# A Participatory Modelling approach for enabling Nature-based Solutions implementation through Networking Interventions

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### Abstract

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**Abstract**
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**Keywords:** NBS design and implementation; Social Network Analysis; Fuzzy Cognitive Map; Networking Interventions.

## 1. Introduction
Nature-based solutions (NBS) have become not only a complementary but a valid alternative to grey infrastructures for coping with climate-related risks in urban and rural areas alike (Calliari et al., 2019a; Frantzeskaki, 2019). Moreover, NBS are increasingly recognized for their capacity to support ecosystems functions and to generate ancillary environmental, economic and social benefits considered as essential backbones of actions for climate-change mitigation and adaptation (Bain et al., 2016; Kabisch et al., 2016; Josephs & Humphries, 2018; Cohen-Shacham et al., 2019 ). Nevertheless, moving from planning and designing NBS to implementation remains a challenge (Calliari et al., 2019a; Wihlborg et al., 2019). Several works in the scientific literature were dedicated to detect and analyse the main barrier to NBS implementation. These works demonstrated that physical barriers are less important than those related to governance, socio-institutional and economic dimensions (Calliari et al., 2019b). Other authors (e.g. O'Donnell et al. 2017) showed that the lack of knowledge concerning the NBS impacts – i.e. limited capability to identify and evaluate the multiple NBS benefits and co-benefits – could hamper their implementation. Finally, the social acceptance and the low level of stakeholders' engagement in NBS design were described as a barrier by several authors (Calliari et al., 2019b; Giordano et al., 2020; Pagano et al., 2019; O'Donnell et al., 2017).
The present work contributes to this debate by focusing on the collaboration barriers (Calliari et al., 2019b). NBS implementation is a complex issue, whose effectiveness does not depend exclusively on the capacity and resources of the involved decision-makers, but also on the number and quality

of the relationships with each other (Therrien et al., 2019). By hypothesising NBS design and implementation as collaborative decision-making process, we assume two premises:

a) NBS design and implementation need to be based on inclusive and equitable participatory processes, capable to ensure the active involvement of all different categories of stakeholders and decision-makers. Nevertheless, divergences in values, beliefs and problem frames may lead to collaboration structures that encourage stakeholders and decision-makers to avoid each other, turning the participatory process into a controversial and futile process (Brugnach & Ingram, 2012; Giordano et al., 2017; Howe et al., 2014; Jacobs et al., 2016; Small et al., 2017; Wam et al., 2016; Shrestha & Dhakal, 2019), resulting in a barrier to NBS (Eisenack et al., 2014; Therrien et al., 2019).

b) To effectively implement NBS, the diversity of perceptions, meaning and interpretations of multiple actors should be considered/integrated (Brugnach & Ingram, 2012; Cohen-Shacham et al., 2019). NBS and the associated co-benefits have many potential uses with different values attached, that can be perceived differently from different beneficiaries (Sanon et al., 2012; Jacobs et al., 2016; Small et al., 2017). Collaborative decision-making for NBS implementation requires a clear understanding of the ambiguity among different decision-makers in perceiving and valuing NBS co-benefits (Giordano et al., 2020).

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). Ambiguity, which can be considered as a form of uncertainty and indeterminacy (Brugnach et al., 2011; Van den Hoek et al., 2014), is ineradicable in complex decision-making processes (Jasanoff, 2007). In multi-actors setting the presence of ambiguity may lead either to opportunities for innovation and the development of creative solutions for NBS co-design, or to 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 collaborative decisions (Brugnach et al. 2011)

This work aims to demonstrate that NBS implementation could be facilitated by reducing and aligning divergences and conflicts among different decision-makers. For this, it is necessary to develop and implement disciplined methods that facilitates stakeholders dialogue and reflect on the different sources of ambiguity, indeterminacy and complexity (Jasanoff, 2007).

Most of the approaches described in the scientific literature aiming to eliminate the conflict among different decision-actors, or to reduce it under an acceptable degree, consist in carrying out a consensus reaching process, whose main scope is to achieve (as close as possible to) unanimous agreement (Ding et al., 2019). These approaches assume that conflicts among decision-actors derive from ambiguity in problem framing and non-conformity in their individual objectives and preferences towards alternatives (Liu et al., 2019). Reducing the distances (differences) between decision-actors' preferences may lead to lower level of conflict and higher-quality collaborative decision-making (Herrera-Viedma et al., 2002; Giordano et al., 2007). The above-mentioned approaches neglect the relationships among decision-actors and the role of social network in influencing decision-actors' values and preferences. They are seen as independent individuals (Liu et al., 2019). Nevertheless, individuals do not make decisions in a vacuum, but social interactions can alter preferences, choices and decisions (Kolleck, 2013; Siegel, 2009; Sueur et al., 2012). Evidences demonstrate that the structure of the social networks, both in terms of patterns of connections and the way individuals are distributed across them, affect interdependent behaviour of the agents and the aggregated outcomes of the collective decision process (Siegel, 2009). Moreover, the degree of influence depends on the strength of the relationships between two decision-makers (Liu et al., 2019). Through interaction mechanisms, different decision-actors tend to align their problem frames, overcoming the barriers caused by ambiguity in problem framing (Brugnach et al., 2011; Dewulf et al., 2009; Dewulf & Bouwen, 2012). Conflicts may not occur between decision-makers with a rather different problem frames, but with good relationships (Liu et al., 2019).

This work aims at demonstrating that effective interactions in multi-actors decision-making environment could contribute at reducing the level of conflict due to differences in problem understandings – i.e. risk and co-benefits perceptions – and, consequently, could enable collaborative decision-making for NBS implementation. In line with (Kolleck, 2013), we assume that effective social network has the capacity to promote constant exchange and deliberation, enabling ideological or structural changes and generating new knowledge. This work investigates the suitability of networking intervention approach to enhance the existing network of interactions involving the different decision-actors and stakeholders in NBS implementation (Valente, 2012). Network interventions are based on the diffusion of innovations theory, which explains how new ideas and practices spread within and between communities. Network interventions are purposeful efforts using social network characteristics to generate social influence, accelerate behavioural changes, and enhance organizational performances through punctual interventions in specific nodes of the network, that could act as leverage points in the system (Calliari et al., 2019; Valente, 2012).

In order to answer to the main research questions, we developed a modelling-based approach integrating Social Network Analysis (SNA) and Fuzzy Cognitive Map (FCM). Specifically, SNA is a powerful diagnostic tool to support the detection of the key vulnerabilities in the networks and the nodes for the interventions implementation. FCM were used for capturing and describing the structure and the trends of the system interested by the NBS implementation. The integrated modelling approach allowed to define the most suitable networking interventions through the simulation and comparison of different intervention scenarios (Kok, 2009; Samarasinghe & Strickert, 2013; Voinov et al., 2018). We implemented and tested the approach using a case study in Medina del Campo (Spain).

The manuscript is organized as following. Section 2 describes the different steps of the methodology. Section 3 discusses the results obtained in the Medina del Campo case study, while section 4 is meant to share the main lessons learned from the implementation of the developed methodology.

## 2. Material and Methods

Figure 1 shows the different steps composing the implemented methodology.

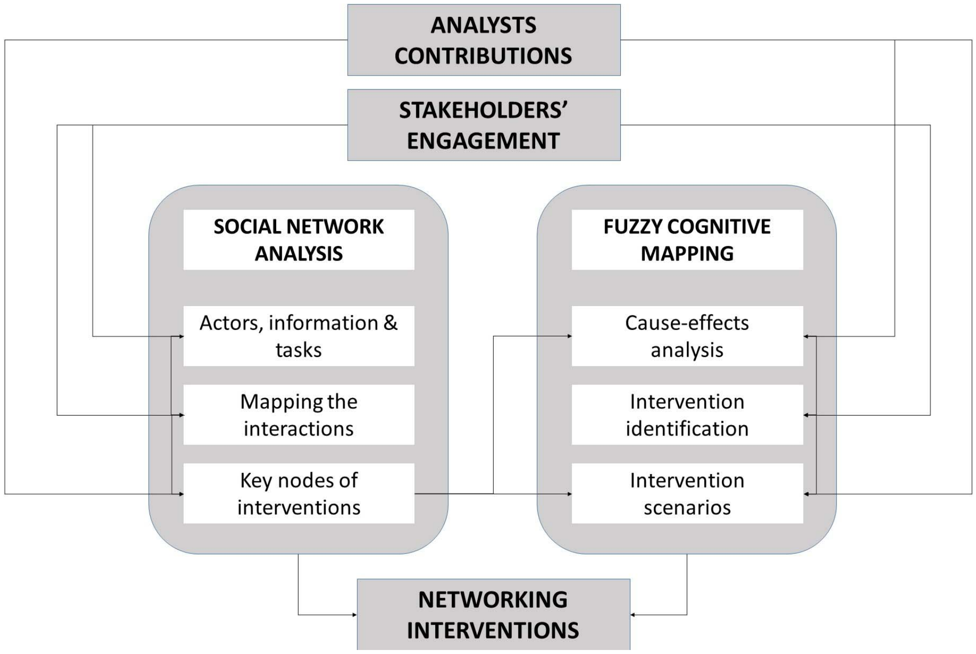



Figure 1: Different phases of the implemented methodological approach

As shown in figure 1, the implemented approach was based on the integration between stakeholders' engagement activities and desktop analysis. Concerning the stakeholders' engagement, both individual semi-structured interviews and workshops were carried out. Specifically, the individual interviews aimed at gathering individual problem understandings concerning the main risks associate with climate change and the most effective risk management measures, including NBS. Moreover, preliminary data about the most important information to be used in risk management and the actors that need to be involved were collected as well. The first workshop was meant to engage stakeholders in mapping the network of interactions activated between the different decision-makers involved/interested in climate-related risks management and NBS implementation.

Two kinds of analysis were carried out referring to the results of the individual interviews and of the first stakeholders' workshop, i.e. the Social Network Analysis (SNA), and the development of FCM-based scenarios. The integration of these two methods allowed us to inform the second stakeholders' workshop whose main scope was to co-define the networking interventions for NBS implementation.

### *2.1. SNA for mapping and analyzing the network of interactions*

SNA has the potential to support the definition of networking interventions by unravelling the complexity of the interaction network affecting the multi-actors decision-making process for NBS design and implementation, and allowing to identify the nodes that play a central role in the process (Calliari et al., 2019b). SNA techniques help to understand existing networks and to identify innovation potentials in order to generate new information and reveal options for structural developments (Kolleck, 2013; Therrien et al., 2019). Given that social interactions alter decision-actor's choices, SNA can help understanding how and why the actors behave the way they do, through the analysis of structural patterns of relations that influence social processes (Borgatti & Foster, 2003). SNA has the capacity to support collaborative decision-making processes by dealing with the following issues: i) identification of networks of interactions (existing, missing and realistic cooperation), and investigation of actors, structures and network boundaries; ii) innovation potentials through network development strategies (where and how cooperation can be optimized, and where and how alterations are possible and reasonable); iii) identification of problems of coordination, information and motivation; iv) identification of weakness in the knowledge transfer process (Kolleck, 2013).

In this work, SNA was implemented to make explicit both the formal and informal networks of interactions in which the different decision-actors dealing with the design and implementation of climate-related risks management measures – including NBS – are involved. Among the different methods available in the scientific literature for modelling and analysing the social networks (e.g. Borgatti, 2006; Ingold, 2011; Lienert et al., 2013), the Organizational Risk Analysis (ORA) approach has been implemented in this work (Carley, 2002). While most of the existing approaches for SNA implementation in multi-actors' decision environment focused exclusively on interaction among actors and on the role of the thrust among them (e.g. Liu et al., 2019), ORA assumes that the interaction among decision-actors is mediated through other elements, such as tasks and information. That is, an effective cooperation among decision-makers requires actors to cooperate in carrying out certain tasks and to exchange information (Giordano et al., 2017). The quality of the collaborative decision-making process can be improved only if the decision-actors have harmonious relations each other, and the information flows effectively within the organization and it is coherent with the complexity of the tasks load for each decision-actor.

The interlocked networks are represented using the meta-matrix conceptual framework, as shown in the following table.

Table 1 Meta-matrix framework showing the connections among the key entities of social network (adapted from (Carley, 2002))

| | **Agent** | **Knowledge** | **Tasks** |
|---|---|---|---|
| **Agent** | *Social network:* map of the interactions among the different institutional actors in the different DRR phase | *Knowledge network:* identifies the relationships among actors and information (Who does manage which information? Who does own which expertise?) | *Assignment network:* defines the role played by each actor in the DRR phases |
| **Knowledge** | | *Information network:* map the connections among different pieces of knowledge | *Knowledge requirements network:* identifies the information used, or needed, to perform a certain task in the DR |
| **Tasks** | | | *Dependencies network:* identifies the work flow. (Which tasks are related to which) |

In order to map the network of interactions among the different stakeholders, and the connection with the information and the tasks, a participatory mapping exercise was designed, involving institutional and non-institutional decision-actors. The initial list of the agents involved in the network of interactions, the task to be carried out in risk management and the information needed were defined referring to the results of the individual interviews, as further described in the text.

During the mapping exercise, participants were requested to mention the tasks that each actor in the list was required to carry out in risk management and NBS implementation. Links were drawn connecting actors and tasks. Then participants were requested to specify with whom the different actors were supposed to cooperate in order to carried out the defined tasks. Finally, the information was introduced in the map. Participants connected the different kinds of information with the tasks this information was supposed to support (Information x Task network), and the actors owning/using the information (Agent x Information network). Once the map describing the Agents-Information-Tasks connections was developed, participants were requested to assign an importance degree to each link according to their own understanding. Three different values were used in this phase, i.e. "High importance" (+++ in the map), "Medium importance" (++ in the map), "Low importance" (+ in the map).

In order to facilitate the analysis of the map of interactions, adjacency matrices were develop referring to the importance degree of the drawn connections (table 2).

Table 2: Example of the Agent X Agent matrix.

| | **$A_1$** | **$A_2$** | **…** | **$A_n$** |
|---|---|---|---|---|
| **$A_1$** | - | $W_{12}$ | … | $W_{1n}$ |
| **$A_2$** | $W_{21}$ | - | … | $W_{2n}$ |
| **…** | … | … | - | … |
| **$A_n$** | $W_{n1}$ | $W_{n2}$ | … | - |

In the previous matrix, $W_{ij}$ represents the importance of the interaction between the agent $A_i$ and the agent $A_j$ as perceived by the agent $A_i$. Similarly, the value of $W_{ji}$ refers to the strength of the interaction between the agent $A_i$ and the agent $A_j$ as perceived by the agent $A_j$. The linguistic assessment used by the stakeholders during the participatory mapping exercise were translated into fuzzy weights. See Giordano et al. (2020) for further details on the use of fuzzy linguistic functions.

Similarly, the Agent X Tasks, Agent x Information and the Information X Tasks matrices were developed. The matrices were then used to graphically represent the interaction network activated when designing and implementing NBS for dealing with climate-related risks.

### *2.2. FCM for describing and analyzing the system dynamic behavior*

FCM can be defined as the graphical representation of the ideas of a group of stakeholders or individuals to give an interpretation to a complex system (Eden, 1988). A FCM is composed by interrelated variables and directional edges, i.e. connections – representing the causal relationships between variables (Kok, 2009; Giabbanelli et al., 2017). The values of the FCM variables are defined using the fuzzy values, and the connections are defined by a fuzzy weight which describes the strength of the causal relationship between two variables (Kosko, 1986). The connection strength indicates the stakeholder's perceived influence of two variables on each other (Özesmi and Özesmi, 2004). The fuzziness of a FCM occurs in the process of assessing intensity values on reciprocal effects between variables, according to the stakeholders' understanding of the system structure. FCM allows to capture the essence of the whole system comprehensively (Samarasinghe & Strickert, 2013). 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).

Different approaches for building FCM are available. Firstly, the stakeholders' knowledge can be collected either through direct elicitation – stakeholders are actively engaged in defining the variables and causal connections in FCM – or indirect elicitation – textual information, like interviews transcripts or existing texts, is used by an analyst to develop the FCM (LaMere et al., 2020). Moreover, individual interactions and group discussion can be organized for FCM development. Considering that this work aimed at analysing the main differences in stakeholders' perceptions, individual FCM were developed. A combination of indirect – through individual semi-

structured interviews – and direct elicitation methods was implemented in this work (Olazabal et al., 2018; LaMere et al., 2020).
The individual interviews were designed in order to collect the stakeholders' understandings about "risk-primary impacts-secondary impacts-vulnerability-measures" perceived chain of causality. The interviews were designed in such a way as to make the cause-effect relations immediately identifiable in the stakeholders' argumentation (LaMere et al., 2020). A structured approach was implemented in order to derive FCM from individual interviews (Jetter & Kok, 2014; Olazabal et al., 2018). Keywords in the stakeholders' argumentation were detected – i.e. the cause variables and the effects variables in the FCM (Kim & Andersen, 2012) – and the causal connections among them were defined – i.e. the links in the FCM.
In order to use FCM for supporting the definition of the most suitable networking interventions, the individual FCM were aggregated. Following (Özesmi & Özesmi, 2004), the adjacency matrices were coded. In doing this, all stakeholders were considered as equal, without assigning them different level of expertise. The aggregation of the individuals' FCM required the clarification of the concepts meanings and the standardization of the concepts names. For a more detailed description of the issues to be addressed during the FCM aggregation process and the methods to be used, please refer to (Jetter & Kok, 2014; Olazabal et al., 2018; Giordano et al., 2020). The aggregated FCM allowed to: i) represent the feedback structure of systems being modelled; and ii) simulate the dynamic evolution of the system due to the implementation of the networking interventions.

### *2.3. Integrating SNA and FCM for networking interventions definition*

This section describes the SNA-FCM integrated approach for supporting the definition of the most suitable networking interventions, aiming at enhancing the collaborative network for the NBS design and implementation. Specifically: i) SNA was implemented for detecting the main barriers hampering the interactions among the different decision-makers, and for identifying the entry point for the interventions aiming at enhancing the network effectiveness; ii) FCM-based approach was implemented for explaining the cause-effects chains leading to the barriers to collaboration and for defining the most suitable networking interventions.
Concerning the first point, graph theory measures were implemented. In this work we assumed that a key vulnerability in the organization can be due agents – e.g. a key actor is rather marginal in the network – information – e.g. important information is not adequately shared – and tasks – e.g. due to a limited level of cooperation – or a combination of the three categories. The following graph theory measures were implemented in the network analysis. For a more extensive description of the graph theory measures, a reader could refer to (Freeman, 1978; Carley et al., 2007).

Table 3: Graph theory measures for detecting key vulnerabilities in the network of interaction.

| Network | Measure | Meaning |
|---|---|---|
| Agent X Agent<br>Agent X Knowledge<br>Agent X Task | Centrality degree<br>Centrality hub<br>Centrality hub | An agent with a few and weak connections with the others (low level of centrality) would not be capable to carry out important tasks and share key pieces of knowledge |
| Agent X Knowledge<br>Knowledge X Knowledge<br>Knowledge X Task | Most knowledge<br>Centrality degree<br>Centrality hub | A piece of knowledge with a high centrality degree and high centrality hub degree (Knowledge x Task) is key in the process because it enables the access to other pieces of knowledge and allow the fulfilment of several tasks. Nevertheless, a low most knowledge measure means that it has a low level of access for many agents, i.e. it is not adequately shared. |
| Agent X Task | Most task | A task with a high centrality degree has to be carried out in |

| | | |
|---|---|---|
| Task X Task | Centrality degree | order to enable the fulfilment of the other tasks. A low Most task measure means that this key task is not cooperatively performed. The risk of failure is high, leading to the impairment of the other tasks. |

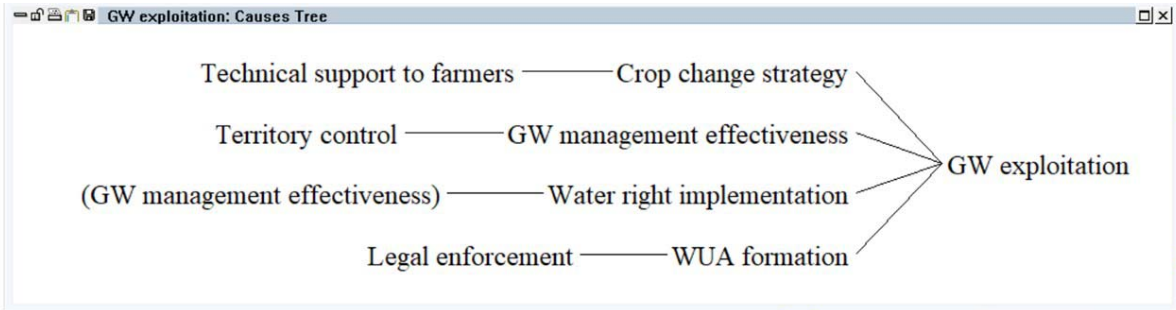
As shown in the table 3, different measures were aggregated in order to detect the key vulnerabilities in the network of interactions. Specifically, an agent could be considered as a vulnerable element if she/he has a low centrality degree – that is, weak connections with the other actors – and a high number of tasks to be carried out in the collective process for risk management. In this conditions, the agent would not be able to cooperate with the others and, thus, there is the risk of not fulfilling the tasks. Similarly, an agent with high most knowledge degree has access to a high number of pieces of important knowledge. Nevertheless, a low centrality degree in the Agent X Agent network means that this agent is poorly connected in the network, reducing the effectiveness of the knowledge flow within the network.

A piece of knowledge could represent a vulnerability if it is central in the process – i.e. enable the access to other kinds of knowledge and/or allow the fulfilment of important tasks – and it is not effectively shared within the network. Finally, a task could represent a vulnerability if it carried out by a single agent and if it plays a key role in activating other important tasks. In these conditions, if the exclusive agent would fail in carrying out this task, the whole process will be affected.

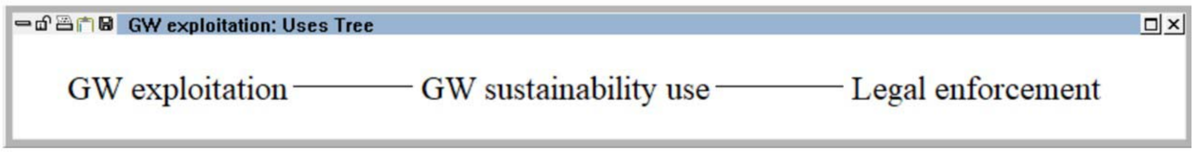
The results of this analysis allowed to detect the key vulnerabilities in the interaction network that need to be tackled through the design and implementation of the network interventions. These vulnerabilities can be considered as entry points for the interventions. Nevertheless, SNA does not provide clear indications about the most effective interventions to be implemented in order to reduce/eliminate the network vulnerabilities. A FCM-based approach was, then, implemented for supporting the design of the interventions and for simulating intervention scenarios.

The aggregated FCM (see previous section) was used to: i) explain the main reasons leading to a detected vulnerability – e.g. why an actor is isolated in the network? What are the main barriers hampering the effective sharing of an information? - and, ii) analyse how the detected SNA vulnerabilities may affect the effectiveness of the risk management process and NBS implementation – e.g. what could happen if a certain information is not shared? What could be the negative impact on the NBS effectiveness due to the low centrality of a certain decision-actor?

To this aim, the cause-effects structure of the aggregated FCM was accounted for. The analysts identified the variables in the FCM associated to each of the SNA vulnerabilities. Then, the "causes tree" and the "uses tree" analysis available in the Vensim® software were implemented. Figure 2 shows examples of both the causes tree and uses tree.




(a)




(b)

Figure 2: Results of the FCM cause-effects structure analysis: (a) Causes tree; (b) Uses tree.

The results were used to inform a participatory exercise aiming at defining the most suitable networking interventions to be implemented in order to overcome the detected barriers. Participants were provided with: i) the SNA results concerning to the nodes in the network that need to be interested by the interventions; and ii) the results of FCM analysis concerning the main causes of the detected vulnerabilities in the network; and iii) their impacts on the effectiveness of the NBS. Participants were, then, required to suggest interventions capable to address the causes leading to the vulnerabilities and/or to reduce the impacts of these vulnerabilities on the NBS implementation.
The aggregated FCM was, then, used for simulating intervention scenarios and, thus, for selecting the most suitable networking interventions. To this aim, FCM-based intervention scenarios were simulated. The FCM capability to allow the understanding of system trends based on "what-if" scenarios were used in this work. The FCM-based scenarios allowed stakeholders to compare the effects of different management interventions (Voinov et al., 2018). In this work, scenario was defined as a quantitative description of the future conditions of the studied system, told through the values of the FCM variables, offering an internally consistent and plausible explanation of how events unfold over time (Kok, 2009). The simulated outcomes – that is, the state of the FCM variables after the model simulation – were used to describe the different intervention scenarios. The input variables for each scenario were those related to the networking interventions. The intervention scenarios were compared accounting for their impacts on the NBS effectiveness.
A semi-dynamic FCM simulation approach was implemented in this study. As described in Giordano et al. (2020), this approach aims at introducing time and delays in the FCM, making the model capable to simulate processes related to NBS implementation – e.g. socio-institutional processes, behavioural changes, governance transition. The aggregated FCM was discussed by the stakeholders during the participatory exercises. They were requested to identify the links characterized by a delay. Then, they were requested to describe the variation of the edges in the FCM over time. For sake of simplicity, three time steps were considered, i.e. short-, medium-, and long-term. Three different time-dependent adjacency matrices were developed and used for performing three consequential FCM simulations. The aggregation of the FCM variables' states in the three time steps allowed us to define the expected dynamic evolution of the system. Three

sequential adjacency matrices were developed in three time steps: short-, medium and long-term (Giordano et al., 2020)

Prior to use the aggregated FCM for simulating the intervention scenarios, the model was validated. A group discussion with a limited number of stakeholders – that is, the most experienced ones - and leaded by the analysts, was organized to this aim. The FCM was considered validated if it adequately describes the participants' understanding of the risk to be dealt with and the role of NBS. The results of the discussion were used for improved the FCM capability to describe the participants' understanding of the system dynamic.

The validated FCM was used for simulating the intervention scenarios (Kok, 2009; Giordano et al., 2020). The comparison among the dynamic evolution of the systems in the different intervention scenarios was used for facilitating the debate among the participants and, then, the selection of the most suitable networking interventions.

The following section describes the implementation of the described methodology in the Medina del Campo case study.

## 3. Results

### *3.1. NBS for managing climate-related risks in Medina del Campo*

Medina del Campo Groundwater Body (MCGB) is located in the Duero River Basin, North West central Spain. It covers a surface of 3,700 km$^2$ extending over four provinces that host over 154 municipalities (CHD, 2013). Agriculture plays a main role in local economy, particularly in the rural areas, being irrigated agriculture the main water use (96%) followed by urban consumption and industrial uses. The area has a low average precipitation and is prone to periodic drought spells. As a result, surface water resources are scarce, with only three seasonal surface water courses that have limited intermittent flows along the year. Therefore, the water supply and the economy of the region heavily depend on the aquifer. There are currently 5,495 groundwater concessions for agricultural use issued over a surface of 45,115 ha of irrigated area (CHD, 2013). The intensive exploitation of MCGB over the last decades has put the groundwater body at risk from both the qualitative and quantitative standpoints (Water Framework Directive 2000/60/EC), while seriously impacting the associated surface ecosystems. Meanwhile, droughts also cause serious economic losses in agriculture that are contributing to a severe decrease in rural population. The objective of the case study was to assess the potential and impacts of a series of selected Nature Based Strategies combining green and soft or management solutions to generate adaptation capacity for the regional agriculture against more frequent droughts due to climate change, as well as to stop the degradation of the groundwater status and associated ecosystem services. Specifically, two NBS were selected in previous stakeholders' meeting, i.e. the Managed Aquifer Recharge and the Crop change (Pengal et al., 2017).

The activities described in this work aimed at detecting and analysing the barriers to NBS implementation due to lack of collaboration among the different decision-makers. Networking interventions were, then, defined by interacting with the local stakeholders.

Stakeholders and institutional analysis was carried out in order to identify the stakeholders to be involved in the different phases of the work (table 4).

Table 4: List of stakeholders involved in the different phases of the participatory process.

| Stakeholder | Role in the process |
|---|---|
| Farmers | Individual farmers who hold a water right entitling them a certain maximum volume of water for irrigation per year. |
| Farmer associations | Farmer Unions representing the interest of farmers in the different municipalities around Medina. |

| | |
|---|---|
| Irrigation communities/WUAS | Communities composed by nearby farmers that share common irrigation infrastructure or groundwater rights and have self-management capabilities. |
| Local government: municipalities | City planning; water supply; flood management support. |
| Regional government (Junta Castilla y León) | Responsible for regional planning in natural areas; environmental quality; sustainable development strategies at regional level; agricultural development; civil protection |
| Duero River Basin Authority | Main problem owner due to law; responsibility for taking care of national water public domain; water planning; water rights issuer; compliance with WFD, Floods Directive, water quality standards. |
| Local NGOs | Denounce lack of environmental protection compliance, creation of public awareness |
| Academics from local universities | Research in the region related to water risks |
| Insurance sector (Agroseguro, Consorcio de Compensación de Seguros) | Provides insurance to farmers |

Three main stakeholders' activities were carried out in the Medina del Campo, as described in the following:

1) individual semi-structured interviews were carried out involving the stakeholders cited in the table. The protocol for the interviews described in section 2 was implemented. This phase allowed us to collect individual understandings concerning the main climate-related risks in the study area, the potential impacts and the actions to be implemented, including the NBS. Besides, the respondents provide hints about the other actors involved in the risk management, the tasks carried out and the information used/shared during the process.

2) A first participatory workshop was organized in the Arevalo municipality. It aimed at defining the map of interactions activated during the risk management process, and involving actors, tasks and information.

3) A second participatory workshop was organized with the aim of co-defining the interventions to be implemented in order to enhance the effectiveness of the collaboration among different decision actors and, thus, to facilitate NBS design and implementation. The participatory process was informed referring to main barriers to collaboration (SNA results), and the cause-effects chains connecting these barriers to NBS design and implementation (FCM results).

***3.2. SNA for mapping and analyzing the network of interactions***

As described in section 2, the map of interactions connecting agents, knowledge and tasks was developed referring to the results of individual semi-structured interviews and a participatory mapping exercise. Specifically, the interviews were used to define the set of agents, knowledge and tasks that need to be accounted for in the analysis. Table 5 shows the list of actors used during the SNA phase.

Table 5. List of actors used during the SNA and their acronyms.

| Actors | Acronym |
|---|---|
| Duero River Basin Authority | CHD |
| Ministry of Agriculture | MP |

| | |
|---|---|
| Civil Protection Agency | CPA |
| Municipality | MU |
| Provice Authority | PA |
| Local communities | MC |
| Universities and research centers | UNI |
| Regional Authority | RA |
| ONG | ONG |
| Local Civil Association | LA |
| Water User Association | WUA |
| Farmers | FAR |
| Farmers Association | FAA |
| Private and Public enterprises | PPE |
| Insurance companies | IC |

During the participatory mapping exercise, and referring to the list of agents, participants were requested to describe the existing connections among them. They were also requested to assign an importance degree to each link connecting two actors. Three different values were used in this phase, i.e. “High importance” (+++ in the map), “Medium importance” (++ in the map), “Low importance” (+ in the map). Figure 3 shows the discussion for the development of the Agent X Agent map. Similarly, the other maps were developed by interacting with the participants.


Figure 3: Results of the participatory mapping exercise.

In order to carry out the SNA, the participatory maps were coded in adjacency matrices, accounting for the weights assigned by the participants. Table 5 shows the adjacency matrix of the Agent X Agent network.

Table 6: Adjacency matrix for the Agent x Agent network

| | CHD | MP | CPA | MU | PA | UNI | RA | ONG | LA | WUA | FAR | FAA | PPE | IC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CHD | 0 | 3 | 2 | 2 | 1 | 1 | 2 | 2 | 1 | 1 | 2 | 2 | 1 | 0 |
| MP | 3 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| CPA | 2 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| MU | 3 | 1 | 1 | 0 | 2 | 2 | 2 | 1 | 1 | 0 | 1 | 1 | 0 | 1 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PA | 1 | 1 | 1 | 3 | 0 | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 |
| UNI | 1 | 2 | 1 | 2 | 2 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 2 |
| RA | 3 | 1 | 2 | 3 | 1 | 1 | 0 | 1 | 1 | 0 | 2 | 2 | 2 | 0 |
| ONG | 1 | 1 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 0 | 1 | 1 | 0 | 0 |
| LA | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| WUA | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| FAR | 3 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 3 | 1 | 2 |
| FAA | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | 0 | 1 | 2 |
| PPE | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| IC | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | 2 | 0 | 0 |

Figure 4 shows the graphical representation of the obtained maps. The ORA software was used in this work for developing and analysing the maps.

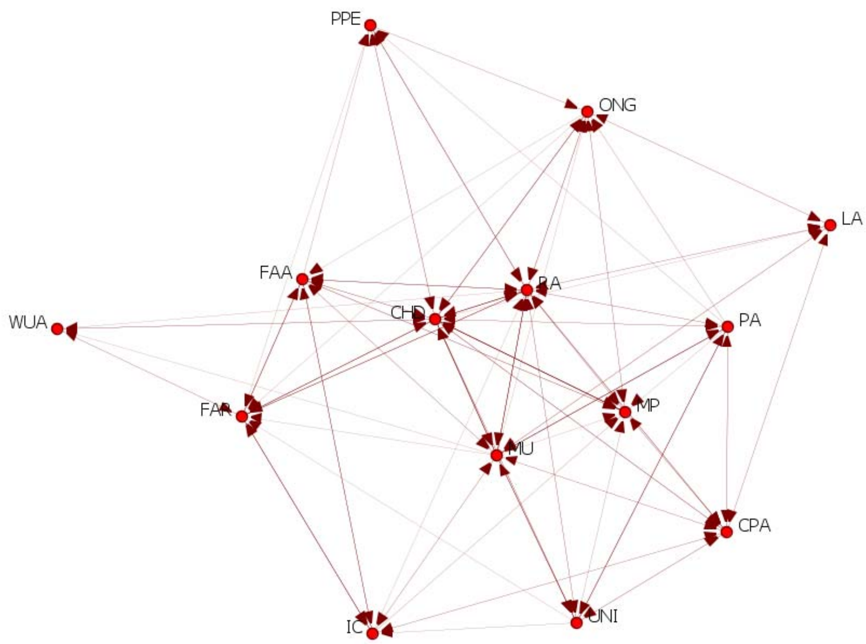



Figure 4: Agent x Agent map of interactions. The links are characterized by a different thickness according to the weight assigned in the adjacency matrix.

### ***3.2. FCM for describing and analyzing the system dynamic behavior***

Following the methodological steps described in section 2, the results of the individual semi-structured interviews were analysed and used as basis for the development of the individual FCM. The main concepts and the causal connections were, hence, detected and reported in the FCM. Moreover, the fuzzy weights were assigned to the causal connections accounting for the stakeholders' problem understanding. Figure 5 shows the FCM developed referring to the narrative collected from two of the involved stakeholders.

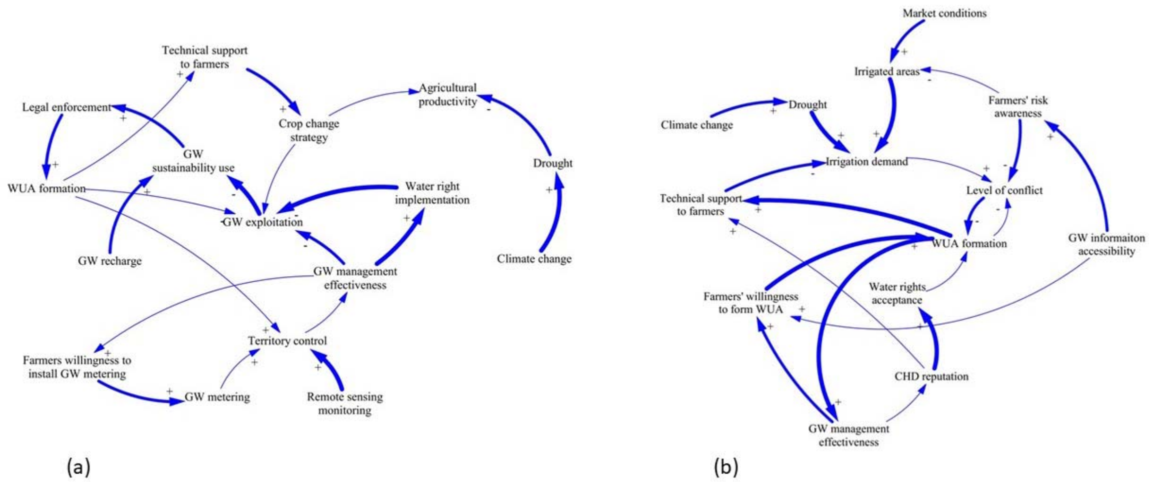



Figure 5: FCM developed using the stakeholders' interviews: a) CHD; b) WUA.

Prior to use the FCM for supporting the definition of the networking interventions, the aggregation method for individuals' FCM described in section 2.2 was implemented at this stage of the work. Figure 6 shows the aggregated FCM.

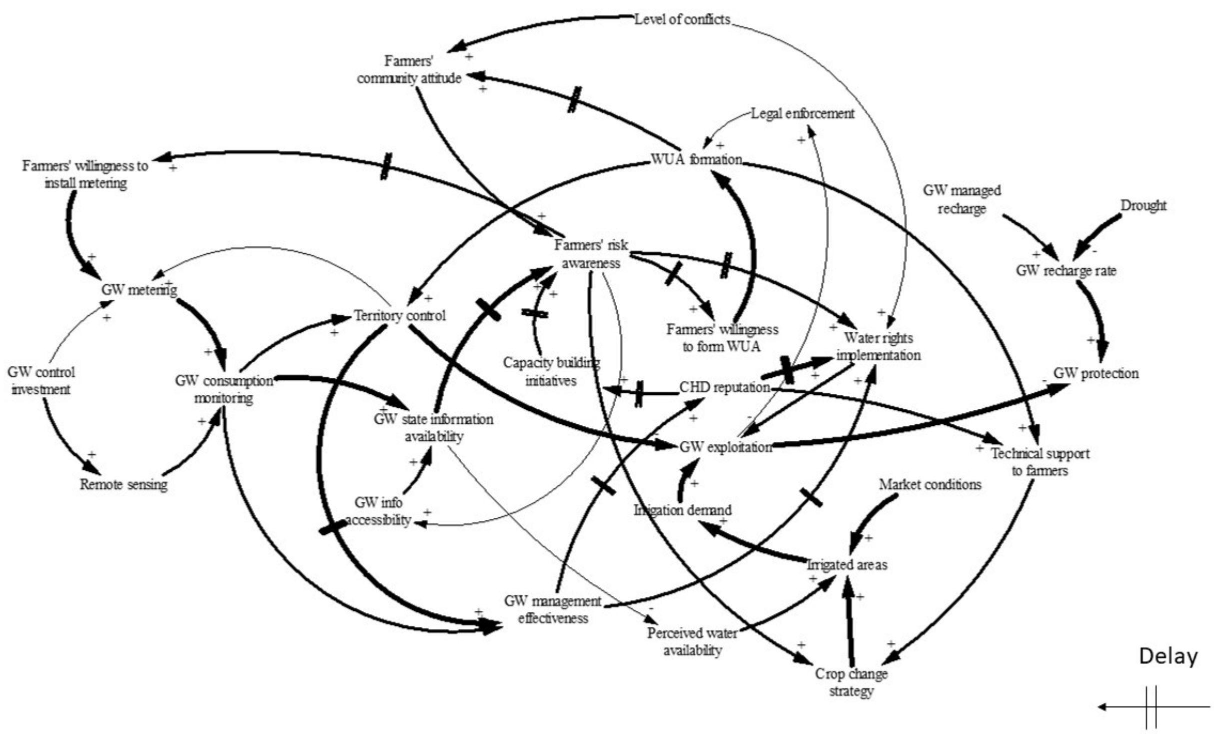



Figure 6: Aggregated FCM describing the causal connections among the different variables influencing the effectiveness of NBS.

The aggregated FCM was discussed and validated by interacting with a selected group of stakeholders. Delays were, then, introduced in the FCM, as shown in the figure 6 (links with delay symbol). For these links, the stakeholders were required to describe the expected change of the weights in the three time steps, as described in section 2.2. Three sub-sequential matrices were developed for simulating the FCM-based scenarios (Giordano et al., 2020).

The model was developed considering that the main climate-related risk in the area is the drought and that the main goal of the risk management strategy is the protection of the groundwater (GW), even in case of severe drought. As stated previously, two NBS were already selected by the stakeholders, i.e. Managed Aquifer Recharge (MAR) and the crop change. The following sections describes the SNA-FCM integrated approach implemented in the Medina del Campo for detecting the key barriers hampering the NBS implementation due to lack of collaborative decision-making and for defining suitable networking interventions.

### *3.3. Implementing the SNA-FCM integrated approach for networking interventions definition*

The first step in the integrated approach regards the detection and analysis of the key vulnerabilities in the existing network of interactions among the different decision-actors. To this aim, the graph theory measures described in table 3 were implemented. The results are described in the table 6.

Table 7: Key vulnerabilities in the network of interactions for Medina del Campo.

| Key vulnerabilities | Type | Meaning in the NBS process |
|---|---|---|
| WUA | Agent | This agent is characterized by a quite low centrality degree in the Agent X Agent network. That is, it has few and weak connections with the other actors. It is supposed to carry out important tasks and has access to important pieces of knowledge. |
| Water rights management | Task | This task has a high centrality degree in the Task X Task network. Therefore, it enables the fulfilment of other important tasks. Nevertheless, it is connected exclusively with the CHD. |
| Technical support for crop selection | Knowledge | This piece of knowledge plays a key role in carrying out the most important tasks (Knowledge X Task network). Nevertheless, it has a low Most knowledge degree in the Agent X Knowledge network and, thus, it is not effectively shared in the network. |
| GW state | Knowledge | This piece of knowledge has a high centrality degree in the Knowledge X Knowledge network, which means that is enables the access to other important pieces of information. Nevertheless, only few agents have access to it (Agent X Knowledge network). |

The results of the SNA allowed to detect the key nodes in the network for the implementation of the networking interventions. That is, these results showed that, in order to enhance the collaboration among decision-makers for NBS design and implementation, efforts were required for: i) making the WUA more central in the process; ii) facilitating the co-implementation of the water rights management; iii) enhancing the sharing of the technical information for crop changes; and iv) enhancing the sharing of the information regarding the GW state and the associated risks. However, the SNA results did not explain how the vulnerabilities of the interaction networks could actually affect the NBS design and implementation, and did not provide hints on how to deal with those barriers. The FCM-based approach was, then, implemented in order to support the design of the different potential networking interventions and to select the most suitable ones.

On the one hand, FCM-based approach aimed at analysing if and how the key vulnerabilities, detected through the SNA, could actually hamper the implementation and/or reduce the effectiveness of the selected NBS. On the other hand, it aimed at supporting the identification of the networking interventions during the participatory exercise.

Concerning the first goal, a comparison between the "Business-As-Usual" (BAU) and the NBS scenarios was carried out. The BAU scenario was characterized by the drought conditions and by a high level of groundwater consumption due to the water demand for the irrigation. The NBS scenario was characterized by drought conditions and by the implementation of the two above mentioned NBS. Figure 7 shows the comparison between the values of the variable "GW protection" in the two scenarios.

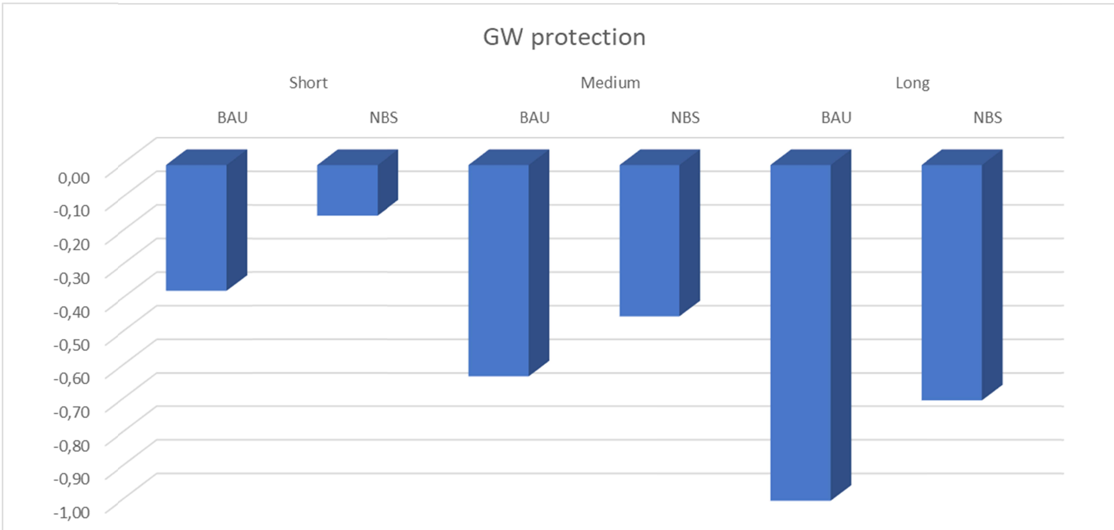



Figure 7: Comparison between the BAU and NBS scenarios in the three time steps of the quasi-dynamic FCM.

As shown in figure 7, the variable "GW protection" - which is directly affected by the "GW exploitation" - had the most significant increase in the short period, even if it is still negative. Nevertheless, the positive impact due to NBS implementation is diluted in the medium and, even more significantly, in the long term. This is mainly due to the limited change registered in the FCM variables connected with farmers' behaviour concerning the use of GW for irrigation purposes. Specifically, the FCM analysis showed that the selected NBS did not have significant impacts on two central elements in the model, i.e. the CHD reputation and the farmers' risk awareness. This, in turn, negatively affected the implementation of the water rights management, with limited capability of the CHD to control and reduce the GW exploitation. These conditions negatively affect the NBS implementation.
The aggregated FCM was, then, used for complementing the SNA results in order to define the networking interventions and to assess their effectiveness. Two kinds of analysis were carried out. FCM was used for assessing to what extent and why the key vulnerabilities detected through the SNA can affect the NBS implementation. Then, FCM was used to detect and analyse the main causes leading to the key SNA vulnerabilities.
The first vulnerability detected through the SNA was related to the agent WUA. The associated variable in the FCM is "WUA formation". As shown in the model, the value of this variable is weakly influenced by the "legal enforcement", and strongly affected by the "Farmers' willingness to form WUA", whose value in turn depends on the "farmers' risk awareness". The value of the "WUA formation process" has a strong effect on the variable "territory control" and, consequently, on the "GW exploitation" (figure 8).

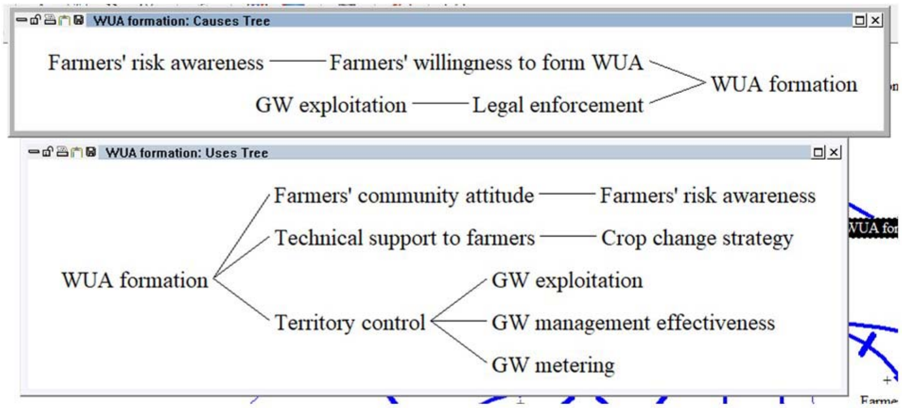



Figure 8: Analysis of the cause-effects chain regarding the WUA formation variable in the aggregated FCM

The second key vulnerability in the SNA is the task "Water rights management". The connected variable in the FCM is the "Water rights implementation", whose value is strongly affected by the "CHD reputation" - which mainly refers to farmers' perception of CHD – the "Farmers' risk awareness" and the "GW management effectiveness". This means that, according to the aggregated FCM, the water rights would be implemented if farmers would perceive positively the CHD role in the GW management, and if farmers would have a positive opinion of the GW management effectiveness. The effective implementation of the water rights would lead to a reduction of the GW exploitation.

The third key vulnerability in the network of interactions is the technical support to farmers for enabling crop change. The value of this variable in the FCM is weakly affected by the WUA formation process, i.e. the WUA can facilitate the flow of technical information towards the farmers. Moreover, the FCM shows that the effectiveness of the flow of technical information is affected by the CHD reputation. Finally, the availability of the technical support impacts the farmers' willingness to implement crop changes strategies and, thus, reduce the GW exploitation.

Finally, the fourth key vulnerability in the network of interactions was the "GW state information". The FCM shows that the value of this variable is affected by the availability and reliability of data on the GW consumption (i.e. GW metering), and by the CD reputation, which affects the reliability of the GW information. The availability of GW state information is expected to have an impact on the farmers' risk awareness and, consequently, on the formation of WUA and the implementation of the crop change strategy. As already explained, the WUA formation would facilitate the control of the GW exploitation and, hence, GW protection.

The results of this analysis were used for informing the stakeholders' engagement in defining the networking interventions. A second workshop was organized in the study area, involving institutional actors, farmers, representatives of farmers' association and local citizens (figure 9).


Figure 9: Participatory workshop for defining the networking interventions.

At the beginning of the workshops, participants agreed to merge two of the detected vulnerabilities, i.e. the WUA formation and the management of water rights. According to participants' opinion, the connection between these elements were considered too tight to allow a separate discussion. Therefore, participants were divided into 3 small groups, composed by maximum 10 stakeholders. Each group focused on one of the identified vulnerabilities. The results of the FCM analysis were used to inform the participants about both the explanations of the key vulnerabilities – e.g. why the WUA has a low centrality degree? - and the main consequences on the NBS implementation.

Participants were requested to identify Actors, Tasks and Information that need to be introduced in the network in order to overcome the defined vulnerabilities. Table 7 shows the results of the stakeholders' discussion in the three groups.

Table 8: Interventions mentioned by the stakeholders during the workshop.

| **Vulnerability** | **Actors** | **Knowledge** | **Tasks** |
|---|---|---|---|
| WUA formation and water rights management | Municipalities<br>Regional Authority<br>Ministry | Information on the water right assignment process | Detect illegal GW exploitation<br>Enhance transparency of the process<br>Create a register of the rights |
| GW state information | Ministry of environmental<br>CHD<br>Famers | Climate information<br>Water footprint label for the products<br>GW extraction costs<br>Virtual water | Sustain rural eco-tourism<br>Consumers awareness raising<br>GW metering |
| Technical support to farmers for crop changes | Technicians<br>Regional Authority<br>Universities and research centres<br>Farmers organization | Crop water requirements<br>Information drought resistant crops<br>Market evaluation | Enhance CAP distribution<br>Training on novel crops<br>Crop-based water allocation<br>Awareness raising on sustainable agriculture |

The interventions suggested by the stakeholders were integrated in the FCM in order to simulate intervention scenarios, and, thus, assess their effectiveness in facilitating the NBS implementation.

To this aim, the FCM was modified accounting for the results of the stakeholders' discussion. Firstly, a strong causal link was added between the variables "WUA formation" and "Water rights implementation". Secondly, the interventions were translated into FCM variables and connected to the main vulnerabilities, either directly or through other elements in the FCM.

Figure 10 shows the FCM with the interventions selected during the stakeholders' workshop.

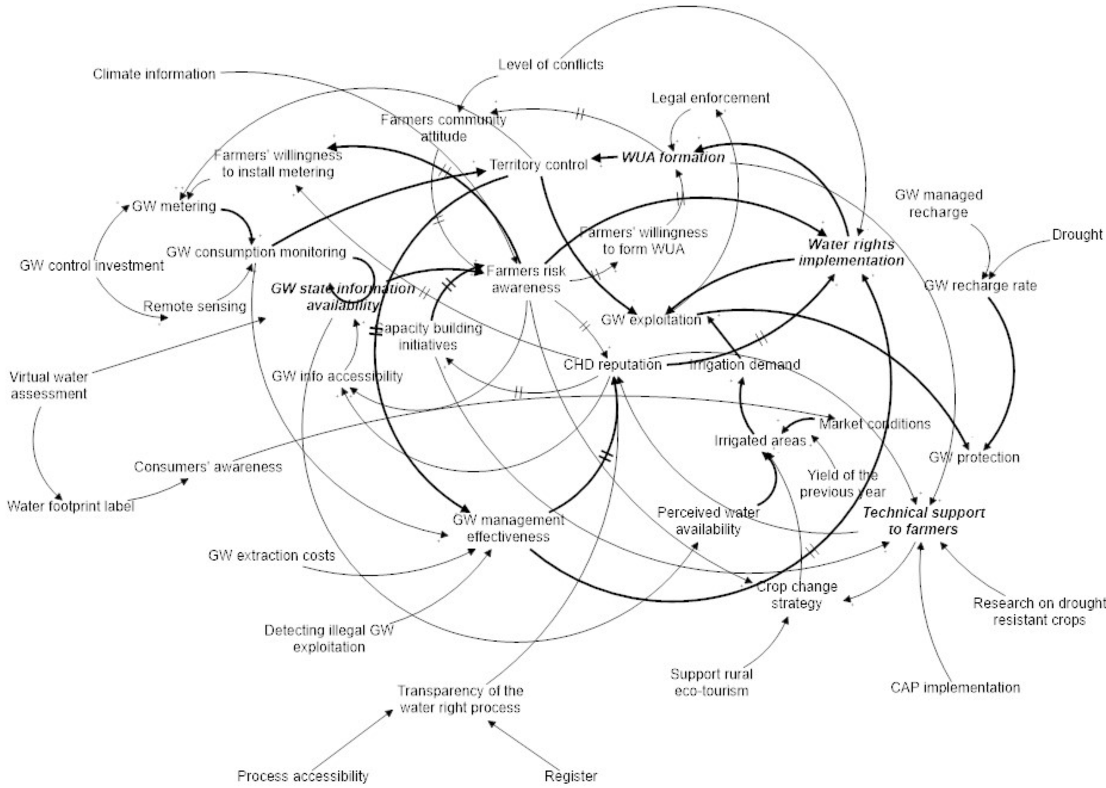



Figure 10: Aggregated FCM after the introduction of the networking interventions.

The modified FCM was, then, used for simulating intervention scenarios. That is, the FCM variables associated to the interventions defined during the workshop were activated in the FCM (Giordano et al., 2020).

Three different networking strategies – i.e. composed by several networking interventions – were simulated in the aggregated FCM, as shown in the table 8.

Table 9: Networking strategies for addressing the SNA detected vulnerabilities

| Networking strategy | Vulnerability addressed | Networking interventions |
|---|---|---|
| ST. 1 | WUA formation and water rights management | Detect illegal GW exploitation<br>Transparency of the water right process<br>Create an accessible register |
| ST.2 | GW state information | GW control investment (GW metering)<br>Eco-tourism<br>Consumers' awareness<br>GW extraction costs<br>Water footprint label<br>Virtual water |
| ST.3 | Technical support to farmers for crop change | Drought resistant crops<br>CAP implementation |

| | | |
|---|---|---|
| | | Market evaluation support<br>Training and capacity building |

The aggregated FCM was, then, used to simulate the three interventions scenarios and to assess the effectiveness of the proposed measures. Figure 11 shows the dynamic evolution of the FCM variables due to the implementation of ST.1.

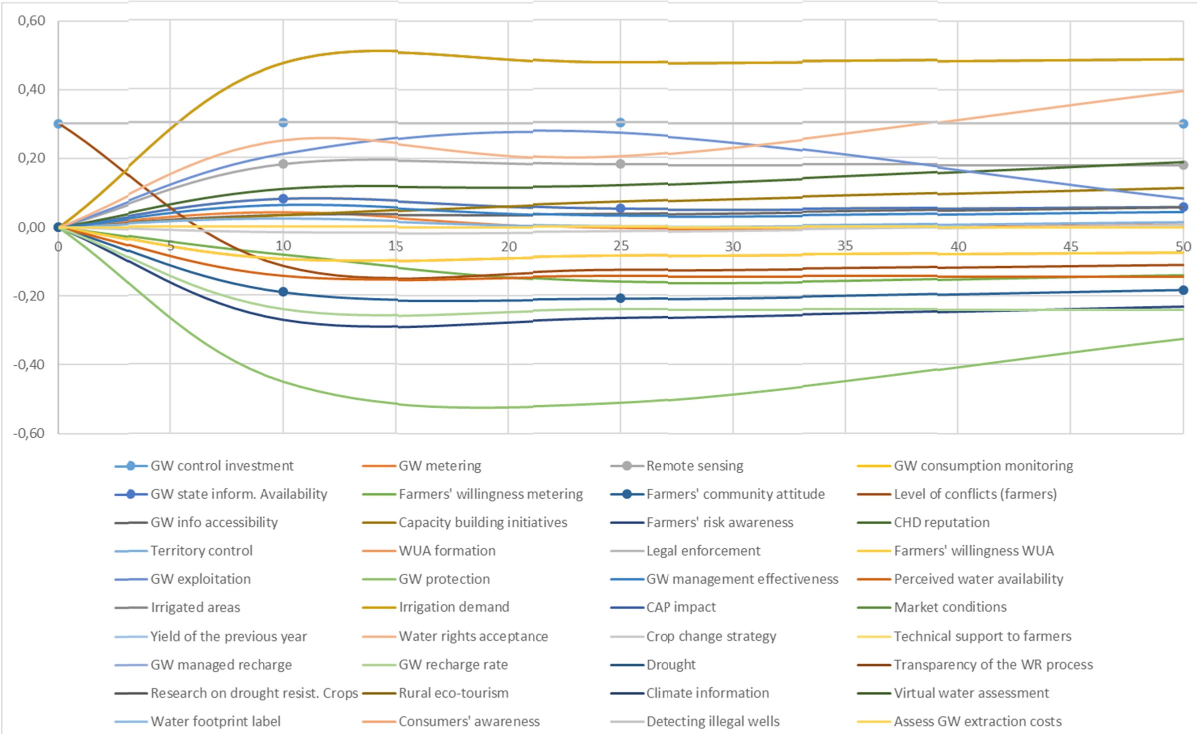



Figure 11: Dynamic evolution of the FCM variables due to ST.1 implementation.

Figure 12 shows the comparison among the three scenarios for what concerns the impacts of the selected interventions on the NBS effectiveness. For sake of clarity, figure 12 shows the comparison exclusively for the two key objectives, i.e. “GW consumption” and “GW protection”, and for the key SNA vulnerabilities.

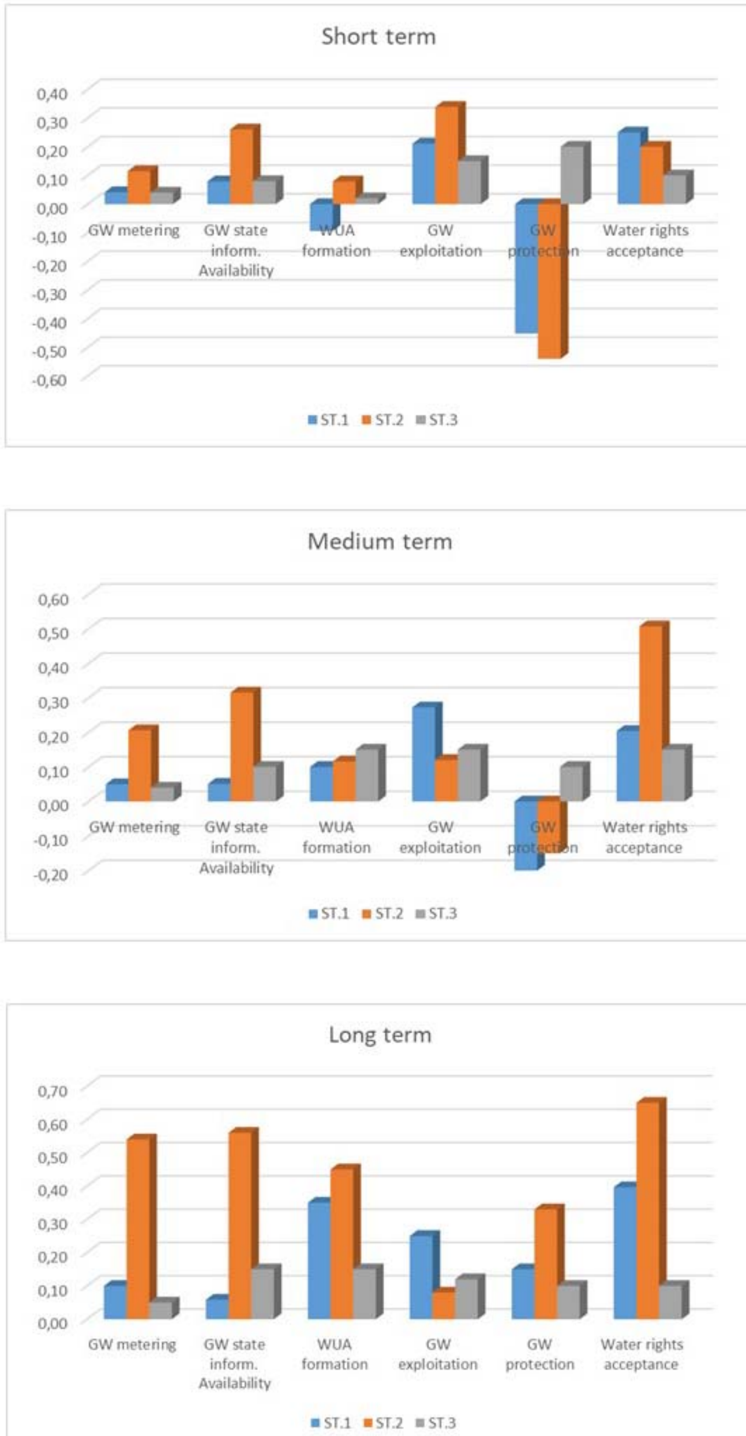



Figure 12: Comparing the impacts of the three networking strategies on NBS implementation.

The quasi-dynamic FCM allowed us to assess the networking strategies' effectiveness in three time steps. Figure 12 shows that the most effective networking strategy is the one aiming at enhancing the availability, reliability and accessibility of the information related to the GW state. This strategy had a rather low impact in the short term, because the availability of information on GW state requires time to affect the farmers' behaviour. In the long term, this intervention strategy had a twofold positive impact. On the one hand, it could lead to an increase of the farmers' risk awareness and, in doing so, it could contribute to enable the shift towards less water-demanding crops. Moreover, the increase of farmers' awareness could lead to an effective process of WUA creation, with positive impacts on the CHD capability to control the GW use and, finally, on the effectiveness of the technical support for reducing water consumption. On the other hands, the availability of reliable information on the GW state could allow the CHD to enhance the effectiveness of the territory control and the GW management. This, in turn, could have a positive impact on the farmers' perception of the CHD role and, consequently, could lead to a higher acceptance of the water rights management process.

The first networking strategy, aiming at facilitating the WUA creation and water rights acceptance, had positive in the medium and long term, but lower than those caused by the ST.2. This is mainly because the interventions suggested by the stakeholders in this strategy aimed mainly at increase the control of the territory, with a limited impact on the farmers' awareness. Finally, the ST.3 had a quite positive impact in the short term, because of the technical support for changing crops and reducing irrigation demand. Nevertheless, the proposed interventions did not affect key elements in the FCM, such as the CHD reputation.

## 4. Discussion

This section is meant to discuss to what extent the activities carried out in the Medina del Campo allowed us to demonstrate the suitability of the described methodology for supporting the implementation of the NBS and enhancing their effectiveness. To this aim, we firstly describe the lessons learnt concerning the actual impacts of the collaboration barriers in hampering the NBS design and implementation. Then, the suitability and replicability of the integrated SNA-FCM method for supporting the definition of the networking interventions are discussed in this section.

Several works are mentioned in the scientific literature dedicated to detect and analyse the main barriers hampering the NBS implementation (e.g. O'Donnell et al., 2017; Ruangpan et al., 2020). Nevertheless, the existing works seem to neglect the role played by the network of interactions among the different decision-actors in enabling/hampering the NBS implementation process. The results obtained in Medina del Campo showed, on the one hand, that ineffective interaction networks represent a barrier to NBS implementation. Lack of information sharing – i.e. limited access to GW state information – might affect the decision taken by the other actors – i.e. the farmers – hampering the implementation of the selected NBS. Moreover, the low level of involvement of potentially key actors, such as the WUA, could prevent key tasks from being performed – i.e. the implementation of the water right policy and the access to technical support for crop change – and, thus, affect the NBS effectiveness. Finally, the results showed that the key tasks carried out by a single agent, with limited cooperation in the network, represent a vulnerability because it prevents this task to be considered as consensual, that is accepted by the other agents. E.g. the assignment and management of the water rights was not accepted by the other agents because it was perceived as not-transparent and exclusive prerogative of the CHD.

On the other hand, the results in Medina del Campo demonstrate that overcoming the barriers to collaboration and enhancing the effectiveness of the network of interactions, through the implementation of the networking interventions, could have positive impacts on the NBS implementation and effectiveness, as discussed in the previous section. Therefore, this work demonstrates that, in addition to socio-economic, technical and institutional barriers, NBS implementation claims to detect and overcome those related to the interaction between the various decision-actors.

A key innovation brought by this work concerns the implementation of the SNA-FCM integrated approach, aiming to detect the collaboration barriers to NBS implementation and to define the networking interventions for overcoming those barriers. The use of SNA in this domain is not new (e.g. (Calliari et al., 2019; Manson et al., 2016; Therrien et al., 2019). Nevertheless, in many cases the analysis of the network is limited to mapping the social network – i.e. the interactions among different agents – and using metrics for describing the structure of the network. Therrien et al. (2019) suggested to characterize the connections among the actors accounting for three main elements, that is, type of connections (collaboration, funding, etc.), strength and quality (openness, competition, history, etc.). Calliari et al. (2019) describes a mixed-method approach, based on the integration between quantitative and qualitative SNA. In line with these efforts, the results obtained in this work demonstrate that the performances of collaborative decision-making depend on interplaying factors – i.e. actors, knowledge and tasks. Therefore, this work showed that the detection of barriers to NBS implementation requires to extend the analysis of the interactions among agents, enhancing the understanding of how the information flows through the network of interactions, and how the shared information allowed the involved actors to cooperate in carrying out key tasks in the process. To this aim, the combination of different graph theory measures demonstrated to be effective in detecting the key vulnerabilities in the network of interactions.

Our experiences demonstrate that, although innovative, SNA approach does not provide enough information for defining the networking interventions. SNA is a powerful tool for detecting the key nodes – i.e. entry points – of interventions (e.g. Giordano et al., 2017; Calliari et al., 2019 ). The integrated implementation with the FCM allowed to overcome these drawbacks. The integrated SNA-FCM method allowed us: i) to unravel the complex network of interactions taking place between the various decision-actors; ii) to detect the key vulnerabilities in the network; iii) to analyse the causal connections leading to the detected vulnerabilities in the network; iv) and to explain why those interaction vulnerabilities represented a barrier to NBS implementation. This analysis greatly supported the process for defining the interventions to be implemented in order to overcome the detected barriers. Moreover, the FCM characteristics contributed to facilitate the interaction with the stakeholders. Firstly, compared to other system modelling approaches – e.g. stock-and-flow – FCM describes causal connections that are relatively simple to be understood by non-experts. FCM comprehensibility for the participants increases its legitimacy in the decision-making context. Therefore, stakeholders were facilitated in participating to the discussion for the definition of the networking interventions. Secondly, FCM was based on the knowledge collected through the interaction with the stakeholders. Therefore, participants were capable to recognize their contributions in the model, developing a sense of ownership toward it and the obtained results. The participatory process for the FCM developed contributed to build relationships between the stakeholders and the analysts (LeMere et al., 2020).

Another important innovation demonstrated by the obtained results concerns the necessity to introduce the time dimension in the definition of the networking interventions. As shown in the section 3, the interventions' impacts may occur at different time steps. Some of the selected interventions have substantial impacts in the short term, that could be diluted in the medium and long term. Other interventions may have limited impacts in the short terms – i.e. those aiming at fostering behavioural changes – but are characterized by strong and durable impacts in the long-terms. Neglecting the time scale of these processes could lead to erroneous and over-simplified selection of networking interventions. The semi-dynamic FCM method implemented in this work demonstrated to be suitable in making decision-makers capable to account for the time dimension in assessing interventions' effectiveness.

In order to enhance the replicability of the adopted approach, the main drawbacks of the integrated SNA-FCM method are described here. The main limitation concerns the biases that the analysts could introduce in several phases of the described methods (LeMere et al, 2020). Firstly, during the development of the map of interaction to be used for the SNA. The adopted approach is a semi-quantitative one. Contrarily to the quantitative approach, based on the numbers of contacts between different agents, the proposed approach refers to the stakeholders' judgements concerning the importance of the different connections in the map. Therefore, the analysts are required to translate a qualitative statement into a number for the SNA model. Fuzzy linguistic functions were used in this work in order to reduce the analysts' biases in this step. Nevertheless, this required to interact with the stakeholders in order to build the fuzzy functions (Page et al., 2012), which could have an impact on stakeholders' fatigue. This is a key issue to be addressed when defining the plan of the stakeholders' engagement activities. Secondly, during the development of the individual FCM, analysts may introduce biases in the attempt to reproduce stakeholders' mental model from the interviews (LeMere et al., 2020). To address this issue, the interview framework was structured in a way to lead stakeholders to be explicit about the causal realtionships in their problem framing. Moreover, the validation phase, carried out prior to use the FCM for simulating scenarios, allowed us to corroborate the indirect elicitation (analysis of the interviews) with a direct elicitation.

## 5. Concluding remarks

Enabling NBS design and implementation and enhancing their effectiveness in reducing climate-related risks requires shifting the focus from technical barriers toward those related to the socio-economic domains. In line with these works, the experienced carried out in Medina del Campo aimed at enabling the NBS implementation by overcoming the collaboration barriers. By conceptualizing the NBS as a collaborative decision-making process, this work describes a SNA-FCM integrated approach for encouraging the interactions between the various decision-actors involved/interested in NBS implementation despite the diversity in risk and benefits perceptions, meanings and values. The obtained results showed that, by enhancing the interaction mechanisms, facilitating the flow of information and enabling collaboration in performing key tasks, divergent problem frames can still yield collective actions. To this aim, the integrated SNA-FCM provides decision-makers with useful information concerning: i) the main drawbacks (vulnerabilities) of the existing network of interactions; ii) the entry points for the interventions – i.e. the actors to be interested by the networking interventions; the information to be shared; and the tasks to be carries out in cooperation with the others; and iii) the most suitable interventions to be implemented.

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