilly and Polic 2005; Bradford et al. 2012).

Thus, the findings to date support the idea that gender roles within the household and community may have direct implications for the successful prevention, mitigation, and management of hazard situations. Moderating social and demographic factors such as age, education, income, and marital status can also play a role gender-wise. As a simple example, one's economic status enables a better absorption and recovery from losses. Perhaps less obvious is the finding that women have been found to have a higher sensitivity to possible monetary losses (Ho et al. 2008; Kung and Chen 2012). However, having adequate resources does not on its own ensure that women are not exposed to stress, anxiety, and concern about evacuation and losses, job security, or the health, safety, and well-being of family and friends (Enarson and Phillips 2008). Poorly maintained and inadequate infrastructures are typical of low-income women. At particular risk are single-mothers, who also tend to have lower economic means and educational levels (Donner 2003; Donner and Rodríguez 2008). Single parents typically have the same worries as two-parent households but have added responsibilities for protecting and preparing the family for an emergency. This solo status can be easily unnoticed in the recovery process (Parkinson and Zara 2013). Two-parent families are typically better placed, both financially and psychologically. However, even in these types of families, there can be considerable gender disparity. For example, in Kenya, 29% of the women interviewed had no formal education and 77.5% depend on their husband's income to survive (Nyakundi et al. 2010). On the other hand, living in a community with a considerable proportion of highly educated women increases personal disaster preparedness and provides easier access to and seeking out of disaster-related information (Muttarak and Pothisiri 2013).

### *6.2.2 Flood risk in Serbia*

Floods are the most common natural hazard risks in Serbia (Dragicevic et al. 2011; Petrović et al. 2015). Their frequency, intensity, and location across the territory make them a continuous threat to the ecological, economic, and social spheres (Ristić et al. 2012). The potentially floodable area, considered for a return period of 100 years, covers an area of 16,000 km$^2$ (Figure 6.1), where 500 large settlements, 515 industrial assets, 680 km of railroads and approximately 4000 km of roads are at risk (Petrović et al. 2014). The most vulnerable area is the northern part of Serbia, in the main river catchment of the country where the Danube River is located. The degree of vulnerability of the population and its properties are not uniform, but vary depending on the type of natural disaster and expected potential damage (Dragicevic et al. 2011; Dragićević et al. 2013). In the period from 1915 to 2013, 848 flood events accounting for 133 deaths were registered (Petrović et al. 2014). In detail, the events with the most impact occurred in the Kolubara (June 1996; May 2011), Great Morava (July 1999), Kolubara and Drina (June 2001), South Morava (November 2007), West Morava, Drina and Lim (November 2009), Great Timok (February 2010), Pèinja (May 2010), and Drina (December 2010) watersheds (Ristić et al. 2012). The most critical event occurred in May 2014 (Figure 6.2), affecting the territories of Serbia, Bosnia-Herzegovina, and Croatia (ACAPS 2014). The precipitation exceeded 200 mm in a day and was the most dramatic event registered since 1961 (Tošić et al. 2016), affecting more than 1.6 million people (22% of the country's population) (ACAPS 2014). However, the evacuation procedures were difficult to manage because of the failure of people to move away from hazard areas.

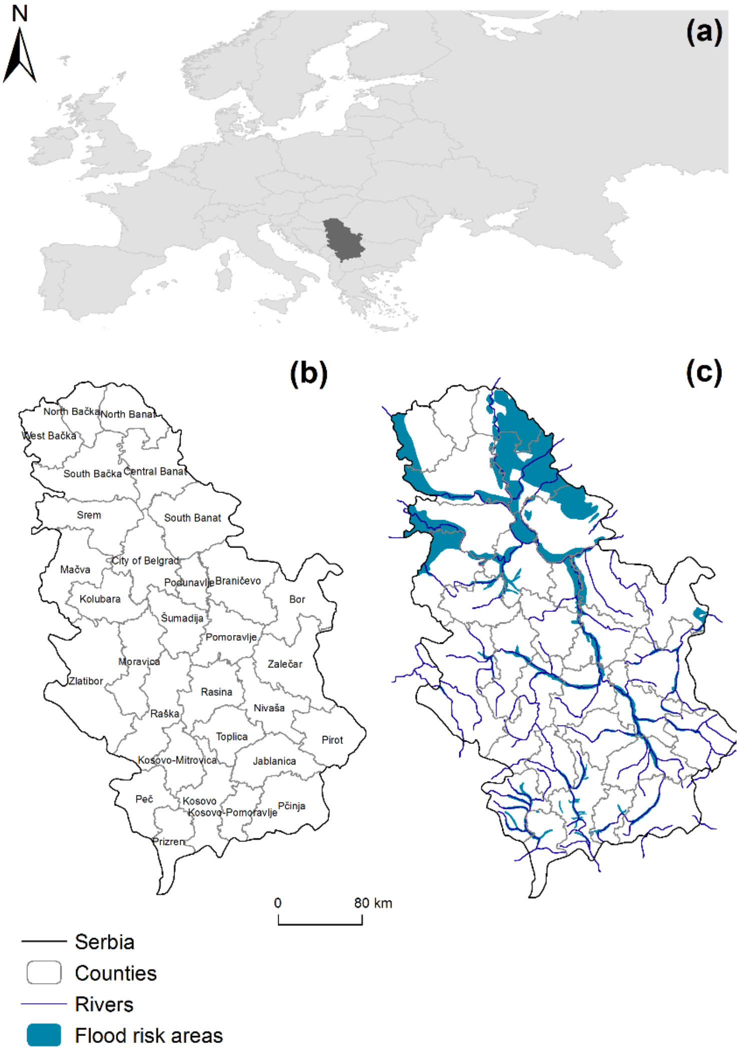


Figure 6.1 (a) Location of Serbia (b) Counties of Serbia (c) Flood risk map in a 100-years return period with rivers location.

Such reactions highlighted a general mistrust of individuals in localities within the government's actions, specifically regarding mitigation, including evacuations, coupled with low levels of awareness and preparedness (Cvetković et al. 2015; Cvetković and Sandić 2016; Cvetković 2016).


Figure 6.2 The most critical flood event occurred in 2014. (a) flooded hotel in Obrenovac (b) flooded streets in Obrenovac (c) citizens' evacuation in Obrenovac (d) rescue helicopter in Obrenovac

## 6.3 Materials and methods

### *6.3.1 Study area*

A series of 2500 face-to-face interviews were conducted during the whole of 2015 in 19 of the 191 municipalities in the Republic of Serbia (Table 6.1). All subjects gave their informed consent for inclusion before they participated in the study, and the University of Belgrade provided ethical approval for this research. These communities were chosen for their different demographic and social characteristics, being a census-based representation of the whole population of Serbia. In these municipalities, participants were selected randomly (first stage: parts of the community in the research were selected; second stage: streets or sections of streets were determined by the level of primary causal units; third stage: each research core was determined as the path with specified start and end points of movement; fourth stage: selection of respondents was conducted following the procedure of the next birthday for adult members), with the number of respondents being proportional to its size, using a representative sampling approach (Paul and Bhuiyan 2010). Interviews were carried out for six months, and the participation rate was 96%.

Table 6.1 Name and ID code of the municipalities involved in the survey. The number of interviews is also shown. The location of the municipalities involved and the complete table of all Serbian municipalities (with ID) are shown in the Appendix B.

| ID | Municipality | Interviews |
|---|---|---|
| 19 | Kraljevo | 141 |
| 27 | Šabac | 140 |
| 34 | Novi Sad | 150 |
| 47 | Obrenovac | 178 |
| 57 | Kragujevac | 191 |
| 60 | Smederevska Palanka | 205 |
| 70 | Smederevo | 145 |
| 100 | Rekovac | 50 |
| 102 | Kruševac | 180 |
| 115 | Paraćin | 147 |
| 125 | Batočina | 80 |
| 126 | Lapovo | 39 |
| 128 | Svilajnac | 115 |
| 147 | Sremska Mitrovica | 174 |
| 149 | Loznica | 149 |
| 151 | Bajina Bašta | 50 |
| 152 | Užice | 147 |
| 154 | Priboj | 122 |
| 182 | Sečanj | 97 |

### *6.3.2 Demographic characteristics*

The interviewees, 50.2% (1256) women and 49.8% (1244) men (Table 6.2), were representative of the gendered stratification of the country, which registers 51.3% women and 48.7% men (Statistical Office of Serbia, 2016). The average age of respondents was 40 years old, and the most represented category was those younger than age 30 (711; 28.4%). From the sample, it appears that the majority (41.7%) had a secondary (four years) educational degree, and very few completed a higher level of education (university, 20.2%; doctoral studies, 0.4%). In the household sample, married people accounted for 54.6%.

Table 6.2 Basic socio-economic and demographic information of respondents (N=2500) in a gendered classification. In brackets there are percentages. Missing values in the sums correspond to people that did not complete the questionnaire entirely.

| Variable | Category | Total | Male | Female |
|---|---|---|---|---|
| Age (years) | Young (18-38) | 1265 (50.6) | 594 (46.96) | 671 (53.04) |
| | Adult (39-68) | 1182 (47.28) | 623 (52.71) | 559 (47.29) |
| | Old ( >68) | 53 (2.12) | 27 (50.94) | 26 (49.06) |
| Education level | Compulsory education[1] | 1987 (79.08) | 1025 (51.58) | 962 (48.42) |
| | University and higher[2] | 513 (20.92) | 219 (42.69) | 294 (57.31) |
| Marital status | Single-headed household[3] | 644 (45.36) | 317 (49.22) | 327 (50.78) |
| | Two-headed household[4] | 1856 (54.64) | 927 (49.95) | 929 (50.05) |
| Income[5] | Low income | 1663 (66.5) | 834 (50.15) | 829 (49.85) |
| | High income | 666 (33.5) | 343 (51.50) | 323 (48.50) |

[1] Primary school degree (N=180); Secondary degree – 3 years (N=520); Secondary degree – 4 years (N=1042); High school diploma (N=245)

[2] Bachelor degree (N=439); Master degree (N=65); PhD or equivalent (N=9)

[3] Single (N=470); Divorced (N=99); Widow/Widower (N=75)

[4] Married (N=1856)

[5] Considered below and above the National monthly average net salary. Retrieved from: http://publikacije.stat.gov.rs/G2018/PdfE/G20181260.pdf

### *6.3.3 Questionnaire design*

The structured questionnaire was developed using close-ended, multiple choice questions, and 5-point Likert scale questions. The first part of the questionnaire related to the socio-demographic characteristics of the interviewees to assess the social background of the respondents and their gender. Subsequent sections included questions related to risk awareness, risk preparedness, rescue management and assistance, and information and education (Appendix A, Table A1). Several published survey approaches were consulted (Turner et al. 1986; Mulilis and Lippa 1990; Hurnen and McClure 1997; McClure et al. 1999) and adapted according to the social and flood hazard environment of Serbia. During July 2014, a pilot pre-test of the questionnaire was conducted in Batočina (central Serbia) with 75 people with the aim of checking the comprehensibility and performance of the questionnaire. In that pilot effort, participants were chosen randomly across the municipality and were interviewed in a central location (i.e., the main public square).

### *6.3.4 Analyses*

Statistical analysis of data was conducted using the Statistical Package for the Social Sciences (SPSS) program. First, we tested the variable 'gender' to validate our central hypothesis by using a multivariate analysis. A Chi-square test of independence ($\chi^2$) was used to determine the connection between gender and risk awareness, confidence in the positioning of household furniture, inventory of essentials, evacuation and rescue management, personal assistant of flood victims, economic support reception centers, flood occurrence information, the location of flood risk education, and source of training. Assessment of the impact level was performed by the phi coefficient, where a higher number indicated a stronger relationship between two variables (Cohen 1988). For tables larger than 2×2, to assess the impact level, we used the Cramer's V coefficient, which considers the number of degrees of freedom. To test the connection between gender and continuous dependent variables regarding individual preparedness, household preparedness, community preparedness, national preparedness, rescue management efficiency, confidence and trust, and unwillingness to become engage, Pearson correlation was used. Before proceeding to the implementation of the statistical test, we examined the general and specific underlying assumptions to ensure their appropriateness. The internal consistency of Likert scales for the 16 items is good with a Cronbach's alpha of 0.80. External validity is established by using risk perception to predict intended behaviors to anticipated flooding episodes, giving $x^2 = 33.15$, $p = 0.000$.

The interaction between gender and other socio-economic or demographic variables are poorly investigated in disaster research, even if there are fundamental in programming sensitive management and assistance actions. For this reason, we gave insights regarding gender and age, income, marital status and educational level about threat appraisal, preparedness, information and communication of significant variables. We performed analysis of variance and chi-square test of independence according to the unit of measurements of the variable implied.

## 6.4 Results

In order to test the central hypothesis of which gender is a predicting variable in all the stages of the disaster cycle, a multivariate regression analysis was used identifying the extent to which the seven independent variables were associated with five socio-economic variables: gender, age, education, marital status, and income. According to Table 6.2 categories, females, young, single-headed households, university and higher educated respondents and high income people have been coded as 0; 1 have been assigned otherwise. Previous analyses showed that the assumptions of normality, linearity, multicollinearity and homogeneity of variance had not been violated. The results of the multivariate regressions of perceived preparedness (individual and household) and risk (Table 6.3) show that the most important predictor of individual preparedness is gender (β=-0.143), and it explains 14.3% variance in individual preparedness, followed by the marital status (β=-0.092, 9.2%), and level of education (β=-0.059, 5.9%). The remaining variables (e.g., age and income level) did not have significant effects on individual preparedness. This model ($R^2$=0.032, Adj. $R^2$=.029, F=15.12, t=28.26, p=0.000) with all mentioned independent variables explains the 29.4% variance of individual preparedness and represent a good level of explanation based on standards in psychological research. Further analyses showed that the most important predictor of household preparedness is gender (β=-0.049) explaining the 4.9% of variance ($R^2$=0.009, Adj. $R^2$=0.007, F=4.36, t=51.25. p=0.000). The remaining variables did not have significant effects on household preparedness. The results of the multivariate regressions of flood risk map knowledge showed that the most important predictor of flood risk map knowledge is the educational level (β=-0.078) explaining the 7.8% of variance. Gender did not have significant effects on flood risk map knowledge.

Table 6.3. Multivariate regression analysis results in predicting individual and household preparedness and flood risk map knowledge (N=2500).

| **Predictor variable** | **Individual preparedness** | | | **Household preparedness** | | | **Flood risk map knowledge** | | |
|---|---|---|---|---|---|---|---|---|---|
| | **B** | **SE** | **β** | **B** | **SE** | **β** | **B** | **SE** | **β** |
| Gender | -.304 | .044 | -.143** | -.097 | .040 | -.049* | -.030 | .050 | -.012 |
| Age | .003 | .002 | .038 | .045 | .046 | -.021 | .214 | .058 | .077** |
| Marital status | -.072 | .020 | -.092** | -.032 | .041 | -.016 | -.128 | .052 | -.051* |
| Income | .020 | .026 | .017 | -.043 | .043 | -.021 | .105 | .030 | .067** |
| Education | .050 | .019 | .059* | .005 | .018 | -.007 | .212 | .056 | -.078** |

*p=0.05 ***p*≤0.01

In the multivariate logistic regression model in Tab. 6.4, four independent variables (preventive measures, consent evacuation, personal assistance of flood victims, supplies) were included which had statistical significance ($p$<0.05). More specifically, in the first step a logistic regression was applied to test the combined effects of the different factors included in the proposed model (gender, age, marital status, income level and education level) for consent evacuation (table 6.3). The model (with all the predictors) was statistically significant $\chi^2$=15.024, (5, N=2377) $p \leq .010$ and explains between 6% (Cox & Snell) and 11% (Nagelkerke) of variance. The results of the regression indicated the two predictors have a unique, statistically significant contribution to the model (income level $p<0.01$, and education level $p<0.05$). It was found that income level was the strongest predictor for consent evacuation with odds ratios of 1.44. In the same way, we tested the combined effects of the different mentioned factors included in the proposed model for preventive measures. The model was statistically significant $\chi^2$=35.968 (5, N=2500), $p \leq 0.000$ and explains between 14% (Cox & Snell) and 26% (Nagelkerke) of variance. Also, the results of the regression indicated the three predictors have a statistically significant contribution to the model (gender $p<.05$, education level $p<.05$ and marital status $p<0.01$). Gender was the strongest predictor preventive measures with odds ratios of 1.33. Also, we tested the combined effects of the different mentioned factors included in the proposed model for the personal assistance of flood victims. The model was statistically significant $\chi^2$=91.84, (5, N=2500), $p \leq 0.000$ and explains between 3.6% (Cox & Snell) and 6.1% (Nagelkerke) of variance. The results of the regression indicated the three predictors have a statistically significant contribution to the model (gender $p<0.01$, and age $p<0.01$). Gender was the strongest predictor in the willingness to assist personally flood victims with odds ratios of 2.44. About the supplies, the results show the model was not statistically significant $\chi^2$=8.78, (5, N=2500) $p \leq 0.121$ and only gender was the significant predictor with odds ratios of 1.21.

Table 6.4. Multivariate binary logistic regression analyses used to assess the explanatory power of four chosen predicting variables.

| **Predictor variable** | **Preventive measures** | | **Evacuation consent** | | **Personal assistance of flood victims** | | **Supplies** | |
|---|---|---|---|---|---|---|---|---|
| | B | SE | B | SE | B | SE | B | SE |
| Gender | .287* | .116 | .045 | .119 | .945** | .116 | .197* | .094 |
| Age | .113 | .132 | -.088 | .141 | .625** | .140 | -.167 | .107 |
| Marital status | -.518** | .124 | -.123 | .123 | .096 | .114 | .129 | .097 |
| Income | -.229 | .123 | .371** | .125 | .127 | .121 | -.093 | .101 |
| Education | -1.49* | .163 | -.329* | .137 | -.061 | .124 | .047 | .104 |

*$p$=0.05 **$p \leq 0$ .01

From these results we can validate our hypothesis that gender is an important variable in this research.

### 6.4.1 Risk awareness

We were interested in exploring an individual's levels of threat appraisal according to a gender perspective. Threat appraisal comprises the product of objectively assessed measures of probability and consequences of risk. In this manuscript, we are evidencing the importance of all these components that construct individuals' conceptualization of flood risk. The results showed a statistically significant difference in the awareness of a flood risk map; women (87.7%) had higher scores ($p$=0.014). This finding related to gender can be explained at least in part by educational attainment. That is, women with higher levels of knowledge of flood occurrence (and maps) were also found to have a higher level of education ($p$=0.000). Furthermore, in this research, it was found that married women and men had a higher knowledge when compared to single person families ($p$=0.005). It appears that single headed households did not have the same concerns as those of two-headed households, perhaps grounded in the carry-over related to increased responsibilities in the family context.

However, a higher division appeared concerning the health consequences. When asking people to assess their knowledge about the health consequences of floods, it appeared that women (79.1%), compared to men (76.8%), showed more sensitivity to the health effects associated with flooding, but this was not statistically significant (Table 6.5). This could be ascribed to a combination of gender effects and the employment status of women. At a glance, women in Serbia are housekeepers and child carers, making them more likely to be more sensitive to environmental threats. Based on a flood likelihood scenario, on a scale of 1 to 5, it was found that the flooding likelihood of occurrence during the period of one year had a mean value of 2.58 (SD 1.36) for males and 2.53 (SD 1.34) for females, whereas it was 2.84 (SD 1.38) for males and 2.85 (SD 1.37) for females based on a 5-year probabilistic approach (Table 6.5). Thus, across genders in this study, there was a low awareness that these events would occur in the future, and no statistical differences were found. People seemed to perceive that they were safe from the possible occurrence of these events, even if they displayed specific knowledge about floods and their negative consequences. For this reason, we explored in more detail whether there were some drivers concerning this lack of general awareness from a gender perspective. As expected, respondents with a higher awareness of flood risks perceived a higher flood probability (within 1 year) (men $\bar{x}$= 2.78; women $\bar{x}$= 2.83).

Table 6.5 Pearson correlation and Chi-square test analysis between risk awareness and gender. Standard deviation in parenthesis.

| Variable | Sig. (2-tailed) | Pearson Correlation | Men | Women |
|---|---|---|---|---|
| Awareness of flood possiblity in 1 year | 0.387 | −0.017 | 2.58 (1.36) | 2.53 (1.34) |
| Awareness of flood possiblity in 5-year | 0.856 | 0.004 | 2.84 (1.38) | 2.85 (1.37) |
| Awareness on flood risk locally | 0.020 | 0.330* | 2.78 (1.25) | 2.83 (1.25) |
| **Variable** | **Sig. (2-tailed)** | **$X^2$** | **Men** | **Women** |
| Having flood knowledge | 0.167 | 1.90 | 76.8 | 79.1 |
| Awareness of flood risk map | 0.014* | 6.06 | 84.3 | 87.7 |
| Awareness of health risk from flood | 0.064 | 3.42 | 41.2 | 44.9 |

*Correlation is significant at the 0.05 level (2-tailed).

In this regard, a higher education has been seen to be a significant determinant ($p$=0.021) for men for both the flood occurrence scenarios and the opposite for female respondents ($p$=0.013) underlined women's higher fear derived from a low education.

### *6.4.2 Flood preparedness*

The other main focus of this research was an attempt to predict future disaster occurrence, often without considering whether people are prepared (or not). According to the transtheoretical model of change (Citizen corps 2006), preparedness behavior readiness can be thought of in terms of different 'stages of change': the pre-contemplation, contemplation, preparation, action, and maintenance stages. In total, 2297 people who answered the question 'What stage of preparedness do you feel in response to a possible flood event?', the highest percentage consisted of those who did not intend to change or did not think about changes in the next six months (the so-called pre-contemplation or 'non-thinking') with a value of 60.3% (Table 6.6). In addition, as seen in the table, males tended to report more active stages of change (preparation, action, maintenance). Expanding on these premises, the theory of planned behavior (Ajzen et al. 1991) clarifies that an individual's intentions to perform a given behavior vary according to a combination of subjective norms and perceived behavioral controls unique to each individual. For this reason, it is interesting to examine how flood preparedness varies across different demographic groups. Such variations reflect the extent to which factors can shape community-driven efforts and education, supporting efforts to be prepared for and cope with flood events.

Table 6.6 Preparedness level in a gendered perspective (n=2,297) based on the transtheoretical model.

| **Preparedness level** | **Description** | **Male** | | **Female** | |
|---|---|---|---|---|---|
| | | **f** | **%** | **f** | **%** |
| Pre-contemplation | An individual does not intend to change or not consider changes shortly (in the next six months) | 649 | 56.3 | 735 | 64.2 |
| Contemplation | An individual is not prepared at present. However, intends to undertake certain activities in the next six months | 144 | 12.5 | 147 | 12.8 |
| Preparation | An individual has considered changing his behaviour in the next month | 141 | 12.2 | 100 | 8.7 |
| Action | An individual has changed behaviour in the recent past, but the changes did not come to life | 101 | 8.8 | 75 | 6.6 |
| Maintenance | An individual has changed his behaviour, and changes started | 45 | 3.9 | 37 | 3.2 |
| Total | | 1153 | 100 | 1144 | 100 |

These results were also in line with the answers provided when respondents were asked to express from 1 to 5 their level of preparedness at the individual, household, community, and national levels. In fact, women expressed lower levels of self-confidence in being prepared for a flood event, with a mean value of 2.83 versus men with a mean value of 3.13 in individual preparedness ($r=0.142$, $p=0.000$). The same pattern of results was found for household preparedness (2.99 for women and 3.08 for men, $p=0.019$, $r=0.047$), highlighting that women were not as confident in household readiness. Community and national preparedness answers did not indicate significant differences between women and men, with both underestimating their capacity.

Greater perceived preparedness reported by men might be borne of the fact that typically in Serbia, they engage in service in the army during which they are trained to manage emergency situations (Baćanović 2014), perhaps leading to a more generalized perception of being more proactive and ready when situations call for participation. Cultures, where there are family marginalization and lower levels of involvement in community networks and less preferential treatment for women, may culminate with women evaluating their preparedness to be lower than that of men including when thinking about a possible hazard event and when at greater exposure risk. It may also be that women are just more realistic in evaluating household preparedness. As a result, and with respect to a starting point for reducing gender-based differences and risks, good knowledge of the surroundings may translate into a more exceptional individual's capacity to cope with natural hazards

A low level of preparedness was related to lower capacity and willingness to protect ($p$=0.001). However, men registered a higher propensity in undertaking preventive measures with a significant value of 0.004 and a higher knowledge of the security procedures for responding to a possible flood event ($p$=0.000). By contrast, women expressed the view that they had no time for dealing with these problems (r=0.040, $p$=0.020), especially unmarried women (unmarried $\bar{x}$=3.38; married $\bar{x}$=2.63; $p$=0.000). That is, women's many household, child-rearing, and related responsibilities may lead to a focus that allows them less time to consider the additional responsibility of being prepared for a possible natural hazard event.

From further analysis, we found significant relationships between preparedness and education, age, marital status and income. Poorly educated men and highly educated women perceived themselves to be the most well prepared (men $p$=0.000; women $p$=0.025). Concerning age, both younger female and male felt that they were more equipped compared to other adults and elders perceiving a higher level of preparedness as an individual and household level. We found some statistical differences between individual/household preparedness and single women vs. married women (both > than 30 years old) (Individual preparedness: $p$=0.000; Household preparedness: $p$=0.000). Married women and men feel to be more prepared to overcome the negative occurrences of floods at an individual and household level. Female-headed households generally perceived themselves to be more vulnerable to floods compared with their counterpart households with both spouses. This could be explained by the fact that households with both spouses are better placed both financially and psychologically. They are therefore able to respond to flood risks in a better mental and emotional state than are their single counterparts. Wealthier men feel to be more risk takers and well equipped ($p$=0.008), while statistics concerning women were not significant. Generally, people with higher possessions and income feel less vulnerable to the negative occurrence being able to manage the emergency. A higher awareness of flood risks correlated positively with a higher assessment of preparedness (men $p$=0.000; women $p$=0.000). This means that a good awareness and preparedness campaign might translate into effective flood risk preparedness and mitigation measures at the individual and household levels.

Actions useful in the wake of a possible flood event include the handling of utilities (electricity, gas, water). For this reason, we asked people to assess their confidence in dealing with these. It was found that men had higher rates of knowledge confidence regarding where water valves ($p$=0.000, male 86.5%, female 73.4%), gas valves ($p$=0.000, male 65.3%, female 42.2%) and electricity ($p$=0.000, male 87.8%, female 69.9%) devices were located in the household (Table 6.7). We first asked people whether they stored essential amenities and second, to choose from a list of which ones they had. More men than women reported having an inventory of essentials useful for the response process (27% and 23%, respectively). It was found that more men (a higher percentage) than women possessed a radio-transistor ($p$=0.044), shovel ($p$=0.000), hack ($p$=0.000), and hoe or spade ($p$=0.003) (Table 6.7).

Table 6.7. Pearson correlation and Chi-square test results between flood preparedness and gender. Likert scales means are shown and standard deviations are presented in parenthesis for the first two set of variables.

| | Variable | Male | Female | Sig. (2-tailed) | Pearson Correlation |
|---|---|---|---|---|---|
| Perception of preparedness | Individual preparedness | 3.13 (1.06) | 2.83 (1.01) | 0.000 | −0.142 ** |
| | Household preparedness | 3.08(0.995) | 2.99 (0.968) | 0.019 | −0.047 * |
| | Community preparedness | 2.96 (1.16) | 2.94 (1.15) | 0.568 | −0.012 |
| | National preparedness | 2.84 (1.10) | 2.88 (1.11) | 0.310 | 0.020 |
| The reason for not taking precautions | Expectation from others | 2.63 (1.36) | 2.68 (1.29) | 0.378 | 0.018 |
| | Not being at risk | 2.93 (1.48) | 2.91 (1.41) | 0.736 | −0.007 |
| | Not having time | 2.57 (1.32) | 2.70 (1.35) | 0.020 | 0.047 * |
| | Expensive | 2.74 (1.27) | 2.77 (1.36) | 0.638 | 0.010 |
| | Fail to provide safety | 2.88 (1.36) | 2.91 (1.25) | 0.077 | 0.036 |
| | Not prevent the consequences | 2.86 (1.36) | 2.92 (1.35) | 0.401 | 0.017 |
| | **Variable** | **Male** | **Female** | **Sig. (2-tailed)** | **$X^2$** |
| Inventory of essentials | Radio-transistor | 19.5 | 15 | 0.044 * | 4.04 |
| | Shovel | 46.6 | 32.9 | 0.000 * | 24.30 |
| | Hack | 32.4 | 18.5 | 0.000 * | 31.41 |
| | Hoe, spade | 37 | 28.9 | 0.003 * | 9.13 |
| | Water storage | 41.3 | 51.7 | 0.016 * | 8.240 |
| | Food | 59.8 | 65.3 | 0.298 | 0.350 |
| Confidence in the positioning of house furniture | Water valves | 86.5 | 73.4 | 0.000 * | 77.85 |
| | Gas valves | 65.3 | 42.2 | 0.000 * | 112.1 |
| | Electricity | 87.8 | 69.9 | 0.000 * | 110.2 |

*Correlation is significant at the 0.05 level (2-tailed), **Correlation is significant at the 0.01 level (2-tailed).

On the other hand, a higher percentage of women, compared to men, reported having water storage ($p=0.016$) and a higher proportion of food supplies (male 59.8%, female 65.3%). In our results, women were also found to be more sensitive to essential household content protection, including significantly more women compared to men reporting that they had secured copies of important personal, financial, and insurance documents in a safe place ($p=0.003$, female 31.4%; male 24.2%).

### *6.4.3 Evacuation and rescue management*

First responders, of course, play an important role in the protection and rescue of people in disasters caused by flooding. When examining the perception of citizens regarding the efficiency of first responder actions on a scale from 1 to 5, it was found that men displayed slightly greater levels of confidence in planned emergency activities of authorities in almost all the choices provided (efficiency of fire department: men (3.56), women (3.44), $r=-0.045$; emergency medical services: men (3.55), women (3.43), $r=-0.44$; headquarters for disasters: men (3.75), women (3.69), $r=0.790$ (Table 6.8).

Generally speaking, and in contrast to the standpoint of the answers given, the trust in family members as actors from whom help could be expected was significantly more pronounced for women compared to men, with mean values of 4.31 and 4.20, respectively ($r=0.042$, $p=0.037$). Some slight gender differences were also found regarding confidence and trust in different organizations. Females tended to rely more on police activities ($r=0.041$, $p=0.043$, male $\bar{x}=$ 3.25, female $\bar{x}=$ 3.36); international humanitarian organizations ($p=0.043$, male $\bar{x}=$ 2.46, female $\bar{x}=$ 2.50), non-governmental humanitarian agencies (male $\bar{x}=$ 2.30, female $\bar{x}=$ 2.34), neighbors (male $\bar{x}=$ 3.56, female $\bar{x}=$ 3.63), religious community affiliations ($r=0.064$, $p=0.002$, male $\bar{x}=$ 2.38, female $\bar{x}=$ 2.43), and the army (male $\bar{x}=$ 3.56, female $\bar{x}=$ 3.58). Males, in reverse, tended towards a higher confidence in the fire department (male $\bar{x}=$ 3.63, female $\bar{x}=$ 3.61), emergency aid bodies (male $\bar{x}=$ 3.48, female $\bar{x}=$ 3.40), and themselves (male $\bar{x}=$ 3.14, female $\bar{x}=$ 3.06). Similar results were found in a study regarding trust in Serbia, which observed that the church, the police, and the army were the three principal organs in which people trusted the most for crisis management (Table 6.8) (Kešetović 2013).

In contrast to the literature, in this research, it was found that men (52.6%) reported being more willing to accept evacuation orders compared to women (47.4%) ($p=0.023$) and especially low income men ($p=0.002$). An examination of the preferred evacuation strategies revealed statistically significant differences across all items. Men preferred to remain in the house, but moved to higher floors (male 52.6%, female 39.9%) or evacuated to friends (male 39.9%, female 32.2%). It seems that men have less confidence in the escape routes of the public authorities even if they accepted the need to evacuate. They expressed a preference for remaining in their houses or going to people located close by. On the other hand, women would evacuate to neighbors (female 52.6%, male 9.4%), to designated reception centers (female 16%, male 10.7%), and other empty/safer apartments (female 3.7%, male 2.9%) ($p$=0.000) (Table 6.8).

Table 6.8 Pearson correlation and Chi-square test results between gender and evacuation and rescue management. Likert scales means are shown, and standard deviations are presented in parenthesis for the first two set of variables.

| | Variable | Men | Women | Sig.(2-tailed) | Pearson Correlation |
|---|---|---|---|---|---|
| Rescue management efficiency | Police efficiency | 3.30 (1.29) | 3.27 (1.27) | −0.013 | 0.528 |
| | Fire Department efficiency | 3.56 (1.27) | 3.44 (1.31) | 0.021 | − 0.045 * |
| | Ambulance service efficiency | 3.55 (1.17) | 3.44 (1.27) | 0.019 | − 0.44 * |
| | Army efficiency | 3.75 (1.30) | 3.69 (1.36) | 0.245 | − 0.024 |
| | Headquarters emergency situations efficiency | 3.35 (1.32) | 3.36 (1.40) | 0.005 | 0.790 ** |
| Confidence and trust | Family member | 4.20 (1.27) | 4.31 (1.18) | 0.037 | 0.042 * |
| | Neighbors | 3.56 (1.28) | 3.63 (1.21) | 0.148 | 0.029 |
| | International humanitarian organization | 2.39 (1.18) | 2.43 (1.11) | 0.419 | 0.016 |
| | Non-governmental organization | 2.46 (1.21) | 2.50 (1.13) | 0.379 | 0.018 |
| | Religious community | 2.31 (1.25) | 2.47 (1.19) | 0.002 | 0.064 ** |
| | Police | 3.25 (1.37) | 3.36 (1.25) | 0.043 | 0.041 * |
| | Fire department | 3.63 (2.27) | 3.61 (1.19) | 0.726 | − 0.007 |
| | Emergency head | 3.48 (1.23) | 3.40 (1.24) | 0.122 | − 0.031 |
| | Army | 3.56 (1.36) | 3.58 (1.32) | 0.768 | 0.006 |
| | Self-organized | 3.14 (1.33) | 3.06 (1.34) | 0.166 | − 0.028 |
| | **Variable** | **Men** | **Women** | **Sig. (2-tailed)** | **$X^2$** |
| Escape route | Consent to evacuate | 52.6 | 47.4 | 0.023 * | 0.880 |
| | Home—higher floors | 52.6 | 39.9 | 0.000 * | 22.24 |
| | Friends' house | 39.9 | 32.2 | | |
| | Neighbors | 9.4 | 52.6 | | |
| | Reception centers | 10.7 | 16 | | |
| | Empty/Safer apartments | 2.9 | 96.3 | | |
| Evacuation plan | Evacuation plan for vulnerable family members | 3.5 | 4 | 0.005 * | −0.06 |
| | Family dialogue on evacuation plan | 16.6 | 14 | 0.117 | 4.28 |

**Correlation is significant at the 0.01 level (2-tailed), *Correlation is significant at the 0.05 level(2-tailed).

Keeping oral or written response plans can also significantly contribute to more efficient evacuation strategies at the household level. For this reason, we asked people to state whether they had a plan for possible evacuation or whether they had ever held planning discussions in the case of an upcoming flood event. Although generally low rates of the possession of written plans were reported, women (4%) displayed a slightly higher percentage compared to men (3.5%) ($p$=0.005). Additionally, females (55.2%), when compared to males (51.5%), displayed higher sensitivity to the evacuation procedures of the elderly, the disabled, and infants. There was no statistically significant difference between men and women regarding planning discussions of the case of an upcoming flood event. Here again, women demonstrated more sensitivity in taking care of aspects of household organization and safety.

### *6.4.4 Assistance*

Gender was also evaluated as a variable predicting the willingness to assist, with men more likely to report being a volunteer during a disaster compared to women. Men (23.5%), compared to women (11.1%), reported greater assistance of flood victims, as well as higher participation with respect to economic support (men 28.1%, women 6.1%; $p$=0.004). This latter form of assistance can be considered as 'passive engagement' (Table 6.9).

Table 6.9 Pearson correlation and Chi-square test results between assistance and gender. Likert scales mean are shown and standard deviations are presented in parenthesis for the first set of variables.

| | **Variable** | **Men** | **Women** | **Sig. (2-tailed)** | **Pearson Correlation** |
|---|---|---|---|---|---|
| Unwillingness to become engaged | Any difference | 2.65 (1.24) | 2.58 (1.25) | 0.217 | −0.026 |
| | Expected from others | 2.76 (1.21) | 2.70 (1.22) | 0.294 | −0.22 |
| | State body tasks | 2.98 (1.21) | 2.93 (1.22) | 0.316 | −0.021 |
| | Expected from peers | 2.98 (1.21) | 2.93 (1.27) | 0.041 | −0.043 * |
| | Lack of time | 2.42 (1.19) | 2.29 (1.20) | 0.338 | −0.020 |
| | High cost | 2.65 (1.27) | 2.42 (1.20) | 0.007 | −0.056 ** |
| | **Variable** | **Male** | **Female** | **Sig. (2-tailed)** | **$X^2$** |
| Type of assistance | Personal assistance of flood victims | 23.5 | 11.1 | 0.000 ** | 63.6 |
| | Economic support | 28.1 | 33.6 | 0.004 * | 8.38 |
| | Reception Centers | 3.7 | 6.1 | 0.000 * | 6.32 |

**Correlation is significant at the 0.01 level (2-tailed), *Correlation is significant at the 0.05 level (2-tailed).

Similar to assisting flood victims directly, more active participation was detected from the women's side; however, generally low base rates were reported, that is, the findings indicated that women (6.1%) reported significantly more proactive attitudes about effective assistance at reception centers compared to men (3.7%) ($p$=0.000). Young women (p=0.008) and men (p=0.032) consider more to be engaged in assistantship to flood victims also providing economic support. The same results have been found for married individuals concerning both genders. To recall previous results, it seems that the lack of time and the higher vulnerability of single individual families make them less interested in getting engaged in the recovery process. Unexpectedly, low income women (p=0.000) and men (p=0.000) are more prone to support financially flood victims. This behavior is translated might be seen as 'unquestioning obedience' or 'altruism' that often comes from less wealthy individuals.

### *6.4.5 Information and education*

When people were asked to state the source from which they received information on floods, a gender-based relationship emerged (Table 6.10).

Table 6.10. Chi-square test results between gender and information- and education-predicting variables.

| | **Variable** | **Male** | **Female** | **$X^2$** | **Sig. (2-tailed)** |
|---|---|---|---|---|---|
| Flood occurrence information | Family members | 29.3 | 33.1 | 3.87 | 0.015 * |
| | Neighbors | 18.3 | 13.8 | 8.46 | 0.049 * |
| | Friends | 12.3 | 9.5 | 4.47 | 0.004 * |
| | Relatives | 12.7 | 11.3 | 0.995 | 0.034 * |
| | School | 12.8 | 15.4 | 3.23 | 0.319 |
| | College | 6.9 | 4.5 | 5.72 | 0.072 |
| | Work | 16.8 | 11.8 | 11.80 | 0.017 * |
| | Religious community | 2.8 | 2.4 | 0.199 | 0.001 * |
| | Television | 54.8 | 63 | 16.27 | 0.655 |
| | Radio | 16.3 | 15.2 | 0.403 | 0.000 * |
| | Press | 29.5 | 33.9 | 5.11 | 0.526 |
| | Internet | 24.4 | 33 | 20.74 | 0.024 * |
| The place of flood risk education | School | 36.5 | 28.7 | 2.11 | 0.347 |
| | Family | 41.4 | 44.1 | 4.92 | 0.000 * |
| | Work | 36.5 | 28.7 | 16.88 | 0.000 * |
| Source of training | Television | 62.3 | 62.4 | 0.000 | 1.00 |
| | Radio | 13.3 | 11.8 | 1.20 | 0.273 |
| | Video games | 3.1 | 0.5 | 20.11 | 0.000 * |
| | Internet | 20.6 | 28 | 10.01 | 0.000 * |
| | Lecture | 30.3 | 31.4 | 0.318 | 0.573 |

* Correlation is significant at the 0.05 level (2-tailed).

Women were informed by technological sources (television, press, and the Internet) and family compared to their male counterparts, who reported relying more on neighbors, friends, and place of work. This might be explained by the fact that women are typically confined in the house, working and child rearing, possibly then giving them a sense of being isolated from various sources of communication, except other family members. By contrast, men may have more opportunities through greater interaction with the community. Furthermore, 38% of both women and men expressed a strong desire to obtain training on how to respond to a possible flood event through the Internet or TV. Internet was the most preferred by married individuals, young people and low income respondents. Low educated (p=0.000) and young men (p=0.000) stated to prefer to get trained by videogames. For this reason, we asked people to assess whether they had received education on these hazards by mentioning the factors involved. Among school, family, and work, people seemed to consider family as the main source of education for floods, with a higher and statistically significant percentage of women with respect to men (p=0.000). On the other hand, men (36.5%), with a higher percentage than women (28.7%), noted that their place of work educated them about flood hazards (p=0.000). Education from school received lower rates of endorsement among both men and women (26.5%) (Table 6.10).

## 6.5 Discussion

This research suggests that in Serbia, there may be gender differentiation across phases of the disaster cycle. However, it is important to note that it is not just a matter of difference, as underlined by Gustafson (1998). Gender is not a merely a variable that assesses the differences between men and women in the wake of disasters. It is also how living conditions, demographic and economic attributes, behaviors and beliefs reflect gender power relations in this context. Once recognized, rather than expose problems exclusively, disasters and disaster preparedness can also be seen as opportunities to facilitate or provide opportunities for the empowerment of traditionally marginalized groups (Lovekamp and Arlikatti 2013).

Assessing gender discrepancies can help policy makers recognize local capacities and provide opportunities for the less powerful to make disaster preparedness and relief more effective. The failure in understanding local relationships and social networks may disadvantage communities including women, men and their families and networks who face these events. One pathway for learning and integrating gender in emergency management practices includes success stories.

For example, in Bangladesh, with the introduction of improved gender-responsive disaster management, Cyclone Sidr in 2007 took a lower number of female lives when compared to previous disasters and before this policy (Ahmad 2012). Similar records have been found in response to tropical cyclones in Vanuatu in the South Pacific Ocean. In his report for Care International, Webb (2015) demonstrated that gender-sensitive disaster risk reduction (DRR) programming contributed to reducing the impact and damage from Cyclone Pam when compared to a community that did not undertake the same plan. In Macedonia, the UNDP (2010) included and trained women at the National Crisis Management Center for earthquake and flood preparedness. This initiative, undertaken in 2008, served as a best practice for gender inclusion in DRR that led to the drafting of gender-sensitive risk management plans at a national level. Successful community-based management actions depend on how public authorities' mainstream the preparedness and recovery of men and women after disaster events and how well gender-different realities are noticed and dealt with. Thus, to assist public authorities to organize gender-sensitive management plans, it is necessary to know how people differentially prepare and react to catastrophic events from a gender perspective.

Gender dynamics in the disaster context should be of interest, not only at policy levels, to government, non-governmental, and international organizations and projects. They should also be a priority for researchers and emergency management practitioners, who need to contribute more in their studies and their practice to find a gender differentiation in how men and women perceive, prepare for, tolerate, and react to natural disasters, including in combination with different socio-cultural and economic backgrounds.

## 6.6 Conclusions

In this work, gender differences were found in a large sample in Serbia regarding a range of flood preparedness indicators. Although there were some variables that indicated no significant or slight differences, larger magnitude and significant differences appeared to revolve around men's perceptions of being more prepared and being more active or willing to be involved in or led by community-level activities. Women generally reported being less confident, but perhaps had more realistic views about being prepared while also reporting more household- and family-level cares, concerns, and preparedness behaviors in selected areas. Such a pattern may be underpinned, at least to some extent, by gender-specific roles linked to the household and to community access, leading to a state of affairs that lead to less ability to connect with active social networks within the community, coupled with being less informed and able to be involved in larger decision-making processes. For this purpose, planners might consider how this may affect the way authorities can reach those people with hazard information and emergency warnings. Importantly, based on current findings coupled with other research on different gender profiles, both women and men should be seen as valuable resources that might combine complementary strengths to maximize preparedness, response, and recovery. That is, promoting more gender-related dialogue that aims to leverage the respective strengths of women and men requires women to be increasingly empowered to take leading roles in building disaster resilience.

In this work, females reported greater organization of essential supplies and emergency amenities, saving important documents, and dealing with the financial matters of the household. This should be taken not only as an advantage but also perhaps as a proxy for a more embedded sense of prioritizing the security of the household, which makes them more motivated for prioritizing household and family concerns. This includes emphasizing their role in emergency management messaging for preparing the family for a possible hazard situation. Men appeared to be more confident in managing an emergency situation, including the perception that they were better prepared to take action, including physical preparedness and response. Additionally, women had fewer opportunities to maintain a high level of social networking in the community, which may lead to them being less informed. This might then underpin women expressing TV as the main channel of flood hazard information and education.

Regarding the main outcomes of this research, at a political level, it is thus important to:

- Learn more about and emphasize the role of women and men in emergency management planning and messaging;
- Engage in more in-depth research on gender roles, including more in-depth qualitative or mixed methods research that uses interviewing and/or focus group methodologies on gathering more in-depth information;
- Develop strategies to empower women, educate men, and promote the genders working together synergistically to prepare effectively while also perhaps, at the same time, overcoming gender stereotypes;

- Promote gender-sensitive preparedness by using networks that appeal to and advocate for women, including those that have a long history of assessing and addressing public health issues (e.g., women's social and health care providers);
- Use a range of communication channels for increasing hazard knowledge and preparedness, including gender-related scenarios or case studies that appeal to people and promote empowerment and working cooperatively together within households and communities;
- Include flood hazard education in children's school curricula, including education on gender empowerment and cooperation in the context of creating a current and future population that has resilience and risk management knowledge and skills, including being able to prepare for and solve problems linked to a range of risk scenarios in life such as flooding and other natural hazards.

Based on the current quantitative research, there is an increasing need for more gender-focused mixed methods research to contextualize gender discrepancies in more depth and at a local scale. Doing so can better target and tailor disaster management planning and preparedness, response, and recovery education campaigns. Such work could result, perhaps even quite significantly, in fewer victims of events such as floods, lessening economic losses, and reducing other consequences.

*Author Contributions:* V.M.C. conceived and designed the questionnaire with inputs from A.Ö. and S.D. V.M.C. contributed to acquisition and with G.R. performed the computational framework and analyzed the data. G.R. structured the manuscript and interpreted the data and prepared the manuscript drafts, in collaboration with V.M.C. and Prof. Kevin Ronan. V.M.C., G.R., A.Ö., P.T., and S.D. critically reviewed the data analysis and contributed to the content for revising and finalizing the manuscript.

# Appendix A

Table A6.1 Set of variables and unit of measurement.

| Variable | Units of Measurement |
|---|---|
| *Threat appraisal* | |
| Flood knowledge | Dummy variable (yes/no/not sure) |
| Flood risk map knowledge | Dummy variable (yes/no/not sure) |
| Flood-related health risks | Dummy variable (yes/no/not sure) |
| 1-year flood likelihood scenario | 5-Point Likert scale |
| 5-year flood likelihood scenario | 5-Point Likert scale |
| Feeling of danger | 5-Point Likert scale |
| *Flood preparedness* | |
| Preparedness | Transtheoretical model (Citizens Corps 2006) |
| Individual preparedness | 5-Point Likert scale |
| Household preparedness | 5-Point Likert scale |
| Community preparedness | 5-Point Likert scale |
| National preparedness | 5-Point Likert scale |
| Unwillingness to protect | Multiple choice question: (1) Expectation from others, (2) Not being at risk, (3) Not having time, (4) Expensive, (5) Fail to provide safety, (6) Not prevent the consequences |
| Preparation usefulness for the future | 5-Point Likert scale |
| Confidence in the positioning of house furniture | Dummy variable (yes/no): (1) Water valves, (2) Gas valves, (3) Electricity |
| Confidence in handling house furniture | Dummy variable (yes/no): (1) Water valves. (2) Gas valves, (3) Electricity |
| Inventory of essentials | Dummy variable (yes/no): (1) radio-transistor, (2) shovel, (3) hack, (4) hoe, spade, (5) water storage, (6) food |
| Confidence in the location of financial documents | Dummy variable (yes/no) |
| *Evacuation and rescue management* | |
| Escape route | Multiple choice question: (1) Home- Higher floors, (2) Friends' house, (3) Neighbors, (4) Reception centers, (6) Empty/Safer apartments |
| Consent to evacuate | Dummy variable (yes/no) |
| Family dialogue on evacuation plan | Dummy variable (yes/no) |
| Evacuation plan for vulnerable family members | Dummy variable (yes/no) |
| Rescue management efficiency | 5-Point Likert scale: (1) Police, (2) Fire Department, (3) Ambulance service, (4) Army, (5) Headquarters emergency situations |
| Confidence and trust | 5-Point Likert scale: (1) Family member, (2) Neighbors, (3) International humanitarian organization, (4) Non-governmental organization, (5) Religious community, (6) Police, (7) Fire department, (8) Emergency head, (9) Army, (10) Self-organized |
| *Assistance* | |
| Willingness to assist community recovery | Dummy variable (yes/no) |

| | |
|---|---|
| Type of assistance | Dummy variable (yes/no): (1) Personal assistance of flood victims, (2) Economic support (3) Reception Centers |
| Unwillingness to become engaged | Level of agreement on a 5-point Likert scale: (1) Any difference, (2) Expected from others, (3) State body task, (4) Expected from peers, (5) Lack of time, (6) High cost |
| *Information and education* | |
| Flood occurrence information | Dummy variable (yes/no): (1) Family members, (2) Neighbors, (3) Friends, (4) Relatives, (5) School, (6) College, (7) Work, (8) Religious community, (9) Television, (10) TV, (11) Radio, (12) Press, (13) Internet |
| Flood risk education | Dummy variable (yes/no): (1) School, (2) Family, (3) Work |
| Desire to be trained | Dummy variable (yes/no) |
| Preferable training source | Dummy variable (yes/no): (1) Television, (2) Radio (3) Video games, (4) Internet, (5) Lecture |

# Appendix B

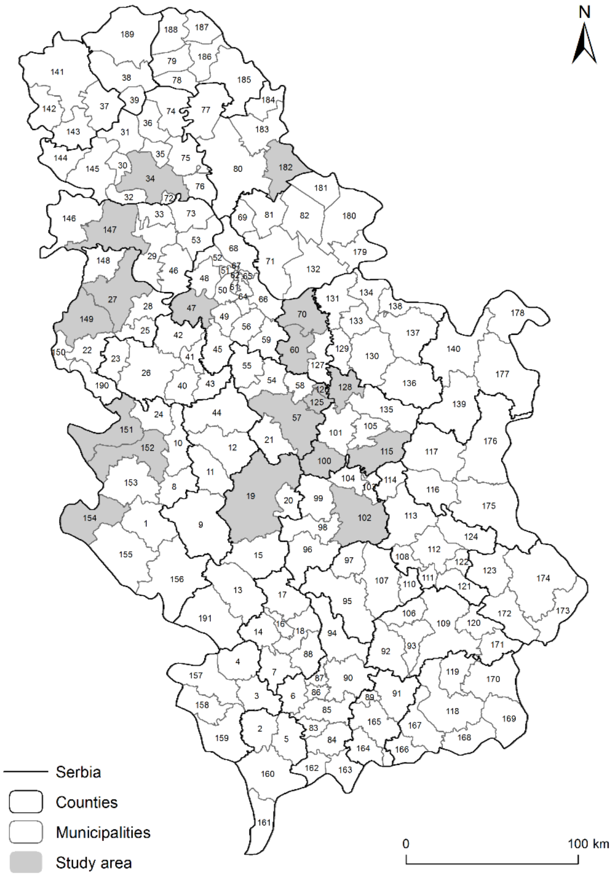


Figure B6.1 Study areas location (grey). Numbers refer to the ID of the municipality

Table B6.1 The ID of the municipality and belonging county in Serbia as shown in FigureB6.1

| ID | Municipality | County | ID | Municipality | County |
|---|---|---|---|---|---|
| 1 | Nova Varoš | Zlatibor | 96 | Brus | Rasina |
| 2 | Orahovac | Prizren | 97 | Blace | Toplica |
| 3 | Klina | Peč | 98 | Aleksandrovac | Rasina |
| 4 | Istok | Peč | 99 | Trstenik | Rasina |
| 5 | Suva Reka | Prizren | 100 | Rekovac | Pomoravlje |
| 6 | Glogovac | Kosovo | 101 | Jagodina | Pomoravlje |
| 7 | Srbica | Kosovo-Mitrovica | 102 | Kruševac | Rasina |
| 8 | Arilje | Zlatibor | 103 | Ćicevac | Rasina |
| 9 | Ivanjica | Moravica | 104 | Varvarin | Rasina |
| 10 | Požega | Zlatibor | 105 | Ćuprija | Pomoravlje |
| 11 | Lucani | Moravica | 106 | Bojnik | Jablanica |
| 12 | Cacak | Moravica | 107 | Prokuplje | Toplica |
| 13 | Novi Pazar | Raška | 108 | Merošina | Nivaša |
| 14 | Zubin Potok | Kosovo-Mitrovica | 109 | Leskovac | Jablanica |
| 15 | Raška | Raška | 110 | Žitoradja | Toplica |

| | | | | | |
|---|---|---|---|---|---|
| 16 | Zvečan | Kosovo-Mitrovica | 111 | Doljevac | Nivaša |
| 17 | Leposavić | Kosovo-Mitrovica | 112 | Niš | Nivaša |
| 18 | Kosovska Mitrovica | Kosovo-Mitrovica | 113 | Aleksinac | Nivaša |
| 19 | Kraljevo | Raška | 114 | Ražanj | Nivaša |
| 20 | Vrnjačka Banja | Raška | 115 | Paraćin | Pomoravlje |
| 21 | Knić | Šumadija | 116 | Sokobanja | Zalečar |
| 22 | Krupanj | Mačva | 117 | Boljevac | Zalečar |
| 23 | Osecina | Kolumbara | 118 | Vranje | Pčinja |
| 24 | Kosjerić | Zlatibor | 119 | Vladičin Han | Pčinja |
| 25 | Koceljeva | Mačva | 120 | Vlasotince | Jablanica |
| 26 | Valjevo | Kolumbara | 121 | Gadzin Han | Nivaša |
| 27 | Šabac | Mačva | 122 | Niška Banja | Nivaša |
| 28 | Vladimirci | Mačva | 123 | Bela Palanka | Pirot |
| 29 | Ruma | Srem | 124 | Svrljig | Nivaša |
| 30 | Bački Petrovac | South Bačka | 125 | Batočina | Šumadija |
| 31 | Vrbas | South Bačka | 126 | Lapovo | Šumadija |
| 32 | Beočin | South Bačka | 127 | Velika Plana | Podunavlje |
| 33 | Irig | Srem | 128 | Svilajnac | Pomoravlje |
| 34 | Novi Sad | South Bačka | 129 | Žabari | Braničevo |
| 35 | Temerin | South Bačka | 130 | Petrovac | Braničevo |
| 36 | Srbobran | South Bačka | 131 | Pozarevac | Braničevo |
| 37 | Kula | West Bačka | 132 | Kovin | South Banat |
| 38 | Bačka Topola | North Bačka | 133 | Malo Crnice | Braničevo |
| 39 | Mali Ioš | North Bačka | 134 | Veliko Gradiste | Braničevo |
| 40 | Mionica | Kolumbara | 135 | Despotovac | Pomoravlje |
| 41 | Lajkovac | Kolumbara | 136 | Zagubica | Braničevo |
| 42 | Ub | Kolumbara | 137 | Kučevo | Braničevo |
| 43 | Ljig | Kolumbara | 138 | Golubac | Braničevo |
| 44 | Gornji Milanovac | Moravica | 139 | Bor | Bor |
| 45 | Lazarevac | City of Belgrade | 140 | Majdanpek | Bor |
| 46 | Pecinci | Srem | 141 | Sombor | West Bačka |
| 47 | Obrenovac | City of Belgrade | 142 | Apatin | West Bačka |
| 48 | Surčin | City of Belgrade | 143 | Odzaci | West Bačka |
| 49 | Barajevo | City of Belgrade | 144 | Bač | South Bačka |
| 50 | Čukarica | City of Belgrade | 145 | Bačka Palanka | South Bačka |
| 51 | Novi Beograd | City of Belgrade | 146 | Šid | Srem |
| 52 | Zemun | City of Belgrade | 147 | Sremska Mitrovica | Srem |
| 53 | Stara Pazova | Srem | 148 | Bogatic | Mačva |
| 54 | Topola | Šumadija | 149 | Loznica | Mačva |
| 55 | Arandjelovac | Šumadija | 150 | Mali Zvornik | Mačva |
| 56 | Sopot | City of Belgrade | 151 | Bajina Bašta | Zlatibor |
| 57 | Kragujevac | Šumadija | 152 | Užice | Zlatibor |
| 58 | Raca | Šumadija | 153 | Čajetina | Zlatibor |

| | | | | | |
|---|---|---|---|---|---|
| 59 | Mladenovac | City of Belgrade | 154 | Priboj | Zlatibor |
| 60 | Smederevska Palanka | Podunavlje | 155 | Prijepolje | Zlatibor |
| 61 | Rakovica | City of Belgrade | 156 | Sjenica | Zlatibor |
| 62 | Savski Venac | City of Belgrade | 157 | Peć | Peč |
| 63 | Vračar | City of Belgrade | 158 | Dečani | Peč |
| 64 | Voždovac | City of Belgrade | 159 | Djakovica | Peč |
| 65 | Zvezdara | City of Belgrade | 160 | Prizren | Prizren |
| 66 | Grocka | City of Belgrade | 161 | Gora | Prizren |
| 67 | Stari Grad | City of Belgrade | 162 | Strpce | Kosovo |
| 68 | Palilula | City of Belgrade | 163 | Kačanik | Kosovo |
| 69 | Opovo | South Banat | 164 | Vitina | Kosovo-Pomoravlje |
| 70 | Smederevo | Podunavlje | 165 | Gnjilane | Kosovo-Pomoravlje |
| 71 | Pančevo | South Banat | 166 | Preševo | Pčinja |
| 72 | Sremski Karlovci | South Bačka | 167 | Bujanovac | Pčinja |
| 73 | Indjija | Srem | 168 | Trgovšte | Pčinja |
| 74 | Bečej | South Bačka | 169 | Bosilegrad | Pčinja |
| 75 | Abalj | South Bačka | 170 | Surdulica | Pčinja |
| 76 | Titel | South Bačka | 171 | Crna Trava | Jablanica |
| 77 | Novi Bečej | Central Banat | 172 | Babušnica | Pirot |
| 78 | Ada | North Banat | 173 | Dimitorvgrad | Pirot |
| 79 | Senta | North Banat | 174 | Pirot | Pirot |
| 80 | Zrenjanin | Central Banat | 175 | Knjaževac | Zaječar |
| 81 | Kovačica | South Banat | 176 | Zaječar | Zaječar |
| 82 | Alibunar | South Banat | 177 | Negotin | Bor |
| 83 | Stimlje | Kosovo | 178 | Kladovo | Bor |
| 84 | Urosevac | Kosovo | 179 | Bela Crkva | South Banat |
| 85 | Lipljan | Kosovo | 180 | Vršac | South Banat |
| 86 | Kosovo Polje | Kosovo | 181 | Plandište | South Banat |
| 87 | Obilić | Kosovo | 182 | Sečanj | Central Banat |
| 88 | Vučitrn | Kosovo-Mitrovica | 183 | ÄitiÜte | Central Banat |
| 89 | Novo Brdo | Kosovo-Pomoravlje | 184 | Nova Crnja | Central Banat |
| 90 | Pristina | Kosovo | 185 | Kikinda | North Banat |
| 91 | Kosovska Kamenica | Kosovo-Pomoravlje | 186 | Čoka | North Banat |
| 92 | Medveđa | Jablanica | 187 | Novi Kneževac | North Banat |
| 93 | Lebane | Jablanica | 188 | Kanjiža | North Banat |
| 94 | Podujevo | Kosovo | 189 | Subotica | North Bačka |
| 95 | Kuršumlija | Toplica | 190 | Ljubovija | Mačva |
| | | | 191 | Tutin | Raška |

CHAPTER 7

# FLOOD RISK PERCEPTIONS AND THE WILLINGNESS TO PAY FOR FLOOD INSURANCE IN THE VENETO REGION OF ITALY[6]

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## 7.1 Abstract

The floodplain of the Veneto region (north-east Italy) is one of the most inhabited and economically competitive urban landscapes in Europe. Moreover, the area is heavily flood-prone with large current and growing impacts in the light of climate change and socio-economic development. Recent flood events have severely affected the area, causing millions of euro in damage. Therefore, it is important for all flood-prone individuals to actively manage and limit flood risk through the wide-scale employment of flood risk management strategies. For this reason, an online-survey of Veneto region residents was conducted asking questions of flood risk perceptions, preparedness and preferences towards flood risk insurance schemes. An analysis of this data indicated that flood risk knowledge is essential to increase people capacity to tolerate and react to those events. Trust on authorities, however, make private mitigation measures less attractive. The same is for insurance schemes, where people seem reluctant to undertake them mainly due to the unaffordable costs. Social bonds have been seen to be important in individuals' perceptions and desirable actions toward floods. These results are critical for optimizing the government design of risk management policies, for supporting the insurance companies to assess their premiums' level and, and for providing recommendations on household risk mitigation measures.

## 7.2 Introduction

Across Europe, floods cause about one-third of the economic losses from natural hazards (de Moel and Aerts 2011) with an expected annual monetary losses of 4.2 billion euros in the European Union (Jongman et al. 2014). Flood impacts are large today and are projected to increase due to a combination of climate change and socio-economic development (IPCC 2014; Jongman et al. 2014; Winsemius et al. 2016). Therefore, managing flood risk is important. Property- or individual-level flood risk management strategies can play a role in flood risk management (Kreibich et al. 2015).

There is a broad range of actions that can be undertaken. Broadly speaking these protective actions can be divided into those that physically limit flood impacts and those that transfer financial losses (Hudson et al. 2016). Physical protective actions comprise anticipatory building adjustments such as permanent or temporary water barriers, moving personal goods to higher positions (López-Marrero 2010). The representative instrument for risk transfer is flood insurance. Flood insurance has gathered much attention due to increasing global flood losses (Surminski et al. 2015) and the ample evidence that insurance is more effective than ex-post disaster aid (Ranger and Surminski 2011). However, a limitation of flood insurance does not reduce by itself the potential damage suffered rather the negative long-run impacts from a slower recovery (von Peter et al. 2012; Abbas et al. 2015). For both sets of actions seeking out information has been seen to promote adaptation (Martin et al. 2007).

Moreover, the two sets of protective action (structural measures and insurance) can be interlinked. This is especially true if flood insurance is risk-based. Risk-based flood insurance means that premiums are altered in line with the risk faced. Therefore, an individual that undertakes protective actions should be offered a lower premium thereby acting as a risk management incentive. However, this avenue for flood risk management requires an individual to buy a flood insurance policy or physical flood protection measures. Therefore, for a given study area it is important to understand the shape of the willingness to pay (WTP) distribution for insurance. This is because for a flood insurance market to be developed, there must be a sufficient degree of overlap between the premiums charged and what people are willing to pay. Therefore, in order to understand the employment of property- or individual-level flood risk management strategies it is important to explore an individual's knowledge about and preferences towards flood risk management. Understanding an individual's knowledge is essential for understanding an individual's willingness to implement property-level adaptation strategies (Botzen et al. 2009b; Botzen and van den Bergh 2009). Given the movement towards integrated flood risk management where all individuals threatened by flooding are expected to play a role in overall flood risk management, this is an important research agenda (Bubeck et al. 2016). Addressing this research agenda can provide insights and recommendations to improve overall flood risk management practices (Pathirage et al. 2012).

In understanding how individuals prepare for flooding the Protection Motivation Theory (PMT) has become a leading theory in explaining the uptake of protective actions (Bubeck et al. 2012; Bamberg et al. 2017). The PMT frames decision making as the eventual result of two key elements: the threat appraisal, the degree to which someone feels threatened, and coping appraisals, someone's self-stated personal capacity to undertake protective actions. While it is debated which of these two factors is the most important (Bubeck et al. 2012; Atreya et al. 2015; Bamberg et al. 2017; Richert et al. 2017). An individual must consider themselves to be threatened by flooding and capable to undertake a particular strategy to employ a given adaptation strategy.

Threat and coping appraisals reflect an individual's subjective understanding of the flooding threat faced. Subjective risk perceptions occur due to the range of local conditions (Salvati et al. 2014) altering how an individual conceptualizes both the flooding threat faced (Slovic 2016) and their potential adaptation strategies (Thieken et al. 2016). Therefore, given the role of the subjective understanding of flood impacts and experiences, it is critical to understand which local conditions are essential for determining action. Once, these factors are understood better overall flood risk management strategies can be designed.

The various factors that can influence this subjective understanding of flood risk originate from a variety of sources. One source is an individuals' socio-economic conditions as different socio-economic conditions expose people differently to disaster risk (Laska et al. 2007; Hale et al. 2018) and their ability to act (see, Qasim et al. 2015; Osberghaus 2017; Bera and Daněk 2018). A second source is an individual's psychological characteristics. The relevant psychological factors can be defined as worry, risk perception and previous experience. These factors can be useful predictors for an individual willing to take protective actions (Atreya et al. 2015; Richert et al. 2017). A third set is geographical attributes can influence people' willingness to undertake protective actions. For instance, a positive correlation has been found with proximity to the source of the hazard due to the greater promise of the threat in daily life (Botzen et al. 2009b; Petrolia et al. 2013; Atreya et al. 2015).

A final set of influencing factors is based on how the individual is integrated into society. An example is the trust of an individual in local flood risk management authorities given that flooding is a complex problem (Wachinger et al. 2010). Similarly, trusted risk communication efforts can encourage proactive flood risk management (Samaddar et al. 2012). Moreover, if an individual's neighbours undertake proactive flood risk management, they are also more likely to undertake a protective action as well (Lo 2013). These social interconnections are known as social capital, which is based on an individual's trust in their community or across different groups in society (Pelling and High 2005). Social capital is a local concept, and these local interactions can create a degree of 'place attachment'. The concept of place attachment can explain the relationships the human has with the surrounding environment (Low and Altman 1992). These bonds to both the 'place' and 'people' can affect disaster preparedness and response in the wake of floods, as reported by Mishra et al. (2010).

Overall, given the importance of local conditions and cultural contexts in determining whether an individual undertakes a protection action in a range of studies is required. In order to further develop this literature, we conducted a survey of the Veneto area of North East Italy by conducting an online survey in order to better understand flood risk perceptions and the WTP for flood insurance. Understanding these factors is vital for supporting the development of flood insurance in Italy. With this in mind, our core research objectives are:

1) Understanding the threat appraisal of individuals and explanatory power do psychological, experiential and socio-economic variables have in this regard;
2) Evaluating the role of flood threat appraisal compared to a set of other natural hazards, called risk salience valuation
3) Framing the preparedness of people and their coping actions in front of possible flood event occurrence;
4) Understanding the role of flood insurance schemes and to which extent people are willing to pay for those products.

Our findings are relevant for the design of effective risk management policies by arguing for the active inclusion of social aspects into policy design. When designing flood risk management policy bi-directional communication is essential for helping threatened individuals to understand the problem and co-create possible solutions by proactively participating in the decision-making process.  This is because as argued by Baan and Klijn (2004) "sustainable solutions can be found only when qualitative research on human values and perceptions is investigated".

## 7.3 Case study area

### *7.3.1 Veneto region physical geography and flood risk*

Italy is particularly sensitive to flooding as over the period of 1990-2006 Italy suffered from an economic loss of around 20bn euros in total (Llasat et al. 2010). Moreover, this period is not as exceptional as Italy's history is marked by devastating flood disasters (Mysiak et al. 2013).
The Veneto region encompasses an area of 18400 km$^2$ of which the floodplain occupies about 55%. The plain was formed by the actions of the Po, Adige, Brenta, Piave, and Tagliamento

rivers (Dal Ferro et al. 2016). The floodplain of the Veneto region has a high level of human and landscape interactions (Alfieri et al. 2016; Sofia et al. 2017). Therefore, the region is an example of the consequences that such strong interaction might cause. Overall, the region has a long history of flood disasters due to this human-nature interaction (Castiglioni 1977). The Veneto region has suffered significant floods in November 1966 (Regione del Veneto 2011) and 2010 (Figure 7.1). The 2010 flood was one of the most severe floods recorded in the last 50 years. Between 31$^{st}$ October and 2$^{nd,}$ November 2010, the region registered an average of 173mm of rainfall with peaks of 540 mm (Coelli and Manasse 2014). This flood caused the displacement of 500,000 people and caused over a billion euros of damage. Moreover, according to Sofia et al. (2017), there has been an intensification of flood events since the early 20$^{th}$ century to 2010.

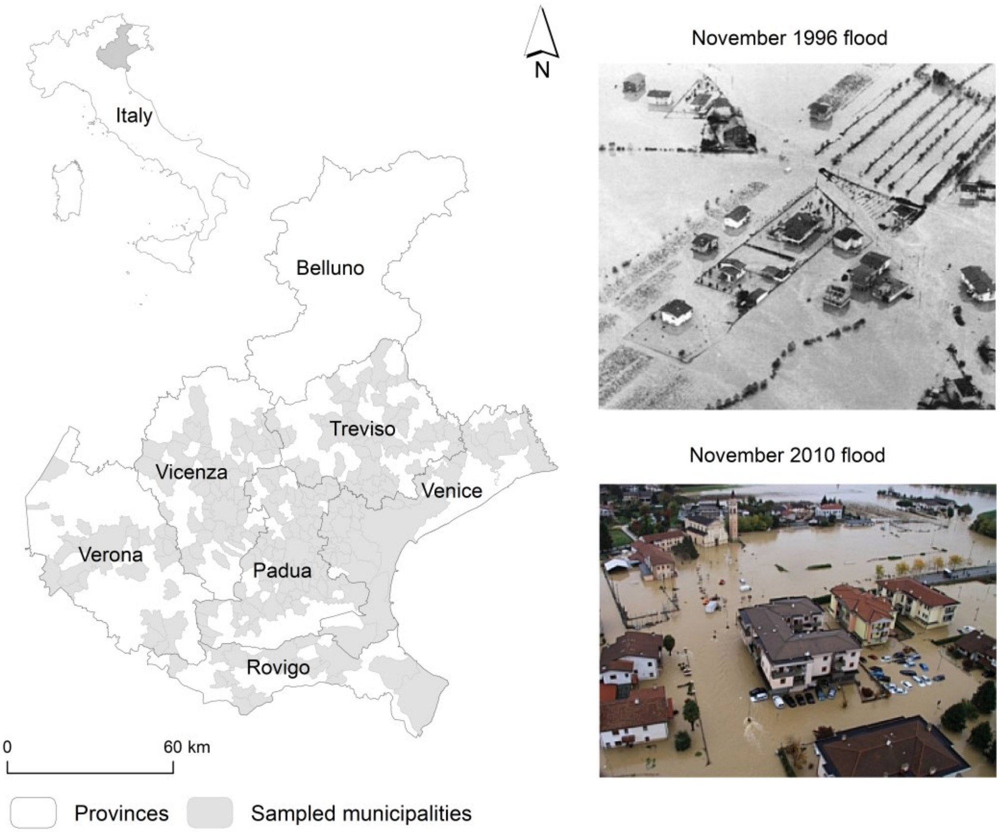


Figure 7.1 Veneto region study case and related provinces. Sampled municipalities are coloured in grey. On the right November 1996 (Mont D'Arpizio 2016) and 2010 floods (Meloni 2012)

### 7.3.2 The flood insurance market in Italy

Insurance schemes across the globe develop based on the environmental and cultural contexts of the individual country, which produces a range of different insurance market (CEA 2011; Maccaferri et al. 2012; European Commission 2017).

The consequence of the individualized development process for Italy is the absence of a well-developed flood insurance sector for private-property. This is highlighted by the finding that in 2016 only 2.1% of the whole private-property insurance market was insured against flooding (Ania 2016). Moreover, the total coverage or compensation available from the available insurance coverage is also limited (Ania 2016). In response to this ill-developed aspect of the insurance market, the Italian government copes with flood occurrence by declaring a state of calamity or emergency (*stato di calamità* or *stato d'emergenza* respectively) depending on the subjects involved (Table A7.1, in the Appendix A).

Once a state of emergency has been declared, those affected can receive economic assistance from the government. Accordingly, Zampetti et al. (2012) find that this has resulted in large government expenditures for financial aid, but this aid that was still insufficient to fully compensate the reported flood damage. While ex-post support can assist the recovery process for those affected by a flood, it also translates into people's lack of adoption of protective measures or insurance. This mechanism is called charity hazard (Raschky et al. 2013), in which altruism could play a negative role in people's flood risk management behavior (Buchanan 1975).

## 7.4 Methods and data section

### 7.4.1 Survey description and sample characteristics

The data used in this study was collected through a questionnaire linked to the online public portals of the Department of Land, Environment, Agriculture and Forestry website (University of Padova). The Department Director revised and approved the questionnaire, which was subsequently pre-tested with a sample of 30 people. The questionnaire was accessible from late March until December 2017. The questionnaire was disseminated via social media across several environmental agencies, private associations and municipalities. Concurrently, an email to all the Civil Protection Departments of Veneto region containing the survey was sent to aid the diffusion of the survey further. Finally, a hard copy was provided to reach the elderly.

The questionnaire included 33 questions (quantitative and qualitative) and was structured in three sections: flood risk perception, the preparedness actions, the acceptance of an insurance scheme and the willingness to pay for flood insurance. A total of 849 responses were collected. Once all responses were collected, responses from Belluno province were excluded since flood events in this mountainous landscape are of a very different origin and were not directly comparable. Out of the 512 municipalities, 236 were covered by the respondents, giving the survey representativeness of 95% (confidence interval) and a margin of error of 4.69%.

The data from closed-ended questions were coded whereas qualitative answers coming from multiple choice questions (including spontaneous additions from respondents) were categorized, and then coded similarly to the other questions. A complete description of the variables is found in Table 7.1.

The majority of respondents are originated from Padua (31%), while the smallest contributing area was Rovigo (7%). Self-reported males account for 58% of responses and self-reported females for 41% of responses. The average age is 43 years old. The majority of respondents reported having a high school diploma (38%), while 35% of respondents have a university degree, while 13% have a higher degree. The majority of respondents are employed (71% are employed), while the remaining tend to be jobless or retired. However, while the majority of people are employed, just 40% feel comfortable with their income. Regarding family composition, the average household consisted of 3 members in the study area. Concerning personal familiarity with flood events, 58% of respondents have experienced a flood, 12% have suffered damage from a flood, and 56% know someone that experienced financial losses from flooding. Homeowners are 63% of the sample. The sample size and characteristics had adequate power to detect the variability of the region while matching the overall characteristics of the local population.

The key dependent variables are the threat appraisal, flood preparedness, the WTP for flood insurance. The threat appraisal variable was calculated by averaging the feeling of danger for one's house and one's physical safety. The flood preparedness variable was gathered by asking people their personal feeling of readiness, providing a subjective viewpoint. The insurance WTP question was an open-ended question where the respondent was invited to provide how much they would be willing to pay for an annual insurance policy in protection of flood events, considering a limited coverage for the building (excluding furniture), with a coverage of 50% of the value of the building and a deductible of 5% of damage suffered.

Risk salience defined as "the phenomenon that when one's attention is differentially directed to one portion of the environment rather than others, the information contained in that portion will receive disproportionate weighting in subsequent judgments" (Taylor and Thompson 1982) has been used as comparative variable of flood threat appraisal toward a set of other natural hazards. Also, these values have been used as a proxy for risk perception and preparedness. As argued by Mccoy and Walsh (2017) risk salience can be used to explain individual behaviours and mitigation actions that might be different according to the source of danger. This is of particular importance because, in disaster research, risk salience has not been widely investigated. This is a possible limitation as risk salience may provide further insights into the current low levels of awareness and preparedness of flood events by proposing different hazard scenarios. According to the physical geography of the area, a set of high-damaging low probability hazards have been proposed, such as landslides, floods (again), tornado, sea storms, and earthquakes.

Table 7.1 Variables description, unit of measurement, mean and standard deviation (SD) value.

| **Variable name** | **Variable type and unit of measurement (model)** | **Mean** | **SD** |
|---|---|---|---|
| *Risk perception* | | | |
| Threat appraisal | Dummy (High=1, otherwise=0) | 0.29 | 0.45 |
| Likelihood of occurrence | Dummy (High=1, otherwise=0) | 0.51 | 0.5 |
| Flood cause | Dummy (Human>Climate=1; otherwise=0) | 0.9 | 0.3 |
| Flood risk knowledge | Dummy (High=1, otherwise=0) | 0.37 | 0.48 |
| Trust on flood mitigation actions | Dummy (High=1, otherwise=0) | 0.19 | 0.39 |
| Place attachment | Dummy (High=1, otherwise=0) | 0.73 | 0.44 |
| Perceived preparedness | Dummy (High=1, otherwise=0) | 0.19 | 0.4 |
| *Preparedness actions* | | | |
| Active actions (seeking for information, sandbags, insurance policy, emergency kit, etc.) | Dummy (High=1, otherwise=0) | 0.75 | 0.43 |
| None actions might help me | Dummy (High=1, otherwise=0) | 0.06 | 0.24 |
| None actions because I am not at risk | Dummy (High=1, otherwise=0) | 0.08 | 0.27 |
| None actions because it is Government task | Dummy (High=1, otherwise=0) | 0.17 | 0.38 |

| | | | |
|---|---|---|---|
| *Flood experience* | | | |
| Direct experience | Dummy (yes=1, otherwise=0) | 0.59 | 0.49 |
| Direct experience with damage | Dummy (yes=1, otherwise=0) | 0.12 | 0.33 |
| Indirect experience with damage | Dummy (yes=1, otherwise=0) | 0.57 | 0.49 |
| Proximity to river | Dummy (≤500 m, otherwise=0) | 0.31 | 0.46 |
| | | | |
| *Province* | | | |
| Padua | Dummy (yes=1, otherwise=0) | 0.32 | 0.46 |
| Rovigo | Dummy (yes=1, otherwise=0) | 0.07 | 0.25 |
| Treviso | Dummy (yes=1, otherwise=0) | 0.17 | 0.37 |
| Venice | Dummy (yes=1, otherwise=0) | 0.16 | 0.37 |
| Verona | Dummy (yes=1, otherwise=0) | 0.08 | 0.27 |
| Vicenza | Dummy (yes=1, otherwise=0) | 0.21 | 0.4 |
| | | | |
| *Risk salience* | | | |
| Feeling of danger from earthquake | Dummy (High=1, otherwise=0) | 0.37 | 0.48 |
| Feeling of danger from tornado | Dummy (High=1, otherwise=0) | 0.49 | 0.5 |
| Feeling of danger from flood | Dummy (High=1, otherwise=0) | 0.35 | 0.48 |
| Feeling of danger from landslide | Dummy (High=1, otherwise=0) | 0.05 | 0.23 |
| Feeling of danger from storm surge | Dummy (High=1, otherwise=0) | 0.02 | 0.14 |
| | | | |
| *Socioeconomics* | | | |
| Gender | Dummy (Female=1, otherwise=0) | 0.41 | 0.49 |
| Age | Category (≤30=1; 31-50=2; 51-65=3; 65+=4) | 2.11 | 0.85 |
| Education | Dummy (University and higher=1, otherwise=0) | 1.77 | 0.63 |
| Income | Dummy (High=1, otherwise=0) | 0.4 | 0.49 |
| Family members | Category (≤2=1; 3-4=2; 5+=3) | 1.77 | 0.63 |
| Employment | Category (Employed=1 no employed=2 retired=3) | 1.37 | 0.67 |
| | | | |
| *Household characteristics* | | | |
| Home ownership | Dummy (yes=1; otherwise=0) | 0.65 | 0.48 |
| Presence of underground | Dummy (yes=1, otherwise=0) | 0.54 | 0.5 |
| House surface (mq) | Category (≤100=1, 101-149=2, 150+=3) | 1.92 | 0.84 |
| | | | |
| *Insurance* | | | |
| Insurance coverage | Dummy (yes=1, otherwise=0) | 0.23 | 0.42 |
| Willingness to insure (imitation)* | Dummy (High=1, otherwise=0) | 0.3 | 0.46 |
| Willingness to insure (once flooded)* | Dummy (High=1, otherwise=0) | 0.48 | 0.5 |
| Willingness to pay* | Continuous (Euro) | 272.45 | 773.54 |

| | | | |
|---|---|---|---|
| Willingness to have National compulsory insurance only for people at risk | Dummy (High=1, otherwise=0) | 0.57 | 0.5 |

*This question has been addressed only to individuals without any insurance coverage

### *7.4.2 Statistical methods*

The statistical analysis carried out has the purpose of finding correlations and directions rather causal relationships. This is due to the limitations due to the sampling approach and potential endogeneity when trying to identify causal relationships. Therefore, our study identified directions for future research that can employ experimental statistical techniques.

Logit models were carried out to explore a wide range of variables possibly influencing people threat appraisal, and perceived preparedness. Whereas for the willingness to pay we ran a Heckman, selection model, also called 'generalized Tobit model' (Amemiya 1984; Amemiya 1985). This is because many respondents provided a zero WTP or did not answer. However, the model did not display sufficient statistical quality. Therefore, a qualitative analysis has been carried out underlying the limitation mentioned above.

Concerning the logit models, due to the nature of the sample (self-selected), a reduction method is employed to help identify which variables may be the most important for the locals. This means that the first evaluation comprised of running the logit models with all the variables (Table 1) and then removing non-significant variables (at the 10% level) for the complete model output. For each model, the estimate (β), standard errors (S.E.), significant values (*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$), and odds-ratio have been shown.

## 7.5 Results and discussion

### *7.5.1 Threat appraisal*

The overall threat appraisal seems to be quite low, with a mean value of 0.29 (see Table 7.1), though the respondents were slightly more afraid for their property than for themselves.

The variables that explain a higher individual's perception of flooding, being a threat after the backward iteration process, are shown in Table 7.2. The results indicate that a higher feeling of danger is positively associated with flood risk knowledge and a belief that floods have a high likelihood of occurrence. These relationships are unsurprising as they are directly related to concern. Similarly, respondents living close to major rivers also were associated with a higher threat appraisal. Communities living in the province of Rovigo feel a higher level of flood risk perceptions even if they have not been experiences recent flood events. This means that past catastrophic events (i.e. Po river overflows) are lively in peoples' minds or they strongly see related issues, i.e. land subsidence (Carminati and Martinelli 2002; Manieri 2009; Baldi et al. 2009; Amadio et al. 2013b). Finally, homeownership was also positively associated with higher threat appraisal. Homeowners have more risk-related problems due to the higher possible losses they can suffer during a flood, as compared to tenants. This means that the sample interview showed a high-risk awareness (as a combination of worry, knowledge and expected occurrence), and the more people are aware, the larger the demand to reduce such risk (Raaijmakers et al. 2008).

However, a negative association was found between trust and threat appraisal. Trust forms an essential element of social capital which may indeed display a negative relationship with risk perceptions as was found in a study for Austria (Babcicky and Seebauer 2017). The open-ended question responses indicate that this relation may have occurred from the firm belief that the state was insufficiently managing the threat posed by flooding. For example, about 35% of respondents believed that the finances for flood risk management were poorly managed combined with a perceived believe that flooding was not a high priority (27%). It appears that respondents judged their feeling of worry based on a fragile sense of protection the institutions give to them, being quite generalized in several Italian case studies (De Marchi et al. 2007; Scolobig et al. 2012).

Table 7.2 Logit regression: determinants of threat appraisal (n=845)

| **Explanatory variable** | **β** | **S.E.** | **Odds Ratio** |
|---|---|---|---|
| Likelihood of occurrence | 2.382*** | 0.290 | 10.824 |
| Flood risk knowledge | 0.459** | 0.224 | 1.583 |
| Trust | -0.727** | 0.327 | 0.483 |
| Direct experience with damage | 0.991*** | 0.311 | 2.693 |
| Indirect experience with damage | 0.428* | 0.243 | 1.534 |
| Proximity to river | 0.609** | 0.243 | 1.838 |
| Homeownership | 0.538* | 0.330 | 1.713 |
| Rovigo | 1.210*** | 0.445 | 3.354 |
| Verona | 0.704 | 0.500 | 2.022 |
| Constant | -3.839*** | 0.463 | 0.022 |
| Log L | 496.485 | | |
| Cox and Snell pseudo $R^2$ | 0.242 | | |
| Nagelkerke pseudo $R^2$ | 0.348 | | |

| % of correctly classified cases | 78.2 |
|---|---|

However, Kuhlicke et al. (2011) reported that in Italy when the trust in voluntary organizations, municipalities and the Civil Protection people can successfully decrease the vulnerability of individuals. This contradiction may be the result of the sample self-selection where respondents with a propensity to not trust the current flood risk managers were more likely to respond.

### *7.5.2 Risk salience*

Section 7.4.1 noted we used risk salience as a proxy for risk perception and preparedness across disaster types. However, after the backward iteration process, none of the selected risk salience variables is included in the final model.

Despite this, the most fearfully perceived hazard were tornado events (see Table 7.1). The occurrence of tornadoes in Italy has received little attention so far, due to poor documentation (Miglietta and Matsangouras 2018). Although infrequent, Veneto region is prone to these events registering in 2015 an F4 tornado in Venice province causing one dead and 84 injured (Pipinato 2018). This event received an exceptional degree of media coverage and for this reason, easily recalled when asked about fearful hazardous events. Memories are shaped (and falsely shaped), by people's knowledge and beliefs, attention, and motivation (Kaplan et al. 2015). All these processes can be exacerbated by the media and the information coming from them.

Following tornadoes, earthquakes are the second more feared events. The Veneto region due its topography and geology is not highly prone to seismic hazards. However, the higher concern might come from central Italian earthquakes. More so than tornadoes, media coverage of earthquakes has, after the 2009 L'Aquila earthquake, acted as an amplifier of risk (Scolobig et al. 2014). Flooding is ranked third on the scale. We can detect a slightly higher risk perception when framed about other potential hazards (0.29 vs 0.35). A McNemar test is used to determine if there are differences on a dichotomous dependent variable within the same population. The result is 0.000 significant (on 840 valid cases) demonstrating that the two groups are statistically different. Note 481 people remained with their low levels of threat appraisal, whereas 118 presented an increased feeling of danger. Just 61 decreased showed lower levels of dread. This finding indicates that the hazard background in people's mind contextualizes their survey respondent answers. Understanding this background can allow research and policy to be translated into effective action. For example, the role played by information and media needs to be actively considered in order to make sure flood risk management policy is contextualized correctly.

### *7.5.3 Flood preparedness*

The average respondent's self-preparedness to deal with a flood occurrence is relatively low (0.19, Tab. 7.1). Approximately 71% of respondents' state that they have already taken or will undertake in the next months some attempt to limit flood damage or inform themselves. Nearly 16 % of respondents stated that they do not intend to take any preparatory actions. Primarily, this is because of their belief that it is the government's responsibility to protect them from flooding. The remaining 6% display a more fatalistic perception of flooding in that taking action at the individual level is not effective, displaying a sense of powerless.

Table 7.3 indicates a positive correlation between flood risk knowledge and perceived preparedness. Additionally, it appears that when perceived preparedness is high, they feel less the danger because of confidence in their capacities to cope with them (hence the negative correlation with the threat appraisal). However, this result might seem counterintuitive in light of the empirical literature (i.e. Slovic 1987; Kellens et al. 2013; Qasim et al. 2015) which argues that, for example, negative emotions, such as worry of flooding can encourage a person in taking preparatory measures (Hudson et al. 2017). However, Raaijmakers et al. (2008) debate that a better-prepared society will worry less about the eventual flood similar to how increases in social capital may strengthen a respondent's perception that they can undertake preparation actions at the expense of lower risk perceptions as flooding is seen as less of a threat (Babcicky and Seebauer 2017).

In the context of authorities, again trust seems to be predictive of flood preparation. However, this is contrary with respect threat appraisal. Cisternas et al. (2016) find that this is a situation in which trust does not favor people taking responsibilities for their flood preparedness.

Direct experience helps to motivate people to prepare for future floods. Unexpectedly, suffering an economic loss from a flood does not the same potential influence; rather it appears that the experience itself is sufficient. The presence of a nearby river is associated with a lower level of preparedness. An explanation of this is that these residents are less directly influenced by a possible flood and hence may overestimate their actual level of preparedness.

Gender appears to be a predictor of self-perceived preparedness level as we find a tendency for males to be associated with a higher value. In Italy, in line with the finding highlighted by Roder et al. (2017), the position of women in the job-market sector results in women displaying the lowest labor market participation compared to other developed countries (Bernardi 2004). Also, their lower perceived preparedness is also found in other studies regarding Northern Italy (see, e.g. (De Marchi et al. 2007; Miceli et al. 2008; Scolobig et al. 2012)). For example, De Marchi et al. (2007) argue that men have a higher perceived preparedness because of their greater involvement in local associations and social networks.

Table 7.3 Logit regression: determinants of personal flood preparedness (n=831)

| **Explanatory variable** | **β** | **S.E.** | **Odds Ratio** |
|---|---|---|---|
| Threat appraisal | -0.672** | 0.296 | 0.511 |
| Flood risk knowledge | 1.976*** | 0.237 | 7.212 |
| Trust | 0.775*** | 0.265 | 2.170 |
| Risk salience: flood | 0.435 | 0.280 | 1.545 |
| Direct experience | 0.800*** | 0.249 | 2.226 |
| Proximity to river | -0.435* | 0.258 | 0.647 |
| Padua | -0.888** | 0.342 | 0.411 |
| Rovigo | -0.678 | 0.523 | 0.508 |
| Treviso | 0.108 | 0.349 | 1.114 |
| Venice | -0.693* | 0.362 | 0.500 |
| Verona | 0.254 | 0.401 | 1.289 |
| Gender | -1.061*** | 0.258 | 0.346 |
| Place attachment | 0.875*** | 0.294 | 2.399 |
| Constant | -2.960*** | 0.442 | 0.052 |
| Log L | 540.530 | | |
| Cox and Snell pseudo $R^2$ | 0.236 | | |
| Nagelkerke pseudo $R^2$ | 0.370 | | |
| % of correctly classified cases | 83.5 | | |

Others socio-economic variables failed to have significant direct effects on flood preparedness intentions, in addition to building characteristics, and risk salience. The role of place attachment and flood preparedness has been discussed by Mishra et al. (2010). Those communities showing the strongest bonds have more capacity to be prepared for risky situations. We find evidence supporting this argument via our study of place attachment which indicates a positive correlation with perceived preparedness. This, in turn, highlights the importance of social capital in determining how individuals act in the face of flooding.

### *7.5.4 Willingness to insure and to pay for flood insurance*

Section 7.3 noted that the flood insurance penetration rate in Italy is very low. However, over 18% of the sample stated to have flood insurance coverage, which is significantly above the average penetration rate in the Italian flood insurance market. This value may indicate an increased interest towards insurance or a false belief that their home insurance covers damage caused by flooding (Oulahen 2015). This uncertainty is supported by the fact that about 5% of respondents did not know if their house was insured or not. This may indicate a low level of financial knowledge. Only people property-owning and females' respondents were found to be more likely to buy an insurance policy. These were the only two variables from a logistic regression model which were found to be significant at the standard levels.

On analyzing the reasons behind those who are not protected by insurance (multiple answers were allowed), 23% of respondents stated that they were interested, but the cost was not convenient. About one-fifth of respondents stated that they to do not know of the existence of these products (holding across education levels). Similar to the results regarding threat appraisal 17% of respondents did not consider the purchase of flood insurance because they do not feel to be at risk of flooding. Moreover, 14% of respondents expect financial assistance from the government in case of flood damage, indicating the presence of charity hazard as this was their reasoning for not buying flood insurance. Finally, the remaining 13% stated that they did not believe in the insurance system overall and hence did not buy insurance. Additionally, while the Italian national budget has been able to cope with the costs of post-catastrophe relief activities, this will become a larger burden in the future as flood risk grows. Moreover, according to Zampetti et al. (2012), the official costs of damages presented by the municipalities in the period 2009-2012, amounts to 2.2 billion euros, almost three times the resources made available. This combination of responses is a problem for the Italian flood insurance market as they show how the demand for private insurance coverage is limited. This problem is further compounded by the reliance on inadequate central government compensation creates a growing recovery financing gap. Overall, there are significant hurdles to overcome for the successful development of an insurance market.

A potential avenue for overcoming these hurdles is through increased social interaction. This is because 19% of respondents considered investing in insurance if they knew some friends, neighbourhood or close people to have an insurance policy. As found by McGuire (2015), insurance purchase is more influenced by social norms and societal expectations. Additionally, reducing the degree of government compensation would also likely increase the potential for a flood insurance market to develop. This is because a reduction in government compensation will lessen the influence of charity hazard, which in turn increases the opportunity cost of not being insured. An increase in the opportunity cost of not being insured should result in the long-run translate into increased demand for flood insurance. However, reforming current governmental behavior to not provide ad-hoc compensation may be difficult. Therefore, a stepping stone may be to only provide ad-hoc compensation to those who actively protected themselves with a sufficient degree of flood insurance coverage. In effect, this policy change would allow private insurers to provide compensation for relatively common floods, while the government assists in compensating extreme flood events. Developing a public-private partnership in this direction may allow both sets of actors to provide sufficient compensation after a flood to promote a sustainable recovery.

Section 7.4 noted that WTP was included in the survey via an open-ended and self-stated continuous value. Table 7.4 describes the frequency-bins of the values provided by the people without any insurance coverage, providing a first attempt at identifying solutions for the uninsured population.

Table 7.4 Open-ended WTP (in Euros per year) aggregated into three classes.

| **Bid offered** | **Frequency** | **%** |
|---|---|---|
| 0 | 37 | 8.0 |
| >0 - 250 | 309 | 67.0 |
| >250 - 500 | 46 | 10.0 |
| >500 | 69 | 15.0 |
| Total | 461 | 100 |

No answers, n=186

Among those interested in undertaking such a policy, they most would spend in a range of 0 to 250 euro per year. According to this range, ones might have assumed from the answers provide and described above, that the most people cannot afford were on a range higher than 250 euro. However, the high rate of no-answers and some zero WTP values might indicate a misunderstanding in the complex task of determining what they would be willing to pay. A modest percentage of respondents (16%) stated that they would spend 500 euros annually reaching, in some cases, up to 1000 euros. Among the latter respondents, 24 respondents have a WTP higher than 5% of the average regional annual income, which could be considered unaffordable.

An additional source of comparison would be towards the potential premiums charged. Premiums are estimated according to the data and methods presented in Appendix. The data presented in Appendix B (Table B7.1) indicates that risk-based insurance premiums could be over 800 euros a year. This is due to a combination of high flood risk and relatively low levels of flood protection. Flood protection infrastructure is estimated to be designed against the 1/60 year return period (Scussolini et al. 2016). The risk-based premium estimate with the current protection standard is clearly far outside of what households are willing to pay. This finding holds if protection standards are doubled as the premiums fall to over 500 euros a year. Increasing the protection standards to a 1/250-year protection standard would render premiums to about 250 euros a year. This increase in protection standards would render premiums within the willingness to pay range for about 25% of respondents. Therefore, without an increased understanding of the benefits of insurance by itself, it appears very difficult to establish an insurance market based on risk-based premiums by merely increasing flood protection.

Overall, the respondents appear reluctant to undertake insurance coverage for flood events. This is problematic for insurers because flood risk tends to be geographically clustered, limiting the potential for geographical diversification, and result in large numbers of claims in a short period (Charpentier 2008). This can result in primary insurers having difficulty in insuring flood risk at an affordable rate, which may become more difficult in the future (Hudson 2017). This is unless there are suitable mechanisms in place to support them (Kunreuther 2015). For example, national compulsory insurance for flood-threatened communities bounded with government support can help develop sustainable flood insurance sectors. About 45% of respondents support the idea to have national insurance for the communities that live in risky areas. However, Linnerooth-Bayer et al. (2011) show that low trust in key institutions and lack of a proper market in the country raise the question whether the institutional context in Italy is sufficiently mature for such schemes to operate. Assuming that flood insurance was based compulsory for all households in the Veneto region, the estimated insurance premium (see Appendix B in the supplementary information) falls to between 30-40 euros per year. This value is within the WTP range of 92% of the responses given making highly likely to be acceptable. However, structuring flood insurance like this would remove the risk signalling ability of flood insurance, lowering the overall adaptation potential. Moreover, in order to prevent such cheap insurance premiums acting as a subsidy for further developing flood-prone areas additional spatial planning or enforced flood-proofing will be required.

### *7.5.5 Implications of the results*

The results presented above have two interlinked implications for flood risk management in Italy. This first implication is that while sufficient flood insurance coverage can bring several advantages regarding flood risk management. However, the survey results indicate that this is a very sensitive topic, as nearly 50% of the sample did not provide a value for the WTP question, was a far higher non-response rate than the other survey questions relating to individual-level flood risk management strategies. Therefore, in order to overcome these hurdles, further risk communication and education campaigns are required in order to help describe the benefits of insurance and to normalize insurance as a possible adaptation action. This is because respondents with a better-developed flood-knowledge displayed positive responses across all areas of study. A potential target of this communication or education campaign is developing the support for the compulsory insurance fund the majority of respondents supported. Moreover, by formalizing disaster compensation through a compulsory insurance fund, the government's wish to act after a flood can be better integrated with the insurance industry's responses. This combination of actors can help to limit the occurrence of charity hazard.

The risk education campaigns may not only bring positive benefits regarding insurance but also for threat appraisal and the level of perceived preparedness. This is due to the positive association found between knowledge and these variables. However, a logistic regression (see Table A7.2, Appendix A) identifies that the most significant predictor of flood knowledge is knowledge through, or links with, friends and family. The relative importance of this for our sample may indicate that many people are passive receivers of expert knowledge that might translate into an ineffective identification of the actions to be done. Especially when combined with the findings from the risk salience investigation, that evidenced the essential understanding of the local context of human behaviours. This, in turn, implies that communication efforts should be tailored to the specific individuals or communities. Additionally, the importance of friends and family regarding flood risk knowledge may further indicate the importance of community-based adaptation projects to help re-enforce this linkage and informal avenues of knowledge dissemination. In this context good coordination and networking between individuals and groups of organizations and authorities are essential for effective governance, leading to a consensus-building to make decisions. Government is the key to arise a culture of risk, stimulating people's adoption of private mitigation measures showing a strong leadership sharing common goals. Trust plays a fundamental role in this regard because mistrust might be the cause of unsatisfactory performance level in the disaster management. The Civil Protection Departments, as key actors in flood management and policy, can act as bridges in transmitting trust to peoples and authorities likewise, being at the centre of community-driven actions. They need to be part of the everyday conversation with the community, using their communication channels, i.e. social media, newspaper etc., increasing civic participation in disaster planning and response. The capacity of communities to develop a degree of resilience depends on pre-existing conditions evidenced in this research. The premises evidenced so far do not depict a totally negative situation marked by a low level of awareness, preparedness, willingness to invest financially in insurance products and low trust in authorities' actions. It evidenced even a strong social cohesion, a higher sense of knowledge and responsibility that is the core of community resilience that is a strategy for disaster readiness.

## 7.6 Conclusions and practical implications

Under the lens of the increasing flood impacts worldwide, there is a growing need for well-developed and considered policy interventions. Among these interventions, public policy needs to focus their attention towards increasing the understanding of natural hazard risks to increase their awareness and mitigation behaviours. In line with this, the role of insurance for flood protection gained much attention as an effective tool that could promote a greater degree of forward-looking disaster risk management in places where this instrument is still underemployed.

To address this task, a northern Italian region, Veneto, was chosen as the study area. The Veneto region is a highly anthropogenic landscape that is prone to flooding creating a large economic burden. An online survey was conducted asking the respondents three main topics: flood risk perception, the flooding preparedness actions, and flood insurance preferences. The statistical and qualitative analysis was conducted in order to conclude to improve flood risk management across Italy through a greater understanding of individual-level perspectives.

This research argues that there are cognitive, social and practical rationales behind the respondent's answers, whereas the influence of personal characteristics on their actions and beliefs was limited. The most important variable connected to threat appraisal and perceived preparedness was flooding knowledge, underlying that people do not disregard the suitable information. When risk knowledge is high, there is also a greater opportunity to include flood-prone people in the flood risk decision-making process. A proactive involvement of the community in flood risk management can also aid in transferring this knowledge into the wider community. However, the diffusion of such information would require a sufficient level of trust across and within stakeholder communities. Our results indicate a trade-off between threat appraisal and perceived preparedness if trust grows which can complicate this process. An aspect of this may be because of negative public sentiment towards the current flood risk managers. Addressing the sources of this negative public sentiment could address this trade-off. The role that the media plays is fundamental in this regard for amplifying or alter the understanding of flood risk and how the socio-political sphere acts.

In regard to the acceptability of flood insurance has evidenced that people seem reluctant to buy flood insurance, being discouraged by the cost or simply because they did not know the existence or need for such products. The average amount people have been willing to pay was to 250 euros, which is likely far below the premiums charged if they are risk-based but would be sufficient for compulsory solidarity based insurance scheme. Therefore, the development of a functioning flood insurance market would require the increased collaboration between the government and private insurers so that their actions are commentary rather than overlapping. Moreover, such joint activity can also leverage both stakeholders' knowledge on how to successfully communicate information and the need to be insured and what can be expected. Risk communication and education strategies should be initially targeted on developing support and increased understanding of the role that flood insurance could play in helping to manage the impacts of flooding. Moreover, there is also a need to involve other parties in this dialogue, such as the construction industry and banks, to help foster people to undertake flood risk management actions.

*Author Contributions:* G.R. devised the project, the main conceptual ideas and proof the outline in collaboration with P.T. G.R. and P.T. designed the questionnaire with inputs from Prof. Anna Scolobig and Prof. Mara Thiene. G.R. and P.T. contributed to the acquisition of the data and G.R. and P.H. analyzed and interpreted the them. P.H. performed the analysis in the Appendix B. G.R. and P.H. contributed to the content for revising and finalizing the manuscript with consultation of P.T.

# Appendix A

Table A7.1 Summary table is highlighting the differences between Emergency State decree and Calamity State decree declarations Own elaboration from Protezione Civile (2010)

| | **Emergency state declaration** | **Calamity state declaration** | |
|---|---|---|---|
| *Addressee* | Population assistance, public services and strategic infrastructures | Industry, trade and crafts assistance | Agriculture assistance |
| *Intervention* | Recovery phase, reconstruction excluded | Partial restoration of the damages | |
| *Decision-making body* | Council of Ministers on a proposal of President of the Council of Ministers and/or the Civil Protection Undersecretary | President of the Council of Ministers on a proposal of the Minister of Industry from signalling of municipalities | Minister for Agriculture, Food and Forestry from signalling of regions. Actualization within 60 days after the event. |
| *Regulation* | Law 225/92, art. 5 | Law 50/52 -on | Law 185/192 |

Table A7.2 Logit regression: information sources determinants of the level of flood risk knowledge (n=843)

| **Explanatory variable** | **β** | **S.E.** | **Odds Ratio** |
|---|---|---|---|
| National initiatives | -.0133 | 0.268 | 0.876 |
| Social media | .361 | .232 | .119 |
| Press | .124 | .212 | .559 |
| Municipalities initiatives | -.454 | .310 | .143 |
| TV/Broadcast | -.297 | .223 | .183 |
| Personal Interest/Research | .124 | .215 | .565 |
| School | .280 | .242 | .249 |
| Volunteer activities | .030 | .320 | .927 |
| Friends | .429* | .237 | .070 |
| Constant | -.625*** | .205 | .002 |
| Log L | 600.236 | | |
| Cox and Snell pseudo $R^2$ | 0.023 | | |
| Nagelkerke pseudo $R^2$ | 0.032 | | |
| % of correctly classified cases | 62.1 | | |

# Appendix B

Data on flood risk is taken from the GLOFRIS flood risk model as accessible from the Aqueduct website (https://floods.wri.org). The model was developed in Ward et al. (2013) and Winsemius et al. (2013) and has been extensively tested and applied across several applications.
The impacts selected are total affected GDP and urban damage as estimates for monetary impacts. The total population affected for the 100 and 1000 year floodplains are also taken. These values are taken across the provinces in the studied provinces of the Veneto region of North East Italy.
The data provided is for the years 2010 and the average ensemble estimate across a range of socio-economic and climate change scenarios for 2030. It is assumed that flood impacts grow linearly between these time points. Moreover, an estimate of the total population of the Veneto region in 2017 is also taken from Eurostat (variable id: tgs00096). Data on flood protection is taken from the FLOPROS database.
An approximation of risk-based flood insurance premiums is calculated following eq. 1:

$$\pi_{i,j} = \frac{E(Flood\ impact - Deductible\ |Flood\ protection)_i}{Number\ of\ households_{i,j}} \quad (1)$$

In eq. 1, $\boldsymbol{\pi}_{i,j}$ represents the premium for province $i$ in the Veneto region for floodplain $j$, which is equal to the expected net flood damage borne by a household for a given level of flood protection in place. The deductible is assumed to be 5% of the damage suffered, resulting in the insurer compensating 95% of the damage suffered.
Floodplain $j$ can be selected from one of three options as based on return-periods: 1/100, 1/500, 1/1000. This represents the area of the Veneto region that can be affected by a given flood.
The number of households is calculated by dividing the total population affected by a flood of return period $j$ divided by the average number of people per household. The number of people per household is assumed to be equal to 3 following our survey results.
The results for eq. 1 indicate the average risk-based premium. Instead, if the total population of the Veneto region was used, the estimate would no longer be risk-based but would be more representative of a nationally compulsive insurance scheme.
The data from GLOFRIS does not separate flood impacts across sources and as such these values are likely to be the upper estimate of insurance premiums. However, some of this overestimation is mitigated due to eq. 1's exclusion of insurer surcharges from costs, profits, or

uncertainty related factors. This is because of a great deal of uncertainty in these values from the scientific literature.

Table B7.1 Estimated average insurance premiums in Euros per year

| **Explanatory variable** | **1/100 floodplain** | **1/500 floodplain** | **1/1000 floodplain** | **Regional pool** |
|---|---|---|---|---|
| *Affected GDP* | | | | |
| Rovigo | 1228 | 1177 | 1147 | |
| Padua | 1228 | 1182 | 1122 | |
| Verona | 1212 | 1178 | 1149 | |
| Vicenza | 2406 | 2376 | 2297 | |
| Venice | 1228 | 1176 | 1175 | |
| Treviso | 1257 | 1126 | 1123 | |
| Average premium across studied provinces | 1466 | 1408 | 1368 | 40 |
| *Urban damage* | | | | |
| Rovigo | 852 | 817 | 796 | |
| Padua | 840 | 809 | 768 | |
| Verona | 1330 | 1293 | 1261 | |
| Vicenza | 1513 | 1494 | 1444 | |
| Venice | 313 | 300 | 300 | |
| Treviso | 147 | 131 | 131 | |
| Average premium across studied provinces | 936 | 909 | 880 | 30 |

CHAPTER 8

# FINAL REMARKS

Nowadays, there is a big debate that involves the terms ‘disasters’ and ‘natural disasters’, and the use/misuse scientists and practitioners are making with them. For physical scientists, the ‘natural’ attribute to disasters is the description of the causal relationship of these events, whereas social scientists attribute ‘natural’ in an interpretative form rather than descriptive one because there would not be disasters without the human component. This epistemological debate arises the need to think about disasters more comprehensively, as an ‘assemblage’ of social and natural factors, mutually interconnected, that give challenges for institutional and educational renovation. The theory is essential to our scientific knowledge and approach to hazards and disasters. However, it is more than a narrative, because it represents the choices regarding our approach in studying these events and the way we are coping with them. What increases or decreases a negative occurrence is the way these components interact with each other and how we can have a comprehensive view of them. In this regard, this thesis proposes an interdisciplinary approach to advance flood risk knowledge and management by bridging the physical and the social components of disasters. The society is much interconnected with the built environment, modifying its dynamics and experiencing cultural and political changes with unprecedented levels. Therefore, it is essential to understand flood interactions with the human, the landscape and the climate changes in order to target appropriate management actions. These actions need to be included in the disaster dialogue and require the inclusion of communities’ voices.

A human-centred approach, rather than a solely hazard-centred view, has been fostered in all the research outcomes in this thesis because an inclusive community is more effective in the implementation and the success of risk reduction policies. Failing in recognising it might lead to the unsuccessful operation of structural measures undertaken in protection from floods. People's adaptation strategies, however, might be effective only at the moment they are implemented because the consequences of the alteration of climate and ecosystems are accelerating at dramatically higher rates than ever. This means that these adaptation actions might be not as fast as these global environmental changes, rising a question of how people can be able to adjust in this anthropogenic world. A new political agenda can be one of the answers, but governments need to consider such changes, learn from past disasters, incorporate disaster risk management into the investment plan and strengthen institutional and legislative arrangements. Thus, disaster governance needs renovation, the ability to be resilient, to adapt to the dynamic changes (as communities are often asked to do) and empower citizens and communities. Create such a strategy is not straightforward, since risk management policies work at different temporal and spatial scales, and officers might find limitations due to overlapping responsibilities. This opportunity needs to be considered as a springboard to renovate the political organisation to a more geo-politic perspective of change, creating alliances with like-minded organisations and agencies and create momentum for risk reduction activities and campaigns. Governments need to invest in the collection, management and dissemination of risk information, organising awareness campaigns, informative talks, educational plans and children focused activities for helping individuals to be part of the disaster risk reduction agenda. In this way, people would be able to recall past disasters, increase their trust in policies and authorities and recognise environmental criticalities in the place of living. Memory and trust, in fact, have been recognised to be crucial factors in this research, having a strong influence on people conceptualisation of risk and the willingness to take action in front of it. By including vulnerability in our effort to reduce the risk from disaster, we acknowledge the fact that disaster risk not only depends from the hazard and exposure, but it is a reflection of the susceptibility of people and infrastructures. In fact, there are environmental and social conditions that limit their ability to cope with the impacts of natural hazards, and this is the reason why they are called 'vulnerable'. These people are often marginalised and excluded from the political debate putting them in jeopardy when disasters strike. Thus, there is the need to consider these social groups, involve them in the emergency and ensure services and facilities.

Including people in the disaster risk reduction policy is essential but does not require a vertical approach, whether as a top-down or a bottom-up. There is scope to move beyond this vertical representation and examine the horizontal spaces between the physical and the human interactions, without compromising the commitment to reduce disaster risks.

The human being has dramatically altered the Earth, with consequences on flood dynamics, altering ecosystems and exacerbating climatic extremes. However, the debate that views the human being as the responsible for those actions is not on the scope of this thesis, whereas it is essential to consider these actions and the environmental consequences to produce new technological, scientific and theoretical advancements, save more lives and decrease the economic damages of disasters. Undeniably, there are remaining many knowledge gaps in this regard. One of those is how to build a culture of prevention to help future generations to live in a sustained and safe world, because as argued by Kofi Annan:

> "Building a culture of prevention is not easy. While the costs of prevention have to be paid in the present, its benefit lies in the distant future. Moreover, the benefits are not tangible: that are the disasters that did not happen."
>
> Kofi Annan, UN Secretary-General, 1999

CHAPTER 9

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