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Assessing stakeholders' risk perception to promote Nature Based Solutions as flood protection strategies: The case of the Glinščica river (Slovenia)

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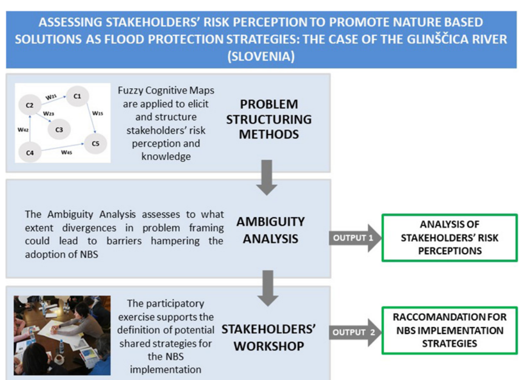
HIGHLIGHTS

- Floods events affect communities and environmental systems across Europe.
- Understanding stakeholders' risk perception enhances NBSs implementation.
- Fuzzy Cognitive Maps are used for eliciting risk perception.
- Ambiguity analysis is the key for enabling collaborative decision-making processes.

GRAPHICAL ABSTRACT



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ABSTRACT

Evidences from flood risk management demonstrated that a deep understanding of the main physical phenomena to be addressed is often not enough but should be also integrated with stakeholders' knowledge and risk perception. Particularly, the effectiveness of flood risk management strategies is highly dependent on stakeholders' perception and attitudes, which play a critical role on how individuals and institutions act to mitigate risks. Furthermore, practitioners and policy-makers realized that grey infrastructures may not be the most suitable solution to reduce flood risk, and that a shift from grey solutions to Nature Based Solutions is required. Within this framework, the present work describes a methodology to enhance the Nature Based Solutions implementation by facilitating the generation, acquisition and diffusion of different stakeholders' risk perceptions. It is based on the combination of Problem Structuring Methods for the elicitation of stakeholders' risk perceptions through individual Fuzzy Cognitive Maps, and Ambiguity Analysis for the investigation of differences in risk perceptions and problem framing. The outputs of the Ambiguity Analysis, used during a participatory workshop, facilitated a dialogue aligning the divergences and promoting the social acceptance of Nature Based Solutions. These results of the implementation of this multi-step methodology in the Glinščica river basin (Slovenia) are discussed.

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1. Introduction

Around 20% of European cities are classified as being vulnerable to fluvial floods. Moreover, the expectation that flood damages may escalate over time with climate and land-use change and social growth in flood prone-areas has raised policy-makers' awareness of the need to implement innovative flood risk management strategies and solutions (De Moel et al., 2012; Domeneghetti et al., 2015; Keesstra et al. 2018).

In the last few decades governments and investors automatically looked to "grey" solutions to reduce flood risk, e.g. dams for water collection, embankment consolidation, etc. (European Environmental Agency, 2017). Nevertheless, past experiences on flood risk strategies have clearly shown that grey infrastructures alone cannot provide a complete protection (European Environmental Agency, 2017). Furthermore, grey infrastructures are capital intensive, may address only some water-related issues and often damage or eliminates biophysical processes necessary to sustain people, ecosystems and habitats, and livelihoods (Palmer et al., 2013; Zischg et al., 2018). Currently, Nature-Based Solutions (NBS) are increasingly adopted as measures for enabling climate change mitigation and adaptation, for reducing flood risks and for enhancing urban ecosystems (Cohen-Schacham et al., 2016; Denjean B. et al. 2017). NBS can reduce risks to people and property as effectively as traditional grey infrastructures, but potentially offering many additional benefits, e.g. improving the natural habitat for wildlife, enhancing water and air quality, improving community socio-cultural conditions (Dong X et al., 2017). NBS are able to combine technical, business, finance, governance, and social innovation, bringing together established ecosystem-based approaches, such as ecosystem services, green-blue infrastructure, ecological engineering, and natural capital (European Environmental Agency 2015; Nesshöver et al., 2016;).

Nevertheless, several barriers are currently hampering the actual design and implementation of NBS for copying with flood risks in urban areas. Among those, the unsuitability of existing methods - i.e. quantitative risk analysis - for copying with the complexity and uncertainty in flood risk management play a key role. There is complexity due to the densely interconnected networks in which decision-actors operate. There is also uncertainty since what other decision-actors involved are going to do is largely unknown, making difficult to predict whether the decisions pay off or not (Rosenhead and Mingers, 2005; Holling, 1978; Pahl-Wostl, 2008; Pagano et al., 2018).

Therefore, quantitative risk analysis is often inadequate, and engaging with multiple stakeholders is increasingly considered as key in designing and implementing successful risk management measures (e.g. Douglas, 1985; Renn 1998; Brugnach et al., 2008a, b; Raymond et al., 2017). Several authors highlighted the need to account for social risk perception in risk management, since the reality perceived affects stakeholders' decisions and could lead to failures in risk management actions (Flynn et al., 1999; Bickerstaff, 2004; Savadori et al., 2004; Harclerode et al., 2016). Social perception of natural hazards is subjective, and the risk associated to a specific natural hazard may differ within and across communities (Figueiredo et al., 2009). Although some studies on risk perception have been carried out (e.g. Birkholz et al., 2014; Chowdhooree et al., 2018), limited research has been conducted on the elicitation and analysis of differences in risk perception. Risk perception, local knowledge, and individual and collective attitudes in managing and adapting to hazards, are strongly influenced by social and cultural factors that reflect the values and history of a community (Weinstein, 1987; Harclerode et al., 2016). These factors are constantly reinforced, modified, amplified or attenuated by interaction processes with the other members of the community (Morgan et al., 1999).

Additionally, in multi-stakeholders settings, such as the risk management, the presence of ambiguity in problem understanding is unavoidable (Ingram and Brugnach, 2012; Pluchinotta et al., 2018). Ambiguity refers to the degree of confusion that exists among actors in a group for attributing different meaning to a problem that is of concern to all (Weick 1995; Brugnach et al., 2008a, b). It originates from differences in objectives, values, background, previous experiences and societal position among the actors (Van den Hoek et al., 2012). Lastly, ambiguity in problem framing may have diverse implications. On the one hand, a diversity in frames can offer opportunities for innovation and the development of creative solutions (Brugnach and Ingram, 2012): a certain degree of ambiguity is desirable to foster the collaborative work needed to enable innovation.

On the other hand, the presence of ambiguity can be a source of discrepancies or conflict in a group (Giordano et al., 2017a, b). When this happens, ambiguity can result in a polarization of viewpoints and the incapacity of a group to create a joint basis for communication and action, conditions that can greatly interfere with the development of collective actions (e.g. Brugnach and Ingram, 2012; Ferretti et al., 2019). Starting from these premises, this work aims at providing answers to the following research questions: i) to what extent ambiguity in risk perceptions represent a barrier to the design and implementation of NBS for risk management? ii) how to use ambiguity for supporting creative decision-making processes in risk management? In order to provide answers to these questions, this work describes a multi-step methodology aiming to elicit stakeholders' risk perceptions, knowledge and problem frames, and to investigate the presence of ambiguity. In order to promote the implementation of NBSs strategies and to identify the potential barriers, the proposed methodology is based on the combination of Problem Structuring Methods (PSMs), and specifically Fuzzy Cognitive Maps (FCMs), and Ambiguity Analysis (AA). The methodology has been applied in the Glinščica catchment case study (Slovenia). After the present introduction, Section 2 discusses the role of risk perception for NBS implementation. Section 3 describes the developed methodology, while Section 4 outlines and discusses the case study. Final remarks and future developments close the paper (Section 5 and 6).

2. The role of risk perception for Nature Based Solutions implementation

Evidences demonstrated that, effective strategies for coping with water-related risks require not only a deep understanding of the main physical phenomena to be addressed, but also an unprecedented level of cooperation between different levels of institutions, the civil society and the private sector (Castán Broto & Bulkeley, 2013). Non-institutional actors – i.e. corporations, NGOs, community groups – are increasingly involved in responding to climate change and associated risks. This means that the risk management is no longer an exclusive matter for public institutions (Cochran & Teasdale, 2011). Therefore, designing risk management measures needs to be considered as a collective decision-making process characterized by multiple-actors with different, and often conflicting, risk perceptions. Risk perception, as defined by the Royal Society's landmark report, involves "people's beliefs, attitudes, judgments and feeling, as well as the wider cultural and social dispositions they adopt towards hazards and their benefits" (Pidgeon et al., 1992). It refers to a person or community's interpretation of the hazard and its risk (Sullivan-Wiley and Short Gianotti, 2017).

According to Savadori et al. (2004), the perceived risk leads the decision-actors to decide and act to reduce the risk. Experts and the public often disagree on the severity of risk attached to a situation given that everyone assigns a different significance to various factors that influence risk (Slovic et al., 1987). This assumes that risk reduction behaviours are undertaken as part of a dynamic and adaptive decision-making process by which individuals and social factors interact (Slovic et al., 2004). Stakeholders' perception and understanding of natural disasters is socially constructed (Boholm, 2003). Therefore, differences in risk perception could lead to conflicting situations hampering the effectiveness of the risk management measures (Giordano et al., 2013).

Furthermore, Renn (1998) structured a framework providing a systematic perspective on risk perception and suggesting four distinct levels of context influencing it. The first level includes the collective and individual heuristics that individuals apply during the process of

Table 1
Synthesis of the reviewed studies concerning flood risk perception.

Approach	Authors	Aim of paper	Methodologies applied
Mixed approach (qualitative and quantitative)	Liu et al., 2018	To assess the flood risk perception of rural households in western mountainous regions of Henan Province, China	(i) Questionnaires (ii) Household Risk Perception Index
	Terpstra, 2011	To test a path model including stakeholders' past experiences, trust and risk perceptions in Netherlands	(i) Questionnaires and surveys (ii) Structural Equation Model
	Miceli et al., 2008	To investigate stakeholders' disaster preparedness and perception for flood risk in an alpine valley, Italy	(i) Questionnaires (ii) Partial Credit Model
	Zhai and Ikeda, 2008	To establish a multi-risk framework for analysing acceptable risk and how other risks affects flood risk acceptability in the Toki-Shonai River region, Japan	(i) Surveys (ii) Rational Action Paradigm (iii) Cross-sectional analysis and covariance structure analysis
	Tania López-Marrero, 2010	To analyse and discuss the role of flood mitigation strategies on stakeholders' adaptive actions in Puerto Rico	(i) Semi-structured interviews (ii) Data processing of descriptive statistics
	O'Neill et al., 2015	To examine the distance between stakeholders' flood risk perception and expert flood risk assessments within the Bray case study, Ireland	(i) Questionnaires (ii) Comparison between cognitive map analysis and slope analysis
	Zaalberg et al., 2009	To understand how citizens take adaptive actions to mitigate flood risk according their previous experience in Netherland	(i) Survey (ii) Protection Motivation Theory
	Botzen et al., 2009	To understand flood risk perception of citizen in Netherland.	(i)Survey (ii) Statistical models
	Raaijmakers et al., 2008	To assess risk perception in Ebro Delta, Spain	(i) Interview/Survey (ii) Taxonomic analysis (iii) Spatial multi-criteria analysis
Qualitative approach	Lara et al., 2010	To examine the social perception of floods in the Costa Brava area, Spain	(i)Interview/Survey (ii)Focus Group sessions
	Bempah and Øyhus, 2017	To examine factors influencing stakeholders' perception and attitude toward flood risk hazards along the Volta River, Ghana	(i) Questionnaires (ii) Focus Group sessions and group discussion

judging (Breakwell, 2007). Increasing the awareness about these heuristics could support the revision of their intuitive judgments or adapt the actor's scope. The second level refers to the cognitive and affective sphere, affecting the perception of the risk. Only few psychology studies have shown that emotions play an important role in stakeholders' decision-making processes (Loewenstein et al., 2001, Slovic et al., 2002). The third level introduces the role of social and political institutions: a significant element is the perception of equity and justice in the distribution of benefits to different social groups (Linneroth-Bayer and Fitzgerald, 1996). The last level includes the social perception of risk and natural hazards referring to the cultural backgrounds influencing decision-making processes. Lastly, stakeholders' risk perception is influenced by communication about risks from external expert sources (Renn, 1998).

Researches on risk communication emphasizes that, beyond accuracy of the message content, the capability of the communication to actually meet the users' needs, in order to boost trust between experts and non-experts (Fischhoff, 1995; Renn and Levine, 1991; Wachinger et al., 2013).

The relationship between what people know and perceive about various types of risks and how risk perception could play in inhibiting or encouraging adaptive actions by individuals and institutions alike has been the subject of several researches across numerous disciplines (e.g. Martin et al., 2007; Kahan et al., 2012; Mees et al., 2018; Hong et al., 2018).

Especially the field of flood risk management offers interesting insights. For instance, Zaalberg et al. (2009) used structural equation to model previous flood experiences associated with intentions to take adaptive actions, while Botzen et al. (2009) investigated factors affecting citizens' flood risk perception.

Table 1 attempts to summarize the different methods mentioned in the scientific literature dealing with risk perception and risk management.

The main distinction is between studies that examined how people perceive flood risks and studies that observed how risk perceptions influence stakeholders' behaviour in response to their exposure to flood risk. From the analysis of the applied methodologies, it can be observed

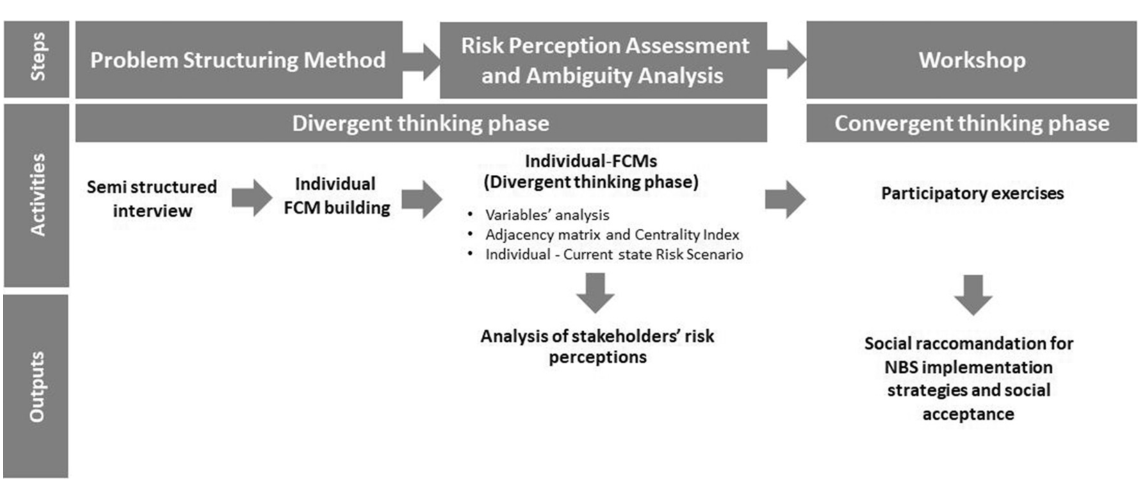

Fig. 1. The developed methodology.

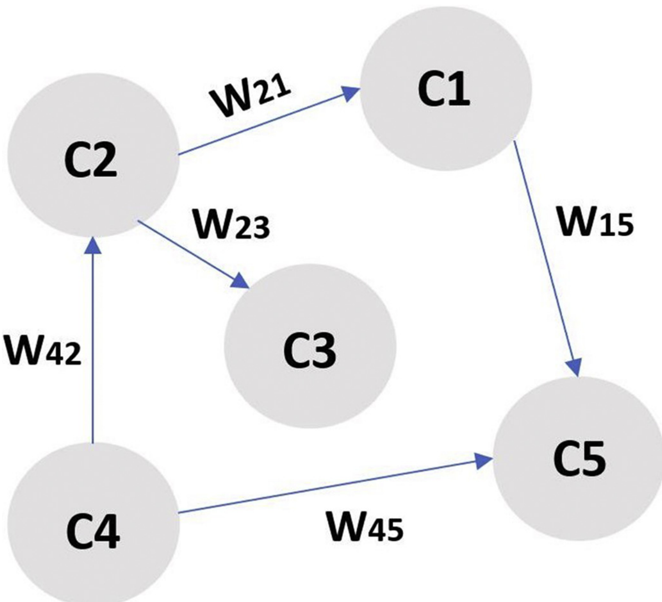

Fig. 2. Example of a generic FCM (adapted from Özesmi and Özesmi, 2004).

that the most used tools to collect information about stakeholders' perception are context-based questionnaires and surveys (e.g. Raaijmakers et al., 2008; Terpstra, 2011). The results are subsequently validated in focus groups or experts structured meeting (e.g. Lara et al., 2010). Concerning the group of stakeholders involved in the activities, most of the reviewed works addressed exclusively citizens located in a flood-prone area. Others involved larger groups of stakeholders, including local authorities and decision makers (e.g. Armas and Avram, 2009; Heitz et al., 2009; Whitmarsh, 2008).

According to the results of the review, the methodological approaches are based on two main phases: (i) information collection through semi-structured interviews or surveys; ii) model building using the parameters emerged during the first phase. Considering the main scope of this work, the review focused mainly on works dealing

Table 2
Topological class, variables description.

Topological class	
Variables	Description
Key risk	The variables representing the risk recognized by the actors and characterized by incoming and outcoming connections
Driver	The variables characterized by out coming connection
Ordinary	The variables characterized by incoming and outcoming connections
Receiver	The variables characterized by incoming connections

with differences in risk perception. Just to mention few of them, Liu et al. (2018) used the Household Risk Perception Index to evaluate the different degree of perception among household groups; O'Neill et al. (2015) highlighted the difference between stakeholders' perceptions using a comparison between cognitive maps and slope analysis; Bempah and Øyhus (2017) use a qualitative research strategy and a narrative approach to investigate the perceptions of flood victims and to describe how two different communities perceive differently the causes of flood risk.

The activities described in this paper are in lines with the results of the above mentioned works but nonetheless it aims to move a step forward in analysing the interactions between risk perception and risk management. That is, this work aims to demonstrate the suitability of the ambiguity analysis in risk perception in enabling the collective process for risk management.

3. Methodological approach

The present section describes the methodology developed and implemented to elicit and structure stakeholders' risk perceptions at different levels (local, regional, national) and sectors (municipality, civil protection, etc). The final aim is to demonstrate how to refer to ambiguity analysis for supporting collective decision-making processes for designing NBS in flood risk management. The developed methodology uses a sequence of divergent and convergent thinking phases. Namely, during the divergent thinking phase, different views of the problem are defined, whereas during the convergent thinking phase, possible solutions are suggested and discussed (see Montibeller et al., 2001).

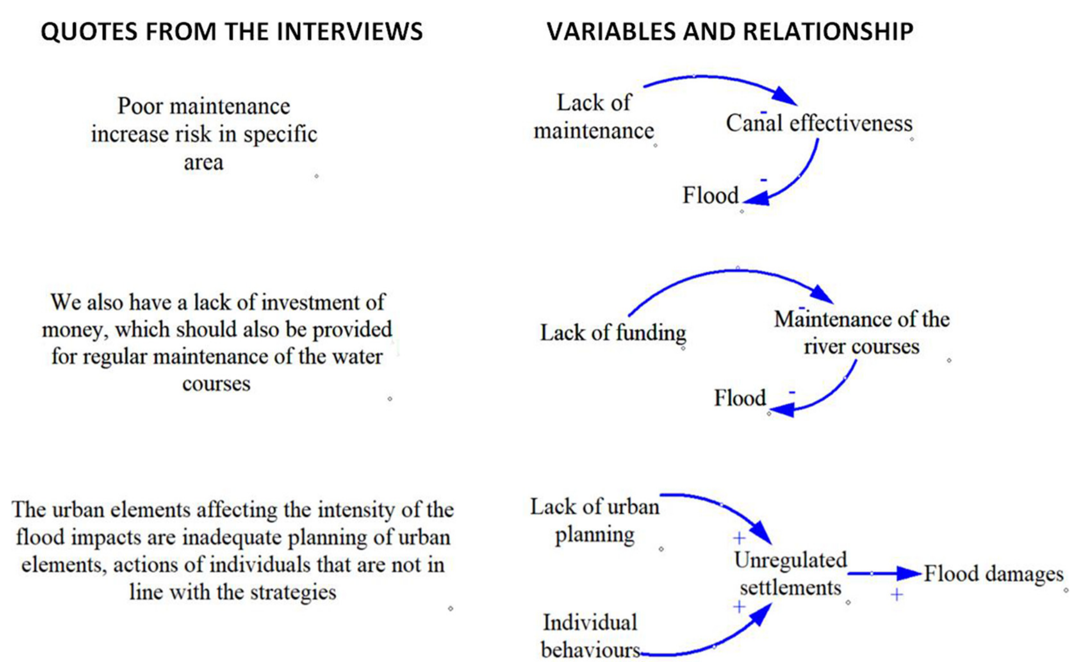

Fig. 3. Examples of quotes translation from the stakeholders' interviews into variables and relationships of FCM.

Table 3
Conceptual meaning class, variables description.

Conceptual meaning class	
Variables	Description
Expected impacts	Items of the FCM directly (primary impacts) or indirectly (secondary impacts) affected by the natural hazard under consideration
Elements of vulnerability	Items of the FCM representing elements susceptible to damages caused by the natural hazard under consideration

Three different phases can be identified. The first two sections represent the divergent thinking phase, whereas the last one aims at supporting the convergent thinking phase (Fig. 1):

1) PSMs, and specifically FCMs, are applied to elicit and structure stakeholders' risk perceptions, knowledge, and problem frames.
2) The Ambiguity Analysis (AA) is carried out through the analysis of individual FCMs in order to highlight similarities and differences among stakeholders' risk perceptions.
3) The results of previous divergent thinking phase were used to support the debate among the different stakeholders in a participatory workshop aiming at co-defining NBS for flood risk management.

3.1. Problem Structuring Methods: semi-structured interview and individual FCM building activities

Firstly, semi-structured interviews are carried out by the team of analysts. This phase has been subdivided into two steps: "interview building" and "interview carry out". The "interview building" activity is based on the definition of a set of questions for collecting information about the problem under consideration (Gimenez et al. 2017). The "interview carry out" task starts with stakeholders' engagement activities. In order to maximize the results, a top-down stakeholder identification practice, which is referred as "snowballing" or "referral sampling", has been implemented (Prell et al., 2008; Reed et al., 2009). Specifically, each stakeholder suggests the involvement of other stakeholders considering their role in the organizational network for NBSs implementation for flood risk management.

Secondly, the information derived from the semi-structured interviews are processed and Individual-FCMs are built (Fig. 2). Indeed, according to Özesmi and Özesmi (2004), FCMs are useful for representing stakeholders' conceptual models. They allow to investigate how people perceive a given system and compare the perceptions of different groups of stakeholders (Kosko, 1986). FCMs are symbolized by a bidirectional graph of nodes (i.e. variables or concepts) and connections between nodes. The connection strength indicates the stakeholder's perceived influence of two concepts on each other (Özesmi and Özesmi 2004). Graphically, a FCM is represented as an oriented graph with feedback, consisting of nodes (C_i) and weighted arcs (W_i) (Fig. 2). Concepts take values in the range between [0,1] and the weights of the arcs are in the interval [−1,1] (Papageorgiou and Kontogianni, 2012).

After the pioneering work of Özesmi and Özesmi (2003) in environmental and ecological management domain, other researchers followed with further implementations of FCMs (e.g. Borri et al. 2013, Borri et al. 2015; Giordano et al., 2017b). For instance, FCMs have been employed in a number of studies related to the evaluation of differences and similarities in structural and functional characteristics of stakeholder's conceptual models for environmental policy (Gray et al., 2012), computational simulations for natural hazard mitigation (Samarasinghe and Strickert, 2013), management in agriculture (Giordano et al., 2007).

The interviews were analyzed in order to detect the keywords in the stakeholders' argumentation – i.e. the variables in the FCM – and the causal connections among them – i.e. the links in the FCM. Following Slegers (2008), the interviews were aimed at collecting actors' experiences about both direct and indirect impacts of climate changes. Participants were required to specify elements which can either increase or decrease those impacts. They were also required to specify both the information used to support the selection, implementation and assessment of the actions needed to cope with the risks related to climate changes.

The following Fig. 3 shows how the stakeholders' narratives, collected during the interviews, were translated into FCM variables and relationships.

3.2. Ambiguity analysis and risk perceptions

In order to carry out the ambiguity analysis, aiming at detecting differences and similarities among stakeholders' risk perceptions, the variables forming the individual FCM were analyzed. To this aim, the variables have been classified according to their the role in the FCM, i.e. *Topological class* (Table 2) and *Conceptual meaning class* (Table 3). *Topological class* refers to the graphic structure of the FCM. It consider the role of each variable, in relation to the connections with the other variables *Conceptual meaning class* describes the expected impacts and the possible elements of vulnerability within the FCM.

According to graph theory, the developed FCMs have been transformed into adjacency matrices (A_{ik}) (Harary et al., 1965), i.e. when a connection exists between two variables of the FCM, the value is coded in a squared asymmetric matrix. For each variable a Centrality

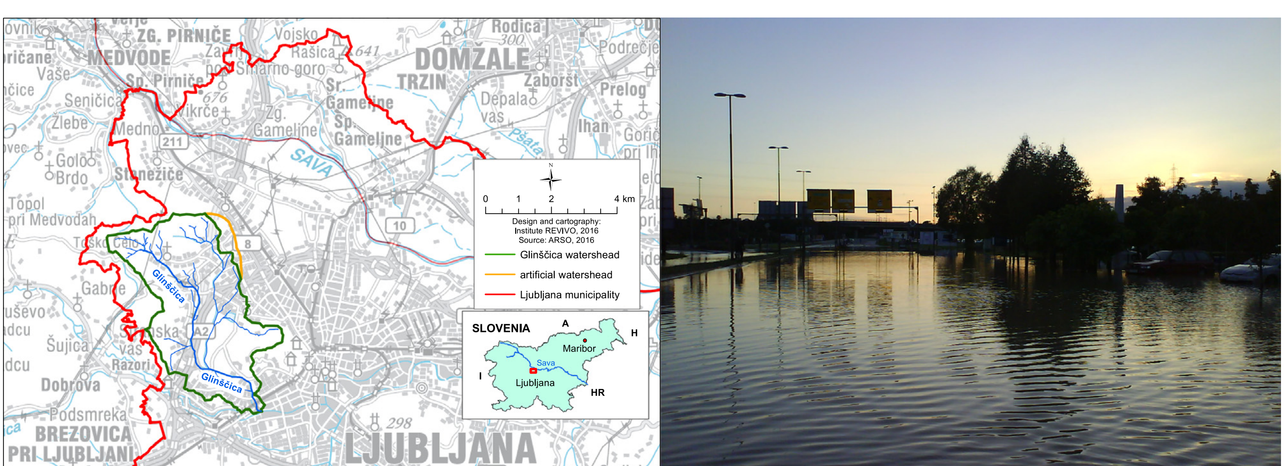

Fig. 4. The study area: municipality of Ljubljana, Glinščica catchment area, Slovenia.

Table 4
Stakeholders involved in the Municipality of Ljubljana case study.

	Stakeholders		Role
1	CIPV	Civil initiative for flood protection of SW part of Ljubljana	Group of local stakeholders providing citizens rescue in case of emergency, flood risk and prevention activities
2	DRSV	Slovenian water agency - Sector for development and planning	It monitors, analyses and forecast natural phenomena and processes in the environment to reduce natural threats to people and property
3	MKGP	Ministry of Agriculture, Forestry and Food of the Republic of Slovenia	It preserves the agricultural sector in terms of the environmental conservation and economic activities
4	MOL nat	Municipality of Ljubljana - Department for nature conservation	It prepares guidelines and recommendations for the environmental protection and the preservation
5	MOL Civ	Municipality of Ljubljana - Department for civil protection and disaster relief	It coordinates and connects the rescue actors within the Municipality of Ljubljana
6	MOL Urb	Municipality of Ljubljana - Department for spatial planning	It prepares strategic plans at urban level and national level
7	MOP Od	Slovenian Ministry of environment and spatial planning, water and investments directorate – Sector for natural disaster rehabilitation	It prepares strategies for natural disaster rehabilitation
8	MOP Var	Slovenian Ministry for environment and spatial planning - Sector for nature protection	It prepares plans for environmental protection
9	RD	Fishing Club Dolomiti	Association of local stakeholders preserving fisheries sector in terms of environmental conservation and economical activities.
10	URSZR	Administration for civil protection and disaster relief	It regulates the implementation of protection strategies of 32 municipalities
11	ZRSV	Institute of the Republic of Slovenia for nature conservation	It supports the writing of plans for nature conservation
12	ZZRS	Fisheries Research institute of Slovenia	It regulates human intervention on stream area

Index (CI) has been calculated, summing the incoming and outgoing connections (Harary et al., 1965, Eden, 1992). Out-degree and in-degree indices describe the aggregated strengths of connections respectively as row and column sums of absolute values (Papageorgiou and Kontogianni, 2012), and CI allows to identify the most important vertices within a graph, accounting for the complexity of its network of connection (Özesmi and Özesmi, 2004).

$$CI = od(v_i) + id(v_i)$$

The out-degree index shows the cumulative strengths of connections A_{ik}exiting the variable, where N is the total number of variables:

$$od(v_i) = \sum_{k=1}^{N} a_{ik}.$$

The in-degree index represents the cumulative strength of variables entering the variable:

$$id(v_i) = \sum_{k=1}^{N} a_{ik}$$

For the purposes of the present work, the values of CI have been used firstly for identifying the most important variables affecting the stakeholder's flood risk perception. This analysis was completed through the detection of the most impacted variables in the FCM. The basic assumption is that the higher the impacts of water-related risk on the variables in the stakeholder's mental model, the more central these issues are in the stakeholders' risk perception. To this aim, two scenarios were simulated using individual FCM process (Kok, 2009), i.e. the Business-As-Usual (BAU) scenario and the risk scenario. The latter is characterized by the activation of the variables connected to flood hazard, e.g. "intense rainfall". The comparison among the states of the variables in the two scenarios allowed us to detect the most impacted variables according to the stakeholders' risk perception.

The most important elements in the stakeholders' risk perception were, hence, detected by aggregating the results of the centrality degree analysis and those of the flood impact assessment.

3.3. Flood risk perception workshop

The divergent thinking phase allowed us to detect and analyse the main differences among the stakeholders' risk perceptions. As already

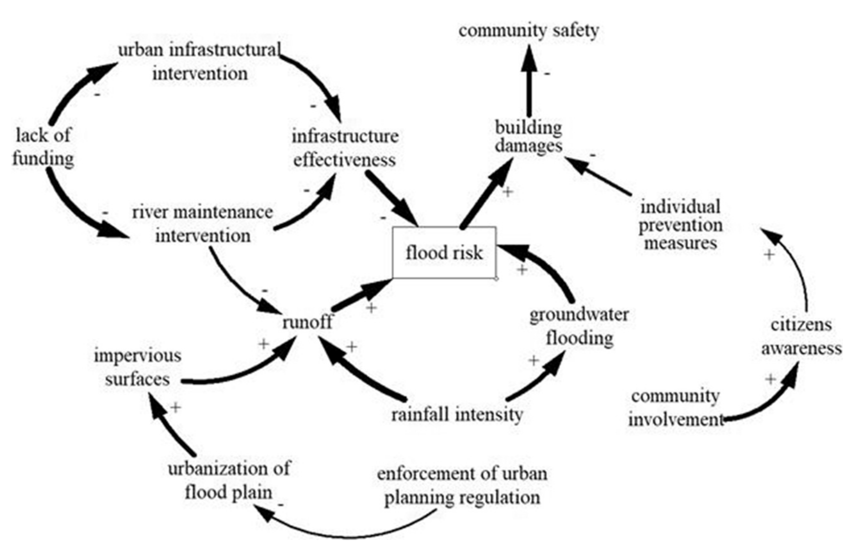

Fig. 5. CIPV's FCM. The weighted arcs take value in the interval [−1;1] according to the relationship among variables perceived by CIPV's.

Table 5
Topological variables identification of CIPV's FCM.

Class	Variables	Variables From CIPV's FCM
Topological	Key risk	Flood
	Driver	Rainfall intensity, Enforcement of urban planning regulation, Lack of funding, Community involvement
	Ordinary	Flood, urban infrastructural intervention, Individual prevention measures, River maintenance intervention, Infrastructure effectiveness, Impervious surfaces, Urbanization of flood plain, Groundwater flooding, Building damages, Citizen awareness, Runoff
	Receiver	Community safety

discussed in the introductory section, ambiguity could be either a source of creativity in the collective decision-making processes, or the cause of the polarization of the viewpoints. Experiences demonstrated that the key to change ambiguity in problem understanding from a barrier to an enabling factor for the collective decision-making processes is the decision-actors awareness of the existence of different, and equally valid, problem framings (Giordano et al., 2017a).

Starting from these premises, the results of the ambiguity analysis were used as basis for the convergent thinking phase, i.e. the achievement of a consensus on the most suitable categories of NBS for reducing flood risk. To this aim, a *Flood Risk Perception Workshop* was organized.

The design of the workshop is supported by the validation and analysis of the Individual-FCMs. Thus, stakeholders' different risk perceptions and problem framing, elicited and investigated in the previous steps, represents the starting point for the collective identification of suitable NBS for flood risk management, sing both technical presentations (i.e. introducing NBS catalogue) and participatory activities.

Specifically, the Individual-FCMs variables are divided into two sets (i.e. *elements of vulnerability* and *expected impacts)* and the related CI comparison are presented to participants. The common variables with higher CI are discussed and ranked by the participants (i.e. from 5 = very important to 1 = not important). The representatives of both institutions and community collectively identify the main features of the flood risk, aligning the stakeholders' perceptions. Afterwards, using both technical presentations (i.e. introducing a NBS catalogue of NBS) and group discussions, participants agree on the most suitable NBS.

4. The Glinščica river (Slovenia) case study

The described multi-steps methodology has been applied to the Glinščica river case study (Fig. 4). The Glinščica catchment area (Slovenia) is situated within the borders of the municipality of Ljubljana and has an area of approximately 17 km^2. Originating at 409 m.a.s.l., in the steep hills lopes of Toško Čelo, the Glinščica river has a torrential character which. This aspect, together with impact of climate change (e.g. less frequent, more intense rainfalls) and urbanization, results in regular flooding.

The activities of the present study were performed with several participants, involved of interested in flood risk management in the Ljubljana municipality, i.e.: 1) Civil initiative for flood protection, 2) Slovenian water agency - sector for development and planning, 3) Ministry for agriculture, forestry and food of the Republic of Slovenia, 4) Municipality of Ljubljana, department for nature conservation, 5) Municipality of Ljubljana - department for civil protection and disaster relief, 6) Municipality of Ljubljana - department for spatial planning, 7) Ministry of environment and spatial planning- water and investments directorate, sector for natural disaster rehabilitation, 8) Ministry for environment and spatial planning - sector for nature protection, 9) Fishing Club Dolomiti, 10) Administration for civil protection and disaster relief, 11) Institute of the Republic of Slovenia for nature conservation, 12) Fisheries research institute of Slovenia. Further information related to the involved stakeholders and their role in flood risk management are provided in Table 4. The choice to involve institutional stakeholders was aimed to understand their perception about flood risk and the potential barriers between different institutional groups In addition, the local stakeholders groups most exposed to flood risk (Civil initiative for flood protection of SW part of Ljubljana and Fishing Club Dolomiti) were involved.

Table 6
Conceptual meaning identification of CIPV's FCM.

Class	Variables		Variables from CIPV's FCM
Conceptual meaning	Expected impacts	Primary impact	Building damages
		Secondary impact	Community safety
	Elements of vulnerability		Citizens' awareness, Lack of funding, Urbanization of flood plain, Groundwater flooding, Infrastructure effectiveness

4.1. Semi-structured interview and individual FCM building

In order to elicit stakeholders' risk perceptions on flood risk and NBS, individual FCMs have been built using the information collected during semi-structured interviews, performed between March and May 2017. The interviews were based on 17 questions grouped according to three main issues: i) stakeholders' previous experience with flood; ii) stakeholders' knowledge regarding strategies used for dealing with risk; iii) stakeholders' awareness on the NBSs use for reducing flood risk. One of the individual FCMs (CIVP) is shown in Fig. 5.

Each variable in the Individual-FCM represents a concept related to flood risk management according to stakeholders' perceptions, while the arcs (marked with a + or a − according to the polarity of the cause-effect connection) display weighted causal relationships between concepts. For instance, according to CIPV's perception, the flood risk is caused by the high value of runoff and groundwater flooding due to heavy rainfall. The value of runoff is generated by the urbanization of flood plain that generates impervious surfaces. Building damages following the flood event, are considered the primary impacts. As a result, it decreases a community safety.

4.2. Risk perception and Ambiguity Analysis

For the sake of simplicity, the results of the individual FCM analysis are discussed with specific reference to the FCMs shown in Fig. 4. A similar procedure was used for all the individual FCMs produced. Firstly, in order to define the key elements, the variables of the CIPV's FCM were categorized into two categories: topological class (Table 5) and conceptual meaning class (Table 6) for more details see Section 3.2).

Some variables are included in the both clusters, e.g. the variable 'Community safety' is a receiver according to the topological meaning, and secondary impact according to the conceptual meaning.

Secondly, an adjacency matrix was derived from the CIPV's FCM. The Centrality Index (CI) was thus computed to identify the most central elements of the FCM. The results are included in Table 7.

Table 7 shows that the most central variable in the set of the 'elements of vulnerability' is 'infrastructure effectiveness' (CI value 2.42). This means that, according to the CIPV's perception, the lack of effective infrastructure increases the urban system vulnerability to flood. 'Groundwater flooding' is significant as well, according to the CIPV's perception, with a CI value of 1.72.

The FCM was, hence, used to simulate the risk scenarios. As already described, the comparison between the BAU and the flood risk scenarios allowed us to detect the most impacted variables, according to the stakeholder's risk perception. Fig. 6 shows the comparison among the two scenarios.

The Fig. 6 shows that the most impacted variables are: Building damages, Community safety, Infrastructure effectiveness, River

Table 7
Centrality Index derived from the CIPV's FCM.

Stakeholder: CIVP	
Elements of vulnerability	Centrality index
Community awareness	0.86
Lack of funding	1.56
Urbanization of flood plain	1.62
Infrastructure effectiveness	2.42
Expected impacts	–
Building damages	2.53
Community safety	0.90

maintenance, Community involvement. The aggregation between the centrality degree and the flood impact assessment allowed us to identify the most important elements in the CIPV risk perception.

The same analysis was carried out for the remaining stakeholders, as shown in the Table 8.

The aggregation between the centrality degree and the impact degree allowed us to identify the key variables for each stakeholders and, thus, to analyse similarities and differences. Specifically, Table 8 shows that most of the stakeholders considered the low level of implementation of the urban and spatial planning as one of the main elements affecting the system vulnerability to flood. According to the stakeholders' problem understanding, this leaded to an increase of the urbanization of the flood plain and, consequently, to an increase of the flood risk. Besides, the lack of institutional cooperation and community awareness seem to reduce the capability of the system to design and implement effective risk management measures. Concerning the perceived impacts, Table 8 shows a high level of consensus about the variables “Building damages”, “Infrastructure damages” and “Agricultural productivity”. Only few stakeholders mentioned the state of the river ecosystem as an important element affected by flood. It is worth mentioning that, in many cases, the centrality of the variables reflects the institutional roles and responsibilities of the involved actors.

The results deriving from divergent phase thinking were the starting point of the convergent thinking phase carried out through the *Flood Risk Perception Workshop*.

4.3. Flood risk perception workshop

The results of ambiguity analysis were used as the starting point for the convergent thinking phase. To this aim, a flood risk perception workshop was organized in the study area, involving the stakeholders that already took part in the previous phases of the analysis. Specifically, the most important elements in the stakeholders' perceptions concerning both the system vulnerability to flood and the main impacts were used for supporting the co-design of the NBS.

The workshop was composed by two main phases: i) consensus achievement over the main goals of the risk management strategies; ii) co-definition of the most suitable NBS for achieving the selected goals.

Concerning the first point, the elements mentioned in Table 8 were used for supporting the discussion. In order to keep track of the differences in risk perception, we did not refer exclusively to the elements mentioned by most of the stakeholders. The Table 9 shows the list of potential goals to be achieved, accounting for the stakeholders' risk perception.

The participants were requested to provide individual inputs concerning the score of the goals listed in Table 9 according to their preference system following a five-points Likert scale (Likert, 1932), i.e. 5 = very important, 4 = important, 3 = fairly important, 2 = slightly important, 1 = not important. The individual inputs were collected and aggregated. The obtained ranking was then discussed by the participants and a consensus was achieved. The five most important goals at the end of the discussion were: i) ‘reducing floodplain occupation’, ii) ‘Increasing funding opportunities for risk reduction’, iii) ‘Increasing community safety’, iv) ‘enhancing the state of the ecosystem’ and (v) ‘Controlling watercourse speed”.

The results of this phase were used to support the discussion concerning the selection of the most suitable NBS, grey and of solutions to be implemented in order to achieve the above mentioned goals. In order to facilitate the participation of not-experts in the discussion, catalogues of potentially suitable NBS and grey solutions were created in advance through an interaction with local experts (Table 10 and Table 11). The list of goals to be achieved allowed us to define a set of potentially suitable “socio-institutional” measures. That is, measure to

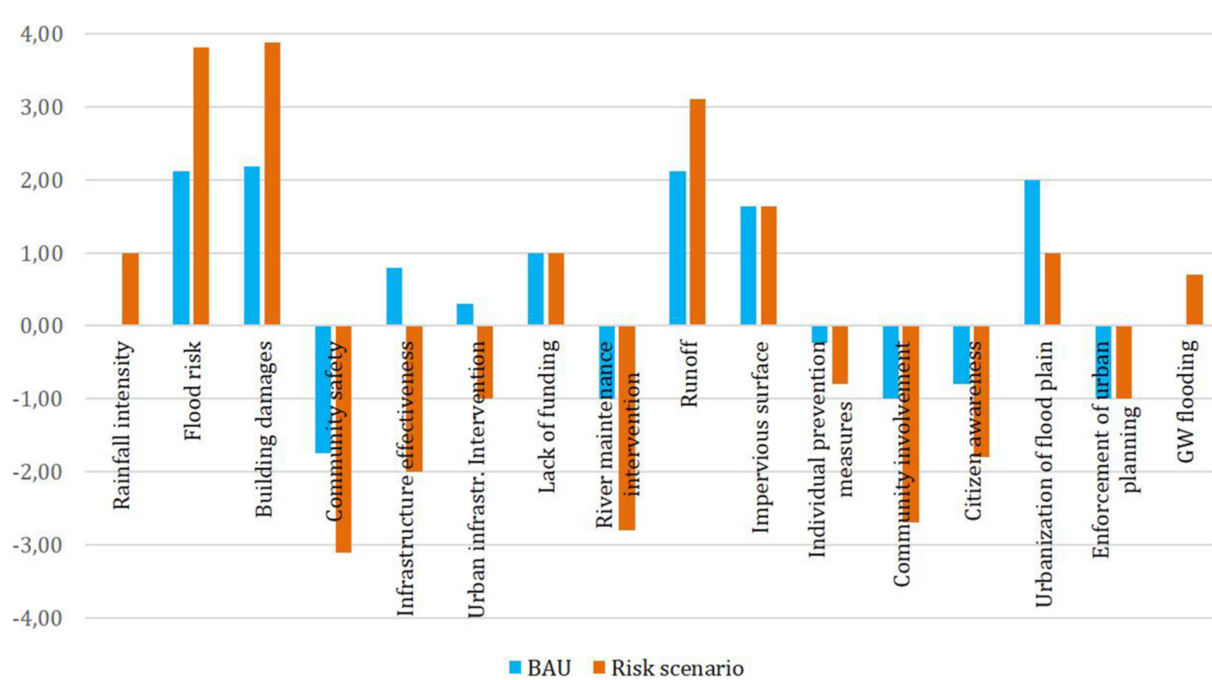

Fig. 6. Comparison between BAU and risk scenario according to CIPV risk perception.

Table 8
The most important elements according stakeholders' perception.

Decision actor	Variable	Centrality degree (value)	Centrality degree (index)	Impacts degree	Importance degree
Civil initiative for flood protection of SW part of Ljubljana	Community awareness	0,86	Medium	Negative	Medium
	Lack of funding	1,56	High	Weakly positive	Medium
	Urbanization of flood plain	1,62	High	Weakly positive	Medium
	Infrastructure effectiveness	2,42	High	Highly negative	High
	Building damages	2,53	High	Highly negative	High
	Community safety	0,90	Medium	Negative	Medium
Slovenian water Agency - sector for development and planning	Lack of spatial planning	1,64	Medium	Weakly negative	Medium
	People awareness	3,44	High	Negative	High
	Agricultural productivity	1,56	Medium	Weakly negative	Medium
	Building damages	0,81	Low	Negative	Medium
	State of the ecosystem	1,56	Medium	Negative	High
	Social vulnerability	0,72	Low	Weakly negative	Low
	Water distribution	0,86	Low	Weakly negative	Low
Ministry for agriculture, forestry and food of the Republic of Slovenia	Lack of urban regulation	2,21	Medium	Negative	High
	Agricultural productivity	1,23	Low	Weakly negative	Low
	Building damages	2,08	Medium	Negative	High
	Green areas quality	0,61	Low	Weakly negative	Low
	Economic losses	2,25	Medium	Negative	High
	State of the ecosystem	1,34	Low	Negative	Medium
Municipality of Ljubljana, Department for nature conservation	Urbanization of flood plain	2,15	Medium	Weakly negative	Medium
	Lack of legislation	1,72	Medium	Weakly positive	Medium
	Urban plan effectiveness	2,82	High	Negative	High
	State of the ecosystem	1,54	Medium	Negative	High
	Building damages	1,84	Medium	Weakly negative	High
	Community safety	1,60	Medium	Negative	Medium
Municipality of Ljubljana - Department for civil protection and disaster relief	Flood plain urbanization	1,31	Low	Weakly negative	Low
	People awareness	0,42	Low	Negative	Medium
	Building damages	1,59	Medium	Negative	High
	Infrastructure effectiveness	2,21	Medium	Negative	High
	Ecosystem quality	0,42	Low	Weakly negative	Low
	Transportation costs	1,20	Low	Negative	Medium
	Economic losses	0,71	Low	Negative	Medium
Municipality of Ljubljana - Department for Spatial Planning	Lack of urban regulation	1,67	Medium	Weakly negative	Medium
	People awareness	0,69	Low	Weakly negative	Low
	Agricultural productivity	0,89	Low	Negative	Medium
	Building damages	1,00	Low	Negative	Medium
	Infrastructure effectiveness	3,00	High	Negative	High
	Economic losses	2,13	Medium	Negative	High
	Plan effectiveness	2,56	High	Negative	High
The ministry of environment and spatial planning – Water and investments directorate – Sector for natural disaster rehabilitation	Urbanization of flood plain	2,89	High	Weakly negative	Medium
	Lack of institutional cooperation	1,76	Medium	Negative	High
	Lack of maintenance of green areas	0,89	Low	Weakly negative	Low
	Infrastructure effectiveness	1,34	Low	Negative	Medium
	Industrial sector	0,89	Low	Weakly negative	Low
	Transportation system	1,23	Low	Negative	Medium
	Agricultural productivity	1,78	Medium	Negative	High
	Urban security	1,56	Medium	Weakly negative	Medium
	Community safety	2,21	Medium	Negative	High
	Recovery costs	1,45	Low	Weakly negative	Low
Fishing Club Dolomiti	Lack of control	1,53	Medium	Weakly	Medium

Table 8 (*continued*)

Decision actor	Variable	Centrality degree (value)	Centrality degree (index)	Impacts degree	Importance degree
				negative	
	Unregulated infrastructures Development	1,31	Low	Weakly negative	Low
	Illegal waste disposal	0,64	Low	Weakly negative	Low
	Building damages	0,33	Low	Negative	Medium
	Ecosystem quality	0,58	Low	Negative	Medium
	Industrial sector	0,11	Low	Weakly negative	Low
	Fish population	0,11	Low	Negative	Medium
Administration for civil protection and disaster relief	Mismanagement of the territory	0,11	Low	Negative	Medium
	Lack of maintenance of green areas	0,7	Low	Weakly negative	Low
	People awareness	0,42	Low	Weakly positive	Low
	Urban infrastructures	0,42	Low	Negative	Medium
	Agricultural productivity	1,2	Low	Negative	Medium
	Building damages	1,11	Low	Negative	Medium
	Community safety	0,72	Low	Negative	Medium
Institute of the Republic of Slovenia for Nature Conservation	Lack of funding	2,25	Medium	Weakly positive	Medium
	Lack of law enforcement	0,78	Low	Weakly negative	Low
	People awareness	1,6	Medium	Weakly negative	Medium
	Infrastructure effectiveness	1,52	Medium	Negative	High
	Building damages	1,03	Low	Negative	Medium
	State of the riverbank vegetation	1,5	Medium	Negative	High
	State of the ecosystem	0,86	Low	Negative	Medium

be implemented together with NBS and grey solutions in order to enhance their effectiveness (Table 12).

Even in this case, participants were required to provide individual scores for the each of the three sets of measures. The aggregated ranking was then challenged in a group discussion. The debate provided several meaningful results, which are summarized in the following. Firstly, although decreasing floodplain occupation could be difficult in densely-urbanized areas, maintaining the current levels of urbanization could one of the most important measures for flood risk management. Secondly, stakeholders underlined that, while the urban planning policy already exists, the enforcement system is ineffective. Several examples of complete ignorance from the enforcement authorities were shared among the group. Finally, participants were not interested in grey solutions. They explicitly required to keep those solutions out of the discussion. Tables 13 and 14 show the co-defined set of NBS and socio-institutional solutions.

Stakeholders recognized that the selected measures simultaneously tackle four of the main goals in the Glinščica catchment. It was suggested by the stakeholders that the dry retention areas should be built in the spaces upstream of the built-up areas and the same holds true for the opening of the flood plains. The stakeholders explained that flood risk management measures have been planned for the Glinščica catchment since the 2010 floods and that one of the dry retention areas has already been built. *Re*-meandering has somewhat contradictory expected impact on the 5 main goals according to the stakeholders. Re-meandering will greatly improve the state of ecosystem and slow the water flow but should be implemented within the opened-up flood plain or within a dry retention area, because it might increase the risk of flooding by slowing the flow and hence will not attribute to community safety. Widening of the stream channel was suggested for the stretch of the Glinščica within the urbanized areas, where buildings and other infrastructure prevent other restoration measures. The concrete lining should be removed, and the more natural two-level channel restored to maintain the ecological flow in the lower, smaller channel during low flows, but to allow the larger volumes during flood events to be discharged efficiently.

As the last suggested measure, retention areas were seen as the least effective in flood risk management, but as an important factor for improving the state of ecosystem and addition to the green areas of the city.

The lack of public funding was recognized by the stakeholders as one of the main issues in flood risk management throughout Slovenia. It was put forward that the 2010 and 2014 floods were the main reason for the fast planning and implementation of the current flood risk management activities in the Municipality of Ljubljana. However, the measures to achieve the increase in public funding were not the aim of this workshop and were not further discussed.

Table 9
List of goals during the workshop.

Reducing the vulnerability	Increasing community involvement
	Enhancing warning system effectiveness
	Enhance infrastructure effectiveness
	Increase institutional cooperation
	Increasing funding opportunities for risk reduction
	Reducing flood plain occupation
	Increasing individual prevention measures
	Enhancing the effectiveness of urban and spatial planning
	Reducing impervious surface
Reducing expected impacts	Increasing community safety
	Enhancing social wellbeing
	Supporting agricultural sector productivity
	Supporting industrial production
	Reducing building and infrastructure damages
	Reducing recovery costs
	Reducing economic losses
	Enhancing the state of the ecosystem
	Controlling watercourse speed

Table 10
List of nature-based solutions list adapted from http://nwrm.eu/.

Nature based solutions	Function for flood reduction
Renaturing urban water bodies	Increase water buffering
Reduce canalization of the urban water bodies	Increase water buffering (transfer)
Re-vegetation in urban areas	Increase water buffering (production)
Re-establishing meandering and oxbows	Increase water buffering(transfer); erosion control
Restore riparian vegetation	Increase water buffering (transfer)
Construction of dry retention areas on flood plains	Increase water buffering (transfer)
Create artificial water bodies for short term water storage	Increase water buffering (transfer)
Use of balancing ponds to release water slowly	Increase water buffering (transfer)
Preventing soil compaction	Increase water buffering (production); water retention
Forest management	Increase water buffering (production)
Wetlands restoration	Increase water buffering (production and transfer)
Stopping water transportation of trunks, branches and leaves	Prevention of bridge and culvert obstruction with solid transport
Preventing new erosion ditches in upper parts of river basin	Erosion and solid transport supply prevention, slow overland flow.
Preventing bank erosion with short and forest vegetation	Bank erosion prevention
Removing cross wise barriers/dams	Decreasing water level during floods
Renaturation of waterbodies	Connectivity of the main channel with side channels, wetlands and oxbow lakes
Rerouting floods to wetlands	Connectivity of the main channel with side channels, wetlands and oxbow lakes
Opening natural flood plains	Connectivity of the main channel with floodplains
Preventing new build up areas on flood plains	Preventing the increase of vulnerability
Removing buildings from flood plains where possible	Diminishing vulnerability

Concerning the socio-institutional measures, it is worth noticing that most of the selected actions were meant to raise community awareness toward flood risk, and to increase the capabilities of the institutional system to guarantee the implementation of the urban and regional plans. As discussed further in the text, participants required to provide further information concerning the costs of the socio-institutional measures.

5. Discussion

We would like to focus this section on two different, but equally import, issues. On the one hand, we assess the suitability of the proposed methodology for eliciting and structuring individual risk perception as basis for the co-design of NBS for flood risk management. This will facilitate the replicability of the adopted methodology. On the other hand, the results of the analysis are used to draw some preliminary conclusions concerning the potential barriers hampering the design and implementation of NBS. Policy suggestions aiming at overcoming these barriers are derived from this discussion.

Table 11
List of grey solutions list.

Grey solutions	Function for flood reduction
Regulation of water treatment structure	Regulation of quantity of high water
Flooded embankments	Prevention of the free flooding of high waters along the floodplain
Transmission objects (dams, thresholds, etc.)	Reducing water energy and the longitudinal fall of the bottom of the riverbed
Vegetation and flag vessels (leaves, branches, trunk, etc.)	Improve the riverbed flow
Local restructuring high water	Reduce high water
Construction of structure	Maximize the transfer capacity for sediment
Sexing the sediment	Increase the bottom of the riverbed and to release the space for the future deposit of the sediment

Table 12
List of “soft-institutional” measures.

Socio-institutional measures
Enforce land protection planning strategies
Enforce urban planning strategies
Territory control (illegal activities)
Implementing projects that target the involvement of local communities
Defining innovative protocol of interaction among different institutions
Increase community protection measures
Controlling water withdrawal from the river
Training for individual protection measures
Subsides for individual protection measures
Developing new recreational areas
Establish innovative and effective water users association (irrigation)
Attracting new investors
Supporting multi-modal transportation
New subsides scheme supporting local economies
Increase funding/investment in the local economy
Increasing the availability of social services

Concerning the first issue, the experiences carried out in Glinščica demo show the FCM capability to structure the complex cause-effect chains affecting the stakeholder's risk perception. To this aim, the framework for the semi-structured interviews was organized according to the *mean-end* approach. That is, interviewed were required to describe the “risk-primary impacts-secondary impacts-vulnerability-measures” perceived chain of causality. This facilitates the developing of the individual FCM starting from the stakeholders' narratives. Moreover, the adopted hierarchical structure of the FCM facilitates the identification of the most important elements in the stakeholders' risk perception, through the aggregation of the centrality degree and the impacts degree, as describe above in the text. A validation phase was carried out with selected stakeholders in order to assess the reliability of the centrality and impact degrees. In most of the cases, the central issues mentioned by the stakeholders coincided with those identified through the adopted approach.

Besides, this work demonstrated the suitability of the adopted ambiguity analysis method for supporting the creative and collaborative decision-making process for NBS design. The modelling approach adopted in the elicitation and structuring of the individual risk perception allowed us to detect divergences and, in some cases, potential sources of conflicts in risk management. These elements were at the basis of the convergent thinking phase. Thus, the evidences collected during the experience in the demo site demonstrate that making the decision-actors aware of the existence of ambiguous problem framing is the key to enable creative and collaborative decision-making processes.

Table 13
List of selected NBS.

NBS
River renaturation
Watershed renaturation
Barriers removal
Retention areas effectiveness
Opening floodplains
Wetlands restoration
River remeandering

Table 14
List of socio-institutional measures.

Socio-institutional measures
Community involvement
Funding opportunities
Funding opportunities for IRR
Institutional cooperation
Insurance policies effectiveness
Training
Infrastructural maintenance
Territory control

Concerning the second point, although we are aware that the results described in this work are mostly demo-specific, general conclusions can be drawn concerning the interaction between risk perception and NBS implementation. It is worth mentioning that the majority of the involved stakeholders cited institutional-related issues as the main elements affecting the vulnerability of the system toward water-related risks. According to their understanding, the lack of institutional coordination and/or capability to control the territory hampered the actual implementation of risk management strategies and urban plans for climate adaptation. Only few of them mentioned physical elements of vulnerability, e.g. infrastructure effectiveness.

The institutional-related issue represents also the most important barrier hampering the effectiveness of the NBS according to the stakeholders' perception. The lack of risk awareness and the low level of institutional cooperation were perceived as issues that need to be addressed prior to start the implementation of the NBS. Therefore, integrated "socio-institutional" – i.e. policies for raising risk awareness, training and capacity building, institutional cooperation protocols, etc. – and green solutions need to be discussed with stakeholders and decision-makers.

The analysis of the results obtained in the Glinščica demo allowed us to detect potential limits of the adopted approach. Firstly, the comparison between the adopted approach and the other methods for supporting the participatory process – i.e. focus groups, participatory modelling, etc. – highlights the amount of time required to carry out the whole process, starting from the individual interviews, modelling the individual risk perceptions and detecting the main differences. Nevertheless, the results showed that making the participants aware of the existing differences greatly facilitate the discussion. Therefore, we can state that the time consuming first part of the process – i.e. the divergent thinking phase and the analysis of risk perception – allowed a fast and effective convergent thinking phase.

Secondly, the adopted method claims for the long term engagement of the stakeholders. Since the divergent thinking phase is based on the elicitation and analysis of the individual risk perceptions, having the same stakeholders participating in all the different phases is a key for the success of the whole process. To this aim, efforts were carried out since the early phases of the method implementation in order to meet the actual needs and concerns of the different stakeholders. The results of the individual FCM analysis concerning the main goals to be achieved were used to enhance the communication between the analysts and the participants.

Finally, the stakeholders expressed the need to have quantitative assessment of the effectiveness of the selected measures in reducing flood risk and expected impacts. According to the opinions collected at the end of the workshop, the FCM capabilities to simulate qualitative scenarios were considered suitable for supporting the initial discussion and the development of sets of measures. Nevertheless, prior to selecting the most effective combination of measures, stakeholders required a more quantitative analysis, with specific reference to the costs and benefits of the chosen actions. To this aim, a System Dynamic Model (SDM) is going to be developed as a future development of the work described in this article. The SDM will be based on the elicited risk perceptions, and integrating physical model for risk assessment.

6. Conclusions

Floods affect communities, environmental systems and urban areas across Europe. The expectation that flood damages may increase over time has increased the policy-makers' awareness for the need of changes in risk management strategies. Particularly, the importance of joining a technical understanding of physical phenomena with the assessment of stakeholders' goals, knowledge and risk perception is becoming increasingly crucial.

As shown in this paper, the study of the risk perceptions among involved stakeholders, based on the combination of PSM and AA, is the starting point for a collaborative decision-making process aimed at the implementation of the NBSs in flood protection strategies. Two results emerged from this work: thanks to the CI comparison it was possible to understand the differences that each actor attributes to a shared problem, thus structuring the divergences of problem frames; on the other hand, the investigation of the ambiguity has been used for a dialogue that aligns the divergences of problem frames. During the *Flood Risk Perception Workshop*, some of the barriers of flood risk management at national scale emerged. These were mainly institutional rejection of proposed measures, opposition from landowners, lack of public funding and lack of law enforcement.

Research efforts should be oriented toward future modelling activities that help to reduce the distance between different risk perceptions among stakeholders and simulate the implementation of NBSs in Glinščica catchment over time. Specifically, the future development aims to build a collective FCM collective to improve the accuracy of outcomes and obtain a reliable and legitimated representation of all the stakeholders' perceptions, and that helps as a basis for development of modelling system.

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