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Public Support for Flood Risk Management: Insights from an Italian Alpine Survey Using Systems Thinking

Rocco Scolozzi [1,*], Anna Scolobig [2,3] and Marco Borga [4]

[1] Department of Sociology and Social Research, University of Trento, 38122 Trento, Italy
[2] Equity and Justice Group, International Institute for Applied Systems Analysis (IIASA), A-2361 Laxenburg, Austria; anna.scolobig@unige.ch
[3] Institute for Environmental Sciences, University of Geneva, 1205 Geneva, Switzerland
[4] Department of Land Environment Agriculture and Forestry, University of Padova, 35122 Padova, Italy; marco.borga@unipd.it
* Correspondence: rocco.scolozzi@unitn.it

Abstract: This study presents the results of a survey on flood risk awareness conducted in the Italian Alps, examining the impacts of a major weather event on public perception and trust. It develops a systems-thinking framework to analyse dynamic feedback loops influencing flood risk management support over time. The survey data collection overlapped with a severe storm event in Central Europe, the storm "Adrian" (also known as "Vaia"). This provided a unique pre- and post-event perspective. Results highlight the critical role of individual knowledge, trust in authorities, and social group dynamics in shaping risk perception processes. The study shows how major weather events can change perceptions, sense of safety, and institutional trust within local communities, and more interestingly, these changes can vary spatially. The findings are summarised using a systems-thinking framework, which helps to identify possible feedback loops between flood risk management interventions and long-term public support. The study emphasizes the importance of forward-looking, systems-thinking approaches in the design, monitoring, and evaluation of flood risk management plans. These approaches allow one to account for often-overlooked dynamics, such as spatially varying feedback loops and counter-intuitive effects, ultimately improving the long-term effectiveness of flood risk management.

Keywords: flood risk management; risk perception; systems thinking; climate change adaptation; community resilience; socio-hydrology

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1. Introduction

Floods are among the most frequent disasters in terms of human and economic impacts [1]. Advances in real-time numerical weather prediction and flood forecasting allow us to quantify the characteristics of heavy storms and their hydrological impacts [2–5]. However, the more sophisticated the forecasting systems are, the more they depend on the availability of quality data and the skills of those who use them to make decisions [6]. In practice, even the best models available may be misleading (e.g., because of insufficient data) or may not be used correctly.

At the same time, even the best communication strategy, the best risk maps, and the best monitoring and alert technologies could have little effect on behaviours if residents and local authorities are not aware of the risks, do not have easy access to the risk information, or do not pay attention. In this respect, it becomes fundamental to understand the conditions for an effective preparation and engagement of local communities in risk management. Risk awareness is a matter that goes beyond the mere management (or prediction) of physical processes and involves cognitive, social, administrative, and regulatory processes; these latter aspects can have different geographies, that is, they can differentiate spatially based on local social processes.

In line with the European Flood Directive (Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007), the United Nations Sendai Framework for Disaster Risk Reduction 2015–2030 recommends moving from a "resistance model", based on "structural measures" (such as artificial riverbanks or dams), to risk management plans that include the resilience of local communities and integrating the structural measures with "non-structural measures", such as communication and participation [7].

The "relational theory of risk" is aimed at improving risk communication [8], and it encourages "risk managers" not only to communicate and inform local groups about the risks calculated by the experts but also to investigate the different values of potentially conflicting groups. The essence of this theory is that risk emerges from the presence of (1) "risk objects" (anything that "poses danger", be it a law, an entity, a human being), (2) "objects at risk", and (3) the causal relationships between (1) and (2). Flood risk is therefore considered a "social construct" that includes water flow management, land use, forest management, and socio-political relationships [8,9]. Similarly, "community resilience" with respect to natural hazards emerges from the actions, social learning, resources, and capabilities of local communities [10]. While the experts' mental models emerge from the formal study of contents (formalised models), lay people's mental models derive from shared knowledge and personal experiences [11,12]. For them, the risk is not a mere probability but a process that is continuously updated and influenced by interactions between subjects, events, and practices: direct knowledge is thus mediated by social relationships (ibidem). One of the goals of risk communication is precisely to understand mental models to support the adoption of effective behaviours for managing risks and their consequences.

The conceptual framework for hazard risk management proposed by Di Baldassarre and colleagues [13] highlights how the impacts and perceptions of natural hazards influence resilience governance, while at the same time risk management can alter the magnitude of impacts and spatial distribution of the hazards. Furthermore, these mutual effects on a local scale are influenced by global factors; for example, climate changes can alter the frequency and severity of extreme weather events [14], while global socioeconomic trends (including population growth, ageing, and urbanisation) can increase risk exposure locally. Despite its relevance, accurate information on resident's risk perception, risk-taking attitude, and trust in authorities is only occasionally available for local risk managers [15,16]; the scientific literature seems to focus each time on a specific set of only a few variables rather than considering the variety of systems and dynamics involved in risk management as a "social construct".

This article presents the results of a survey on flood risk awareness conducted before and after a severe weather event. To contextualize these findings, a systems-thinking approach is employed, providing a conceptual framework to analyse the dynamic relationships between public perception, institutional trust, and support for flood risk management. This integrated approach aims to generate insights directly applicable to policymaking.

The survey was developed as part of the European project called FRANCA (Flood Risk Anticipation aNd Communication in the Alps). It was administered between 2015 and 2019.

The next paragraph contextualizes the research and the LIFE FRANCA project. After presenting the survey findings and their interpretation using a qualitative dynamic model, the Section 5 addresses the key implications for risk communication and management.

2. The Case Study and the Project LIFE FRANCA

The case study presented here is one of the results of the EU-funded project LIFE FRANCA, which had the following objectives:

- Introducing an anticipatory governance approach in the management of natural hazards.
- Developing an effective and continuous communication strategy (differentiated by target) that leads to increasing knowledge and awareness of the natural hazards and to change mental models and the consequent habits and behaviours.
- Supporting the preparation of the population to face flood events through a participatory process involving citizens, technical officers, and decision makers.
- Developing tools and methodologies applicable in other regions and for other risks related to climate change.

The project consisted of a variety of activities, such as a survey about the perception of flood risks, participatory activities such as building of strategic scenarios and Three Horizon workshops, concerning risk management in the next twenty years; educational activities and scientific dissemination; construction of a geo-portal on hydrogeological risk; and training activities for professionals and public servants.

The survey and participatory activities focused on the Trento Province, Northern Italy, with a population of about 540,000 inhabitants, an extension of 6200 km^2, divided into 16 valley communities (“Comunità di Valle”), and with a predominantly alpine landscape.

The survey objectives were to (i) gather information about perceptions and knowledge of flood risks and their management by different target groups, (ii) explore individual resources and trust in institutions in case of emergency, (iii) evaluate the impacts of the LIFE FRANCA project.

3. Material and Methods

3.1. The Survey

The survey was based on a questionnaire that included a total of 11 items, beyond the usual socio-demographic data, such as gender, age, level of education, place of residence, and place of work or main daily activity. Table 1 shows the key items used for data analysis in this paper, while Table S1 in the Annexes includes the full version of the questionnaire. Two specific questions (Q10 and Q11) were defined in order to explore individual resources and trust in institutions in case of emergency, in terms of mental simulation of an individual response in a fictitious but plausible situation.

The questionnaire was administered in different ways using a mix of convenience sampling [17] and purposive sampling [18], looking for both homogeneity within the groups and maximum variation between groups. These two non-probabilistic sampling techniques were aimed at achieving a greater understanding of processes rather than generalisations to the entire national or regional population; in other words, a case study logic underpins the research, instead of sample logic [19].

The questionnaire was printed and distributed (i) in the teaching activities of the project (in schools), (ii) to participants in the project communication events, (iii) by project partners to their networks, and (iv) digitally on the project website. The collection period was approximately 30 months, between May 2017 and December 2019. A total of 1980 respondents filled in the survey.

Table 1. Selected questions of the questionnaire (for the complete questionnaire see Table S1 in the Annexes).

Topic	Code	Question	Type of Answer
Difference between groups	Cat	The project focuses on 5 generic categories of communication and anticipation actors; choose your own or the closest one: • Citizen • Public administrator • Journalist/communication professional • Professional/technician (land management or flood risk sector) • Student or teacher	One option among 5 categories
Risk perception	Q1	How much do you agree with the following statements? • *Floods are a real danger for my territory (Q1.1)* • *Flood events will become more frequent (Q1.2)* • *Risks are minimised by hydraulic defence works in the area (Q1.3)* • *The general population has few tools and little awareness to deal with flood risks (Q1.4)* • *In general, floods do not constitute a concrete danger for Trentino (Q1.5)*	From 1—*disagree* to 4—*agree*
Social capital	Q10	If you were to evacuate tonight, how easily would you find temporary accommodation (e.g., with the help of relatives or neighbours)?	From 1—*no difficulty* to 4—*considerable difficulty*
Trust in institution	Q11	If a notice from the mayor arrives to evacuate the area where you live, would you do it immediately?	From 1—*Certainly, the Mayor has the responsibility and adequate information*, to 4—*After considering my knowledge or other information*

The sampling period included an exceptional storm event. Between 27 and 29 October, 2018, an exceptional storm (named Vaia) affected different areas of the Italian peninsula, in particular over the northeastern regions. Over the eastern Italian Alps, the strong winds, associated with gust values exceeding 50 m s^{-1} (180 km/h) at some locations, caused 41,000 ha of forest damaged and a loss of about 8.5 million m^3 of growing stock. For three days, precipitation accumulation maxima ranged between 600 mm in the central Alps to almost 900 mm in the eastern Italian Alps. For several Alpine areas, this was the largest event over the last 150 years in terms of precipitation accumulation (Figure 1); the ensuing floods and landslides caused several casualties and considerable economic damages [20].

As national and international media coverage lasted several days, and commemorative events in the following two years were widespread, it can be assumed that the entire population of the region had heard of the Vaia event and seen images of the crashed woods and other impacts.

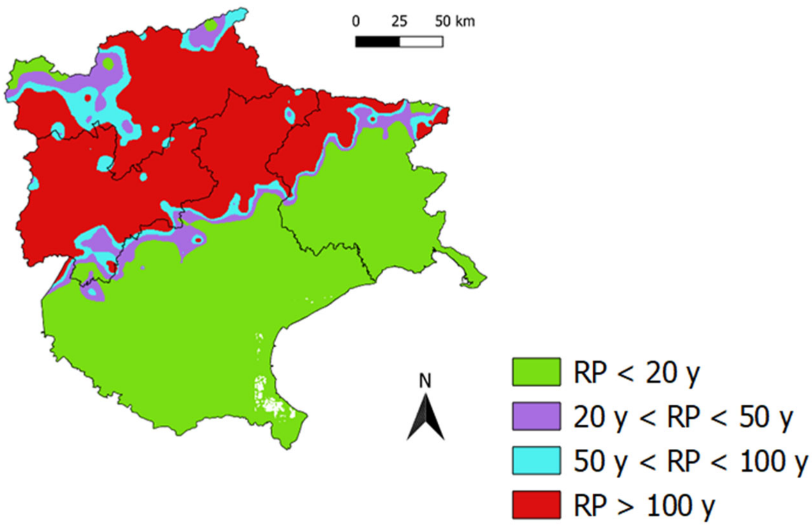

Figure 1. Return period for 72 h accumulated precipitation, based on station data (our elaboration); Trento Province covers about one half of the Trentino-Alto Adige region which corresponds to the polygon with the highest percentage of red areas in the map). RP means Return Period, measured in years.

The answers to the questionnaire were summarised in descriptive statistics and analysed with a comparison between socio-demographic characteristics and key variables. For binary variables (e.g., before/after Vaia, gender) or variables categorized in binary cases (such as experience, grouped education levels, grouped age groups, see Table 2), the differences were evaluated with the Mann–Whitney U Test for independent samples. This test is a non-parametric statistical method used to compare differences between two independent groups when the data do not follow a normal distribution. It evaluates whether the distributions of the two groups differ significantly based on their ranks rather than their actual values, making it a robust choice for non-normally distributed data for variables with multiple categories (such as regions or groups); the Kruskal–Wallis test, also known as nonparametric ANOVA, was applied. This test, an extension of the Mann–Whitney U test, is a non-parametric alternative to one-way ANOVA. It assesses whether or not there are statistically significant differences between the medians of three or more independent groups. Like the Mann–Whitney U test, it operates on ranks rather than on raw data and does not assume normality or homogeneity of variances, making it suitable for data that do not meet the assumptions required for parametric tests. The analyses were conducted using the Jamovi statistical software (version 1.6; www.jamovi.org (accessed on 1 December 2024)). Only highly significant differences, with p values of less than 0.001, are discussed in the following sections.

Table 2. Sample's summary statistics.

Socio-Demographic Groups		Percentage
Gender	Female	47.1%
	Male	52.9%
Age	16–30 years	62.3%
	>30 years	37.7%
Level of education	University degree or higher	39.2%
	Lower education level	60.8%

Table 2. *Cont.*

Socio-Demographic Groups		Percentage
Response period with respect to Vaia	After	69.8%
	Before	30.2%
Category of respondent	Public administrator	3.0%
	Citizen	28.5%
	Journalist	1.9%
	Technicians	9.5%
	Student or teacher	57.2%

3.2. A Conceptual Framework Based on Systems Thinking

In the Province of Trento, the flood risk is managed by the provincial office for watershed management (Servizio Bacini Montani, Mountain Basin Service), which finances structural and non-structural measures on the basis of three-year plans that are updated annually through consultations with local authorities. In some ways, the size of the funding is sensitive to the local demand for protection. After the disastrous Vaia event, which impacted the entire provincial territory, a general increase in demand, and therefore in investments for structural measures, was plausible. Moreover, an increase in economic resources dedicated to disaster risk management has been observed in the three years after the event.

To explore possible feedback loops between risk perception, communication, and management, we propose a conceptual framework (Figure 2) based on a systems-thinking tool, such as a stock-flows model and causal loop diagram. A stock and flow model represents how resources (stocks) accumulate or deplete over time based on the rates of inputs (inflows) and outputs (outflows). Stocks are the "state" variables (e.g., water in a tank), while flows are the rates of change (e.g., filling or draining). A causal loop diagram (CLD) visualizes the feedback structure of a system using variables connected by arrows to indicate cause-and-effect relationships. This helps to identify feedback loops and system behaviour. Arrows are distinguished between two causal polarities: positive (+) where a change in one variable causes a change in the same direction in another (e.g., more effort → better results); negative (−), where a change in one variable causes an opposite change in another (e.g., more resistance → slower progress).

In our conceptual framework, represented as a stock-flows model (Figure 2), the stock variable is the amount of active "flood risk management measures" that can rise by "support increase" and can decline due to "support erosion". Flood risk management measures are intended as a variety of possible measures in action or functioning on a territory, such as structural measures to alter the frequency of events [16], exposure reduction measures such as relocation of functions, services and buildings [21], or measures to reduce vulnerability, such as non-structural measures on a community and individual scale [22]. Associated with "support increase", a variety of social processes could be involved: from political support, or approval of specific plans, or requests for resource allocation (e.g., for the maintenance of hydraulic protection works), to initiatives of citizens. It is assumed that the more support there will be, the more measures will be put into practice or implemented.

Such a conceptual framework is not intended to constitute a new theory of risk perception or replace other previous ones, such as the psychometric paradigm [23,24] and the Protection Motivation Theory [25]; rather, it is used here as a tool to visualise plausible feedback loops in the reality of risk management and to highlight its dynamic complexity [26]. The rationale of the framework presented here lies in the recognition that risk management is not only a technical issue but also a political one, in the sense that it depends on the support and consensus of the local community for its implementation over a medium-long period.

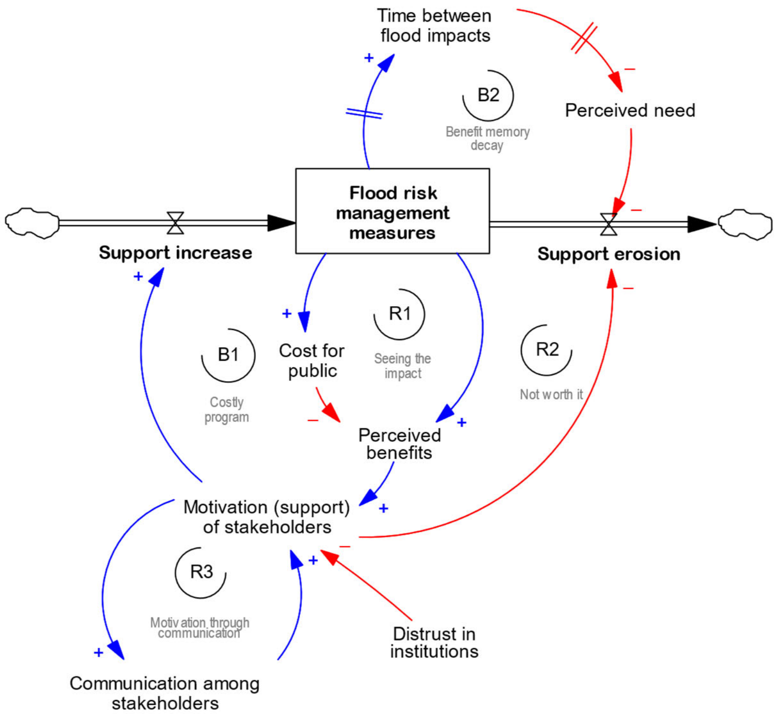

Figure 2. Model illustrating the main feedbacks that can be associated with maintaining flood risk management measures over time.

The stock-flows model represents the minimum system structure capable of explaining some complexity (non-linearity) in risk management. The non-linear nature of socio-hydrological processes is called into question, not only by recent conceptual frameworks but also by formal modelling [27]. Many risk perception studies have focused on the relationship between awareness, willingness to act, and preparedness, or on exploring the links between these variables [28–30].

The stock-flows model recognized and schematized 5 feedback loops related to different processes, involving different actors at different times. Flood risk management measures have perceived benefits that can be amplified through the communication loop (R3); this enacts a reinforcing loop, R1. The same measures may be perceived as costly with respect to the benefits; this can reduce support over time within a balancing loop (B1). The same communication among stakeholders affected by distrust in institutions may increase the support erosion rate within a reinforcing loop (R2). The flood management measures, if effective, may reduce risk exposure and increase the time between perceived impact. This period without impacts may convince someone, after a delay, of the uselessness of such measures; this may lead to a decrease in "perceived need" and therefore support (B2). In fact, the magnitude or frequency of events influences the level of vividness of public memory and the likelihood of direct or indirect (narrated) experiences, which influence public perceptions [30–35]. At the same time, a "distrust in institutions" may compete for support for risk management measures, which may be considered not important nor a priority (respect other local issues). "Distrust in institutions", which translates into attitudes such as "we protect ourselves autonomously", emerged in the participatory activities of the FRANCA project as a possible scenario in which the activation of social capital, which generally improves the community response to adverse events [30–35], replaces public interventions considered dysfunctional or insufficient. In all this, the community sense of self-sufficient security may have an ambiguous relationship, between support and obstacle, with respect to the support of public risk management measures.

Based on the results of the survey we further developed the model of Figure 2 using a system dynamics program (Vensim® PLE, version 9.3.5, Ventana Systems, Inc., Harvard, MA, USA), and by adopting the Agile-System Dynamics approach proposed by Warren [36], in which the simulation models are considered a learning tool by successive approximation, rather than a forecast support. Thus, we added a second stock variable to qualitatively simulate the related dynamics in terms of three plausible dynamics, or what-if scenarios: baseline, decrease of trust in institutions, increase of sense of security. Each stock variable can increase or decrease through the balance loop between them. On the right side of the model, we linked the decrease rate of "risk management measures" to "distrust" in institutions and "sense of security" in order to simulate the qualitative dynamics that emerged in the study. The complete description of the model and related equations is reported in the additional materials.

4. A Selection of Results

We report here a selection of results from the questionnaire:

(i) Respondents generally agreed with the fact that floods are a real threat (80% agree and fairly agree with Q1.1), that flood events will become more frequent in future (96% agree with Q1.2), and that hydraulic protection works are able to minimise the risks (90% agree with Q1.3).

(ii) They agreed that the population has little awareness and tools to manage the resulting risks (91% agree with Q1.4).

(iii) About 65% of respondents remembered at least one flood event (or debris flow) in their municipality or nearby.

(iv) The events mentioned occurred over a period of about 50 years (from 1966 to 2019).

(v) The most cited damages from flood events concern properties, agricultural activities, and common areas.

(vi) Among actions or factors that can increase the flood risks, "building close to water courses", "poor management of water courses", and "increase the impermeability of the territory" were those mentioned the most.

(vii) Among the actions deemed most effective to improve the response to flood events, "improving knowledge of the risk", "training citizens and families on what to do during the event", and "monitoring the minor rivers and streams" were those mentioned the most.

(viii) About 60% of respondents would have some difficulty finding temporary accommodation in case of emergency (Figure 3).

(ix) Less than 50% would follow an evacuation order of the mayor without hesitation (Figure 3).

It is interesting to note that the responses to Q10 and Q11 (regarding temporary accommodation) appear spatially differentiated between the valley communities (with $p < 0.001$ and $p < 0.012$, respectively), and that they are positively correlated ($p < 0.001$). This suggests that where individuals have more difficulty in facing an evacuation, they also show a slightly lower willingness to follow possible evacuation directives (Figure 4).

The same questions show significant differences among the respondent categories (Figure 5): "technicians" and "administrators" declare less difficulty facing an emergency than "journalists" and "students or teachers", while only these latter declare themselves more willing to immediately follow a possible evacuation order than all the other groups. The education level and age significantly differentiate this propensity too, with an apparent greater "autonomy" of decision by graduates and young people.

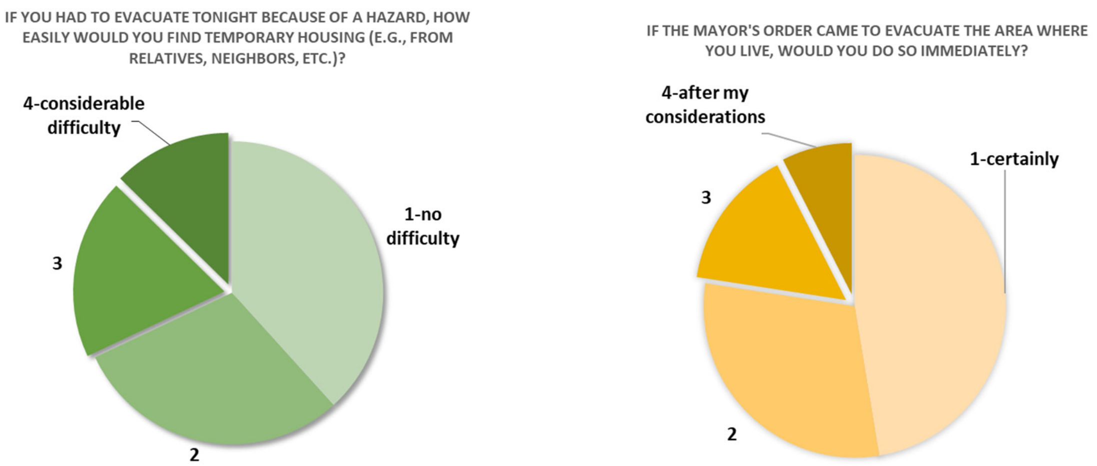

Figure 3. Responses regarding (Q10) the capability to find temporary accommodation in case of evacuation (**left**) and regarding (Q11) the willingness to follow an evacuation order (**right**).

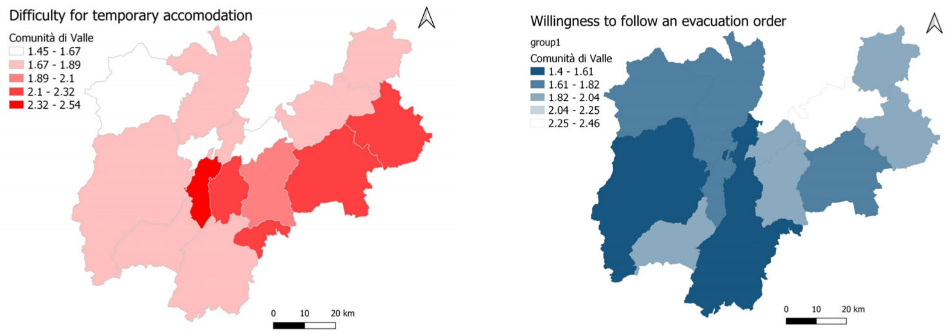

Figure 4. Mean response by valley community regarding "difficulty in finding a temporary accommodation" and regarding the "willingness to follow evacuation order" are spatially differentiated between the areas (the numbers refer to valley community mean values).

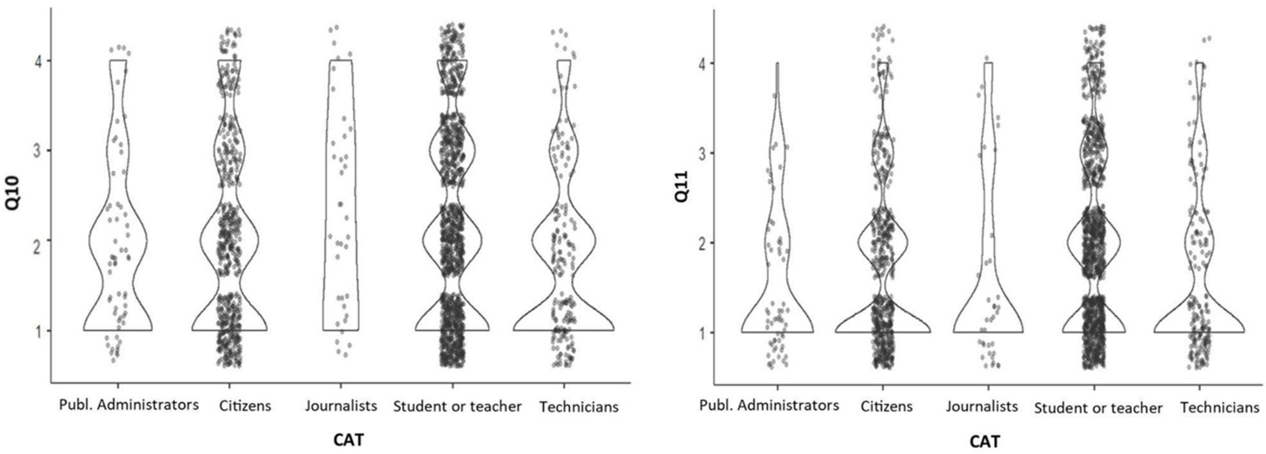

Figure 5. Responses Q10 and Q11 are differentiated between groups (note the shape of the columns).

The Vaia storm seems to have also affected risk perception. The statement regarding the preparation of the Trentino population (Q1.4) changed: before Vaia, most people essentially agreed that the population "has few tools and lack of awareness"; after the event, this agreement significantly diminished (with $p < 0.001$). After Vaia, the relevance for the respondents of "impermeability of the territory" significantly decreased, while it increased the importance of the option "building new or more robust protection works (such as embankments or bridles)". Surprisingly, Vaia seems to have affected the trust in institutions, resulting in a shift in the median of Q11 responses (from 1 to 2), meaning that after the event fewer respondents would be willing to follow hypothetical evacuation directives without hesitation.

In Table 3, we report an extract of statistical analyses, with the significant differences between categories; for a complete picture, see Table S2 in the Annexes.

Table 3. Questionnaire responses for which there are significant differences between groups.

Variable	Before/After Vaia [a]	Category [b]	Experience [a]	Gender [a]	Education [b]	Age [b]	Territory [b]
Risk perception Q1.1	$p < 0.001$	$p < 0.001$		$p < 0.001$	$p < 0.001$	$p < 0.001$	$p < 0.001$
Risk perception Q1.2		$p < 0.001$			$p < 0.001$	$p < 0.001$	
Risk perception Q1.3				$p < 0.001$			
Risk perception Q1.4	$p < 0.001$	$p < 0.001$			$p < 0.001$	$p < 0.001$	$p < 0.001$
Risk perception Q1.5					$p < 0.001$		
Social capital Q10	p 0.371	$p < 0.001$	p 0.051	$p < 0.001$	p 0.088	$p < 0.001$	$p < 0.001$
Trust in institution Q11	p 0.007	$p < 0.001$	p 0.006	p 0.004	$p < 0.001$	$p < 0.001$	p 0.012

[a] U Test of Mann–Whitney, for independent samples, with $p < 0.001$; [b] ANOVA non-parametric, Kruskal–Wallis Test with $p < 0.001$.

Insights from the Qualitative Model

Considering the above supposed feedbacks and the survey results, we played with a simplified model to simulate two processes affecting (Figure 6), over time, public support and decision making regarding flood risk management: an increase in the community's distrust in the public management of flood risks (green line); an increase in the time between the perceived impacts of flood events that corresponds to a decrease in demand for measures (red line). Both processes lead to a decrease over time in support for flood management measures and consequently in the actual number of measures. These emergent dynamics are typical of balancing feedbacks, which tend or oscillate around an equilibrium, after a certain delay, with a different equilibrium value that may change depending on the structure of the system (i.e., other related feedbacks), rarely considered in medium-term plans or policies.

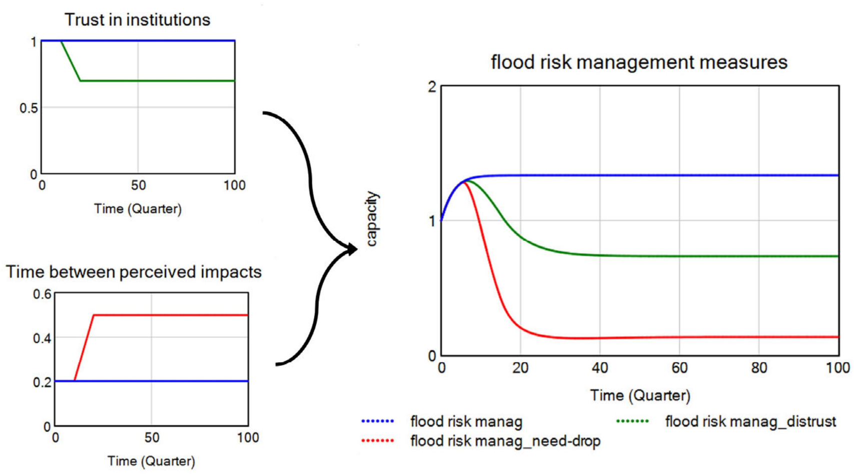

Figure 6. Possible dynamics based on declining trust in institutions (green line) and declining perception of the need for flood management measures (red line), associated to a larger interval between perceived impacts from floods (the simulation model is accessible in the Supplementary Materials).

Again, the model is not intended as a numerical simulation tool but rather as a tool to reflect on the complexities of risk management and to raise new questions. The numbers here are not associated with real measured variables; what matters is the qualitative behaviour over time. Numerical models could be developed in future research. The oversimplified dynamics of trust and the measurement of demand used in the model are actually much more complex; namely, trust can probably be intermittent, influenced by events and their narrative (both unpredictable in the medium term) by the media, institutions, and citizen peers.

5. Discussion

The research has several limitations. First, the study relies on a non-probabilistic sample, which limits the generalizability of the findings to the broader population. Additionally, while the conceptual model effectively highlights qualitative dynamics and feedback loops in flood risk management, it simplifies the complexity of socio-hydrological processes and does not directly incorporate measurable quantitative variables. Finally, although the inclusion of an extreme event like Storm Vaia enriched the analysis, drawing conclusions about long-term behaviours and perceptions requires further longitudinal studies and a broader temporal scope.

On the whole, the respondents to the questionnaire show a good knowledge of the risks and their management; all factors considered most relevant for risk are included in several studies [10,11]. The most cited damages from flood events concern properties, agricultural activities, and common areas and correspond to those recorded by the responsible public offices (unpublished data from the Mountain Basin Service of Trento Province). The perception is also in line with current knowledge, for example, that the frequency of flood events is expected to increase due to climate change [37]. The responses are generally in line with similar studies, some carried out in adjacent or analogous study areas [31,38,39]. Furthermore, the majority of respondents remember flood events or their consequences from first-hand experience. All of these factors are assumed to help keep public interest and support for risk management measures high.

The collected responses do not allow us to say anything about those who did not respond and live with the same risks; nonetheless, the difference between groups is interesting. The categories of respondents, education, and age group were the factors that most differentiated the responses to the questionnaire. The distinction between "categories" of respondents differs from similar studies, in which the sample is clustered according to usual sociological categories such as gender, age, educational qualification, or income, e.g., [10,15,40]. Although there is no objective validation of self-attribution in the five categories, the responses offer operational insights regarding risk governance and attention to the activities carried out by people; for example, commuting workers and students, public employees, technicians, and other citizens may perceive risk and alerts differently and may react differently to public emergency indications.

This suggest that non-structural measures of risk management (communication, participation, training) should not consider the target population as a homogeneous community but must be differentiated by groups and by dedicated analyses. In this regard, a person-centred approach could be functional, typical of design thinking in which the users of the proposed services are carefully characterized on the basis of "personas" models, which include values and preferences as well as levels of knowledge and habits [41].

An interesting aspect related to this is the difference between categories regarding the willingness to follow a hypothetical invitation to evacuate by the mayor: "administrators" and "technicians" seem to follow the evacuation instructions with more hesitation than the group of "students or teachers". The fact that only 47% of the people (in the sample) are prepared, in the event of an emergency, to evacuate immediately without hesitation is "equivalent to having 100 fire extinguishers of which only 47 work immediately"; this analogy emerged in a focus group with public technicians, where we also discovered that this topic had never been considered by local administrators and public technicians.

Furthermore, the spatial heterogeneity of the responses to Q10 and Q11 raises further questions on communication strategies, suggesting that, in addition to being targeted by category, the dialogue between institutions and the population must be differentiated and cultivated locally, albeit with a possible central (provincial) coordination; risk communication should be understood as a dialogic process aimed at building trust between citizens and institutions [42]. For example, it may be useful to define specific training for particular groups (such as local administrators, communicators, or journalists and technicians) and widespread information on flood risk management differentiated for citizens of different ages and different areas. Today, citizens' trust in institutions is severely tested in times of fake news and an easy overestimation of their own knowledge or generalisation errors ("this has never happened here, so it cannot happen", said an "expert" interviewee).

The fact that only 40% would have no difficulty finding temporary accommodation on their own also raises several issues rarely considered by flood risk managers. In parallel, the fact that 60% have some difficulty in finding temporary accommodation raises several issues related to the concept of community resilience that are rarely considered by flood risk managers. A community is resilient when it demonstrates the ability to manage and adapt to a shock (e.g., earthquake, landslide, debris flow), to the extent that its members are interconnected and work together to be able to sustain critical systems (health, communications, accessibility, economic activities) even under stress; increase self-sufficiency in case of limited or temporarily interrupted external resources (water, food, energy); and learn from experience to improve resilience as a community, adapting to environmental, social, and economic changes, without losing the community identity [43].

The inclusion of data regarding the Vaia storm (2018) captures a rare and significant opportunity to observe shifts in public perceptions following an extreme event. Such insights are critical for understanding how crises can alter societal attitudes toward risk and management strategies, which remains relevant as extreme weather events continue to rise due to climate change. The presented study can be considered a pre-post event study, similar to longitudinal studies that allow one to evaluate the variability over time of subjective and social factors of awareness [44,45].

The conceptual framework is directly inspired by the survey findings, offering a structured way to understand how public perception and trust dynamically interact with policy interventions over time. It complements the empirical results by identifying feedback loops that influence the effectiveness and sustainability of flood risk management measures, making it highly relevant for policymakers.

The systems-thinking perspective enhances the survey findings by illustrating the dynamic feedback loops between public trust, perceived risk, and policy interventions. This approach underscores the importance of designing adaptive policies that account for these interdependencies, ensuring sustained public support for flood risk management measures over time. Subjective perceptions, interpretations, understanding, individual and collective ability to react in a functional way to an anticipated or ongoing adverse event, and the collective (community) ability to recover from the exceptional event are all interdependent [29]. The conceptual (stock-flows) model illustrates the minimum system structure able to explain the non-linearity of causal connections between perception and support for risk management measures. The real dynamics are much more complex than those over-simplified and shown. For example, trust or distrust in public institutions could be more fragmented, opposed between different social groups, and much more mobile, with fast peaks due to the amplifications (reinforcing feedback loops) of some contents (e.g., fake news) through web-based media (or online social networks).

Although it is only a starting (simplified) model, one of its promising aspects is its capacity to integrate qualitative and quantitative factors, enabling a richer understanding of these complexities. By combining the qualitative representation of trends and relationships with qualitative insights into societal, institutional, and psychological dynamics, the model can inform more holistic and adaptive strategies for emergency management. This integrated approach challenges the traditional focus on maximising control (and predictability), instead highlighting the importance of balancing quantitative metrics with the nuanced, evolving realities of human behaviour and institutional interactions. In this way, the model not only facilitates deeper reflection but also provides a foundation for developing more effective and context-sensitive risk management practices.

Thus, the contribution enters into the field of socio-hydrology, a wider framework that includes the feedback loops identified in the study from the perspective of long-term resilience of socio-hydrological systems. This concept allows us to link human behaviours, institutional trust, and flood risk management measures with hydrological processes, providing a more holistic perspective. This consideration suggests future research directions regarding the following: (i) how flood risk management measures may interact with support over time, (ii) how to integrate values and other social components in risk management in terms of anticipatory governance [46,47], (iii) how to gather information on the beliefs of an affected community; and (iv) how to engage the population along with institutional actors in a reflection of the consequences of a flood event and their own emerged response capacity. In this respect, it is critical to better understand how shifts in trust and risk perception affect long-term resilience and the adoption of structural versus non-structural measures. These elements will be increasingly relevant in terms of enabling conditions for community resilience. To cultivate these conditions, it will be important to respond to and monitor people's knowledge regarding the state and trends of the systems that sustain their lives, livelihoods, and society; their trust in leaders; their ability to frame problems for effective action in complex social-ecological contexts; and their preparedness to collaborate effectively in situations of uncertainty [48].

The insights derived from our model and survey can inform the development of more effective flood risk management strategies. Specifically, we emphasize the following implications:

Preparedness and the ability to collaborate in situations of uncertainty is neither spontaneous nor binary (present–absent), but must be taught, acquired, and trained collectively. The systems-thinking framework discussed in this paper can be applied to promote community training in workshops dedicated to informed, multi-agency, and participatory approaches. These workshops could enhance the capacity of stakeholders, including community members, local administrators, and experts, to collaboratively address the complexities of flood risk management. All of this could foster social as well as technological and scientific learning, which in turn will support community resilience in dealing with future events.

6. Conclusions

This study highlights the critical role of integrating survey-based insights with a systems-thinking perspective to inform flood risk management strategies. By doing so, it provides policymakers with actionable recommendations on fostering public trust, sustaining long-term support for interventions, and addressing counterintuitive dynamics that may undermine risk management efforts. Understanding the feedback loops active in a territory and their spatially diverse impacts is necessary to enhance the effectiveness of risk management strategies over time.

We found confirmation that lay people's mental models derive from shared knowledge and personal experiences [11], and that the risk is not a mere probability but a process that is continuously updated and influenced by interactions between subjects and events. This study demonstrated how an extreme weather event reshaped the public perception of flood risks, reduced trust in institutions, and influenced the dynamics of public support for flood risk management measures. This could constitute serious problems of public security, strongly connected with public funding, transparency, and sharing the responsibilities in risk management; all these are emerging issues in an increasingly connected society. As a practical insight, building and maintaining trust in institutions should be included in the objectives of non-structural measures of flood risk management, as well as other aspects, such as information and training.

A lesson from this study concerns the relevance of a systems-thinking and a future-oriented perspective; these elements should be explicitly considered in studies and the evaluations of risk management policies in order to support their sustained improvement over time. This implies understanding the "dynamic complexity", which arises from the interactions among the agents in a system over time [26], in addition to the understanding of "detail complexity" [49], associated with forecasting models.

We outlined qualitative dynamics that can offer interesting insights specifically for risk management. From these, it is visibly a balancing (counterintuitive) dynamic: the support for risk management measures might decline as they work (or seem to work), with the risk of not improving the conditions of a territory beyond a certain threshold. This threshold is sensitive to external events (weather) and to internal processes (within communities). Other studies have explored how structural measures can generate a sense of safety, which can act to reduce preparedness and support for risk management. Paradoxical and counterintuitive risk changes have been described as 'levee effect', 'safe development paradox', or 'safety dilemma' (for an overview, see [50]).

All this suggests some issues to explore in future research, such as the following: How can risk mitigation measures be sustained with public support over time? How can risk perception change and influence public support for risk management over time? Under which conditions can local community resources and social capital increase the trust in institutions (creating synergies), and under which other conditions can the opposite happen (causing the system archetype named "accidental adversaries")?

From these considerations, the complexity of socio-hydrological processes is called into question, and it is perhaps greater than that considered in the current practices. Specifically, we identify the following options to improve flood risk management strategies:

(i) Incorporating trust dynamics: our findings highlight the critical role of trust in shaping public support and compliance with flood risk management measures. This suggests that management plans should prioritize transparent communication, foster long-term institutional credibility, and actively engage communities in decision-making processes to build trust and to counter misinformation or the spread of fake news (or conspiracy theories).

(ii) Balancing quantitative and qualitative factors: the integration of qualitative insights, such as the societal perception of risk and trust dynamics, with quantitative metrics (e.g., flood probability and damage assessments) can lead to more adaptive and inclusive management strategies. This approach ensures that management plans address both the technical and social dimensions of risk.

(iii) Developing adaptive and narrative-driven strategies: The findings highlight the importance of incorporating adaptability into risk management plans to account for the unpredictable evolution of events and to take into account societal narratives. This calls for flexible policies that can respond to changes in public sentiment and emerging challenges, rather than relying solely on rigid, control-focused measures. Accordingly, we suggest that future studies could extend the model to explicitly account for the influence of multiple factors (e.g., misinformation), examining their impact on trust dynamics and decision-making processes, within the broader challenges of adaptive governance and resilience-building.

(iv) Leadership and co-design with stakeholders: The findings of this paper align with the distinction between "management" (focused on processes and control) and "leadership" (focused on vision and empowerment); incorporating leadership dimensions in flood risk management might emphasize trust-building, collaboration, and the co-creation of solutions "from below" rather than imposing top-down directives. The results also suggest the need for participatory approaches in the design of flood risk management plans. By involving stakeholders—including local communities, media, and institutions—in the co-design process, plans can better reflect diverse perspectives and gain broader public acceptance, fostering a sense of agency and shared responsibility in building resilience to future extreme events.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/geographies5010003/s1, Figure S1: Descriptive plots about the Vaia windstorm impact on variables; Figure S2: Descriptive box plots about the differences among the respondent categories; Figure S3: The simulation model; Table S1: The complete questionnaire translated from Italian; Table S2: Significant differences in questionnaire responses; Model documentation.

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