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Changes in Hydrological Risk Perception and Implications for Disaster Risk Reduction

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ACTA
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UPPSALA
2021

ISSN 1651-6214
ISBN 978-91-513-1273-6
URN urn:nbn:se:uu:diva-451215

Dissertation presented at Uppsala University to be publicly examined in Hambergsalen, Geocentrum, Villavägen 16, Uppsala, Friday, 15 October 2021 at 10:00 for the degree of Doctor of Philosophy. The examination will be conducted in English. Faculty examiner: Professor Teun Terpstra (HZ University of Applied Sciences, Vlissingen, The Netherlands).

Abstract

Mondino, E. 2021. Changes in Hydrological Risk Perception and Implications for Disaster Risk Reduction. *Digital Comprehensive Summaries of Uppsala Dissertations from the Faculty of Science and Technology* 2064. 88 pp. Uppsala: Acta Universitatis Upsaliensis. ISBN 978-91-513-1273-6.

Economic losses caused by hydrological extremes, such as floods and droughts, are exacerbating because of increased anthropogenic activities and global environmental changes. Understanding how individuals and communities interact with hydrological extremes thus becomes fundamental to develop effective strategies for disaster risk reduction. Risk perception plays an important role in determining how individuals and communities respond to the occurrence of an extreme event. This thesis aims at addressing aspects of risk perception that remain largely unknown. They include: i) how flood risk perceptions change over time, ii) the role of previous experiences, and iii) how the perception of flood risk relates to the perception of other natural hazards, such as droughts. The work is based on survey data collected in different study areas – both in Italy and Sweden at the local and national scales – via longitudinal as well as cross-sectional approaches.

In relation to the three main objectives, this thesis found that: i) flood risk perceptions evolve differently over time depending on social groups; ii) different types of previous experiences with floods directly influence specific facets of risk perception, with knowledge deriving from the experience also playing an important role; iii) flood risk perception is heavily intertwined with drought risk perception. These results have policy and theoretical implications. Concerning the former, they can inform disaster risk reduction efforts in terms of risk communication and promote an integrated management of hydrological risk. As for the latter, they stress the importance of taking social heterogeneity into account when modelling the interaction between the social and the hydrological spheres, as this can influence the community's response to extreme events. Fostering human adaptation to climate extremes is a priority. This thesis argues that adaptation can be achieved by promoting the awareness that not only are we at risk, but also that we have the means to address the risk.

Keywords: risk perception, floods, droughts, disaster risk reduction, sociohydrology

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ISSN 1651-6214
ISBN 978-91-513-1273-6
URN urn:nbn:se:uu:diva-451215 (http://urn.kb.se/resolve?urn=urn:nbn:se:uu:diva-451215)

To the women who fight,

List of Papers

This thesis is based on the following papers, which are referred to in the text by their Roman numerals.

I **Mondino, E.**, Scolobig, A., Borga, M., Albrecht, F., Mård, J., Weyrich, P., & Di Baldassarre, G. (2020). Exploring changes in hydrogeological risk awareness and preparedness over time: a case study in northeastern Italy. *Hydrological Sciences Journal*, 65(7):1049–1059. DOI: 10.1080/02626667.2020.1729361

II **Mondino, E.**, Scolobig, A., Borga, M., & Di Baldassarre, G. (2021). Longitudinal survey data for diversifying temporal dynamics in flood risk modelling. *Natural Hazards and Earth System Sciences*. Accepted.

III **Mondino, E.**, Scolobig, A., Borga, M., & Di Baldassarre, G. (2020). The Role of Experience and Different Sources of Knowledge in Shaping Flood Risk Awareness. *Water*, 12(8). DOI: 10.3390/w12082130

IV **Mondino, E.**, Di Baldassarre, G., Mård, J., Ridolfi, E., & Rusca, M. (2020). Public perceptions of multiple risks during the COVID-19 pandemic in Italy and Sweden. *Scientific Data*, 7(1):1–7. DOI: 10.1038/s41597-020-00778-7

V **Mondino, E.** Droughts and Floods: People's Perception of Hydrological Risk. In Di Baldassarre, G. & Paron, P. (Eds.) *Hydro-Meteorological Hazards, Risks and Disasters.* Submitted.

In Papers I, II, and III I contributed to conceptualisation, study design, data collection, data analysis, writing, editing, and visualisation. In Papers IV and V I contributed to conceptualisation, study design, data analysis, writing, editing, and visualisation.

In addition, during my doctoral studies I contributed to the following papers:

Di Baldassarre, G., Kreibich, H., Vorogushyn, S., Aerts, J., Arnbjerg-Nielsen, K., Barendrecht, M., Bates, P., Borga, M., Botzen, W., Bubeck, P., De Marchi, B., Llasat, C., Mazzoleni, M., Molinari, D., **Mondino, E.**, Mård, J., Petrucci, O., Scolobig, A., Viglione, A., & Ward, P. J. (2018). Hess Opinions: An interdisciplinary research agenda to explore the unintended consequences of structural flood protection. *Hydrology and Earth System Sciences*, 22(11):5629–5637. DOI: 10.5194/hess-22-5629-2018

Di Baldassarre, G., Sivapalan, M., Rusca, M., Cudennec, C., Garcia, M., Kreibich, H., Konar, M., **Mondino, E.**, Mård, J., Pande, S., Sanderson, M. R., Tian, F., Viglione, A., Wei, J., Wei, Y., Yu, D. J., Srinivasan, V., & Blöschl, G. (2019). Sociohydrology: Scientific Challenges in Addressing the Sustainable Development Goals. *Water Resources Research*, 55(8). DOI: 10.1029/2018WR023901

Weyrich, P., **Mondino, E.**, Borga, M., Di Baldassarre, G., Patt, A., & Scolobig, A. (2020). A flood-risk-oriented, dynamic protection motivation framework to explain risk reduction behaviours. *Natural Hazards and Earth System Sciences*, 20(1). DOI: 10.5194/nhess-20-287-2020

Ridolfi, E., **Mondino, E.**, & Di Baldassarre, G. (2020). Hydrological risk: modeling flood memory and human proximity to rivers. *Hydrology Research*. DOI: 10.2166/nh.2020.195

Rangecroft, S., Rohse, M., Banks, E. W., Day, R., Di Baldassarre, G., Frommen, T., Hayashi, Y., Höllermann, B., Lebek, K., **Mondino, E.**, Rusca, M., Wens, M., & Van Loon, A. F. (2020). Guiding principles for hydrologists conducting interdisciplinary research and fieldwork with participants. *Hydrological Sciences Journal*, 66(2):214–225. DOI: 10.1080/02626667.2020.1852241

Brelsford, C., Dumas, M., Schlager, E., Dermody, B. J., Aiuvalasit, M., Allen-Dumas, M. R., Beecher, J., Bhatia, U., D'odorico, P., Garcia, M., Gober, P., Groenfeldt, D., Lansing, S., Madani, K., Méndez-Barrientos, L. E., **Mondino, E.**, Müller, M. F., O'donnell, F. C., Owuor, P. M., … Zipper, S. C. (2020). Developing a sustainability science approach for water systems. *Ecology and Society*, 25(2). DOI: 10.5751/ES-11515-250223

Franceschinis, C., Thiene, M., Di Baldassarre, G., **Mondino, E.**, Scolobig, A., & Borga, M. (2021). Heterogeneity in flood risk awareness: a longitudinal, Latent Class model approach. *Journal of Hydrology*, v(i). DOI: 10.1016/j.jhydrol.2021.126255

Di Baldassarre, G., Cloke, H., Lindersson, S., Mazzoleni, M. **Mondino, E.**, Mård, J., Odongo, V., Ridolfi, E., Rusca, M., Savelli, E., & Tootoonchi, F. (2021). Integrating Multiple Research Methods to Unravel the Complexity of Human-Water Systems. *AGU Advances*, 2, e2021AV000473. DOI: 10.1029/2021AV000473

Mazzoleni, M., Odongo, V., **Mondino, E.**, Di Baldassarre, G. (2021). Water management, hydrological extremes, and society: Modeling interactions and phenomena. *Ecology and Society*. Accepted.

Contents

Abbreviations

CATI	Computer-Assisted Telephone Interview
CLM	Cumulative Link Model
CLMM	Cumulative Link Mixed Model
DRR	Disaster Risk Reduction
EM-DAT	Emergency Database
EWS	Early Warning System
IPAW	Inversed Probability of Attrition Weighing
MSB	*Myndigheten för samhällsskydd och beredskap* (Swedish Civil Contingencies Agency)
NUTS1	*Nomenclature d'Unités Territoriales Statistiques* (Classification of Territorial Units for Statistics)
PMT	Protection Motivation Theory
RCS	Repeated Cross-Sectional
SMHI	Swedish Meteorological and Hydrological Institute
UNDRR	United Nations Office for Disaster Risk Reduction

Introduction

In medio stat virtus

The water environment and human societies have shaped each other since ancient times. People have relied on water not only for their basic needs, such as nourishment and sanitation, but also for transportation, commerce, power production, and recreation (Moran et al., 2018; Postel & Richter, 2003). In the past, several societies thrived because of water. Because of the abundance of water in Mesopotamia, for example, the Sumer could settle and commence their revolutionary agricultural activities (Wilkinson, 2013). As a consequence, the Fertile Crescent between present-day Egypt and the Middle East is still considered the cradle of our civilisation. While water is essential for life on Earth, its excess as well as its shortage can disrupt a fragile equilibrium. The decline of the Maya civilization was partly attributed to water scarcity (Aimers & Hodell, 2011), whereas the Cahokia urban settlements along the Mississippi river disappeared because of intense flooding (Munoz et al., 2015). Today, floods and droughts continue claiming lives and causing billions in damages worldwide (EM-DAT, 2021; World Meteorological Organization, 2021), impacts that could be exacerbated by climate change and the intensifying anthropogenic influence on water systems (Otto et al., 2018; Viero et al., 2019).

The relationship between people and hydrological extremes is not a one-way street. If a tree falls in a forest and no one is around to hear it, does it make a sound? And if a flood occurs and no one is around to bear the consequences, is it a disaster? By choosing to settle in proximity to water because it offers favourable conditions for development, a community exposes itself to a certain degree of flood risk. The magnitude of such risk depends on three aspects: a) the frequency and intensity of flooding; b) how exposed the community is to flooding; c) how vulnerable the community is to flooding (UNDRR, 2021). The community – depending on its means – has the power to alter all these components. It can reduce the frequency of floods by building a levee system; it can reduce its own exposure by moving further away from the river; and it can reduce its vulnerability by adopting risk reduction measures such as early warning systems, or by creating a support system for vulnerable households and businesses. These are examples of how much human agency can shape the effects of flooding.

When a flood event occurs, it unavoidably affects the community not only in terms of damage to property and potential loss of human lives, but also in terms of the affected individuals' perceptions and attitudes towards the hazard itself (Kofman-Bos et al., 2005). Some responses can be considered desirable: the affected community can grow closer together and there can be an increase in risk awareness. However, they can also be undesirable: increased fear may lead to panic or there can be a decrease in trust in the local authorities and institution because of the missed chance of protecting their citizens. The importance of understanding how these perceptions change in the aftermath of an event and how they evolve in the years after is twofold. On the one hand, it can inform disaster risk reduction (DRR) efforts. For instance, knowing how the community perceives the hazard and how this perception changes over time can influence the choice of risk communication strategies, as well as the individuals to be targeted, to prevent complacency while avoiding generating panic (Erev et al., 2020). On the other hand, understanding risk perception is essential for the conceptualisation of human-water systems and their feedback mechanisms, and can shed light on potentially generalisable patterns (e.g. do flood experiences increase risk awareness?).

The following sections serve as a brief background to this thesis by delving deeper into the concept of risk perception, human-water interactions, and their temporal dynamics.

Risk perception

Risk perception is a complex, albeit fundamental, piece of the bigger DRR puzzle. One of its components in particular, risk awareness, plays a key role in informing the decision-making process towards risk reduction. While not a driver of adaptation behaviours per se, awareness can be seen as a *conditio sine qua non*. In this regard, the Protection Motivation Theory (PMT, Rogers, 1983; Rogers & Prentice-Dunn, 1997) argues that the motivation to protect oneself against the negative consequences of an event depends on two factors: how we judge risk and how we judge our coping capacity. If a person is not aware of being exposed to a risk, they will probably not even move to the next step, which is assessing their coping capacity. Thus, while the lack of awareness at the individual level may result in not adopting private protection measures or not stipulating an insurance, at the community level it may hinder the introduction of risk reduction policies. This could eventually result in potentially higher exposure and/or vulnerability of certain groups, especially under exacerbating hazard conditions.

Why then is it critical to know how people perceive risk? As mentioned earlier, the occurrence of a natural hazard event (e.g. flooding) re-shapes the way in which people perceive the hazard. Indeed, the event can disrupt the balance within the community by exacerbating inequalities, by causing trauma

related to death and the loss or damage of property, and by generally challenging the role of institutions and authorities responsible for the management of risk. The influence of the hazard on the individual sphere is then shaped by multiple objective and subjective factors such as previous experiences, hazard knowledge, trust in authorities and institutions, preparedness, and socio-demographic indicators such as age, gender, etc. (see Fig. 1). This, in turn, shapes the way in which individuals and the community prepare for, and respond to, potential future hazards. In the case of flooding, the affected community can decide to adopt structural as well as non-structural measures to deal with flood risk. The former includes engineered measures such as the construction of river levees to reduce flood frequency. The latter includes solutions that do not alter the water flow, such as relocation, Early Warning Systems (EWSs) or risk communication campaigns. The choice of adopting one or more of these risk reduction strategies eventually influences the hazard itself, both in terms of its frequency and of its intensity. As a result, this reciprocal influence evolves over time and is further affected by environmental changes (additionally shaping the hazard's frequency and intensity) and socio-economic trends (additionally influencing the individual's position within their society)(Di Baldassarre et al., 2013). These feedback mechanisms between hazard and society are illustrated in Figure 1.

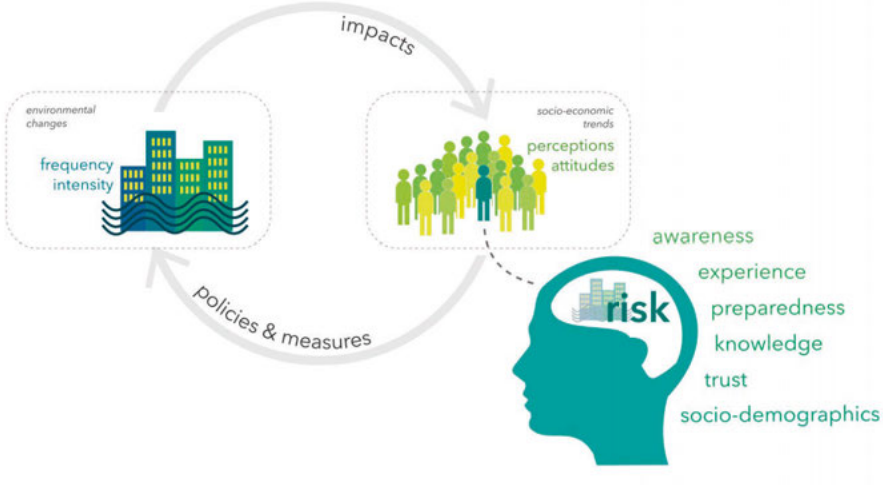


Figure 1. The interplay between hydrological hazards and society (based on Di Baldassarre et al. 2018).

When people judge risk, often they do not rely on a technical risk assessment, but rather on intuitions (Slovic, 1987). These intuitions are driven by direct and indirect experiences, socio-demographic and socio-economic characteristics, as well as socio-psychological factors including, but not limited to, awareness, knowledge, trust, and emotions. Within the flood risk literature,

however, the role of some of these factors is rather debated. For example, some studies found that experiencing a flood event increases our risk awareness (Miceli et al., 2008; Siegrist et al., 2005; Terpstra, 2011), others found the opposite (Halpern-Felsher et al., 2001), and others found no particular correlation between experience and awareness (Scolobig et al., 2012; Whitmarsh, 2008). The confusion around the influence of experience arises from two main factors: the quality of the experience, and the definition of experience. If someone experiences a flood with minor consequences, they could underestimate their exposure or vulnerability in the event of a subsequent future flood. On the other hand, if the consequences were more severe, their awareness of flood risk would likely increase (Wachinger et al., 2013). In addition to the quality of experience itself, the way in which the variable is defined can lead to further contrasts. Some studies prefer precise definitions – for example using damage severity as a proxy, or the number of times one's residence was flooded. Others adopt broader definitions, such as general previous experience with floods (without qualifying its severity, Bradford et al., 2012; Comănescu & Nedelea, 2016; Green et al., 1991; Lawrence et al., 2014; Qasim et al., 2015; Wachinger & Renn, 2010), previous evacuation (which is not always an indicator of having suffered damages too, Botzen et al., 2009; Bradford et al., 2012; Bustillos Ardaya et al., 2017), or just witnessing a flood by being present during the event (Bera & Daněk, 2018; Burningham et al., 2008; Fielding, 2012; Knuth et al., 2014; Santoro et al., 2019; Scolobig et al., 2012; Siegrist et al., 2005). Other factors, such as gender, find more agreement across the literature. Independently from the type of hazard, women tend to have a higher risk awareness compared to men (see e.g. Cordellieri et al., 2016; Cvetković et al., 2018; Galasso et al., 2020; Kim et al., 2018), who tend to show a higher (perceived) coping capacity. This is often a combination of cultural and social aspects, such as the relative power and social status that men hold in the majority of contexts, which can lead to higher sense of safety and security (Finucane et al., 2010).

Knowledge is another factor which plays a critical role in risk perception. Just as Dretske put it, "there is a difference between hearing Clyde play the piano and seeing him play the piano" (1993), there is a difference between imagining and experiencing a flood. Hearing about a flood that we have not experienced directly can also affect our perception of risk, because visual cognition helps us in learning and memorising (Cattaneo & Silvanto, 2015). This visual cognition can be enhanced directly by either experiencing the event, or indirectly by receiving information about floods (e.g. from the news, friends and relatives, through risk communication campaigns, and so forth). The processing of this information then creates knowledge. For this reason, the majority of studies operationalise knowledge as self-assessed knowledge (Kellens et al., 2013; Slovic, 1999), as opposed to actual scientific knowledge about the phenomenon (Botzen et al., 2009), which would be more difficult to assess with a questionnaire survey. Understanding self-assessed knowledge is

particularly relevant within disaster risk reduction, as those individuals with a lower self-assessed knowledge have been found to be more keen in receiving new information, compared to those with a higher self-assessed knowledge, who feel they "know a lot" (Park et al., 1988).

Besides objective and subjective factors, subconscious cognitive processes shape how we judge risk. Our brain regularly uses mental shortcuts, known as *heuristics*, to make decisions under uncertainty (Tversky & Kahneman, 1974). The availability heuristics, whereby a person judges the probability of an event to occur based on the ease with which it comes to mind (first proposed by Tversky and Kahneman, 1973), is particularly relevant when assessing disaster risk. In fact, the ease with which something comes to our mind is not only dictated by our first-hand experiences, but also by the media and by what we are exposed to daily (which contributes to our self-assessed knowledge). Besides, unconscious biases and preconceptions play a crucial role in our cognitive processes. For instance, we usually tend to judge ourselves as less exposed to, or less likely to experience a certain negative event, compared to others, running into what is known as *optimistic bias* (Burger & Palmer, 1992; Trumbo et al., 2014; Weinstein, 1989a, 1989b).

Finally, while individual perceptions are shaped by context-specific factors and cognitive processes, global environmental and socio-economic trends do also play a role in how people perceive risk, and how a certain threat is perceived in relation to other threats. For example, in a changing climate, areas that were traditionally exposed to floods may see an insurgence in the occurrence of drought (Güneralp et al., 2015), and vice-versa, potentially altering residents' perceptions and increasing the complexity of hydrological risk and its management (Ward et al., 2020). Thus, people do not live in an environmental and social vacuum, but in ever-changing socio-economic and climatic conditions and, consequently, flood risk perception should be examined in a broader context.

Temporal dynamics of risk perception

As perceptions are shaped and influenced by the surrounding environment and personal experiences, not only do they differ among individuals, but each individual can exhibit different perceptions at different stages in time (Scolobig et al., 2012). Uncovering how risk perception changes over time contributes to our understanding of how people think about risk, and eventually how they address it. Within the flood risk domain, revealing if, how, and for whom risk perceptions change over time has practical as well as theoretical implications. On the one hand, it can inform DRR efforts in terms of risk communication. Policymakers will have the chance to know if there are particular groups to be targeted and what their characteristics are, as perceptions may change differently for different people. They could also be provided with information on

when it is the best time for an effective risk communication campaign and whether there are windows of opportunity to take advantage of in the aftermath of a flood. On the other hand, risk perception dynamics can be employed in the theorisation of human-water interactions, not only qualitatively, but also quantitatively through the parametrisation of sociohydrological and socio-ecological models.

As such, there is a growing interest in longitudinal studies that follow the evolution of risk perceptions (Bubeck et al., 2020; Hudson et al., 2020; Siegrist, 2013, 2014; Sivapalan, 2015). Before this PhD work was conceived, only a handful of studies explored the evolution of flood risk perception over time, either as main or as secondary focus (Kreibich et al., 2011; Salvati et al., 2014; Terpstra et al., 2009). Over the past four years, there have been additional efforts in trying to understand how these complex dynamics evolve (Bodoque et al., 2019; Bubeck et al., 2020; Seebauer & Babcicky, 2020). All these studies follow various designs, in terms of the type of longitudinal approach, timing of the survey rounds, as well as sampling methodology and survey administration. The majority of studies are based on panel datasets (where the same individuals are interviewed in different survey rounds), and two rely on repeated-cross sectional datasets (different individuals at each survey round, Kreibich et al., 2011; Salvati et al., 2014). Some studies follow a pre-post risk communication design (Bodoque et al., 2019; Charrière et al., 2017; Terpstra et al., 2009), where respondents are surveyed before and after participating to risk communication activities. Others follow a post-event design (Bubeck et al., 2020; Kreibich et al., 2011), where respondents are surveyed right after a flood and then a few months/years later. Others do not focus on any particular event or risk communication campaign (Salvati et al., 2014; Seebauer & Babcicky, 2020). The sampling methodology varies widely across these studies. Salvati et al. (2014) adopted a sample representative at the national scale, Kreibich et al. (2011) a building-specific random sampling, Seebauer and Babcicky (2020) and Charrière et al. (2017) a random sample, Bodoque et al. (2019) a quota sampling, Bubeck et al. (2020) sampled only individuals who were affected by the flood they examined, and Terpstra et al. (2009) surveyed residents who ran for a position in the province's Water Board. Most of the time, surveys were conducted through CATI (Computer-Assisted Telephone Interview) systems (Bubeck et al., 2020; Kreibich et al., 2011; Salvati et al., 2014), while Bodoque et al. (2019) administered them face-to-face, and Seebauer and Babcicky (2020) via post and online. The results in terms of risk awareness dynamics are contrasting, which could partially be attributed to the heterogeneity of the study designs. Some of the authors found an increase in risk awareness over time (Charrière et al., 2017; Kreibich et al., 2011), some a decrease (Salvati et al., 2014), some an increase in perceived probability but no change in perceived impacts (Bubeck et al., 2020), and some no change at all (Bodoque et al., 2019; Seebauer & Babcicky, 2020; Terpstra et al., 2009).

Other studies within the flood risk domain adopted a longitudinal approach, but they did not investigate, or do not report results concerning changes in risk perception (Calvo et al., 2015; Fay-Ramirez et al., 2015; Fothergill, 2003; Ginexi et al., 2000; Hudson et al., 2020; Kaniasty & Norris, 2008; Lin et al., 2017; Osberghaus, 2017; Osberghaus & Hinrichs, 2020). The investigation of risk perception dynamics is thus rather scarce, and consequently there remains uncertainty around general trends.

Aim of the thesis

The scarcity of longitudinal studies on risk perception within the flood risk domain, the limited knowledge about the role of experience, and the need to contextualise the perception of flood risk have implications for DRR as well as for the study of human-water systems. As mentioned in the previous sections, knowing how the perception of risk evolves over time and across different social groups and understanding the role of experience in shaping such perception constitute foundational blocks for the development of effective DRR strategies. Indeed, this can support and inform policymakers not only on groups that should be targeted, but also, for instance, on the timing and content of risk communication campaigns. DRR strategies may also benefit from a broader contextualisation of flood risk perception, as it would provide a better understanding of the salience of flood risk in comparison to other hazards. This can eventually inform on if and how certain risk reduction measures would be received. When it comes to the conceptualisation of human-water interactions, there is a need to further our understanding of general trends in terms of feedback mechanisms. Longitudinal survey data here has a fundamental role as well, in that it allows for exploring causality among factors. These factors, such as previous experience with the event and knowledge about risk, may not only shape risk perception at the time of the occurrence, but potentially also how perceptions changes in the months and years after.

In light of the above, this thesis sets out to reach three main objectives:

a. Understanding how hydrological risk perceptions change over time
b. Untangling the complex role of experience and its relation to knowledge in risk perception
c. Setting flood risk perception in a broader context by exploring its relationship with the perception of drought risk

Methodology

The diversity of this thesis' objectives entailed the adoption of a range of different methods over five case studies, both at the local and at the national scale (see Fig. 2). A questionnaire survey was at the basis of every approach presented here, but the way it was administered, to whom, and when varied depending on the specific goal. The survey was chosen as main tool because it allows to collect large amounts of data in a relatively short timeframe and is thus suitable to assay larger populations (e.g. residents in a particular town or even country). Additionally, with surveys, the researcher can standardise the way in which variables are described so that each person in the study is presented with the same question. This is fundamental when the studied population is large, and it is suitable when the goal is to assess e.g., how certain variables change over time (as the same question can be maintained throughout survey rounds). It also allows to standardise the answers to most of the questions so that they can be put in relation to each other. The surveys conducted in this thesis include, for the majority of the variables, close-ended questions where the respondent can choose an answer either from different categories or on a scale where only the extremes are assigned a value (e.g. from a minimum of 1 to a maximum of 5, with 1-step increments in between). In this sense, while the absolute value chosen is dependent on the value assigned to the extremes of the scale (a prerogative of the researcher) and is not informative per se, when put in relation to the responses given by other respondents it becomes informative of the dynamics within the sample, and to a greater extent within the studied community.

The following sections present the methodology followed to address each objective and ends with some reflections on the limitations of the different approaches, and more broadly of the study design.

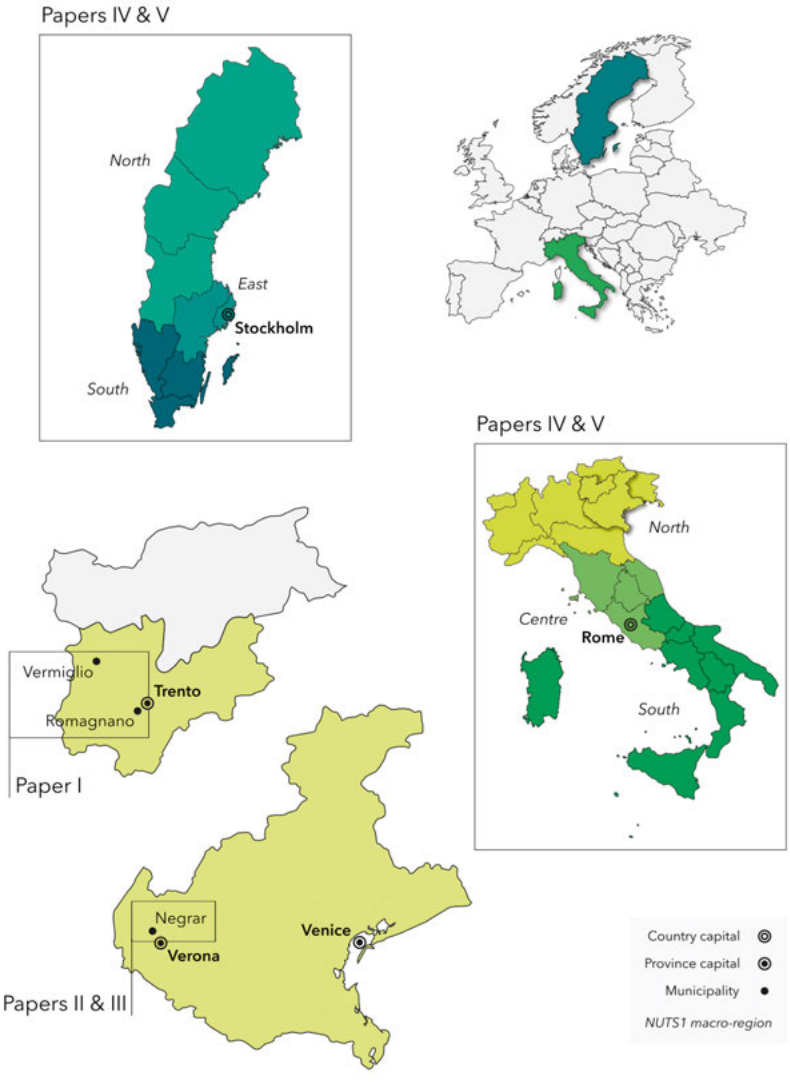


Figure 2. Location of the five case-study areas. Paper I focused on Vermiglio and Romagnano, two municipalities in the Autonomous Province of Trento, Italy. Papers II and III focused on Negrar, a municipality in the Province of Verona, Veneto region, Italy. Papers IV and V focused on Italy and Sweden at the national level, and data in the two countries were aggregated according to the NUTS1 statistical macro-regions (North, Centre, and South in Italy; North, East, and South in Sweden).

Longitudinal surveys to explore changes in flood risk perception

To investigate how flood risk perception evolves over time, this thesis follows two different longitudinal approaches: repeated cross-sectional (RCS, **Papers I** and **II**) and panel (**Paper II**) in three local case studies. Longitudinal survey methods allow to follow the evolution of variables by assessing their value at multiple points in time. The difference between these two methodologies lays in the sampling procedure, but this has implications in terms of transferability of results and potential for statistical analyses. RCS means that at each round, the survey is administered to an entirely new set of individuals. Thus, changes can be explored only on average over the entire sample or by group (e.g. by gender, age, etc.). On the contrary, when following the panel approach, at each round the survey is administered to the same respondents, allowing to follow individuals over time. When selecting one longitudinal approach over the other, few critical factors should drive the choice, including the nature of the studied population, attrition rate, time between survey rounds, theory-testing, statistical power, and time- and cost-effectiveness. While populations change to some extent everywhere, some populations are more static than others, meaning that they change at a lower rate (Yee & Niemeier, 1996). In smaller, provincial areas the population composition is rather static compared to that of bigger urban conglomerates, which regularly experience a high residents' turnover. In this latter scenario, an RCS approach would be better fitted, as the independent samples created during each survey round would be an updated version of the current population composition.

By only including the individuals sampled initially, the panel approach has the issue of *attrition rate*, i.e. the percentage of respondents dropping out of the study in the second (or the following) survey round. High attrition rates may result in *attrition bias* when the respondents do not drop out at random (i.e. they all share some common characteristics), or even in *retention bias* (i.e. the sample size becomes too small to conduct any statistical analysis) (Hudson et al., 2020). Thus, an RCS approach – which does not have attrition issues – may also be more appropriate when a lot of time passes between survey rounds, as the risk of people dropping out is higher over time (Hudson et al. 2020), while a panel approach has higher chances of performing better over shorter time spans. An RCS approach may also be more reasonable when the initial sample is small, as the loss of respondents that may happen with a panel approach can hinder the reliability of the analysis.

These arguments have implications in terms of transferability of results. Results from RCS studies are more likely to be transferable to other areas with similar socio-economic, socio-cultural, and demographic contexts, as they are not relating to specific individuals. Results from panel studies, on the other hand, may be more dependent on (or even unique to) the specific sampled individuals.

Concretely, available resources often constrain the choice to adopt a certain longitudinal approach over another. For instance, an RCS is a more cost-effective alternative to a panel approach, as there is no need to spend time and other resources to keep respondents in the panel, and especially no need to store respondents' sensitive data (such as telephone numbers or addresses) as they will not be needed in the following survey rounds.

In this thesis, **Paper I** follows an RCS approach for two reasons: a) it was not possible to retrace the residents who participated in the first survey; and b) the initial sample size was rather small (N = 100) in both case studies, so an RCS approach was deemed better to avoid even smaller sample sizes in the second survey round. In **Paper II**, both an RCS and a panel study were conducted starting from the same initial sample, and their respective results compared. This design was conceived to explore potential differences between results from the two approaches.

Local case studies

Three municipalities in North-Eastern Italy served as case studies to address how flood risk perception changes over time. Figure 3 shows the timeframe of events and the year when each survey was conducted.

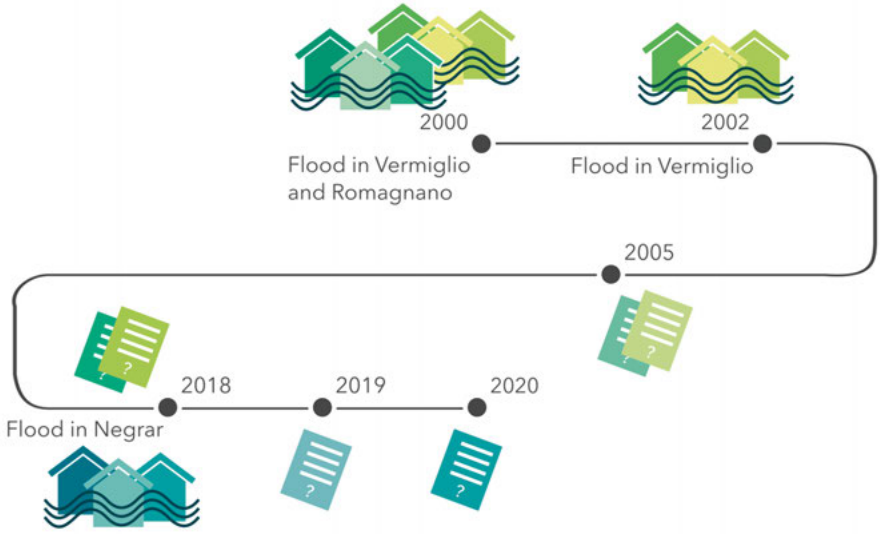


Figure 3. Timeframe of flood events and survey rounds.

Paper I is based on the municipalities of Vermiglio and Romagnano, located in the Autonomous Province of Trento (see Fig. 2), which were both hit by a debris flow in the beginning of the 2000s. These two municipalities were selected because they both saw the occurrence of an event followed by no other

event up to the time of the second survey. This is an optimal condition to explore how risk perception changes in the absence of other extreme events. Vermiglio, an alpine municipality in the Val di Sole, suffered two debris flows, one in 2000 and a second one in 2002. Romagnano, an urban settlement in the outskirts of Trento, suffered a debris flow[1] in 2000. The three events did not result in any casualties, but in 2000 roughly 500 people were evacuated in Romagnano and the second event in Vermiglio destroyed a check dam built after the 2000 debris flow. In 2005, 3 to 5 years after the last event, De Marchi et al. (2007) surveyed the residents to investigate potential links between flood risk awareness and preparedness. In September 2018, the residents of the two municipalities were surveyed again.

Paper II is based on the municipality of Negrar, located in the Veneto region (see Fig. 2). This municipality was selected because the last flood event dates back to 1935, and no other extreme event occurred up until 2018, when in September a severe flash flood hit the small town. The event was thus considered extraordinary because the large majority of residents never experienced something similar before. No casualties were registered, but the event resulted in 10 million € in damages and 3000 affected people. Residents were surveyed in February 2019, six months after the event, and again one year later, in February 2020. Here too, no event occurred between the two survey rounds, but the municipality began the construction of a flood diversion canal which was underway at the time of the second survey. The local authorities also organised a number of events to inform the residents about various aspects of the 2018 flood. These include a) one event where a local meteorological organisation explained the dynamics of the flood from a meteorological and hydrological point of view and b) one event where a co-author of **Paper II** presented the results from the first survey round.

Data collection – Face-to-face surveys, longitudinal approach

Before each survey round (i.e. in 2005 and 2018 in Vermiglio and Romagnano and in 2019 and 2020 in Negrar), local authorities were contacted and a meeting with the mayor was planned to discuss the research activities. The municipalities then independently provided a short list of residents that were willing to be interviewed, together with their contact details (this did not happen when residents were surveyed in Vermiglio and Romagnano the first time by De Marchi et al. 2007). These individuals therefore knew beforehand that they would have been contacted by one of the interviewers. While this was never mandatory, it was a fundamental step to establish trust in the different communities and facilitate the interviewing process.

[1] From here on, these three debris flows will be referred to as floods for simplicity.

In all three areas, in the first survey round (i.e. 2005 in Vermiglio and Romagnano and 2019 in Negrar) residents were sampled following a stratified sampling based on quotas (Stockemer, 2019), representative of the local population in terms of age and gender. In addition to the first contacts list, each interviewer was thus provided with a grid showing how many women and men should be interviewed in each age category. The interviewers started off by contacting the residents on the list provided by the municipality. To maximise randomisation, each interviewer was then assigned a group of streets and was instructed to contact each household in every assigned street. This approach was only possible thanks to the small size of the three study areas. The unit of analysis was the individual, and interviewers were instructed to interview only one person per household and to administer the survey questionnaire face-to-face. All interviewees were informed of the fact that their responses would be kept anonymous at all times.

In the second round of surveys (i.e. 2018 in Vermiglio and Romagnano and 2020 in Negrar), data was collected differently depending on the longitudinal approach adopted. In Vermiglio and Romagnano the approach was repeated cross-sectional (**Paper I**). Here, the second data collection involved only residents who did not fill in the questionnaire the first time. The sampling procedure was therefore the one described before. In Negrar, two approaches were followed in parallel and compared (**Paper II**): repeated cross-sectional and panel. As with Vermiglio and Romagnano, the data collection for the repeated cross-sectional approach involved only those residents who were not interviewed in the first round (and thus followed the same methodology described before). For the panel approach, data collection involved only those residents who were interviewed in the first round and who agreed to be contacted and interviewed again. Table 1 shows the summary statistics for each sample.

Table 1. Summary statistics for the samples of Vermiglio, Romagnano, and Negrar.

Sample	Year	N	Age				Gender %	
			M	*SD*	*Min*	*Max*	*Female*	*Male*
Vermiglio	2005	100	46.1	17.9	19	85	54.0	46.0
	2018	122	50.4	17.8	18	91	51.6	48.4
Romagnano	2005	100	47.8	16.9	18	85	55.0	45.0
	2018	135	50.0	17.5	18	93	52.6	47.4
Negrar	2019	146	53.4	18.0	20	89	52.7	47.3
	2020 RCS*	150	52.0	18.6	19	88	50.0	50.0
	2020 P*	84	53.9	15.7	23	82	50.0	50.0

* RCS = Repeated Cross-Sectional; P = Panel

Examined variables and data analysis

Table 2 shows the main variables employed to investigate risk perception, related questions, and available answers. Here, *risk perception* includes variables measuring the respondent's *risk awareness* and variables measuring the respondent's *perceived preparedness*. If an individual has high risk awareness but also high perceived preparedness, their risk perception may actually be rather low. Thus, adding the perceived preparedness dimension allows to expand the conceptualisation of risk perception. Unless Table 2 specifies otherwise, for the sake of standardisation and comparability the questions asked were identical in every study area and in every survey round. Note that the questions were originally asked in Italian, while Table 2 reports the English translation.

Table 2. Variables used to investigate flood risk perception, related questions, and available answers.

Variable	Question	Available answers*
General safety		
	To what extend does living here in this town make you feel safe?	On a scale from 1, "Minimal safety" to 5, "Maximum safety", or "I don't know"
Risk awareness		
Perceived threat to self	*To what extent do you think floods represent a threat to yourself personally?*	On a scale from 1, "Not at all a threat" to 5, "Serious threat", or "I don't know"
Perceived threat to home	*To what extent do you think floods represent a threat to your home?*	On a scale from 1, "Not at all a threat" to 5, "Serious threat", or "I don't know"
Perceived threat to town as a whole	*To what extent do you think floods represent a threat to the town as a whole?*	On a scale from 1, "Not at all a threat" to 5, "Serious threat", or "I don't know"
Perceived likelihood †	*Do you think floods could occur again here in the future?*	"Yes", "No" "I don't know"
Flood impact		
Damage severity ††	*How severe was the damage you experienced during the 2018 flood?*	On a scale from 1, "No damage" to 5, "Serious damage", or "I don't know"
Expected future damage ††	*How much damage do you think a potential future flood could cause to your home?*	On a scale from 1, "No damage" to 5, "Serious damage", or "I don't know"
Knowledge		
From local sources	*To what extent did knowledge from relatives and friends contribute to your knowledge about floods?*	On a scale from 1, "No contribution" to 5, "Great contribution", or "I don't know"

From official information	*To what extent did official information contribute to your knowledge about floods?*	On a scale from 1, "No contribution" to 5, "Great contribution", or "I don't know"
About structural flood protection	*Do you know of any structural flood protection in this area?*	"Yes", "No" "I don't know"
Trust in local administration		
On risk communication ††	*Should flood risk change in my area, the administration would inform me.*	On a scale from 1, "Completely disagree" to 5, "Completely agree", or "I don't know"
On structural flood protection ††	*I trust the local administration when it comes to structural flood protection.*	On a scale from 1, "Completely disagree" to 5, "Completely agree", or "I don't know"
Preparedness		
Individual preparedness	*How prepared do you think you are to face a flood in case it would occur?*	On a scale from 1, "Not at all prepared" to 5, "Highly prepared", or "I don't know"
Community preparedness †	*How prepared do you think your town is to face a flood in case it would occur?*	On a scale from 1, "Not at all prepared" to 5, "Highly prepared", or "I don't know"

* "I don't know" answers were categorized as *NA* and excluded from the analysis
† asked only in Vermiglio and Romagnano (Paper I)
†† asked only in Negrar (Paper II)

As shown in Table 2, the majority of the examined variables are either ordinal or dichotomous. The main challenge in analysing this type of data lies on the non-parametric nature of the statistical tests and models to be used. Ordinal data such as scales (e.g. from 1, min to 5, max) can often have error structures that are not normally distributed, and thus violate assumptions of the most common parametric statistics (e.g. of linear regressions).

Here, different tests and models were used to longitudinally analyse ordinal and dichotomous data in the two papers. In **Paper I**, differences over time were explored using Chi-square contingency table tests. This test allows to check whether distributions of categorical variables (such as ordinal and dichotomous, in this case) differ from each other, and thus whether respondents at time 2 ($t2$) replied differently from respondents at time 1 ($t1$) (i.e. high X^2 value). The influence of independent variables on risk perception was explored through Spearman's rank correlations, a type of correlation test appropriate for ordinal data, which assesses whether the relationship between two variables can be described using a monotonic function (i.e. a function that never decreases or never increases, depending on the direction). If the coefficient ρ (Spearman's rho) is equal to 1 (–1), then there is a perfect positive (negative) correlation between the two variables.

In **Paper II**, ordinal regressions were used to test both the effect of time and the effect of other independent variables on flood risk perception. Here, two analyses were run in parallel, one on the RCS dataset and one on the panel dataset. For the RCS, ordinal regressions were run through cumulative link models (CLMs, Christensen, 2019), which treat the observations as categorical and ordered in nature. The panel analysis was conducted using cumulative link mixed models (CLMMs, Christensen, 2019), which additionally allow the introduction of random effects for dealing with repeated measures (i.e. when one or more identical measurement are taken on the same individual – in this case, asking the same question two or more times to the same individual). In addition to exploring changes over time over the entire sample, here respondents were grouped according to the amount of damage they suffered during the 2018 flood (a proxy for severity of experience) and gender, to explore whether these two factors influenced the evolution of flood risk perception. Results from the RCS and the panel analyses were then qualitatively compared to check differences in impact and impact direction of time.

Cross-sectional survey to untangle the role of experience and knowledge

As pointed out in the introduction, the unclear effect of experience on the perception of flood risk may partly result from the multiple definitions assigned both to the word *experience* itself and to flood risk perception. Some studies found that experience positively affects risk awareness, some found that it negatively affects it, and others did not find any or an unclear influence. In addition, it is critical to understand how self-assessed knowledge derived from direct experience and from other sources affects risk awareness. This is especially relevant in light of the fact that individuals with a lower self-assessed knowledge have been shown to be keener to receive new information, which has implications in terms of risk communication. Thus, to untangle the confusion in the literature, **Paper III** broke down the concepts of experience and perception by testing the effect that one has on the other under different definitions. Experience was then put in relation to different sources of knowledge to investigate whether some sources have more impact than others.

Data collection – Face-to-face survey, cross-sectional approach

The analysis relies on data collected during the first survey round in Negrar, which has been described previously (see Negrar 2019 in Table 1 for summary statistics on the sample). For this objective, the choice fell on a cross-sectional approach, which means that only one round of surveys was conducted. Cross-sectional studies are rather versatile in that they are resource-friendly (only

one recruitment of respondents needed) and there is no risk of losing respondents over time because data are collected in one survey round only. For this reason, they are better suited to explore how prevalent certain factors or behaviours are in a population (Sedgwick, 2014), but they don't allow to explore causation. In fact, a cross-sectional approach is not recommended when investigating changes over time or when inferring causality, because the absence of the temporal dimension could even lead to misleading results (as briefly exemplified by Siegrist, 2013). In this case, however, the goal was to break down the different types and definitions of experience, knowledge, and risk perception to see whether these were the cause of confusion around their interactions, and not to investigate how they shape the perception of flood risk over time.

Examined variables and data analysis

Table 3 shows the four definitions of experience and five definitions of knowledge that were tested. The variables used to test experience range from more general definitions, such as length of residence in the area, to more specific ones, such as damage severity. This approach allows to test how much the variable choice influences the final result in terms of effect on risk perception. The variables to test self-assessed knowledge include knowledge derived from directly experiencing a flood, from local sources such as relative and friends (local knowledge), from official information (e.g. from the municipality, local authorities, the government, etc.), and from personal searches of information (e.g. internet, libraries, etc.). Threat appraisal before the event was also included under the knowledge variables. The variables used to test risk perception include perceived flood threat to oneself, one's home, and the town as whole, and expected future damage from floods (see Table 2 for information on their relative questions and available answers).

Table 3. Variables used to investigate experience and knowledge, related questions, and available answers.

Variable	Question	Available answers*
Experience		
Length of residence	*How long have you been living here?*	Since birth; Since ____ (year)
Presence during the 2018 event**	*Were you present during the 2018 event?*	"Yes", "No"
Previous flood experience	*Were you ever involved in a similar event in the past, here or elsewhere?*	"Yes", "No"

Damage severity	*How severe was the damage you experienced during the 2018 flood?*	On a scale from 1, "No damage" to 5, "Serious damage", or "I don't know"
Knowledge		
From direct experience	*How much did direct experience with the event contribute to your knowledge of floods?*	On a scale from 1, "No contribution" to 5, "Great contribution", or "I don't know"
From local sources	*How much did information passed on by others (parents, relatives, friends, etc.) contribute to your knowledge of floods?*	On a scale from 1, "No contribution" to 5, "Great contribution", or "I don't know"
From official information	*How much did official information contribute to your knowledge of floods?*	On a scale from 1, "No contribution" to 5, "Great contribution", or "I don't know"
Personal research of information	*How much did your personal research for information contribute to your knowledge of floods?*	On a scale from 1, "No contribution" to 5, "Great contribution", or "I don't know"
Threat appraisal before the event	*Before the 2018 event, did you think something like this could occur here?*	"Yes", "No" "I don't know"

* "I don't know" answers were categorized as *NA* and excluded from the analysis
** Flood occurred on September 1st, 2018 in Negrar, Veneto region, Italy

As in **Paper II**, the statistical analysis was here conducted through single ordinal regressions (using CLMs) and thus the p-values were Hochberg-adjusted for multiple testing. The choice fell on single (as opposed to multiple) regressions because the goal here was not to find a good model fit to predict flood risk perceptions, but rather to test how different definitions of experience and sources of knowledge influence flood risk perception.

Nation-wide surveys to examine the relationship between floods and droughts

As mentioned in the introduction, under changing climate and environmental conditions it is critical to set the perception of flood risk in a broader context. People's perceptions of a hazard are not only driven by factors immediately related to the hazard itself and the individual's characteristics, but they are also shaped by the environment the people are in – including other natural hazards. Because this thesis is focusing on hydrological risk, flood risk perception here is put in relationship with the perception of drought, another water-related hazard. To investigate this relationship, it was crucial to survey a large area that spans across different climatic zones, as drought is a phenomenon with a much larger spatial distribution compared to floods (which are generally more locally confined). This also allows for comparing hydrological

risk perceptions across areas that have different history and experiences with hydrological extremes. Here too, the choice fell on a cross-sectional approach (**Paper V**), as the purpose was not to assess how flood and drought risk perceptions evolve together over time. While this would be a relevant research question and is currently being considered as a future endeavour, the time frame of this thesis would have not allowed for exploring changes over time of a slow onset phenomenon such as drought.

National case studies

Two countries were selected as case studies, Italy and Sweden. This choice was driven by two main factors: a) the different climatic conditions of the two countries, which – incidentally – are projected to change significantly in the next decades, and b) the availability of flood and drought risk perception data at the national scale (**Paper IV**).

Floods are one of the major natural hazards in both countries (Nadim et al., 2008). They occur every year and cause damage across all regions (Boessenkool, 2017; EM-DAT, 2021; MSB, 2021), and they are projected to increase in both countries in the next decades. Sweden will see an increase in extreme precipitation events (SMHI, 2021) and rise from a "very low" to a "medium" flood hazard, while Italy will rise from a "medium" to a "very high" flood hazard in the time period 2071-2100 (Hosseinzadehtalaei et al., 2020).

Concerning droughts, the picture is rather different in the two countries. Even though its central regions were affected by a severe groundwater drought in 2018 (Regeringskansliet, 2018), Sweden will likely see a decline in drought occurrence, as the rest of Northern Europe (Markonis et al., 2021). Italy's southern regions were affected by three major droughts, in 2007, 2012, and 2017 (EM-DAT, 2021), and climate projections for the country show increasing temperature and decreasing precipitations (SMHI, 2021). This will likely entail an increase in drought risk in the Italian peninsula, considering that droughts in Southern Europe are mainly driven by lack of precipitation (Markonis et al., 2021),.

Data collection – Online surveys, cross-sectional approach

The data were collected in August 2020 through an online survey. **Paper IV** reports detailed information on survey administration and design, and ethical approval, thus this section only reports the main aspects. KANTAR Sifo, a Swedish marketing research company (KANTAR Sifo, 2021), was in charge of collecting the data. The company has online survey panels in both Sweden and Italy, comprising of ~100,000 individuals each. Respondents were drawn at random from these two panels to be representative of the population in terms of age, gender, and region of residence. Whenever they fill in a survey, panellists earn points that can be turned into various types of rewards (e.g.

movie tickets, or gift cards). The panellists were contacted via e-mail, and up to two reminders were sent during the survey period if they did not respond the first time. Table 4 presents summary statistics for the two samples.

Table 4. Summary statistics for the samples of Italy and Sweden.

Sample	Year	N	Age				Gender %	
			M	*SD*	*Min*	*Max*	*Female*	*Male*
Italy	2020	2033	49.0	13.9	18	79	55.6	44.4
Sweden	2020	2121	49.6	15.9	18	79	49.3	50.7

Examined variables and data analysis

To investigate potential differences in flood versus drought risk, respondents were assessed on five domains: perceived likelihood, perceived impact, perceived knowledge, perceived preparedness, and individual experience with the hazard. Table 5 shows all the variables with the respective questions and available answers. Differences within and across the two countries and the respective NUTS1 (Classification of Territorial Units for Statistics) regions were investigated through ordinal regressions (using CLMs).

Table 5. Variables used to investigate experience and knowledge, related questions, and available answers.

Variable	Question	Available answers
Likelihood		
	How likely do you think it is that you are directly involved in the following phenomena*?	On a scale from 1, "Very unlikely" to 5, "Very likely", or "I don't know"
Impact		
On respondent	In case you are involved, how much damage do you think the following phenomena* can cause to yourself?	On a scale from 1, "No damage" to 5, "Severe damage", or "I don't know"
On other people in the country	In case they would occur in [country**], how much damage do you think the following phenomena* can cause to others in the country?	On a scale from 1, "No damage" to 5, "Severe damage", or "I don't know"
Preparedness		
Of respondent	How prepared do you think you are to face the following phenomena*?	On a scale from 1, "Not at all prepared" to 5, "Highly prepared", or "I don't know"
Of authorities in the country	How prepared do you think the responsible authorities in [country**] are to face the following phenomena?	On a scale from 1, "Not at all prepared" to 5, "Highly prepared", or "I don't know"
Knowledge		

Of respondent	How knowledgeable are you about the following phenomena?	On a scale from 1, "Not at all knowledgeable" to 5, "Highly knowledgeable", or "I don't know"
Of authorities in the country	How knowledgeable do you think the responsible authorities in [country**] are about the following phenomena*?	On a scale from 1, "Not at all knowledgeable" to 5, "Highly knowledgeable", or "I don't know"
Experience		
	Have you ever experienced any of the following phenomena*, in your country or abroad?	"Yes", "No", or "I don't know"

* Floods, droughts
** Italy, Sweden

The different survey forms can be found in the Appendices. Appendix A1 contains the survey related to **Paper I**, appendix A2 the one related to **Paper II**, Appendix A3 the one related to **Paper III**, and Appendix A4 the one related to **Papers IV** and **V**. Each survey form collected socio-demographic indicators such as age, gender, education, and income. Some of the questions in A1, A2, and A3 are based on De Marchi et al. (2007).

Limitations of the different approaches and study design

While the approaches described above have been selected to suitably address the various research objectives, some limitations remain.

Statistical analyses in **Papers I**, **II** and **III** are all based on relatively small sample sizes. This is due to two main factors: i) the small size of the case study areas themselves, and ii) the available resources and time to administer the survey forms face-to-face. This can eventually lead to issues in the longitudinal approach. As previously mentioned, loss of respondents over time (*attrition rate*) in panel studies is a well-known and common issue (Hudson et al., 2020). Attrition rate can then lead to *attrition bias* if respondents do not drop out at random, and even to *retention bias* when attrition rates are so high that they hinder the statistical analysis. Here, this was accounted for by conducting an Inversed Probability of Attrition Weighing (IPAW, Hernán & Robins, 2020), a method that assigns a heavier weight to the respondents who share similar characteristics with those who dropped out after the first survey round, thus compensating for the loss of respondents. However, a comparison of the results with and without weighing showed that differences were negligible, thus the results section shows and discusses the analysis without IPAWs (as it minimises post-hoc data manipulation).

The survey at the basis of **Papers IV** and **V** did not retrieve detailed information on the respondents in terms of structural and non-structural protection measures adopted by their household, which can affect their perception of risk. Similarly, no data on specific, small-scale flood or drought events which occurred in the respondent's specific area were collected, and these can also affect the respondent's answers to the survey. Besides, this survey was administered during the COVID-19 pandemic, which was and potentially still is dominating the public attention. While this may have biased the absolute values assigned to floods and droughts in terms of risk perception, their relative values (i.e. how they compare to each other) are expected to be unaltered. Adding the temporal dimension to this dataset would help untangle these dynamics and assess whether the COVID-19 pandemic actually influenced the way in which respondents replied to the questions regarding floods and droughts.

Finally, the studies presented in this thesis were all conducted in industrialised, white-majority countries with generally favourable socio-economic conditions. Results may not be directly transferrable to, and may not be valid for different socio-economic and socio-cultural contexts.

Main findings

This section reports the findings associated with the three different objectives. Because each paper aimed at answering its own specific research question(s), only the main results will be discussed here.

Illusory stability of flood risk perception over time

The first objective of this thesis was to unravel how flood risk perception evolves over time, where risk perception is defined as a combination of risk awareness and perceived preparedness. On average, the three case studies show a relatively stable flood risk awareness over time (see Fig. 4 and **Papers I** and **II**), with few significant changes. The perceived threat to oneself is stable over time across study areas, and this may be attributed to the lack of casualties in the flood events examined. Indeed, the fortunate lack of harm to people may have led respondents to feel rather reassured about their own personal safety. Respondents in all three case studies and in both survey rounds show a rather strong optimistic bias, as scores given to the perceived threat to the town as a whole are always higher than those given to the perceived threat to oneself or one's home (see Fig. 4).

The threat to the respondent's home decreased significantly only in Vermiglio (**Paper I**) and in Negrar (but only in the RCS dataset, **Paper II**), the two places where the municipality underwent large structural protection works after the respective events (large check-dam in Vermiglio and diversion channel in Negrar), which may have contributed to an increased feeling of safety. This phenomenon is commonly known as *levee effect* or *safe development paradox* (Di Baldassarre et al., 2018; Viglione et al., 2014; White, 1945), which occurs when the implementation of structural protection measures leads to a greater sense of safety in the floodplains communities and could eventually lead to further urban development in areas at risk. It is indeed difficult, from a risk communication point of view, to convey the fallibility of such measures, which are dimensioned for events only up to a pre-determined intensity (i.e. return period). Any flood exceeding the pre-determined return period would in fact not be contained and could cause even more damage than it would have if the structural measures were not in place (as probably the area would be less urbanised). The perceived threat to the town as a whole significantly decreased

only in Vermiglio (**Paper I**), which is likely also attributable to the newly built check dam (nicknamed "the concrete giant" by locals, see Fig. 5).

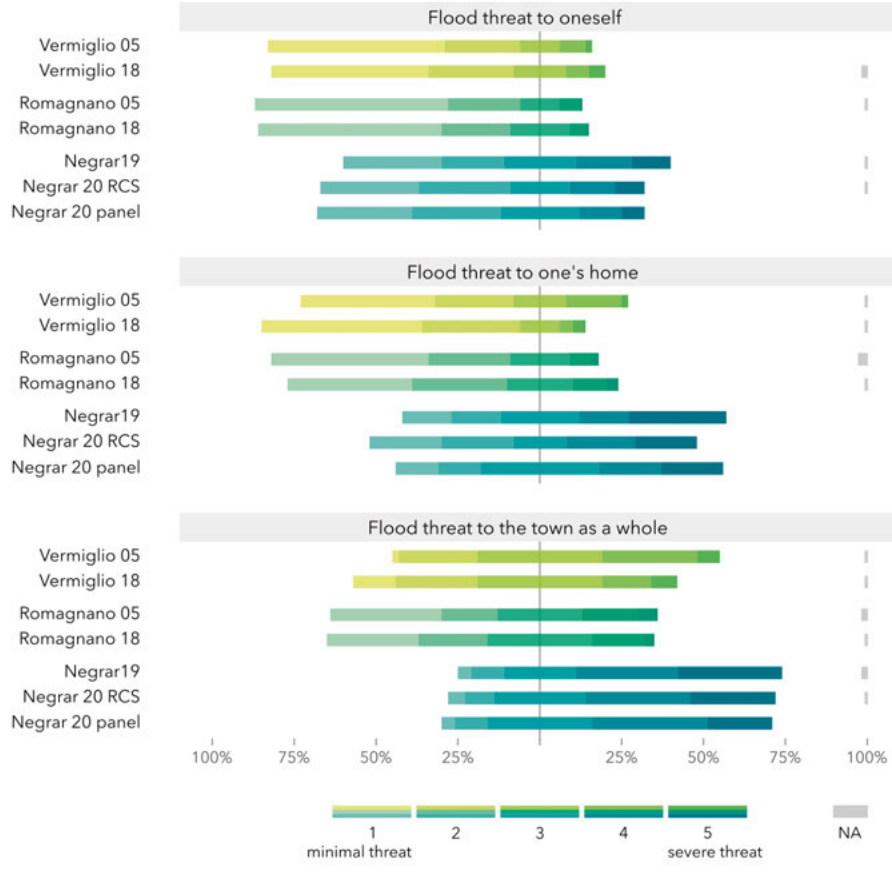


Figure 4. Results from the two survey rounds on perceived threat caused by floods in the three study areas (percentage of responses in each step of the 1–5 scale). The grey bars on the right of the plot show the percentage of "I don't know" answers.

Generally, the lack of changes on average for the majority of risk awareness variables is not surprising. Respondents in Vermiglio and Romagnano were interviewed the first time approximately 3–5 years after the event occurred, and the second time was 13 years after that, while those in Negrar were interviewed 6 months and one year after, respectively. The time frame difference is clearly reflected in their responses. Vermiglio and Romagnano show a quite low perceived threat for themselves and their home (see Fig.4 and **Paper I**), while these values are higher in Negrar, where the memory of the event was still rather fresh at the time of the survey (see Fig.4 and **Paper II**). Not only, the time frame is also likely reflected in the general lack of changes over time. In Vermiglio and Romagnano this could be attributed to the perceived threat already being back to "normal", baseline levels before the first survey round,

and in absence of events remaining at the same level still many years after. In Negrar, on the other hand, the opposite may have happened. Respondents' perceived threat was still high one and half years after the event occurred, thus no changes were detected on average over the samples. The decay of flood memory over time has been previously measured using house prices as a proxy. Right after the events, house purchase prices dropped, but this was followed by an increase in prices again few years after (Atreya et al., 2013; Zhang, 2016), indicating a likely decrease in flood memory and risk awareness in general. While house prices were not used as a proxy here, this awareness fluctuation is evident from the combination of survey results from **Papers I** and **II**.

Figure 5. Downstream (a) and upstream (b) view of the check dam from the road that leads to the village centre in Vermiglio. The infrastructure stands out in an otherwise forest-dominated alpine landscape. *Photo credits: Giacomo Bernello.*

Respondents' perceived preparedness, on the contrary, significantly changed in all case study areas (see Fig. 6). It decreased in Vermiglio and Romagnano (**Paper I**), and it increased in Negrar (but only in the panel dataset, **Paper II**). The fact that perceived preparedness seems to be more sensitive to time than the perceived threat can be attributed to a number of factors. For instance, adopting private flood protection measures, participating in risk communication events aimed at increasing knowledge, and experiencing other events without severe damage can all increase the individual's sense of preparedness. Thus, to further investigate if and how different groups of individuals show different flood risk perception dynamics, in **Paper II** – in addition to assaying changes on average over the entire sample (Fig. 4 and 6) – respondents were

clustered based on gender and amount of damage suffered during the Negrar 2018 flood.

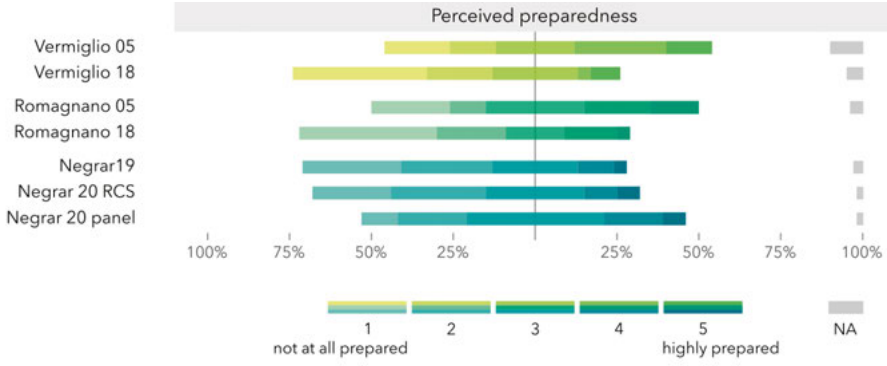


Figure 6. Results from the two survey rounds on perceived individual preparedness in the three study areas. The grey bars on the right of the plot show the percentage of "I don't know" answers.

The results from the clustered analysis show that risk perception dynamics are in fact heterogenous (**Paper II**). For instance, the RCS study shows that while on average the perceived threat to self seems to not have changed over time, it actually decreased for respondents who suffered no damage, and it increased for those who suffered severe damage (i.e. 4–5 on the 1–5 scale). The RCS also shows that the perceived threat to one's home decreased only for women (**Paper II**). Similarly, the panel shows that while the perceived threat to the town as a whole seems stable on average, it actually decreased for women (**Paper II**). This may be partially explained by women's increased trust in authorities when it comes to structural protection works (**Paper II**). In addition, the fact that women have a higher risk awareness than men at the first survey round, but then decreases, shows that gender influences how risk awareness fluctuates. Women seem to have a spike in awareness at first, which then decreases, while men show a more stable awareness over time (**Paper II**).

The trust in the administration on risk communication increased only for respondents who suffered low damage (i.e. 2–3 on the 1–5 scale, **Paper II**). Similarly, the trust in the administration on protection works increased only for respondents who suffered low damage and for women (**Paper II**). Perceived preparedness also increased only for those who suffered low damage (**Paper II**). This phenomenon is known as *risk perception paradox*, and confirms previous findings on the influence of experience (Wachinger et al., 2013): if the flood experience was not particularly severe, it is likely that the perception of risk actually decreases (Deeming, 2008; Green et al., 1991; Mileti & O'Brien, 1993; Wachinger & Renn, 2010). Here, the stability of risk awareness and the increase in perceived preparedness point towards a decrease

in risk perception for respondents who suffered low damage, but not for others.

The nuanced role of experience

Adding on about experience and its severity, the second objective of this thesis was to untangle its complex role and its relation to knowledge in shaping flood risk awareness. **Paper III** shows that the influence of experience is truly multifaceted. Distinct types of experience have a different impact depending on the risk awareness variables assayed. Specific definitions of experience are shown to directly influence many risk awareness variables. For example, being present during the event, i.e. witnessing the event with one's own eyes, is shown to influence the perceived threat to oneself. Suffering damage, instead, is more likely to impact the perceived threat to the home and the town (as shown also in **Paper II**). This can be attributed to the nature of the experience itself. For example, the fact of witnessing a flood can help us produce a mental imagery of what would happen to us should we be hit by a flood, thus increasing our worry for ourselves. On the other hand, more generic definitions, such as asking about a general previous experience with the event, indirectly influence risk awareness. A general previous experience positively affects the knowledge derived from direct experience, which in turn positively affects all risk awareness variables (self, home, and town). The majority of respondents have in fact indicated that direct experience is their greatest source of knowledge when it comes to floods. This shows that it is not only the experience itself, but also how we process it and what we learn from it that actually influences our awareness. Following these findings, **Paper III** proposes a typology based on experience and knowledge, to facilitate future research on the complex influence of these two variables. The typology (shown in Fig. 7) comprises four types:

- *Inertia*: this type includes individuals who lack or have a low degree of both experience and knowledge, who are therefore less familiar or not familiar at all with the hazard, in a state of inertia, passivity;
- *Tacit/empirical knowledge*: this type includes individuals who only experienced the event but who did not gain any information (or gained very limited information) from other sources of knowledge;
- *Theoretical knowledge*: this type includes individuals who only gained information from other sources of knowledge but who never experienced the hazard;

- *Wisdom*: this type includes individuals who experienced the hazard and who gained information from various sources of knowledge, who therefore gained wisdom by integrating experience and knowledge.

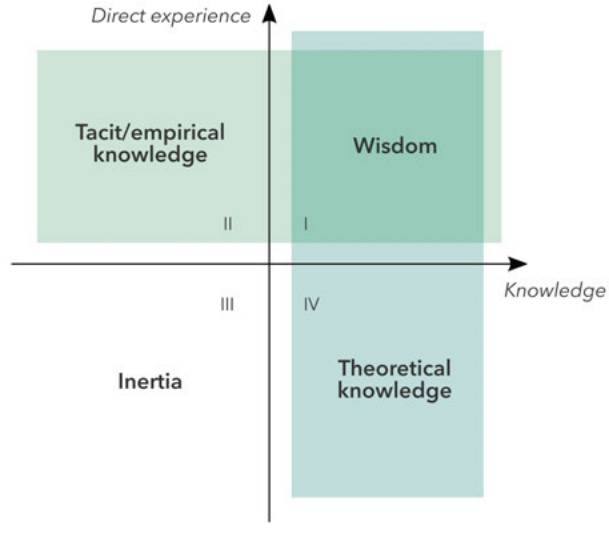


Figure 7. Experience-Knowledge typology (**Paper III**).

Aristotle introduced the concept of theoretical knowledge for the first time in his *Nicomachean Ethics* (350 B.C.). He defines theoretical knowledge as the one of the *spectators*, that is, what comes from "standing back" and "looking on". Here, the spectator can be the one who gains knowledge from secondary sources, without having experienced any flood. Tacit knowledge was later introduced by Polanyi (1966), who defines it as that which comes from direct experience, hidden and implicit. In philosophy, this is also known as empirical knowledge, as opposed to knowledge derived from theory. This typology can be useful to categorise respondents depending on their experience and knowledge of the hazard and evaluate whether these characteristics can explain differences in the perception of risk. It can also be employed for the design of tailored risk communication strategies. For instance, individuals on the left side of the typology may benefit from an increased communication in terms of what to do and how to behave when a flood occurs. Individuals with empirical knowledge can collaborate with those with theoretical knowledge and design risk communication activities for those in the quadrant III, i.e. those who have neither experience with nor knowledge of floods.

The intertwining of flood and drought risk perception

The third, and last, objective of this thesis was setting floods in a broader context by exploring the relationship between flood and drought risk perception in Italy and Sweden. **Paper V** shows that experience plays a critical role also in the combination of flood and drought risk perception. The geographical distribution of flood and drought experience varies quite widely across and within the two countries, and it is reflected in how flood and drought risk are perceived. Flood risk perception is rather homogeneous in terms of both perceived likelihood and perceived impact on the respondent (see Fig. 8).

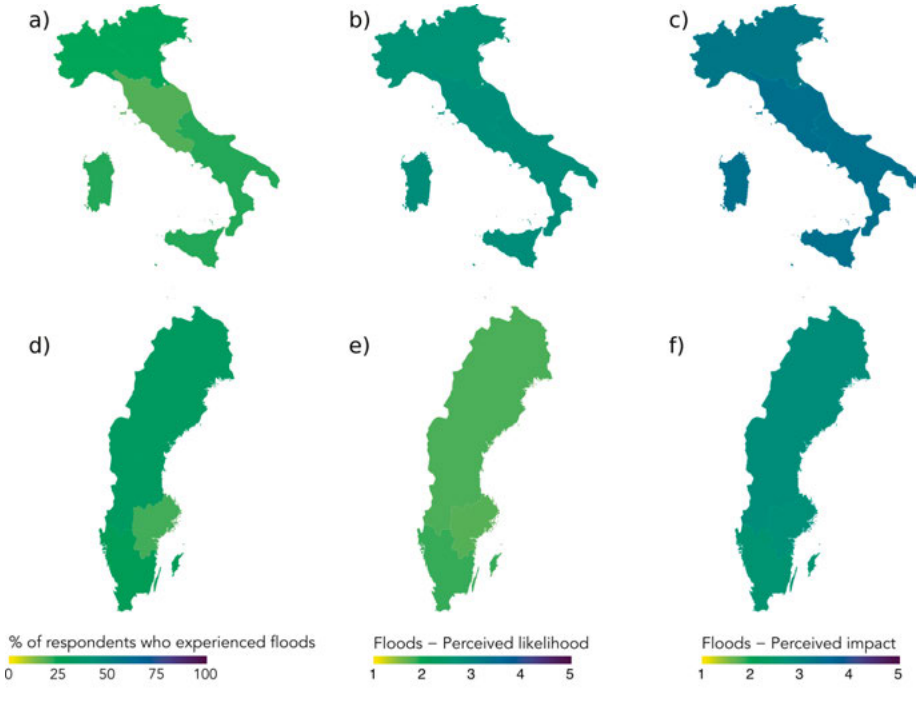


Figure 8. Results from the two nation-wide surveys in relation to flood experience (a, d), perceived flood likelihood (b, e), and perceived flood impact (c, f).

Drought risk perception is instead much more zonal, with southern regions both in Italy and Sweden showing a significantly higher degree of both perceived impact and perceived likelihood, compared to the rest of the respective countries (as shown in Fig. 9). These findings are not surprising, as floods are a capillary hazard that can occur and cause severe damage almost everywhere, while droughts are much more tied to the geography and climate of an area. For example, Italy's southern regions, show a higher risk perception compared to the rest of the country (see Fig. 9a, b, and c). This could be explained by the heavy reliance on agriculture typical of the area paired with a generally drier climate. In addition, floods have a much more rapid onset compared to

droughts, and their negative consequences are immediate and generally confined to the place of occurrence. Because of the slower onset of drought, its consequences stretch over a longer time span and have many direct and indirect effects that can resonate elsewhere (Stanke et al., 2013).

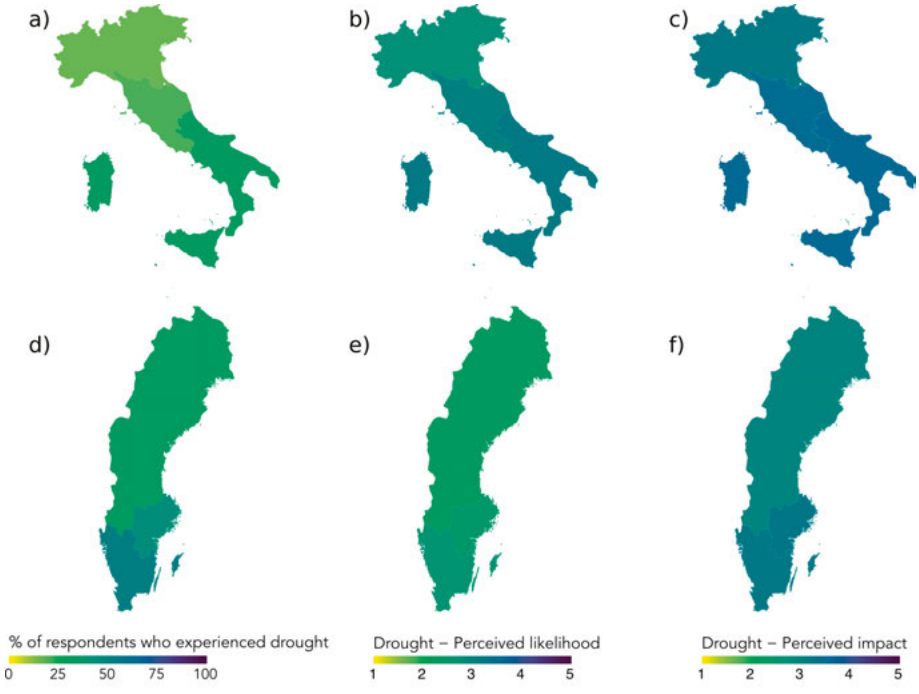


Figure 9. Results from the two nation-wide surveys in relation to drought experience (a, d), perceived drought likelihood (b, e), and perceived drought impact (c, f).

Despite these regional differences, **Paper V** shows that experiencing one hydrological extreme influences not only the perceptions towards that same hazard, but also towards the other extreme. This reflects the intertwined nature not only of the two natural phenomena (i.e. floods and droughts as two sides of the same coin), but also of people's perception of them. In Italy as well as in Sweden, drought experience, perceived likelihood, and perceived impact have been found to be significantly associated with flood experience, perceived likelihood, and perceived impact. In both countries, respondents who reported having experienced drought were also more likely to report having experienced a flood. This results in respondents showing a high perceived likelihood and impact of drought also showing a high perceived likelihood and impact of floods, here too in both countries. Winsemius et al. (2015) previously documented the combined exposure to floods and droughts, and the amount of people exposed to both is forecasted to increase globally (Güneralp et al., 2015).

Conclusions

In relation to its three objectives, this thesis has shown that: a) flood risk perception follows different trajectories over time depending on gender and experience; b) experiencing a flood influences our flood risk perception not only directly, but also indirectly through knowledge gained directly from the experience itself; and c) flood risk perception is substantially intertwined with the perception of drought risk. These findings have a number of practical as well as theoretical implications, as not only they can inform water management, but also contribute to the psychological and behavioural debates on protection motivation and, more in general, adaptation to natural hazards risk. This concluding section will discuss how DRR and the conceptualisation of human-water systems can both benefit from this thesis' contribution and will set the path for how future research can build up on these findings to further risk reduction efforts and improve the understanding of human-water interactions.

Implications for DRR

DRR is becoming increasingly relevant to address worsened climate conditions and the increase in natural hazard occurrences. Nonetheless, the DRR machine is run by many different actors (e.g. scientists, practitioners, policymakers, local communities, to name a few). Understanding each other and each other's (sometimes diverging) motifs and objectives is a first step towards an efficient and coordinated effort to run the machine. The results of this thesis shed light on the local communities' perspectives in terms of flood and drought risk. **Papers I** and **II** as well as previous studies (Seebauer & Babcicky, 2020) have shown that flood risk perception is likely to start decreasing from around 1.5 to 2 years after a flood event (in absence of other consequent events). In light of this, risk communication campaigns are likely to be more effective when conducted after the end of this 2-year period, when the perception of risk is starting to decrease. This timeframe can be seen as a window of opportunity to implement risk communication strategies that take into account the fact that flood risk perception changes differently for different groups of people. As shown in **Paper II**, women tend to have a higher risk awareness right after the event compared to men, but then it decreases over time, while for men it tends to be more stable. The severity of experience also affects the temporal dynamics of flood risk perception, with people suffering

only small damage showing a decrease in awareness and an increase in perceived preparedness. Risk communication campaigns should particularly be careful to this aspect, as it could create a false sense of safety in residents potentially at risk.

The presence of large structural protection measures can also contribute to a (often) false feeling of safety in residents, who may be led to believe that these measures eliminate risk of serious damage (as shown in **Paper II**). This can eventually lead to a transfer of responsibility from the individual to the measures themselves and more broadly to the authorities responsible for their implementation (Terpstra & Gutteling, 2008). While certainly the responsibility for risk reduction should not fall entirely on the private citizen, the more actors (private and public) involved in risk reduction efforts, the higher the probability of success in reducing and/or mitigating risk.

On the other hand, experiencing an event, especially one that causes severe damage, has been shown to increase the awareness of flood risk (**Papers II** & **III**). The negative experience of the event, which creates a moment of high attention in the community, can and should be used as a trampoline for risk communication, to promote awareness at the community level and also to show the importance of adopting protective behaviour at the individual level. For instance, the post-flood informative events organised by the municipality in Negrar have taken advantage of the window of opportunity to inform the citizens on the causes of the flood. Afterwards, residents who participated to some of these events reported a higher knowledge acquired through official information than those who did not.

In general, risk reduction strategies should also consider the intertwined nature of flood and drought risk perception. DRR strategies implemented to mitigate flood risk can often end up exacerbating drought risk, and vice versa (see, for instance, Ward et al., 2020). **Paper V**, however, shows that this divide in the implementation of risk reduction strategies is not reflected in the perception of flood and drought risk. This is a positive finding, as it shows that there would likely be support for an integrated management of hydrological risk, i.e. one that address flood *and* drought risk, ensuring that one end does not hinder the other.

Implications for conceptualising human-water systems

The conceptualisation and modelling of human-water systems, which is at the core of disciplines such as sociohydrology, aims at simplifying the studied systems so that general trends can be explored and understood. Indeed, the simplicity that a model should achieve is not the one deriving from lack of knowledge or information, but rather the one that derives from a critical understanding of the complexity and uncertainty behind coupled human-water systems and the ability to present it in a simple way (see Fig. 10). To reach the

other side of complexity, it is fundamental to unravel its many levels, such as for instance the uncertainty behind hydrological predictions as well as human behaviour. This thesis contributes to this effort by showing that, quite trivially, people's perceptions of hydrological risk are not homogeneous, and should be accounted for when modelling human-water interactions in the field of flood risk.

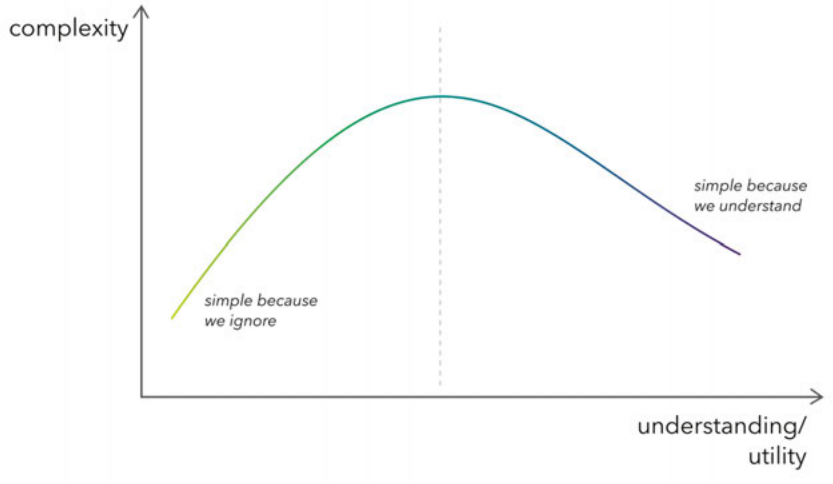


Figure 10. Graphical representation of the concept of *simplicity on the other side of complexity*.

System dynamics models of human-water systems are based on differential equations aimed at qualitatively describing how e.g. risk awareness is built up, how it changes over time, and how it relates to preparedness (Di Baldassarre et al., 2013; Di Baldassarre et al., 2015; Garcia et al., 2016; Gonzales & Ajami, 2017; Kuil et al., 2016; Viglione et al., 2014; Yu et al., 2017). Longitudinal survey data, such as those presented here, can be used to evaluate the explanatory value of the model by comparing the model outcomes with the results of the survey. **Paper I** showed that the dynamics of awareness and preparedness should be separated, as not only are they not suitable proxies for each other, but different groups of people may show different levels of awareness and/or preparedness, potentially leading to misleading description and projections of the coupled system. This has been additionally confirmed in **Paper II**, where – as mentioned earlier – results show awareness and preparedness trajectories depend not only on gender, but also on the severity of the experience with floods. In this regard, this thesis calls for a more heterogeneous representation of society within system dynamics models of human-water systems.

Longitudinal data on the social dimension of the model should also be employed carefully depending on the initial aim of the model. Different types of longitudinal data, e.g. RCS versus panel, can contribute to different kinds of

models. Models that are aimed at generalizing human-water interactions, and thus untied from a specific case study, can benefit from longitudinal data collected via an RCS approach, where the community, and not the individual, is followed over time. On the other hand, models that are aimed at theory-testing may benefit more from a panel dataset, as hypothesised connections between variables can be related to a single individual. This is also because the statistical power of the analyses that can be conducted with the two approaches differs. Panel datasets allow for lower standard errors than RCS ones, hence their better suitability for theory-testing, which often requires a more in-depth analysis of the data. Converging results from an RCS and a panel study (as shown in **Paper II**) are particularly valuable if a model is developed for a specific case study, as obtaining the same result following different approaches can be an indicator of robustness.

I would not give a fig for the simplicity this side of complexity, but I would give my life for the simplicity on the other side of complexity.
– Oliver Wendell Holmes Jr.

An outlook

This thesis has shown the importance of understanding how hydrological risk perception changes over time, differs among individuals, and is influenced by a variety of societal and environmental factors. Building on these findings, future efforts may consider exploring such changes and differences even further, and for longer time frames, to advance our understanding of the complex dynamics of risk perceptions and public attitudes. This is particularly relevant in a world that is experiencing disruptive climatic changes, where the occurrence of extreme events of any kind is slowly becoming the norm. Fostering human adaptation to these unprecedented conditions is a priority. This starts with promoting the awareness that we are, indeed, in dire straits, but that we also have the agency and the capacity to address the risk and, eventually, adapt.

Sammanfattning på svenska

Vatten och samhälle: ett komplext förhållande

Människor och vatten har format och påverkat varandra sedan urminnes tider. Människor är beroende av vatten inte bara för sina grundläggande behov, utan också för transport, handel, elproduktion och rekreation. Vatten är viktigt för livet på jorden, men både överskott och brist på vatten kan rubba en redan skör balans. Översvämningar och händelser av torka skördar idag dödsoffer och orsakar ekonomiska skador för miljarder, effekter som kommer förvärras av klimatförändringarna och med en fortsatt ökad mänsklig påverkan på vattensystemen (t.ex. genom ökad urbanisering och vattenförbrukning).

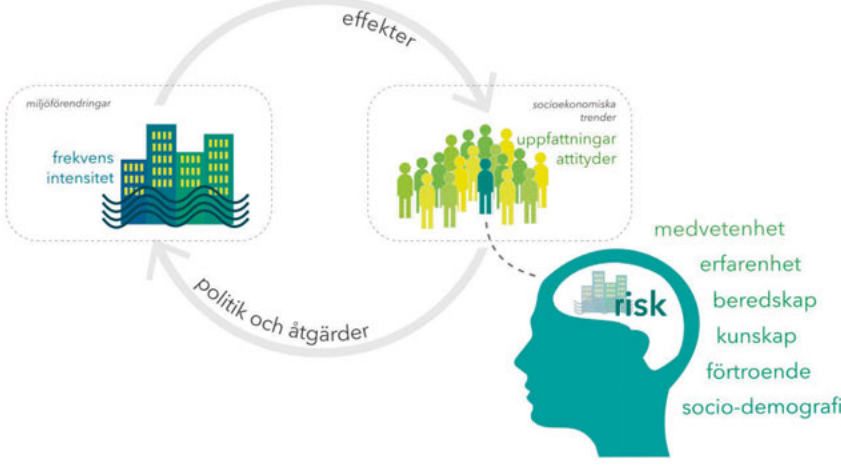
Ett exempel på detta komplexa förhållande är att människor väljer att bosätta sig i närheten av vattendrag på grund av dess fördelar (t.ex. välbefinnande och rekreationsområden), och utsätter sig därmed för översvämningsrisker. Storleken på dessa risker beror på tre faktorer: a) hur ofta översvämningar inträffar och hur intensiva dessa är, b) samhällets exponering, och c) samhällets sårbarhet. Beroende på samhällets resurser, har människan möjlighet att påverka alla dessa faktorer. Samhällen kan minska frekvensen av översvämningar genom att bygga dämningssystem; de kan minska sin egen exponering genom att bosätta sig längre bort från vattendrag; och de kan minska sin sårbarhet genom att vidta riskreducerande åtgärder eller genom att skapa ett stödsystem för sårbara hushåll och företag. Detta är bara några exempel på hur människans agerande kan påverka förekomsten och effekterna av en naturolycka. Människans agerande styrs dock av flera faktorer, bland annat dess riskuppfattning. Riskuppfattningen är inte den enda drivkraften, men en viktig sådan. Om en naturolycka, exempelvis en översvämning, inträffar påverkar den samhället inte bara i form av skador på egendom och eventuella förluster av människoliv, utan också i form av de berörda individernas uppfattning och attityd till själva faran.

Vad är riskuppfattning och varför är den viktig?

Riskuppfattning är en dynamisk process som ständigt utvecklas över tid. Detta gör det svårt att fastställa vilken nivå av riskuppfattning som finns i ett visst samhälle och hur den förändras, till exempel efter en översvämning. Dessutom beror riskuppfattningen både på subjektiva och objektiva faktorer. Tidigare

erfarenheter, kunskap om risker, förtroende för myndigheter och institutioner, beredskap och sociodemografiska indikatorer som ålder och kön bidrar till vår riskuppfattning. Det är dock fortfarande oklart hur vissa av dessa variabler, exempelvis erfarenhet, påverkar oss. Slutligen påverkas riskuppfattning ytterligare av miljöförändringar och andra naturolyckor (som dessutom formar riskens frekvens och intensitet) och socioekonomiska trender (som dessutom påverkar individens ställning i samhället). Att veta hur riskuppfattning fungerar och förändras över tid är viktigt på grund av två skäl. Å ena sidan bidrar det till insatser för katastrofriskreducering eftersom vi till exempel kan utveckla bättre strategier för riskkommunikation om vi vet hur människor uppfattar risker. Å andra sidan hjälper det oss att förstå de mekanismer som driver samspelet mellan människor och vattensystem ur ett teoretiskt perspektiv. Systemet människa-hydrologisk risk är schematiskt beskrivet i Figur 1.

I min avhandling ämnar jag ge svar på följande forskningsfrågor: (1) Hur förändras riskuppfattning över tid? (2) Hur påverkas riskuppfattningen av tidigare erfarenheter? (3) Hur förhåller sig uppfattningen om översvämningsrisk till andra riskuppfattningar, såsom risk för torka?



Figur 1. Förhållandet mellan hydrologiska risker och samhället (baserat på Di Baldassarre et al. 2018).

Låt oss fråga folket!

För att besvara dessa tre forskningsfrågor genomförde jag undersökningar på olika samhällsnivåer, både på lokal nivå via invånare i översvämningsdrabbade byar, samt på högre samhällsnivå, såsom hela länder. Undersökningarna har genomförts genom att låta deltagare fylla i enkätstudier, vilket är ett

kraftfullt verktyg för att förstå hur individer uppfattar vissa faktorer, och framför allt hur individens riskuppfattning förhåller sig till andras uppfattning.

För att besvara den första forskningsfrågan undersökte jag tre samhällen i nordöstra Italien: Vermiglio (TN) och Romagnano (TN) i den autonoma provinsen Trento, och Negrar (VR) i regionen Veneto. De två förstnämnda drabbades av översvämningar 2000 och 2002, medan Negrar drabbades av översvämningar 2018. Dessa tre samhällen undersöktes två gånger: Vermiglio och Romagnano 2005 och sedan igen 2018, Negrar 2019 och sedan igen 2020. I alla tre fallen genomfördes den första enkätstudien efter det att översvämningen inträffat. Respondenterna fick frågor om sin riskmedvetenhet, sin upplevda beredskap, sitt förtroende för skyddsåtgärder, sitt förtroende för myndigheter, den skada de drabbats av under översvämningen och sin tidigare erfarenhet av översvämningar. Jag genomförde sedan en statistisk analys för att se om det fanns skillnader mellan de två enkätstudierna. Den här metodiken möjliggjorde analys av hur riskuppfattningen efter en händelse förändrades över tid.

För att besvara den andra forskningsfrågan använde jag de uppgifter som samlades in under den första enkätstudien i Negrar. En första enkätstudie här var tillräcklig för att besvara frågan, särskilt eftersom en andel av respondenterna upplevde översvämningen nyligen. Här analyserade jag olika typer av "erfarenheter" (exempelvis skadornas storlek, närvaro under händelsen osv.) för att särskilja den oklara roll som denna variabel har för riskuppfattningen.

För att besvara den tredje forskningsfrågan utförde jag en enkätundersökning för mer än 2 000 personer, både i Italien och i Sverige, för att undersöka hur uppfattningen om översvämningsrisker förhåller sig till riskuppfattningen om torka, som är två sidor av samma mynt. Här var det nödvändigt att undersöka ett större urval jämfört med de två första forskningsfrågorna, eftersom de olika klimatzonerna i de två länderna kan medföra en skillnad i riskuppfattning. Detta gjorde det också möjligt att få med ett urval av personer som antingen har upplevt en eller båda riskerna, eller som aldrig upplevt någondera.

Vad berättade de för mig?

Analysen av enkätstudierna resulterade i tre huvudresultat. Det första resultatet visade att uppfattningen om översvämningsrisker förändras över tid på olika sätt för olika sociala grupper, beroende på till exempel kön och hur stora skador de drabbats av under översvämningen. Särskilt kvinnor tenderar att ha en högre riskmedvetenhet direkt efter händelsen som sedan minskar snabbare över tid, jämfört med mäns riskmedvetenhet som tenderar att vara lägre och mer stabil över tid. Människor som endast drabbats av lindriga skador uppvisar en minskning av riskmedvetenheten och en ökning av den upplevda beredskapen, och visar därmed en högre nivå av självförtroende över tid (jämfört med dem som inte drabbats av några eller betydande skador). Detta kan leda

till en underskattning av framtida översvämningskonsekvenser, vilket kan vara problematiskt, särskilt om det kombineras med en motvilja mot att vidta skyddsåtgärder.

Det andra resultatet visar att erfarenhet påverkar olika aspekter av riskuppfattningen beroende på vilken typ av erfarenhet det rör sig om. Att personligen bevittna en översvämning påverkar till exempel riskmedvetenheten i fråga om det upplevda hotet mot en själv. Att drabbas av skador påverkar å andra sidan mer det upplevda hotet mot ens hem och tillhörigheter. Att uppleva en översvämning påverkar också allmänhetens riskuppfattning indirekt, genom den kunskap som vi fick under händelsen.

Slutligen, det tredje resultatet visar att uppfattningen om översvämningsrisker är starkt sammanflätad med riskuppfattningen om torka. Det är till exempel mer sannolikt att människor som upplevt översvämningar också har upplevt torka. Följaktligen så anser människor som tror att översvämningar är mycket troliga att inträffa i framtiden också att händelser torka är mycket troliga, och vice versa.

Vad kan vi dra för lärdomar av deras svar?

Dessa resultat har både politiska och vetenskapliga konsekvenser. De förstnämnda gäller främst katastrofriskreducering, medan de sistnämnda gäller konceptualiseringen av system mellan människa och vatten.

När det gäller katastrofförebyggande åtgärder har denna avhandling visat hur viktigt det är att förstå att riskuppfattningar inte bara varierar mellan olika människor, utan också att de förändras på olika sätt över tid beroende på individuella egenskaper och erfarenheter. Detta är särskilt relevant för utformningen av effektiva strategier för riskkommunikation, särskilt gällande vikten av att anta ett skyddande beteende. Dessutom verkar den sammanflätade riskuppfattningen kring översvämningar och händelser av torka vara en stabil grund för att främja en integrerad hantering av hydrologiska risker. För närvarande tenderar hanteringen av hydrologiska risker att fokusera på antingen den ena eller den andra av de två riskerna (dvs. antingen översvämningar eller torka). Men katastrofförebyggande åtgärder för den ena risken kan dock förvärra konsekvenserna av den andra, vilket gör att de båda riskerna bör beaktas parallellt.

När det gäller konceptualiseringen av system mellan människa och vatten uppmanar dessa resultat till en hänsyn till den sociala heterogeniteten när man utformar matematiska modeller och datasimuleringar över samspelet mellan sociala och hydrologiska processer. Även om syftet med en modell är att förenkla det studerade systemet för att förstå dess underliggande dynamik, bör denna förenkling bygga på systemets komplexitet och inte på en bristande förståelse av dess komponenter. En modell som syftar till att syntetisera systemet människa-vatten bör vara tillräckligt enkel för att vara begriplig och

användbar. Samtidigt bör den ta hänsyn till att alla individer inte tänker, agerar och reagerar på samma sätt, eftersom denna heterogenitet kan påverka den samlade reaktionen på extrema händelser.

Översatt med hjälp av Johanna Mård och Sara Lindersson

Riassunto in italiano

Acqua e società: una relazione complicata

Le persone hanno influenzato e trasformato l'ambiente idrico, e viceversa, sin dall'antichità. L'umanità infatti dipende dall'acqua non solo per i suoi bisogni di base, ma anche per i trasporti, per il commercio, per la produzione di energia, e per la ricreazione ed il benessere. Però, se da un lato l'acqua è fondamentale per la vita sulla Terra, troppa o troppo poca acqua possono rovinare un delicato equilibrio. Ancora oggi, alluvioni e siccità continuano a causare vittime e devastazione, ed il loro impatto potrebbe essere ulteriormente inasprito dai cambiamenti climatici e dall'intensificarsi dell'attività umana sui corsi d'acqua e sul sistema idrico in generale (per esempio tramite l'aumento dei consumi e l'urbanizzazione).

Per fare un esempio di questa relazione complicata, si consideri una comunità in prossimità di un corso d'acqua. Tale comunità beneficia di un facile accesso alle risorse idriche e vanta condizioni favorevoli per i trasporti e lo sviluppo socioeconomico. Al tempo stesso, la comunità si espone ad un certo livello di rischio alluvionale. La misura di questo rischio dipende da tre componenti principali: a) la frequenza e l'intensità delle inondazioni; b) quanto la comunità è esposta alle inondazioni (es. quanti sono i residenti e i beni presenti nella pianura alluvionale); c) quanto la comunità è vulnerabile alle inondazioni (es. qual è il livello di povertà, quante persone hanno adottato misure protettive, ecc.). A seconda dei suoi mezzi, la comunità può alterare queste tre componenti. Può ridurre la frequenza delle alluvioni ed esondazioni ad esempio costruendo un sistema di argini; può ridurre la propria esposizione ad esempio costruendo nuove abitazioni più lontano dal fiume; infine può ridurre la propria vulnerabilità ad esempio creando un sistema di previsione piene e allerta e/o offrendo supporto finanziaro per le famiglie e le imprese meno agiate. Questi sono alcuni esempi di come una comunità possa influenzare l'incidenza e i danni causati dalle alluvioni. Tali interazioni sono però condizionate da molteplici fattori, tra i quali la percezione del rischio. Infatti, anche se la consapevolezza del rischio non è una condizione sufficiente di per sé per ridurre il rischio (si pensi, ad esempio, alla limitata disponibilita di mezzi economici per i meno abbienti), è però una condizione necessaria. L'occorrenza di un evento estremo come un'alluvione, inoltre, colpisce la comunità non solo dal punto di vista materiale, ad esempio causando danni alle proprietà o addirittura perdita di vite umane, ma anche dal punto di vista psicologico.

Cos'è la percezione del rischio e perché ce ne deve importare?

La percezione del rischio è un processo dinamico, che quindi cambia continuamente nel tempo. Questo la rende difficile da studiare, e rende difficile capire quale sia il livello di percezione in una comunità in un certo momento, e come questo cambi all'occorrere di un evento alluvionale. In aggiunta, la nostra percezione del rischio è influenzata da fattori sia soggettivi che oggettivi. Per esempio, esperienze precedenti, conoscenza del fenomeno, fiducia nelle istituzioni, preparazione, e indicatori sociodemografici (es. età, genere, occupazione) contribuiscono tutti alla nostra percezione del rischio. Il ruolo di alcuni di questi fattori, come ad esempio le esperienze precedenti, resta però ancora da chiarire. A complicare le cose, si aggiunge il fatto che le nostre percezioni sono ulteriormente influenzate sia dai cambiamenti a livello ambientale e globale (che influiscono sulla frequenza e sull'intensità dei fenomeni naturali), sia da trend socioeconomici (che determinano la nostra posizione all'interno della società). Capire come le percezioni degli individui colpiti funzionino e cambino nel tempo è perciò essenziale per due motivi. Da un lato, può supportare gli sforzi per ridurre il rischio idrologico perché ci permette ad esempio di sviluppare strategie migliori per la comunicazione del rischio. Dall'altro, ci aiuta a capire i meccanismi che governano la coevoluzione dei sistemi socio-idrologici (ovvero dell'interazione tra persone e ambiente idrico) da un punto di vista teorico. Questo sistema fenomeno-società è rappresentato schematicamente in Figura 1.

Pertanto, in questa tesi cerco di dare una risposta a tre domande: (1) come cambia la nostra percezione del rischio alluvionale nel tempo? (2) Qual è effettivamente il ruolo giocato dalle nostre esperienze precedenti? (3) Come si inserisce la percezione del rischio alluvionale nel palcoscenico globale e in relazione ad altri rischi?

Chiediamo alle persone!

Per dare risposta a queste tre domande, ho condotto dei sondaggi in varie comunità, alcune più piccole, come i residenti di piccoli paesi alluvionati, e altre più grandi, come intere nazioni. I sondaggi, effettuati tramite la compilazione di un questionario, sono infatti uno strumento efficace per capire come un individuo percepisce determinati fattori, e soprattutto come la percezione di un singolo si relaziona alla percezione degli altri.

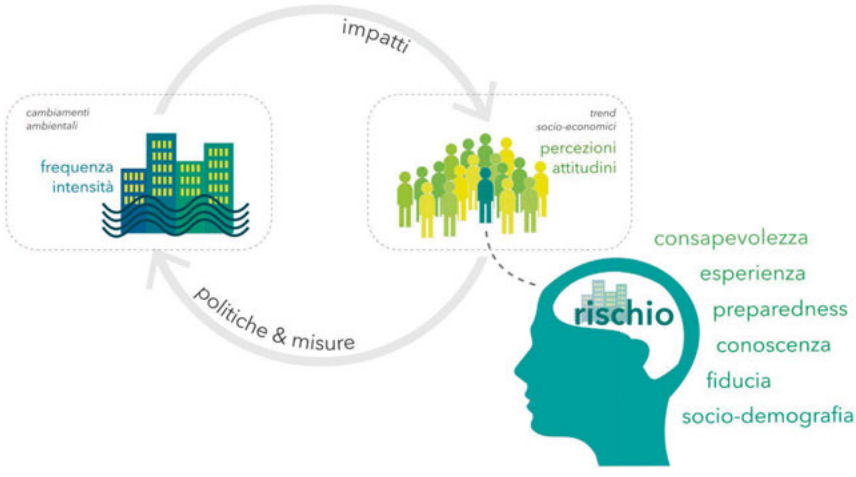


Figura 1. La relazione tra società e fenomeni idrologici (basata su Di Baldassarre et al. 2018).

Per rispondere alla prima domanda, ho condotto un sondaggio in tre comunità nell'Italia del nord-est, a Vermiglio e Romagnano nella Provincia Autonoma di Trento, e a Negrar (VR) nella Regione Veneto. Le prime due furono entrambe colpite da un'alluvione nel 2000 (Vermiglio poi di nuovo nel 2002), mentre Negrar nel 2018. In tutti e tre i casi, sono stati condotti due sondaggi, uno dopo l'evento (nel 2005 a Vermiglio e Romagnano e nel 2019 a Negrar) e uno qualche tempo dopo al primo sondaggio (nel 2018 a Vermiglio e Romagnano e nel 2020 a Negrar). Agli intervistati sono state fatte delle domande sulla loro consapevolezza del rischio, la loro preparazione ad affrontare eventuali eventi alluvionali, la loro fiducia nelle misure di protezione e nelle istituzioni, i danni subiti dall'alluvione e loro eventuali esperienze precedenti. Tramite un'analisi statistica dei dati raccolti, ho poi cercato di capire se ci fossero differenze tra le risposte date la prima e la seconda volta. Questo tipo di studio infatti permette di capire come (e se) le percezioni cambino nel tempo, in seguito ad un'alluvione.

Per rispondere alla seconda domanda, ho invece utilizzato soltanto i dati raccolti nel primo sondaggio condotto a Negrar, nel 2019. Questi dati erano infatti sufficienti, poiché parte degli intervistati avevano da poco subito l'evento alluvionale (circa 6 mesi prima), condizione ideale per studiare il ruolo dell'esperienza nella percezione del rischio. Qui ho analizzato diverse tipologie di esperienza (es. il solo essere presenti durante l'evento, la quantità di danni subiti, ecc.) per districare e chiarire il loro ruolo.

Infine, ho condotto un sondaggio su più di 2000 individui, sia in Italia che in Svezia, per rispondere alla terza domanda e capire come la percezione del rischio alluvionale si relaziona con la percezione del rischio di siccità, due facce della stessa medaglia. In questo caso, è stato necessario condurre il

sondaggio su molti individui residenti in diverse zone climatiche, poiché questo potrebbe influenzare particolarmente la percezione del rischio di siccità. Inoltre, questo ha permesso di includere nella ricerca non solo individui che hanno avuto esperienze precedenti con i due fenomeni (alluvioni e siccità), ma anche coloro che non ne sono mai stati colpiti, estendendo il campionamento a tutta la nazione.

Cosa mi hanno detto?

L'analisi dei dati provenienti dai vari sondaggi ha portato alla luce tre risultati principali. In relazione alla prima domanda, ovvero come cambia nel tempo la nostra percezione del rischio idrologico, sono giunta alla conclusione che la percezione del rischio cambia in modo diverso per ognuno di noi a seconda di determinate caratteristiche. Per esempio, le donne tendono ad avere una percezione più alta subito dopo l'evento, che poi diminuisce in maniera più brusca rispetto agli uomini, che invece tendono ad avere una percezione più stabile nel tempo. Anche l'ingenza dei danni subiti influenza questo cambiamento nel tempo. Infatti, le persone che hanno subito danni di poco conto mostrano una diminuzione di consapevolezza del rischio e si sentono più preparati, nel tempo, rispetto agli individui che o non hanno subito alcun danno o ne hanno subiti di ingenti. Questo sembra indicare un aumento di sicurezza in sé stessi/e comprovato dal fatto che l'alluvione ha sì causato dei danni, ma non così gravi da preoccuparsene. Ciò può portare queste persone a sottovalutare potenziali future alluvioni, atteggiamento relativamente pericoloso specialmente se abbinato ad una scarsa inclinazione all'adozione di misure protettive.

In relazione alla seconda domanda, sul ruolo dell'esperienza nella percezione del rischio alluvionale, i dati sembrano indicare che diversi tipi di esperienza influenzano diverse componenti della percezione. Per esempio, essere testimoni di un'alluvione, ovvero essere presenti durante l'evento, influenza la percezione del rischio per sé stessi. Invece, subire danni influenza maggiormente la percezione del rischio per la propria casa e i propri beni. Vivere l'esperienza di un'alluvione sembra inoltre influenzare la percezione del rischio non solo direttamente, ma anche indirettamente attraverso la conoscenza che ne deriva.

Infine, in relazione alla terza ed ultima domanda, i dati mostrano che la percezione del rischio alluvionale è fortemente intrecciata alla percezione del rischio di siccità. Per esempio, le persone che hanno riportato di aver subito un'alluvione, avevano anche più probabilità di aver subito una condizione di siccità. Di conseguenza, le persone che pensano sia probabile che un'alluvione si verifichi di nuovo in futuro, tendono anche a pensare che la siccità possa verificarsi di nuovo in futuro, e viceversa.

Che cosa significano le loro risposte?

I risultati di questa tesi hanno implicazioni sia dal punto di vista pratico, in termini di riduzione del rischio, sia dal punto di vista teorico, per lo studio dei sistemi socio-idrologici. Per quanto riguarda la riduzione del rischio, questa tesi mostra quanto sia importante capire che le percezioni cambiano non solo da persona a persona, ma anche che cambiano nel tempo in modo diverso a seconda di certe caratteristiche individuali. Questo è particolarmente rilevante per la pianificazione di strategie per la comunicazione del rischio che siano efficaci, specialmente quando si comunica l'importanza di adottare misure di protezione a livello di nucleo abitativo. Inoltre, il fatto che la percezione del rischio alluvionale sia fortemente legata alla percezione del rischio di siccità sembra costituire una base solida per la promozione di una gestione *integrata* del rischio idrologico. Ancora oggi, la gestione del rischio idrologico tende spesso a favorire un estremo invece dell'altro (es. gestione incentrata sulle alluvioni, o gestione incentrata sulla siccità). Purtroppo, però, focalizzarsi sulla gestione di uno solo dei due rischi può addirittura inasprire le conseguenze del rischio che viene trascurato. Perciò diventa sempre più importante fare sì che la gestione del rischio idrologico tenga conto di entrambi gli estremi.

Per quanto riguarda lo studio dei sistemi socio-idrologici, questa tesi sottolinea l'importanza di tenere conto dell'eterogeneità sociale quando si costruiscono modelli dinamici sull'interazione tra persone e ambiente idrico. Infatti, nonostante lo scopo di un modello sia quello di semplificare il sistema di studio così da capirne le dinamiche di fondo, questa semplificazione dovrebbe basarsi sulla conoscenza e accettazione della complessità del sistema, invece di ignorarne alcune componenti o dinamiche. Da un lato, un modello con lo scopo di sintetizzare l'interazione tra persone e ambiente idrico deve essere abbastanza semplice da essere comprensibile ed utile. Dall'altro, però, deve tenere in conto che non tutti gli individui all'interno di una società pensano, agiscono, e reagiscono allo stesso modo, poiché questa eterogeneità può influenzare la risposta collettiva ad eventi estremi.

Acknowledgements

These past four years have been the most challenging and the most rewarding adventure I've ever embarked on. This inward journey made me who I am today, and for this I am beyond thankful to the many who were (and are) by my side.

Giuliano, thank you for having believed in me since day one. I cannot really find words to express how grateful I am and how lucky I've been to be part of you vibrant, inclusive, productive, and exciting research group. Thanks to you, I grew as a scientist and as a person, I learned how to deal with unpleasant situations, and I understood how to smoothen my edges. Sharing a drink with unknown Chinese men and running a Tough Viking race are only few of the amazing memories I will always bring with me. **Johanna**, thank you for always knowing what to do and for being there whenever I needed advice, in terms of research as well as personal development. **Anna**, and **Marco**, you have been the best mentors and co-authors I could ask for. You have been extremely supportive throughout these four years and none of it would have been possible without your invaluable inputs and thoughtful comments.

This thesis would have not been possible without the help and contribution of all my field assistants. **Elena**, **Giacomo**, **Viviana**, **Antonio**, **Davide**, **Federico**, **Fiorella, Flavio**, **Giovanna**, **Giulia**, **Linda**, **Luca**, **Manuel**, **Mattia**, **Tania**, **Riki** e **Valeria**: we spent such awesome times together, in Trentino and in Veneto. I will never forget the door-knocking, the endless phone calls, and the great wine. You have been fundamental to this project. In this regard, I also want to thank the **Centre for Natural Hazards and Disaster Science** (CNDS) and everyone in it, not only for funding my doctoral studies, but also and especially for being a great interdisciplinary hub. I've learnt so much just being a part of it.

My time at Geocentrum has been an emotional rollercoaster. It started with despair and fear of not fitting in, but then I met colleagues who immediately turned into some of my closest friends. **Elisa** and **Maurizio**, you have made my time here so worthwhile. You were always there, even just for a coffee or for some time off work. You understand me so well, I love you. I also want to thank everybody in our research group, **Kaycee**, **Elena Ridolfi**, **Maria**, **Frederike**, **Vincent**, and **Elena Raffetti**, for every *fika*, discussion, and

hydrosocial event that we shared. I was also lucky enough to share my office with two other wonderful people, **Sara** and **Georgeos**. The atmosphere in our little room was always relaxed and we could always joke around and exchange opinions on the aesthetics of our graphs (but not only). **Chiara**, we got to know each other only later, but I'm so glad we did because we had so much fun. **Lucia**, **Kevin**, and **Christoffer**, our cycling team is newborn, but I hope it lives on!

Vermiglio & Romagnano, September 2018

Top, from the left: Giacomo Bernello, Davide Zanella, Elena Mondino, Manuel Comberlato, Flavio Taccaliti.

Bottom, from the left: Linda Libardoni, Valeria Amelii, Elena Poli

In the background: Vermiglio

Negrar, February 2019

From the left: Giulia Bisoffi, Elena Mondino, Giacomo Bernello, Federico Professione, Elena Poli, Viviana Bort

Negrar, February 2020

Top, from the left: Niki Rigo, Giacomo Bernello, Elena Mondino, Luca Pressi, Giovanna Caramuta, Mattia Balestra

Bottom, from the left: Antonio Pica, Tania Di Mascia, Fiorella Coco, Elena Poli

Uppsala means a *real deal* of friendship. **Carolina**, la mia sorella acquisita, I cannot thank you enough for everything that we shared. You helped me through my darkest time and you gave me the gift of yoga, which I will bring with me forever. **Malin**, for the countless times we baked together to get through dark Swedish winters and for always being there. **Boris**, for teaching me how to survive myself and my emotions, you are a living example of

strength. **Sascha**, for being the glue who brought us all together: without you, I wouldn't be here today thanking you all. **Giulia** and **Simone**, it rarely happens to me to find someone with whom I feel so at ease, thank you for welcoming me in your woods. **Philipp** and **Madee**, our companions of endless *raclettes* and *fondues*, thank you for always being up for anything and for joining us on many weekend getaways. **Dennis** and **Sofia**, you welcomed me in Uppsala so warmly and you gave me a roof. I will never forget your help and support and the great times we had together in Råbyvägen. And finally, my climbing crew, **Nicolas**, **Mario**, **Marco**, **Venu**, **Achmed**, **Luca**, **Emma**, **Ginho**, and **Juliana**, what a blast in Klättercentret and Palermo!

Peggy, tack så jättemycket för allt du lärde mig! Du var den bästa lärare som man kan tänka sig! Våran tid tillsammans var otrolig kul och jag kommer alltid minnas våra små trädgårdsmöten.

To my best friends **Bonita** and **Ioana**, my two soulmates. You are so far away and I miss you incredibly much, but you have been (and are) my greatest allies in the good, the bad, and the ugly.

Rimane poi un'altra parte di me, quella rimasta in Italia. La lontananza dai propri luoghi è un piccolo vuoto incolmabile, ma è anche motore di curiosità e scoperta. Questa parte di me è mantenuta viva dalle mie amiche e amici di sempre **Elisabetta**, **Maki**, **Sara** e **Filippo**. Con voi, nel tempo, sono diventata chi sono oggi, e ve ne sono infinitamente grata.

Mamma, **papà** e **Michi**, grazie per aver sempre e costantemente creduto in me e per avermi dato tutti gli strumenti per realizzare i miei sogni.

And **Julian**, for being so much more.

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Appendices

A1 – Survey form related to Paper I

FEELING OF SAFETY

1. How long have you been living in _____ (town name)?
   1. From birth *(jump to question nr. 3)*
   2. From |__|__|__|__| (yyyy)

2. If you haven't always lived in _____ (town name), where did you live before?
   1. Another municipality in the same region (specify _____)
   2. Somewhere else in Italy (specify _____)
   3. Somewhere else abroad (specify _____)
   4. Another *frazione* in the same municipality

3. Do you belong to any local associations, groups, clubs in _____ (town name)?
   1. Yes (specify _____)
   2. No

4. Are you or anyone in your family a member of the voluntary fire brigades?
   1. Yes, myself
   2. Yes, one or more of my family members (specify _____)
   3. Yes, myself and one or more of my family members (specify _____)
   4. No

5. [On a scale from 1 (min) to 5 (max)] To what extent living in _____ (town name) make you feel safe?

Minimum safety				Maximum safety	I don't know
1	2	3	4	5	0

6. Answering the previous question, what was the first thing that came to your mind?
   1. Feeling of safety within the community (proximity of family and relatives, trust, etc.)
   2. Hydrogeological safety (floods, natural hazards, land geology, etc.)
   3. Social safety (theft, robbery, immigration, drug dealing, etc.)
   4. Economic safety (unemployment, poverty, etc.)
   5. Environmental safety (traffic, smog, etc.)
   6. Two or more of the above
   7. Other (specify _____)

RISK ASSESSMENT

7. [On a scale from 1 (min) to 5 (max)] Considering hydrogeological phenomena (floods, landslides, etc.), to what extent do you think they pose a threat to _____ (town)?

Not at all				Severe threat	I don't know
1	2	3	4	5	0

8. Why?
   1. Unpredictability and exceptionality of hydrogeological phenomena
   2. Presence of structural protection works
   3. Personal knowledge of the landscape
   4. Quality of land management
   5. Other (specify _____)

9. [On a scale from 1 (min) to 5 (max)] Considering hydrogeological phenomena, to what extent do you think they pose a threat to your home?

Not at all				Severe threat	I don't know
1	2	3	4	5	0

10. Why?

_____

11. [On a scale from 1 (min) to 5 (max)] Considering hydrogeological phenomena, to what extent do you think they pose a threat to you personally?

Not at all				Severe threat	I don't know
1	2	3	4	5	0

12. Why?

_____

13. [On a scale from 1 (min) to 5 (max)] In the following list, could you indicate to what extent each of these events could pose a threat for you or your household?

	Not at all				Severe threat	I don't know
1. Earthquake	1	2	3	4	5	0
2. Terror attack	1	2	3	4	5	0
3. Robbery	1	2	3	4	5	0
4. Drought	1	2	3	4	5	0
5. Fire	1	2	3	4	5	0
6. Large carnivores attack	1	2	3	4	5	0

EXPERIENCE

14. Have you ever been involved, in the past, in hydrogeological phenomena or similar events here or elsewhere?
   1. Yes, in |__|__|__|__| in (location) _____
   2. No

15. Do you think that hydrogeological phenomena could occur again here in the future?
    1. Yes (because _____)
    2. No (because _____) *(jump to quest. nr. 17)*
    3. I don't know (because _____) *(jump to quest. nr. 17)*

16. If you think that a hydrogeological phenomenon could occur again [answer nr. 1 to question 15], within how many years according to you?
    1. Within the next _____ years
    2. I don't know

17. To the best of your knowledge, did any hydrogeological phenomena occur in Trentino-Süd Tirol in the past five years?
    1. Yes (specify _____)
    2. No
    3. I don't know

PREPAREDNESS

18. [On a scale from 1 (min) to 5 (max)] To what extent do you feel prepared to face a hydrogeological phenomenon, should it occur again?

Not at all prepared				Highly prepared	I don't know
1	2	3	4	5	0

19. Why?

_____

20. [On a scale from 1 (min) to 5 (max)] How did your hydrogeological risk awareness change in the past 15 years?

Decreased		Unchanged		Increased	I don't know
1	2	3	4	5	0

21. Why?

_____

22. [On a scale from 1 (min) to 5 (max)] How did your preparedness to face a hydrogeological phenomenon change in the past 15 years?

Decreased		Unchanged		Increased	I don't know
1	2	3	4	5	0

23. Why?

_____

24. [On a scale from 1 (min) to 5 (max)] To what extent do you think your town is prepared to face a hydrological phenomenon, should it occur again?

Not at all prepared				Highly prepared	I don't know
1	2	3	4	5	0

25. Why?

_____

26. [On a scale from 1 (decreased) to 5 (increased)] How did the following aspects change for you in tha past 15 years?

	Decreased				Increased	I don't know
1. Trust in neighbours	1	2	3	4	5	0
2. Trust in Civil Protection	1	2	3	4	5	0
3. Trust in volunteering organisations (Volunteer Fire Brigades, Nu.vo.la, etc.)	1	2	3	4	5	0
4. Trust in local administration	1	2	3	4	5	0
5. Trust in the State	1	2	3	4	5	0

PREVENTION & STRUCTURAL PROTECTION WORKS

27. Do you know any structural protection works in this area, aimed at reducing damage from hydrogeological risk?
    1. Yes (specify _____)
    2. No *(jump to question nr. 29)*

28. [If they answered yes to the previous question (answer nr. 1 to question nr. 27)] Concerning these structural protection works, to what extent do you agree with the following statements? [On a scale from 1 (min) to 5 (max)]

	Completely disagree				Completely agree	I don't know
1. Structural protection works eliminate the possibility of serious damage	1	2	3	4	5	0
2. Structural protection works are too expensive, compared to their benefits	1	2	3	4	5	0
3. Structural protection works give a feeling of safety to people living in the area	1	2	3	4	5	0
4. Structural protection works foster economic development	1	2	3	4	5	0

29. There exist different measures to prevent and reduce damage from hydrogeological phenomena. According to you, what would be the most urgent here in _____ (town name)? [max 2 answers]
    1. Build new structural protection works such as dams, check dams, barriers, diversion channels, etc. (or improve the existing ones)
    2. Ensure a better maintenance of the existing ones
    3. Manage the land differently (specify _____)
    4. Improve the preparedness of those people who live in risk areas (through exercises, courses, etc.)
    5. Other (specify _____)

30. Hydrogeological phenomena cause greater damage to buildings in risk areas. According to you, what is the situation here in _____ (town name)?
    1. Nothing was ever built in risk areas
    2. In the past something was built in risk areas
    3. Nowadays something is built in risk areas
    4. Both in the past and nowadays something was/is built in risk areas
    5. I don't know

KNOWLEDGE AND RISK COMMUNICATION

31. Knowledge about hydrogeological phenomena can come from various sources. [On a scale from 1 (min) to 5 (max)] To what extent did the following contribute to form your knowledge about hydrological phenomena?

	Not at all				Significant contribution	I don't know
1. Direct experience	1	2	3	4	5	0
2. Knowledge and experienced passed on from relatives, friends, etc.	1	2	3	4	5	0
3. Official information	1	2	3	4	5	0
4. Personal search	1	2	3	4	5	0
5. Other (specify _____)	1	2	3	4	5	0

32. To the best of your knowledge, were there public events to communicate information on hydrogeological phenomena?
    1. Yes (specify _____)
    2. No *(jump to question nr. 35)*
    3. I don't know *(jump to question nr. 35)*

33. To the best of your knowledge, did these events mention any of these topics?

	Yes	No	I don't know
1. Risk awareness and knowledge	1	2	0
2. How to implement private risk reduction measures (before and during the event)	1	2	0
3. Emergency plan and risk communication	1	2	0
4. Other (Specify_____)	1	2	0

34. Did you participate to said events?
    1. Yes (specify_____)
    2. No
    3. I don't know

35. In the following list there is a number of elements which can be used for reducing hydrogeological risk. [On a scale from 1 (min) to 5 (max)] To what extent the following elements make you feel safe?

	Minimum safety				Maximum safety	I don't know
1. Structural protection works	1	2	3	4	5	0
2. Early warning systems	1	2	3	4	5	0
3. Civil Protection	1	2	3	4	5	0
4. Voluntary Fire Brigades	1	2	3	4	5	0
5. Information received	1	2	3	4	5	0
6. Personal experience	1	2	3	4	5	0
7. Neighbours	1	2	3	4	5	0
8. Your home	1	2	3	4	5	0
9. Other (specify _____)	1	2	3	4	5	0

36. In case a hydrogeological phenomenon would occur, [on a scale from 1 (individual) to 5 (authorities/associations)] where should the responsibility to intervene fall?

Individual				Authorities/associations	I don't know
1	2	3	4	5	0

37. According to you, what is the best way to communicate risk?

_____

38. Does the Province of Trento have activities or tools to mitigate risk?
    1. Yes (specify _____)
    2. No

39. Would you like to receive more information on hydrogeological phenomena?
    1. Yes (specify which _____)
    2. No

40. Would you like to receive more information on the tools used by the Province of Trento to mitigate risk?
    1. Yes
    2. No

SOCIO-DEMOGRAPHIC INDICATORS

41. Year of birth |__|__|__|__|

42. Gender
    1. Male
    2. Female

43. Highest education achieved (lower secondary, upper secondary, university degree, etc.)

_____

44. [On a scale from 1 (min) to 5 (max)] To satisfy the needs of your household, your household income is:

Insufficient				More than sufficient	I don't know
1	2	3	4	5	0

A2 – Survey form related to Paper II

FEELING OF SAFETY

1. How long have you been living in Negrar?
   1. From birth (*jump to question nr. 3)*
   2. From _____ (yyyy)

2. If you haven't always lived here, where did you live before?
   1. Another municipality in the same region (specify _____)
   2. Somewhere else in Italy (specify _____)
   3. Somewhere else abroad (specify _____)
   4. Another *frazione* in the same municipality

3. [On a scale from 1 (min) to 5 (max)] To what extent living in Negrar make you feel safe?

Minimum safety				Maximum safety	I don't know
1	2	3	4	5	0

4. [On a scale from 1 (min) to 5 (max)] In the following list, could you indicate to what extent each of these events could pose a threat for you or your household?

	Not at all				Severe threat	I don't know
1. Earthquake	1	2	3	4	5	0
2. Terror attack	1	2	3	4	5	0
3. Robbery	1	2	3	4	5	0
4. Drought	1	2	3	4	5	0
5. Fire	1	2	3	4	5	0

RISK ASSESSMENT

5. [On a scale from 1 (min) to 5 (max)] Considering floods, to what extent do you think they pose a threat to

	Not at all				Severe threat	I don't know
1. Your home	1	2	3	4	5	0
2. You personally	1	2	3	4	5	0
3. The town as a whole	1	2	3	4	5	0

6. [On a scale from 1 (min) to 5 (max)] How much damage do you think a potential future flood could cause to your home?

No damage				Severe damage	I don't know
1	2	3	4	5	0

7. [On a scale from 1 (min) to 5 (max)] How did your flood risk awareness change, compared to one year ago?

Decreased		Unchanged		Increased	I don't know
1	2	3	4	5	0

PERSONAL EXPERIENCE

8. Have you ever been involved, in the past, in floods or similar events here or elsewhere?
   1. Yes, in |__|__|__|__| in (location) _____
   2. No

9. In September 2018 a flood hit Negrar. Were you here when the event occurred?
   1.Yes
   2.No (because _____)

10. (Only if already residing in Negrar in September 2018) [On a scale from 1 (min) to 5 (max)] Please assess the severity of the damage suffered by you or your home following the 2018 event:

No damage				Severe damage	I don't know
1	2	3	4	5	0

11. If you suffered damages, what kind?

_____

12. Did you think something like this could occur here, before the 2018 event?
    1. Yes
    2. No
    3. I don't know

13. Do you think a similar event could occur again here in the future?
    1. Yes (because _____)
    2. No (because _____)
    3. I don't know

INDIVIDUAL PREPAREDNESS

14. [On a scale from 1 (min) to 5 (max)] To what extent do you feel prepared to face a flood event, should it occur again?

Not at all prepared				Highly prepared	I don't know
1	2	3	4	5	0

15. [On a scale from 1 (min) to 5 (max)] How did your preparedness to face a flood event change, compared to one year ago?

Decreased		Unchanged		Increased	I don't know
1	2	3	4	5	0

16. Did you adopt any structural protection measure (e.g. movable bulkheads, valves, etc.) for your household? *[In case they adopted them before and after, cross 1 and write a note on the side]*
    1. Yes, before the 2018 event (which? _____)
    2. Yes, after the 2018 event (which? _____)
    3. No

17. (Only if they replied "No" to question nr 16) Why didn't you adopted any structural protection measure to protect your household from floods? [max 2 an-

swers]

1. I don't need them/I live in a safe area
2. I didn't know about them
3. I was interesred, but they are too expensive
4. These events are rare so it would be more a cost than a benefit
5. I don't know who to contact to install them
6. Protection from natural hazards is the local authorities' responsibility
7. I'm not interested
8. Other

18. (Only if they replied "No" to question 16) Do you intend to adopt any in the future?
    1. Yes
    2. No
    3. I don't know

19. (Only if they replied "Yes" to question nr 16 or "Yes" to nr 18) Which was/is the main reason you wan to adopt structural protection measures?
    1. Because it was recommended by friends, relatives, or the local administration
    2. Because I fear the occurrence of a flood
    3. Because I fear damages to my household
    4. Other (specify _____)

20. (Only if they replied "Yes" to question nr 16 or "Yes" to nr 18) [On a scale from 1 (min) to 5 (max)] Concerning structural protection measures:

	Not at all effective				Very effective	I don't know
How effective do you think they are in reducing damage from floods?	1	2	3	4	5	0
	Very low				Very high	I don't know
How do you assess their cost?	1	2	3	4	5	0

21. Did you insure your house against floods?
    1. Yes, before the 2018 event
    2. Yes, after the 2018 event
    3. No
    4. I don't know

22. (Only if they replied "No" to question nr 21) Why didn't you insure your house against floods? [max 2 answers]
    1. I don't need it/I live in a safe area
    2. I didn't know about it
    3. I was interesred, but it's too expensive
    4. These events are rare so it would be more a cost than a benefit
    5. It is not my responsibility, but the landlord's
    6. Protection from natural hazards is the local authorities' responsibility
    7. I'm not interested
    8. Other

23. (Only if they replied "No" to question nr 21) Do you intend to insure your house in the future?

1. Yes
2. No
3. I don´t know

24. Only if they replied "Yes" to question nr 21 or "Yes" to nr 23) Why do you in tend to insure your house against floods?
    1. Because it was recommended by friends, relatives, or the local administration
    2. Because I fear the occurrence of a flood
    3. Because I fear damages to my household
    4. Other (specify _____)

25. [On a scale from 1 (min) to 5 (max)] Concerning insurance:

	Not at all effective				Very effective	I don't know
	1	2	3	4	5	0
How effective do you think it is in reducing damage from floods?						

	Very low				Very high	I don't know
	1	2	3	4	5	0
How do you assess its cost?						

26. Tthere are various measures to reduce and prevent damage caused by floods. According to you, what are the most urgent ones to adopt here in Negrar? [max 2 answer]
    1. Building new structural protection works
    2. A better maintenance of the local streams
    3. A different land management (specify _____)
    4. Improve early warning systems
    5. Improve the preparedness of people living in the town
    6. Other (specify _____)

STRUCTURAL PROTECTION WORKS

27. Do you know any structural protection works in this area, aimed at reducing flood risk?
    1. Yes (which? _____)
    2. No

28. Do you know about this structural protection works? *[show picture of construction site]*
    1. Yes
    2. No *(jump to question nr. 30)*

29. (Only if they replied "Yes" to question nr 28) How did you come to know it?
    1. On my own
    2. Via friends or relatives
    3. Via the local administration
    4. Via newspapers
    5. Other (specify _____)

30. To what extent do you agree with the following statements?

	Completely disagree				Completely agree	I don't know

1. Structural protection works eliminate the possibility of serious damage	1	2	3	4	5	0
2. Structural protection works are too expensive, compared to their benefits	1	2	3	4	5	0
3. Structural protection works give a feeling of safety to people living in the area	1	2	3	4	5	0

KNOWLEDGE

31. Knowledge about flood can come from various sources. To what extent did the following contribute to form your knowledge about floods?

	Not at all				Significant contribution	I don't know
1. Direct experience	1	2	3	4	5	0
2. Knowledge and experienced passed on from relatives, friends, etc.	1	2	3	4	5	0
3. Official information	1	2	3	4	5	0
4. Personal search	1	2	3	4	5	0
5. Other (specify _____)	1	2	3	4	5	0

32. Do you know about other flood events that occurred in this region, or in neighbouring regions, in the last year?
    1. Yes (which? _____)
    2. No

33. Did you participate in informative events on floods and flood risk in the last year?
    1. Yes (which? _____)
    2. No

TRUST IN LOCAL ADMINISTRATION

34. [On a scale from 1 (min) to 5 (max)] To what extent do you agree with the following statements?

	Completely disagree				Completely agree	I don't know
1. The local administration would inform me should flood risk in my area change significantly	1	2	3	4	5	0
2. I trust local administration when it comes to flood protection	1	2	3	4	5	0
3. The local administration has always been efficient when it comes to flood protection	1	2	3	4	5	0

35. In some cases, the public administrations provide support to adopt structural protection measures for private households. [On a scale from 1 (min) to 5 (max)] What support did your household receive from local, regional, or governmental administrations?

	No support				Significant support	I don't know
1. Economical support to finance protection measures against floods	1	2	3	4	5	0
2. Material support (like sandbags or movable barriers)	1	2	3	4	5	0

3. Information and awareness-raising	1	2	3	4	5	0

SOCIO-DEMOGRAPHIC INDICATORS

36. Year of birth |__|__|__|__|

37. Gender
    1. Male
    2. Female
    3. Other

38. The home where you live is:
    1. Yours, your family's
    2. Rented
    3. Other (specifiy _____)

39. Highest education achieved:
    1. Primary school
    2. Lower secondary school
    3. Upper secondary school (3 years)
    4. Upper secondary school (5 years)
    5. University degree

40. [On a scale from 1 (min) to 5 (max)] To satisfy the needs of your household, your household income is:

Insufficient				More than sufficient	I don't know
1	2	3	4	5	0

Do you agree to be contacted again to fill in this same survey in the future?

1.Yes (contact – telephone nr/e-mail: _____)
2. No

A3 – Survey form related to Paper III

LENGTH OF RESIDENCE & SAFETY

1. How long have you been living in Negrar?
   1. Since I was born *(skip to question nr. 3)*
   2. Since _____ (yyyy)

2. If you haven't always lived in Negrar, where did you live before?
   1. In another municipality within the same region (please specify _____)
   2. Elsewhere in Italy (please specify _____)
   3. Elsewhere (please specify _____)
   4. In another *frazione* of the same municipality

3. [On a scale from 1 (min) to 5 (max)] Does "living here" make you feel safe?

Very unsafe				Very safe	I don't know
1	2	3	4	5	0

4. [On a scale from 1 (min) to 5 (max)] In the following list, could you indicate to which extent you think each of these events represents a danger for you personally or for your house?

	Not at all				Serious danger	I don't know
1. Earthquake	1	2	3	4	5	0
2. Terror attack	1	2	3	4	5	0
3. Robbery	1	2	3	4	5	0
4. Drought	1	2	3	4	5	0
5. Fire	1	2	3	4	5	0

5. Are you or anyone in your family a member of the Civil Protection?
   1. Yes, I am a member
   2. Yes, someone of my kin is a member (specify_____)
   3. Yes, both I and a /some kin are members (specify_____)
   4. No

THREAT APPRAISAL

6. [On a scale from 1 (min) to 5 (max)] Considering floods, do you think they are a threat for

	Not at all				Serious threat	I don't know
1. Your house	1	2	3	4	5	0
2. Yourself	1	2	3	4	5	0
3. Your town	1	2	3	4	5	0

7. [On a scale from 1 (min) to 5 (max)] What damages would you expect from a future flood?

No damage				Very serious damage	I don't know
1	2	3	4	5	0

EXPERIENCE

8. In September 2018 in Negrar it happened that _____ (short description of the event). Were you here at that time?
   1. Yes

2. No (why _____)

9. Please rate the seriousness of the damage suffered (by you or your property) after the event of September 2018, if any. [on a scale from 1 (min) to 5 (max)]

No damage				Very serious damage	I don't know
1	2	3	4	5	0

10. Have you ever been involved in similar events in the past, here or elsewhere?
1. Yes, in the year |_|_|_|_| in _____
2. No

11. Before the _____ (yyyy) event, would you think something like this might happen here?
1. Yes
2. No
3. I don't know

PREPAREDNESS

12. [On a scale from 1 (min) to 5 (max)] Presently, how well prepared do you feel to face a flood, in case it happens again?

Not prepared at all				Very well prepared	I don't know
1	2	3	4	5	0

13. Please indicate if and when you intend to adopt the following risk reduction measures. If you already adopted one or more of them, please state whether you did so before or after the September 2018 event.

		Will not adopt	Will maybe adopt in the future	Will adopt soon	Already adopted (post-event)	Already adopted (pre-event)	I don't know
Structural measures I	Elevated ground floor above the most likely flood level	1	2	3	4	5	0
	Reinforced foundations against water pressures	1	2	3	4	5	0
	Backflow valves	1	2	3	4	5	0
Structural measures II	Ground floor and walls made of water-resistant materials	1	2	3	4	5	0
	Special installation (e.g. higher up) of heating and electric system	1	2	3	4	5	0
Avoidance measures	Keeping personal valuables and documents out of flood-prone areas of the house	1	2	3	4	5	0
	Keeping expensive appliances (washing machine, boiler etc.)	1	2	3	4	5	0

Emergency measures	above expected flood levels					
	Adapted use of basement and ground floor	1	2	3	4	5	0
	Mobile barriers (e.g. metal/wood shields) available	1	2	3	4	5	0
	Emergency plan for household in case of floods (e.g. where to go, what to take with me)	1	2	3	4	5	0

14. [On a scale from 1 (min) to 5 (max)] How effective are the risk reduction measures overall at helping to reduce the risk of floods impacting your property and life? (show table)

	Not effective at all				Very effective	Don't know
Structural measures I	1	2	3	4	5	0
Structural measures II	1	2	3	4	5	0
Avoidance measures	1	2	3	4	5	0
Emergency measures	1	2	3	4	5	0

COSTS

15. [On a scale from 1 (min) to 5 (max)] How long will it take you to implement risk reduction measures? (show table)

	Very short time				Very long time	Don't know
Structural measures I	1	2	3	4	5	0
Structural measures II	1	2	3	4	5	0
Avoidance measures	1	2	3	4	5	0
Emergency measures	1	2	3	4	5	0

16. [On a scale from 1 (min) to 5 (max)] How expensive do you think will it be to take risk reduction measures? (show table)

	Very low cost				Very expensive	Don't know
Structural measures I	1	2	3	4	5	0
Structural measures II	1	2	3	4	5	0
Avoidance measures	1	2	3	4	5	0
Emergency measures	1	2	3	4	5	0

REWARDS

17. [On a scale from 1 (min) to 5 (max)] Please indicate how much you agree with the following statements.

	Completely disagree				Completely agree	I don't know
1. I would feel encouraged to take risk reduction measures myself if some of my neighbors, friends or family does the same.	1	2	3	4	5	0

2. I would like to take extra precautions against flooding if I am rewarded or assisted by the government (with subsidies, exemptions, etc.)	1	2	3	4	5	0
3. Taking extra risk reduction measures against flooding is a priority for my household	1	2	3	4	5	0
4. Taking extra precautions against flooding contributes to a safer future for my family and fellow citizens	1	2	3	4	5	0

STRUCTURAL PROTECTION WORKS

18. Are you aware of any works (infrastructures) built in this area as protection from possible damage from floods?
    1. Yes (specify _____)
    2. No *(skip to question nr. 20)*

19. (If you answered yes to the previous question, answer n.1 to question 18) How much do you agree with the following statements? [On a scale from 1 (min) to 5 (max)]

	Completely disagree				Completely agree	I don't know
1. The protection works eliminate the possibility of serious damages	1	2	3	4	5	0
2. The protection works are too expensive compared to the expected benefit	1	2	3	4	5	0
3. The protection works give a sensation of security to people living here in Negrar	1	2	3	4	5	0
4. The protection works promote/help the economic development of our community	1	2	3	4	5	0

KNOWLEDGE

20. There are many ways to learn about hydrological phenomena. Please evaluate how the following have contributed to your personal knowledge about hydrogeological phenomena? [On a scale from 1 (min) to 5 (max)]

	No contribution				Maximum contribution	I don't know
1. Personal experience	1	2	3	4	5	0
2. Local knowledge (e.g. from elderly people experience)	1	2	3	4	5	0
3. Official training and information initiatives	1	2	3	4	5	0
4. Own's initiative	1	2	3	4	5	0
5. Other (specify_____)	1	2	3	4	5	0

TRUST IN GOVERNMENT

21. [On a scale from 1 (min) to 5 (max)] Please indicate how much you agree with the following statements:

	Completely disagree				Completely agree	I don't know

1. The government will inform me if the flood risks in my home area changes significantly	1	2	3	4	5	0
2. I trust the government with regard to protection against flooding	1	2	3	4	5	0
3. The government has always done well in terms of protection against flooding in Italy	1	2	3	4	5	0

PUBLIC ASSISTANCE

22. Sometimes, public bodies offer help with flood protection to private households. What kind of public support from local, regional or national bodies have you received?

	Minimum support				Maximum support	I don't know
1. Financial aid for financing flood protection (subsidies, loans, etc.)	1	2	3	4	5	0
2. Material support, such as distribution of sandbags and other mobile barriers)	1	2	3	4	5	0
3. Information and awareness raising (folders, web-platforms, early warning)	1	2	3	4	5	0

23. Is your home ensured against flooding?

1. Yes
2. No
3. I don't know

SOCIO-DEMOGRAPHIC INDICATORS

24. Year of birth |__|__|__|__|

25. Gender

1. Male
2. Female
3. Other

26. The house you are living in is:

1. Yours/your family property
2. Rented
3. Other (specify _____)

27. Educational qualification (specify the last school/college year attended)

1. Primary school
2. Middle school
3. Professional high school (usually 3 years)
4. High school (5 years)
5. University degree or higher

28. To satisfy the needs of your family, your income is:

Not sufficient				Largely sufficient	I don't know
1	2	3	4	5	0

Would you be willing to take part in this survey again in the future?

1. Yes (contact – phone/email: _____)
2. No

A4 – Survey form related to Paper IV & V

LIKELIHOOD

1. How likely do you think it is that you are directly involved in the following phenomena?

	Not at all likely				Very likely	I don't know
Epidemics	1	2	3	4	5	0
Floods	1	2	3	4	5	0
Droughts	1	2	3	4	5	0
Wildfires	1	2	3	4	5	0
Earthquakes	1	2	3	4	5	0
Terror attacks	1	2	3	4	5	0
Domestic violence	1	2	3	4	5	0
Economic crises	1	2	3	4	5	0
Climate change	1	2	3	4	5	0

IMPACT

2. In case you are directly involved, how much damage do you think the following phenomena can cause to you?

	Not damage				Severe damage	I don't know
Epidemics	1	2	3	4	5	0
Floods	1	2	3	4	5	0
Droughts	1	2	3	4	5	0
Wildfires	1	2	3	4	5	0
Earthquakes	1	2	3	4	5	0
Terror attacks	1	2	3	4	5	0
Domestic violence	1	2	3	4	5	0
Economic crises	1	2	3	4	5	0
Climate change	1	2	3	4	5	0

3. In case they occur in [country], how much damage do you think the following phenomena can cause to others living in [country]?

	Not damage				Severe damage	I don't know
Epidemics	1	2	3	4	5	0
Floods	1	2	3	4	5	0
Droughts	1	2	3	4	5	0
Wildfires	1	2	3	4	5	0
Earthquakes	1	2	3	4	5	0
Terror attacks	1	2	3	4	5	0
Domestic violence	1	2	3	4	5	0
Economic crises	1	2	3	4	5	0
Climate change	1	2	3	4	5	0

PREPAREDNESS

4. How prepared do you think the responsible authorities in [country] are to face the following phenomena?

	Not at all prepared				Highly prepared	I don't know
Epidemics	1	2	3	4	5	0
Floods	1	2	3	4	5	0
Droughts	1	2	3	4	5	0
Wildfires	1	2	3	4	5	0
Earthquakes	1	2	3	4	5	0
Terror attacks	1	2	3	4	5	0
Domestic violence	1	2	3	4	5	0
Economic crises	1	2	3	4	5	0
Climate change	1	2	3	4	5	0

5. In case you are directly involved, how prepared do you think you are to face the following phenomena?

	Not at all prepared				Highly prepared	I don't know
Epidemics	1	2	3	4	5	0
Floods	1	2	3	4	5	0
Droughts	1	2	3	4	5	0
Wildfires	1	2	3	4	5	0
Earthquakes	1	2	3	4	5	0
Terror attacks	1	2	3	4	5	0
Domestic violence	1	2	3	4	5	0
Economic crises	1	2	3	4	5	0
Climate change	1	2	3	4	5	0

KNOWLEDGE

6. How knowledgeable do you think the responsible authorities in [country] are on the following phenomena?

	Not at all knowledgeable				Highly knowledgeable	I don't know
Epidemics	1	2	3	4	5	0
Floods	1	2	3	4	5	0
Droughts	1	2	3	4	5	0
Wildfires	1	2	3	4	5	0
Earthquakes	1	2	3	4	5	0
Terror attacks	1	2	3	4	5	0
Domestic violence	1	2	3	4	5	0
Economic crises	1	2	3	4	5	0
Climate change	1	2	3	4	5	0

7. How knowledgeable are you on the following phenomena?

	Not at all knowledgeable				Highly knowledgeable	I don't know
Epidemics	1	2	3	4	5	0
Floods	1	2	3	4	5	0
Droughts	1	2	3	4	5	0
Wildfires	1	2	3	4	5	0
Earthquakes	1	2	3	4	5	0
Terror attacks	1	2	3	4	5	0

Domestic violence	1	2	3	4	5	0
Economic crises	1	2	3	4	5	0
Climate change	1	2	3	4	5	0

EXPERIENCE

8. Have you ever been directly involved in the following phenomena, in [country] or abroad?

	Yes	No	I don't know
Epidemics	1	2	0
Floods	1	2	0
Droughts	1	2	0
Wildfires	1	2	0
Earthquakes	1	2	0
Terror attacks	1	2	0
Domestic violence	1	2	0
Economic crises	1	2	0
Climate change	1	2	0

SOCIO-DEMOGRAPHIC INDICATORS*

9. What is the highest level of education you achieved?

	Primary school
2	Lower secondary school
3	Professional high-school
4	Upper secondary school/high-school
5	University degree or higher
0	I'd rather not say

10. To satisfy your family's needs, your household income is:

Insufficient				More than sufficient	I'd rather not say
1	2	3	4	5	0

11. Do you have a job?

1	Yes
2	No
0	I'd rather not say

12. [Only if they replied yes to question nr. 11] Which of the following categories best represent the sector in which you are employed?

1	Industry, technology, production	11	Other consultancy services
2	IT & telecommunications	12	Public administration and defense
3	Media e communication	13	School and education (kindergarten to high school)
4	Healthcare	14	Academia and research (university)
5	Construction and real estate	15	Culture, leisure, and free time
6	Trade and commerce	16	Energy and environment
7	Transportation and logistics	17	Agriculture, silvicolture and fishery
8	Hotel and restaurants industry	18	Other services
9	Organisations and associations	19	Other category
10	Bank, finance and insurance	0	I'd rather not say

13. It is said that political opinions can be placed on a left-right scale. Where would you place yourself on such a scale?

Left	Centre-left	Centre	Centre-right	Right	I'd rather not say
1	2	3	4	5	0

**Age, gender, and region of residents were available for each respondent before the survey started and therefore were not asked again.*

Acta Universitatis Upsaliensis

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