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EXECUTIVE SUMMARY

The implementation of NBS for copying with water-related risks is still hampered by several barriers. Among those, the lack of effective information sharing and communication strategies capable of affecting NBS social acceptance plays a key role. The activities described in this deliverable aimed at defining innovative information sharing and communication strategies capable to boost learning processes concerning NBS effectiveness. To this aim, we had a twofold goal. On the one hand, efforts were carried out in order to enhance the contents of the information sharing strategy and meeting the actual stakeholders' information needs. On the other hand, the activities aimed at enhancing the effectiveness of the processes related to information sharing and communication.

The results of the previous activities carried out by WP3 in the NAIAD demos were used to this aim. Specifically, the results of the risk perception analysis and ambiguity analysis (D3.1) were used to identify the benefits and co-benefits that need to be produced through the implementation of the NBS according to the stakeholders' understanding. System Dynamic Models were developed in the some of the NAIAD demos in order to support the stakeholders' involvement in co-designing the most suitable NBS for producing the selected benefits and co-benefits. The results of the Social Network Analysis (D3.1) were used to identify the main barriers that could hamper the NBS implementation and/or reduce their effectiveness due to the limited effectiveness of the interaction network involving the different decision-actors. The results were, then, used to involve local stakeholders in co-defining innovative information and communication strategies for overcoming the selected barriers.

The activities have been carried out in the following NAIAD demos: Ljubljana, Lower Danube and Medina del Campo. In these three demos the developed models were used to facilitate the debate with the local stakeholders during the project workshops organized in the demos.

1. INTRODUCTION: NBS ACCEPTANCE AND LEARNING PROCESSES

Around 20% of European cities are classified as being vulnerable to water-related risks. Moreover, the expectation that damages may escalate over time with climate and land-use change and social growth in risk prone-areas has raised policy-makers' awareness of the need to implement innovative 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 at "grey" solutions to reduce water-related risks, e.g. dams for water collection, embankment consolidation, etc. (European Environmental Agency, 2017). Nevertheless, past experiences on risk management 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). Currently, Nature-Based Solutions (NBS) are increasingly adopted as measures for enabling climate change mitigation and adaptation, for reducing risks and for enhancing urban ecosystems (Cohen-Schacham et al., 2016; Denjean B. et al. 2017). According to the scientific literature, 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 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 water-related risks. Among those, the unsuitability of the most commonly adopted methods - i.e. quantitative risk analysis - for supporting decision-making processes for NBS design and implementation plays a key role. Methods and tools for quantitative risk analysis - e.g. quantitative models - are often inadequate to meet the actual information needs of the different decision-makers involved in the risk management processes. This is mainly due to the differences in the perception of water-related risks between model developers and decision-makers (Lesken et al., 2014). Modellers generally frame water-related risk issues using scientific knowledge and expertise, and assume that with more detailed model information analysis will improve and better decisions can be made. Practitioners and decision-makers, on the other hand, often frame flood risk issues more on societal goals and values (Morss et al., 2005). They need information that supports them in communicating risk management strategies with citizens and stakeholders. As a result of these different perceptions of flood risks, a gap exists between what practitioners' demand from models and what models provide (Lesken et al., 2014). Besides the contents of the information provided by models, also process factors - i.e. how the information is exchanged between the different actors - are expected to be important in enhancing the communication and enabling learning processes in risk perception and management.

The main scope of this work is to fill the gaps between information production and information use in risk management, for supporting the NBS design and implementation process. This work aims at demonstrating that an effective information sharing strategy could have a positive impact on the NBS social acceptance. To this aim, two specific objectives were purchased: i) aligning the contents of the

information to be shared to the actual stakeholders' information needs; and ii) enhancing the effectiveness of the information sharing through the existing interaction network.

Concerning the first point, efforts were carried out in order to identify stakeholders' information needs starting from the risk perception. Specification of information needs is a mean to make a translation from a policy problem into an information management issue; the risk management objectives are translated into information expectations that in turn form the basis for an information production process. As discussed further in the text, in this work we define the stakeholders' information needs as the kinds of information that the stakeholders need in order to assess the effectiveness of NBS in reducing water-related risks. The results of the ambiguity analysis (NAIAD deliverable D3.1) were used to this aim. Concerning the second point, the results of the Social Network Analysis concerning the key elements in the interaction networks and the main barriers hampering the flow of information among the different decision-makers were used to develop innovative information sharing strategies. A System Dynamic Model/ Social Network Analysis integrated approach was developed and implemented.

The methods and tools developed in this phase of NAIAD implementation are described in the following sections. The results from the implementation in the different NAIAD demos are described in Section 5.

2. FROM RISK PERCEPTION TO CO-BENEFITS DEFINITION: THE ROLE OF STAKEHOLDERS' ENGAGEMENT

The results of the stakeholders' risk perception elicitation and analysis were used as the basis for the identification of the co-benefits expected to be produced by NBS. When fulfilling the functions of infrastructures for reducing water-related risks, NBS may simultaneously provide co-benefits in other different elements, such as socio-cultural, socio-economic system, environment, biodiversity, ecosystems, and climate. Evidences demonstrate that enhancing the communication about the co-benefits at different level of decision-makers and citizens is of utmost importance to increase the social acceptance and avoid conflicts.

Starting from these premises, efforts were made in order to identify the most important impacts that different strategies to deal with risks might have in several NAIAD demo cases accounting for the stakeholders' problem understandings. To this aim, the analysis of the developed Fuzzy Cognitive Maps (see D3.1) allowed us to identify the most important elements according to the stakeholders' risk perceptions. That is, the issues that, according to their own perception, need to be addressed.

Figure 1 shows the results of the centrality degree assessment for one of the FCM developed during the first part of the NAIAD implementation in the demos.

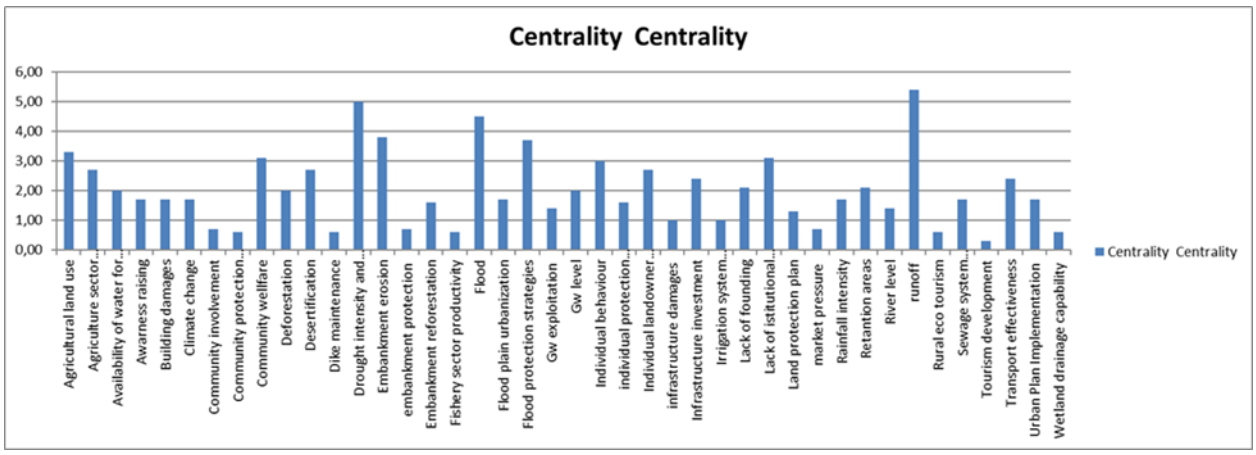

Figure 1. Centrality degree assessment for the identification of the most important issues to be addressed according to the stakeholders' perception.

The list of the most central elements in the stakeholders' risk perception models was, then, used to identify the expected co-benefits. To this aim, WP3 referred also to the results of existing EU funded projects on NBS impact assessment, namely EKLIPSE and CICES, which stress the unique role of NBS in the production of co-benefits. The most central elements were translated in risk management goals and, then connected with the societal challenges mentioned in EKLIPSE project. Finally, the lists of potentially interesting co-benefits and ecosystem services associated to the selected societal challenges were defined. Figure 2 shows the process for defining the list of potentially interesting co-benefits starting from stakeholders' risk perception.

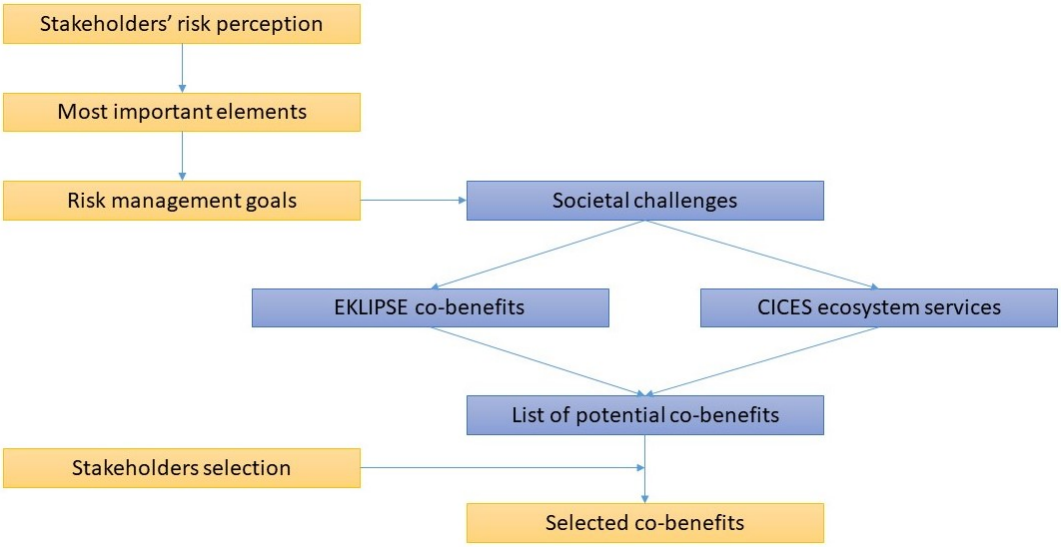

Figure 2. Description of the different phases for defining co-benefits from stakeholders' risk perception.

As shown in the figure, the list of co-benefits developed by WP3 was used for supporting the discussion with the stakeholders in the different demos, whose main scope was to narrow down the list and to introduce different locally-based co-benefits suggested by the stakeholders. Table 1 shows the format that was used for supporting the participants in selecting the key co-benefits.

Table 1. Format used for selecting the key co-benefits in the Lower Danube demo. Stakeholders were required to score the expected co-benefits (3: very important; 2: important; 1: not important). If they think that important co-benefits were missing in the list, they were allowed to add these co-benefits in the list and score them.

N.	Expected benefits and co-benefits	Score
1	Flood peak reduction	
2	Increase the quality and quantity of green areas	
3	Increase biodiversity (Increase Ecosystem State)	
4	Increase the population protected by risk management measures	

5	Increase agricultural productivity	
6	Increase water availability for irrigation	
7	Reduce embankment erosion	
8	Increase water storage	
9	Increase community wellbeing	
10	Improve coordination of risk management strategies within and across level of governance	
11	Increase fishing productivity	
12	Increase community awareness and knowledge about the risk management measures	
13	Increase rural ecological tourism	
14	Increase community risk awareness	
15	Reduce built environment damages (i.e. building, infrastructures)	
16	Minimize erosion/solid transport in the river	
17	Increase public participation in risk management measures design	
18	Increase business productivity (industrial + agricultural)	
19	Social justice and social cohesion	
	…	

Individual inputs were collected and aggregated. We intentionally did not attribute a weight to each collected input. We decided to consider them as equally important, independently from the role and responsibilities of the different stakeholders expressing the scores. The aggregation of the stakeholders' inputs allowed us to selected the most important co-benefits, to be used for supporting the co-design of NBS, as described further in the text.

3. CO-BENEFITS ASSESSMENT: SYSTEM DYNAMIC MODEL AND SCENARIO DEVELOPMENT

In order to assess the actual effectiveness of the NBS in producing the selected co-benefits, a System Dynamic Model (SDM) approach was adopted. The SDM is based on the integration of different stakeholders' risk understandings and problem perception and the physical assessment of the water-related risk. Concerning the latter, efforts were carried out in order to integrate the WP2 results in the developed SDM. The role of the SDM is twofold. On the one hand, it should support the development of an integrated community-based evaluation method, based both on scientific evidences (e.g. deriving from physical risk assessment activities and economic analyses) and on the local /expert knowledge. On the other hand, the SDM will (semi-)quantitatively simulate the impact of specific strategies and tools to deal with water-related risks, supporting a comprehensive analysis of trade-offs among different stakeholders, analysing costs and benefits (including co-benefits) at different scales and on different issues.

The methodology described in the present section has been firstly implemented in the Glinščica river and then replicated in the Lower Danube case study. These case studies are significantly different in terms of hazards and impacts to be considered, but also in terms of scale of the analysis.

3.1 Introduction to SDM

Historically, System Dynamic Modelling (SDM) is an outgrowth of the system dynamics approach firstly proposed by Forrester (1961, 1968, 1987). However multiple recent research activities suggested that almost every business process, and its related components, can be expressed in terms of stocks and flows. Generally speaking, the key aspect of SDM is the capability to describe complex systems in their temporal evolution through the use of specific formal structures, such as feedback loops, stocks and flows. More specifically, SDM consists of qualitative/conceptual and quantitative/numerical modelling methods. Qualitative modelling, e.g. Causal Loop Diagrams (CLDs), improves our conceptual system understanding. Quantitative modelling, e.g. stock-and-flow models, support a thorough investigation and effective visualization of the effects of strategies through simulation (Sterman, 2001).

Stock and flow diagrams are capable to model relationships among variables potentially changing over time. Such models distinguish between two main classes of variables: there are stocks (or level) and flows (or rate). A stock is a measurable accumulation of physical or non-physical resources, and characterize the state of relevant variables of the system keeping memory of their state at previous time steps, thus enabling a description of their evolution. Flows affect the state of stocks via inflows and outflows, thus supporting interconnections among the variables within a system (Sterman, 2000). Figure 3 proposes a basic graphical representation of the stock and flow notation.

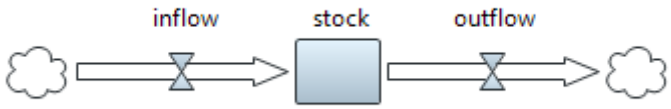

Figure 3. Graphical representation of the stock and flow notation.

According to a wide body of scientific literature, SDM has significant potentialities in modelling complex systems, particularly in case analytical solutions are excessively time consuming or impossible. Particularly, it is highly useful to support decision-making processes, to describe human behaviours, and to analyse organizational evolution. More specifically, such approach may be really useful in describing the way policies, delays, and structures are related, and how they influence the stability of the system. The strength of SDM also lies in its ability to account for nonlinearity in dynamics, feedbacks, and time delays.

The use of SDM techniques may definitely help identifying the main variables fostering or hampering the effectiveness of NBS and analysing the key associated dynamics, focusing on both primary impacts and co-benefits produced. Particularly, the use of SDM aims to evaluate the impact of grey, NBS, soft and hybrid actions and strategies on the state of the main variables of the system. Finally, it has been used to identify critical feedbacks, and to evaluate their influence on the implementation of policies aiming to enhance system resilience to water-risks and produce co-benefits, assessing their evolution with time.

3.2 Overview of the SDM model building process

The process of SDM building typically consists of several phases, i.e.: problem definition, system conceptualization, model formulation, model evaluation/testing, policy analysis and implementation. Figure 4 summarizes the main steps performed for model building and validation.

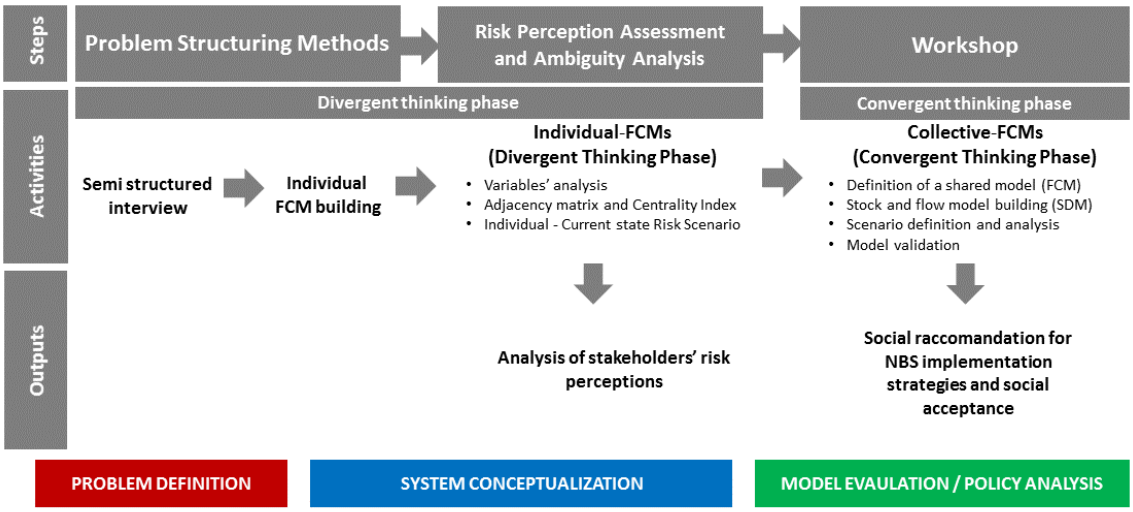

Figure 4. Steps for information collection, model building and validation.

The key phases of the SDM building are detailed in the following subsections. Specific reference is made to the Glinščica river (Ljubljana) case study, which is the most advanced one in the sequence of activities. However, a similar methodological approach is being carried out in the Lower Danube case study.

3.3 KNOWLEDGE ELICITATION

Modelling activities require a careful integration of multiple forms of knowledge. In the work carried out in NAIAD, the integration process concerned mainly the scientific knowledge available in the literature, and the local knowledge held by the stakeholders. Referring to the latter issue, both semi-structured interviews with relevant stakeholders and group activities (focus groups, workshops, etc.) were carried out according to participatory work principles. Some of these activities are still ongoing, and will be performed coherently with the advancement of the NAIAD programme. More specifically, literature evidences are used to support the development of the first version of the SDM identifying the main cause-effect relationships particularly as far as the 'technical issues' are concerned (e.g. the effect of climatic or environmental issues on risk levels). The results of the WP2 modelling activities concerning the assessment of the flood and drought risk will be integrated in the SDM. At this stage of the project implementation, these models were not yet available. Therefore, experts' knowledge was elicited in order to develop the physical risk assessment modules in the SDM. To this aim, the collected knowledge was structured in "if…then" rules-based equations, as described further in the text.

The SDM was used to help identifying the main implications that could be related to the introduction of specific sets of measures, moving from the mere technical effectiveness assessment to the multi-dimensional analysis of socio-economic-environmental effects.

3.4 SDM MODEL BUILDING

One of the main aspects that allow dealing with a complex, integrated and multi-dimensional model is the direct involvement of stakeholders, to support SDM building and validation throughout the NAIAD project. The experts involved in modelling activities (institutional actors, policy-makers, decision-makers, citizens) supported on one hand the phase of conceptual model building, and on the other the definition of the stock and flow model, with its consequential calibration and validation.

The first phase of the WP3 implementation in the demos allowed us to develop individual Fuzzy Cognitive Maps, representing the stakeholders' risk perception (see D3.1). In order to develop the SDM based on the stakeholders' knowledge, the individual FCM were aggregated, allowing to obtained the collective FCM (see Figure 5), which is the qualitative (conceptual) pillar for the stock and flow model building. The results of the ambiguity analysis were used to support the aggregation phase.

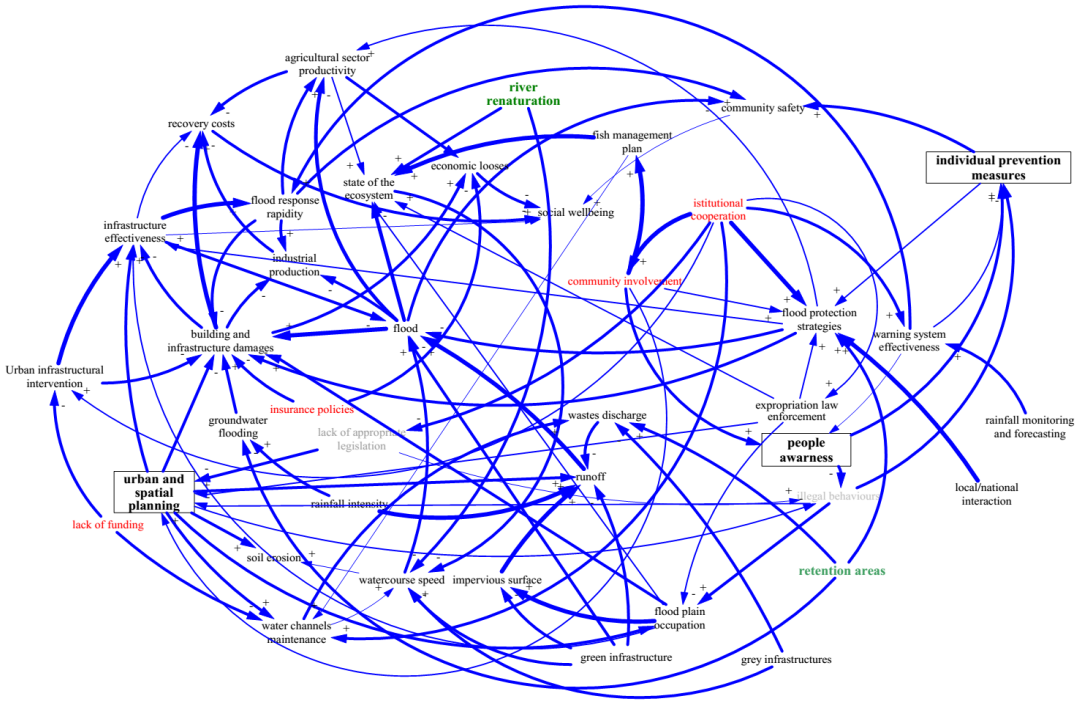

Figure 5. Collective FCM developed for the Glinščica river case study.

The group model building phase was oriented to the aggregation of information and knowledge, for the convergence towards a shared conceptual model, which represents the sum of cause-effect chains regulating the stock and flow model. During specific sessions and using both participatory exercises and individual interviews, the stakeholders validated and integrated the conceptual model, adding or deleting variables and modifying links. The modelling process ended when no new concepts and/or relationships emerged.

Going further into details, once the stakeholders characterized and described the main variables, and their mutual connections, they were also asked to provide a quantitative interpretation of their state (even for non-physical ones) to support the identification of suitable indicators. They also provided a description of the dynamic evolution of such variables with specific attention to the main causes of their change. Full details on the methodological process for the FCM building and validation are available in Santoro et al. (2019). The description of the stock and flow model which was built starting from the FCM is in the following Section 5.

The model was then used to support the co-design of the most suitable NBS for producing the defined co-benefits.

4. MODELLING THE INTERACTION MECHANISMS AND INFORMATION SHARING PROCESSES FOR ENABLING NBS COLLECTIVE DECISION-MAKING PROCESSES

Improving the communication about NBS in order to enable learning processes for NBS acceptance is not exclusively a matter of contents of the information. Efforts are required to enhance the effectiveness of the processes related to information sharing among the different actors. The results of the Social Network Analysis (SNA) described in the D3.1 were used to this aim. Specifically, the analysis of the interactions among the different agents involved/interested in the management of the water-related risks, and between agents and information allowed us to develop policy suggestions and innovative communication strategies concerning NBS effectiveness.

To this aim, the SNA results were integrated with the stakeholders' FCM describing the mental models. As already described in D3.1, the FCM were implemented in order to analyse the stakeholders' risk perception and to model the decision-making processes leading them to reduce their own exposure to water-related risks. The integration with the SNA allowed us to simulate the interactions among the different decision-agents and to analyse the impacts of these interactions, and the flow of information, on the decisions taken by each decision agents. The main scope of this phase is to identify

policy resistance mechanisms due to the actions and reactions of the different decision-agents, that could hamper and/or slow down the implementation of NBS, and/or negatively affect the NBS effectiveness.

The basic assumption of this phase of the analysis is that decision-agents do not act in a vacuum. Therefore, once they take a decision - based on their own risk perception - and implement an action, the latter enters in a universe of actions and interactions affecting the results of the decision-making process (figure 6). Therefore, a model was developed by integrating the FCM and SNA with the aim of simulating the cascade and integrated effects of the decisions and actions of the different decision agents.

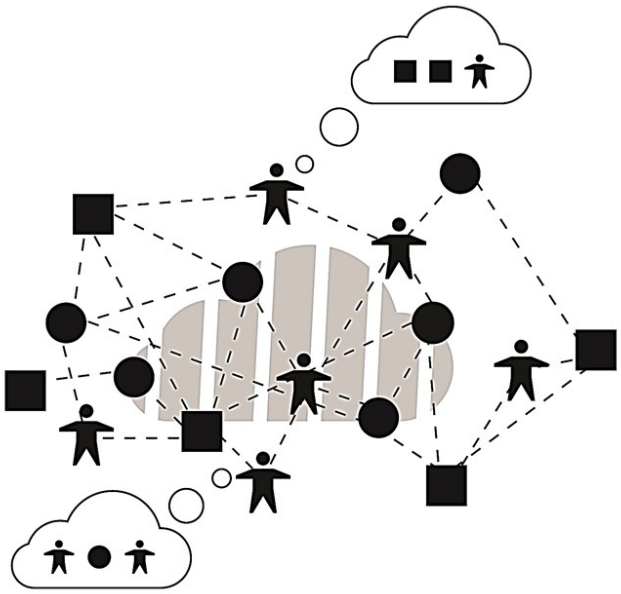

Figure 6. Interaction among decisions/actions and the environment.

To this aim, the results of the individual semi-structured interviews carried out in the first phase of NAIAD implementation in the were used. The format for the interviews has been already described in the D3.1. Here we mainly refer to the questions in the following box.

Box 1 - Questions for gathering information about the interaction mechanisms

What is your role in supporting flood risk management and CC adaptation in the demo?

What are the tasks that you perform to achieve these goals?

What kinds of information do you use to perform your tasks in water-related risk management and CC adaptation?

Could you, please, name the five most important actors (local, regional and national) institutional and non-institutional that can influence the flood risk management and CC adaptation in the demo?

Do you interact with them? Could you, please, describe the kind of interaction (please, select among: i) flow of information – who do you receive info from? Who do you give info to?; ii) cooperating in task performing; iii) flow of resources; iv) informal support, advice or guidance – who do you give informal support/advice to? Who does give you informal support/advice?)

Among these interactions, could you, please, indicate the most important ones in your activities?

According to your experience/opinion, could you describe some limits/drawbacks of the current interaction network hampering the process for the flood risk management (e.g. lack of information sharing, few actors involved in the process, few actors owning too much information, etc.)?

The results of the interviews were there analysed and coded in activity diagrams. These diagrams are based on the UML language and allow to describe the activities carried out by each single decision-agents, the signals (information) used to take decisions and the signals sent to the other decision-agents. Figure 7 shows an example of the activity diagram develop to describe the activities carried out and the information used by Douro River Basin Authority (CHD).

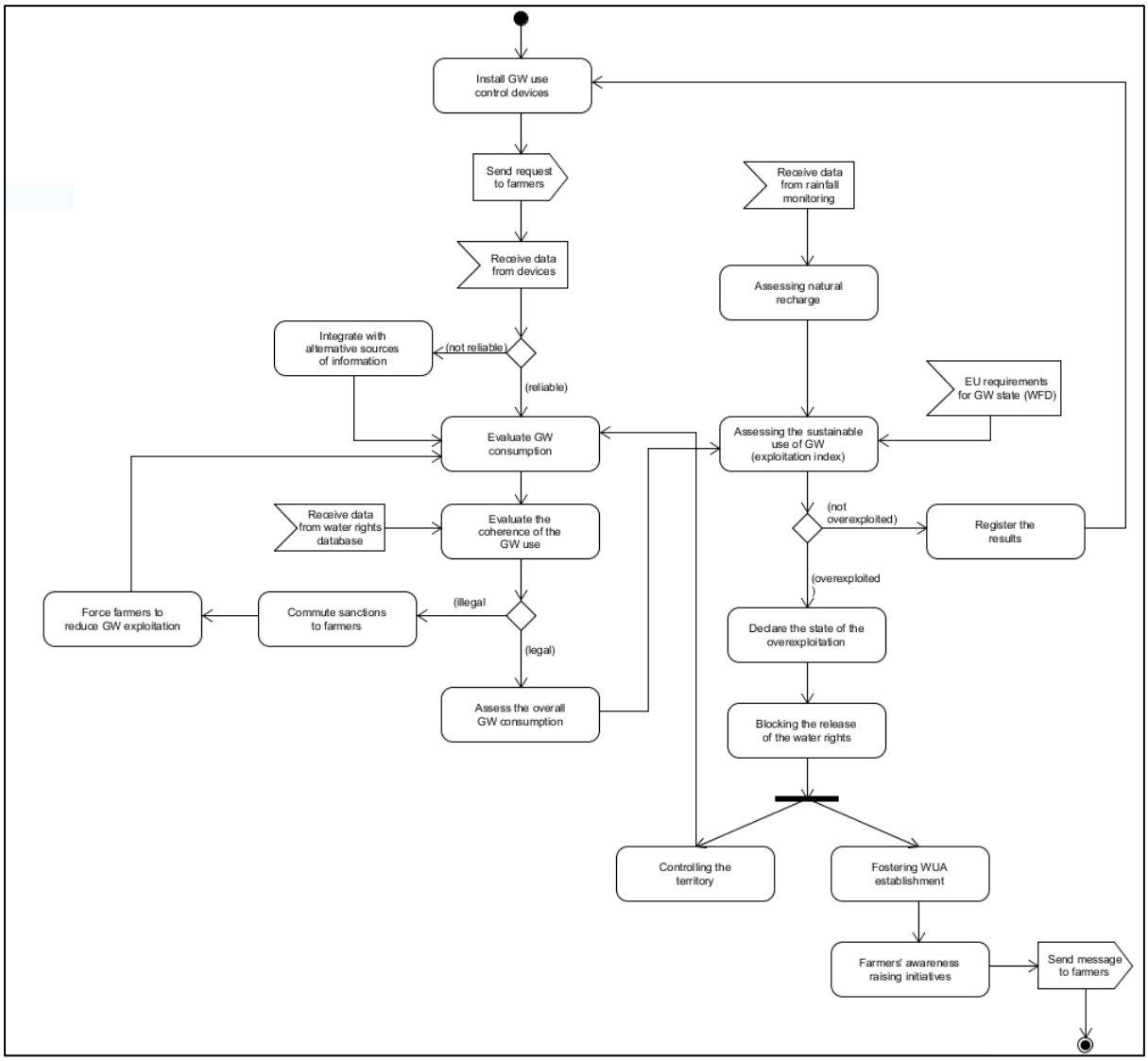

Figure 7. Activity diagram of the CHD (Medina del Campo demo).

To be used for simulating the actions and interactions, the activity diagrams need to be translated into models. In this work, in order to facilitate the integration among the different models in the WP5, a System Dynamic Model based approach was used. The model is characterized by *n* submodules, each describing the decision model for each decision agent. The connections among the submodules represent the interactions among the different decision agents. The links in the model could be either an information link – that is, the connection is based on information sharing – or a causal link – that is, the actions taken by an agent impact the decision-model of the others. The connections were

defined accounting for the SNA results. That is, the Agent X Agent map allowed us to identify who is interacting with whom. The other maps - i.e. Agent X Information; Agent X Task and Information X Task - were used to define the kind of interaction to be modelled.

As discussed further in the text, the SDM/SNA integrated model is used in the demo cases for analysing how the interaction among the decisions and actions implemented by the different decision-agents could affect the implementation and effectiveness of the NBS.

5. RESULTS FROM THE NAIAD DEMOS

5.1 GLINŠČICA RIVER CASE STUDY

Co-benefits definition

Following the methodological approach described in the Section 2, a set of individual interviews with the stakeholders was used to identify the most important benefits (in terms of reduction of water related risks) and co-benefits associated to both NBS and soft measures. The list of the participants can be retrieved in the deliverable D3.1. The results of the FCM analysis were used to support this phase. Specifically, the main issues in the stakeholders' risk perception were used as basis for defining the expected benefits and co-benefits. Table 2 describes the aggregated result, i.e. the average score for every element.

Table 2. Set of benefits and co-benefits identified in the Glinščica river case study.

Expected benefits and co-benefits	Average score
Reduce flood peak	2,74
Increase retention capacity of green areas	2,62
Enhance the control of the water speed	2,56
Reduce building and infrastructure damages	2,56
Reduce runoff	2,39
Enhance biodiversity	2,35

Increase the population protected by risk management measures	2,36
Improve the state of the green areas and ecosystem	2,45
Increase the institutional cooperation for risk management	2,33
Reduce soil erosion	2,29
Social value of urban ecosystem	2,21
Positive health effects of urban green areas	2,23
Increase cultural richness and diversity in urban area	2,30
Recreational values	2,11
Improve community's risk awareness	2,18
Groundwater quality	2,08
Increase the accessibility of green areas	1,95
Enhance air quality	2,04
Increase urban attractiveness toward business companies	1,99
Temperature reduction	2,03
Enhance community involvement in risk management	2,00
Abatement of pollutants	1,93

Starting from the analysis of the Table above, it can be easily argued that besides some elements that are clearly identified as key 'risk-reduction' objectives to achieve (e.g. 'Reduce flood peak', 'Increase retention capacity of green areas', 'Reduce runoff', 'Reduce soil erosion', 'Reduce building and infrastructure damages'), the involved stakeholders perceived and stressed the relevance of additional co-benefits that could be produced by either NBS or soft measures. Interestingly, such co-benefits are related on the one hand to the environment/ecosystem (e.g. 'Improve the state of the green areas and ecosystem', 'Enhance biodiversity') and on the other hand to the socio-institutional frame (e.g. 'Increase the institutional cooperation for risk management', 'Increase the institutional cooperation for risk management'). This result confirms that the selection of a subset of effective

strategies (NBS, soft, hybrid) may have several multi-dimensional impacts that are perceived as crucial by the stakeholders.

SDM for co-benefits assessment and NBS co-design

A stock-and-flow model was developed for the Glinščica river demo. The main objective of this model is to simulate, quantitatively and dynamically, the effects of the main strategies identified (both NBS and soft), with specific reference to the most important benefits and co-benefits discussed by the stakeholders. Additionally, the model may also enhance the process of communication about the effectiveness of both individual and hybrid measures, thus avoiding conflicts and supporting the social acceptance of NBS.

The key assumptions of the model are:

- the duration of the simulation is 50 years. This allows taking into account that many NBS or soft measures require a long time span to become fully effective, and they all provide a gradual contribution to risk reduction.
- The time step of the simulation is 1 year. From a physical point of view, the analysis is performed starting from hydrological information, and analysing the impacts of a 100-years return period flood event.
- The variables are divided into stocks (characterized by accumulation, and keeping memory of previous time steps), flows (ratio of increase or decrease of variables in each time step) and conveyors (with constant values or equations computed in each time step). The states of these variables and the equations behind the model have been defined integrating the expert knowledge collected through the participatory activities summarized in the previous sections.
- The main variables (stocks) are all expressed in dimensionless terms, ranging from 0 to 1 (or 100 in % terms).
- The most relevant dynamics are divided into sub-models, i.e. physical risk assessment, primary impacts and co-benefits, besides the global model.

The global model for the Glinščica river case is proposed in the following Figure 8.

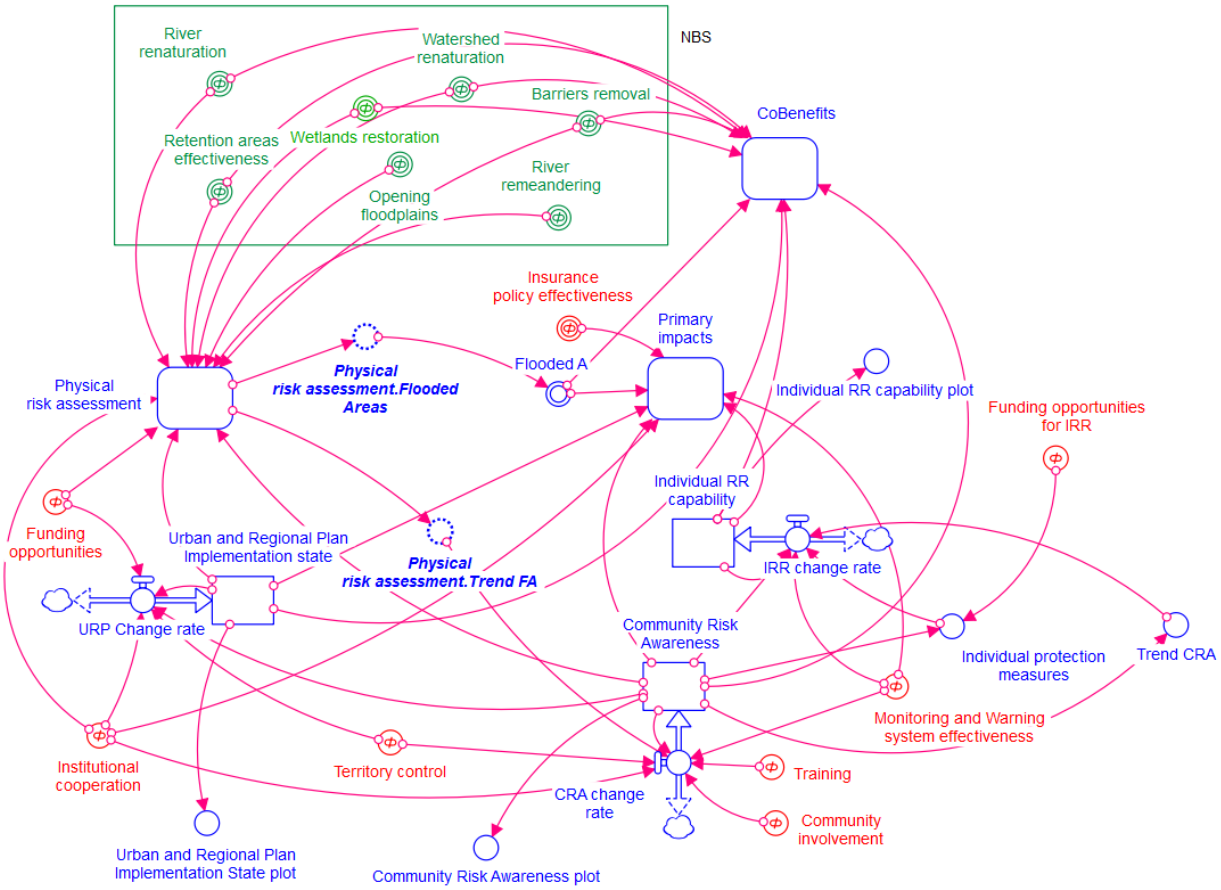

Figure 8. Global stock and flow model for the Glinščica river case study.

Going further into details in the above figure 8, the variables identifying the selected *NBS* are in green. Such variables range from 0 to 1, thus representing a level of implementation of the selected measures from very low (0, i.e. not applied) to very high (1, i.e. applied, fully functioning and effective). Currently, the analysis and tuning of the model have been performed with specific reference to two discrete states, i.e. 0.1 and 0.9. Similarly, the variables in red represent *soft measures*, and they range from 0 to 1, according to their level of implementation.

Basically, the global model includes the main dynamics related to the effects of soft/institutional measures. The dynamics described in this model directly derived from the results of both individual interviews and participatory activities. The underlying equations were built according to the comments provided by the stakeholders on the influence of specific variables (e.g. the weight they

assigned), and on their expected evolution over time. These equations will be fine-tuned when additional knowledge will be available. Particularly, additional expert knowledge will be integrated (e.g. new interviews/results of participatory activities) along with the results of specific models (e.g. for physical risk assessment, economic analysis, environment/ecosystem state, etc.). More specifically, the key stocks are:

- 'Urban and Regional Plan Implementation state': this variable represents the level of implementation of planning regulations at both urban and regional level. This variable depends mainly on the institutional capability to cooperate and provide funding to enhance the control of the territory. It has several impacts, which are related to the physical assessment sub-model (mainly on the evolution of impervious areas and floodplain occupation level), on the impact assessment sub-model (it affects community safety, building damage level and business productivity) and on the co-benefits assessment sub-model (both in terms of biodiversity enhancement and change of the social value of ecosystems).
- 'Community risk awareness': this variable represents the level of awareness of people with respect to the water related risks. It is significantly affected by specific strategies (e.g. the community involvement activities) and by the memory of risk levels (trend of the Flooded Areas). This variable has also significant effects on the physical assessment sub-model (floodplain occupation depends significantly on the risk awareness of the community) and on the primary impacts (community safety).
- 'Individual risk reduction capability': this variable describes the effects of skills, tools and opportunities that concur to define the individual capability to deal with risks. It directly affects all the main impacts (community safety, built environment damage level and business productivity) and some relevant o-benefits, such as the ecosystem state and its social value.

One of the key aspects of SDM is the existence of interconnections between the different aspects that are described, for the sake of simplicity, by individual sub-models but clearly have mutual influences and dependencies. In the following, the individual sub-models are described in full details.

The '*Physical risk assessment*' sub-model (see figure 9) aims at quantitatively characterizing the most influential issues on risk level from a technical point of view. This sub-model has a strongly quantitative basis, since it is grounded in the scientific assessment of risk levels, and on the identification of its main components (hydrologic conditions and groundwater level). Currently it is based on a simplified approach, although the development of physical risk assessment tools could be highly useful to improve its potential. The technical aspects are integrated by expert knowledge as far as the effect of both NBS and soft measures is concerned. This module will integrate the results of the WP2 physical risk assessment as soon as they will be available for this demo.

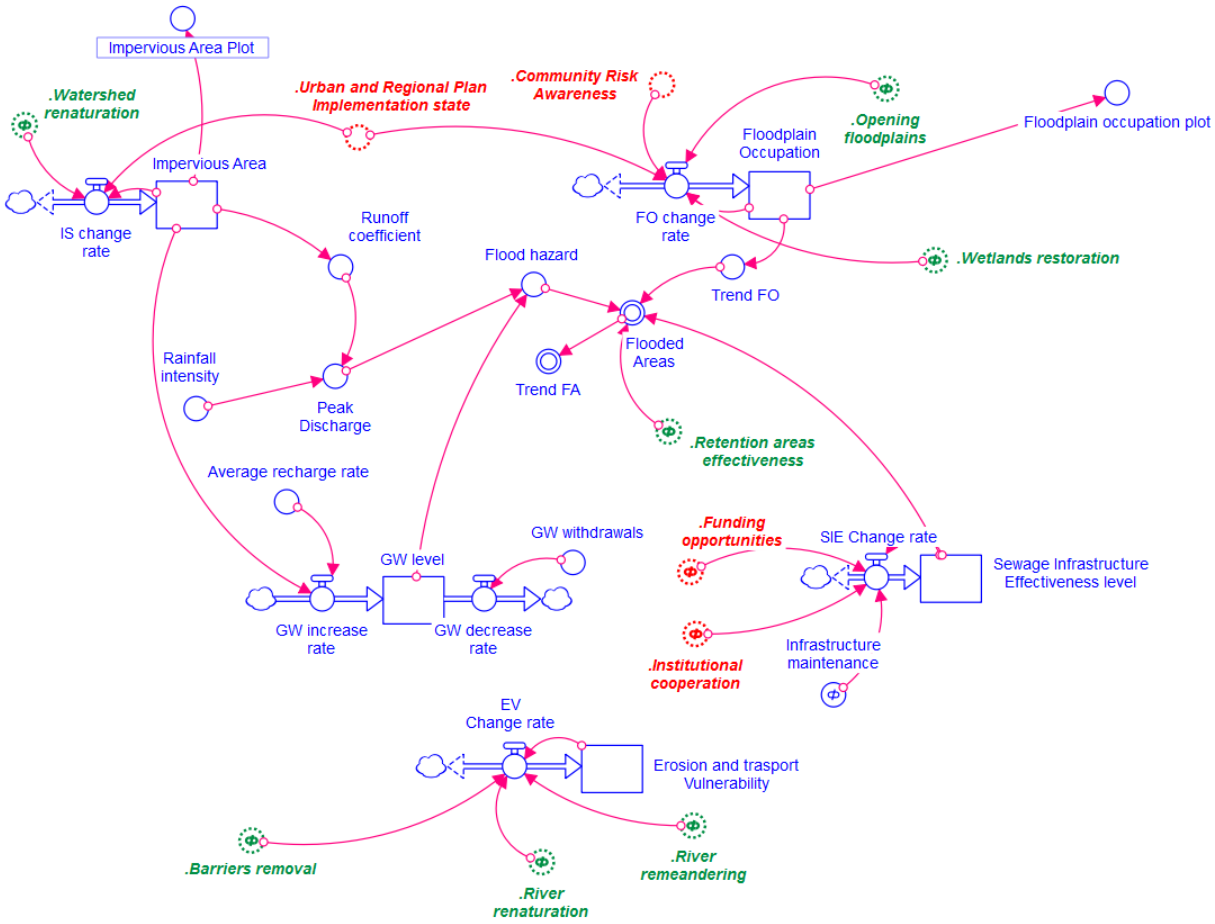

Figure 9. Physical risk assessment sub-model.

With specific reference to the Glinščica river case study, the main aim of the physical risk assessment sub-model is to provide a semi-quantitative analysis of the risk levels that are due jointly to surface runoff and groundwater level raise. Basically, the model aims at estimating the extent of the 'Flooded Areas' under a constant input rainfall event (100 years return period) and variable environmental conditions (e.g. changes in the land use due to NBS and soft measures). The 'Flooded Areas' are expressed in terms of ratio with respect to the current situation (i.e. a value of 2 means that the flooded areas are approximately double than in the current state). More specifically, the effect of natural/climatic conditions is taken into account through a specific subset of parameters, i.e. 'rainfall intensity' and 'average recharge rate' that are constant during a simulation (and fixed according to the current situation). The human influence is described referring to both groundwater ('GW

withdrawals') and runoff dynamics ('impervious area' and 'floodplain occupation'). Going further into details, the 'impervious area' evolves mainly according to the 'watershed renaturation' processes and the 'urban and regional plan implementation state'. Similarly, the 'floodplain occupation' depends on both NBS ('opening floodplains' and 'wetlands restoration') and soft variables ('community risk awareness'). The 'Flooded Areas' are also conditioned by the operation of sewage infrastructures, whose effectiveness and functionality has a significant effect on the impacts of floods. Additionally, the GW level might increase the flood hazard, in case the water table goes beyond a threshold value and thus the surface soil saturates.

The '*Primary Impacts*' assessment sub-model (figure 10) aims at analysing the effect of a specific combination of strategies on the risk level reduction. It is based on the analysis of the expected impacts of selected measures according to the knowledge provided by the stakeholders (with particular attention to the importance that is attributed by different stakeholders to specific impacts). The effect of soft measures is analysed, along with a 'physical' parameter, i.e. the extent of the flooded areas. The main effects of water-related risks are described, following the outcomes of interviews and participatory activities, referring to three main issues, i.e.: a) Community safety (safety and well-being of population), b) Built environment damage level (expected ratio of buildings and infrastructures that can be adversely affected by the hazard), c) Business productivity (potential impact of the hazard on the economic activities in the affected area). The magnitude of impacts is directly dependent on the extent of the flooded areas, but also significantly conditioned by the soft strategies that are put into practice. All the cited impacts concur to the definition of a global level of economic losses.

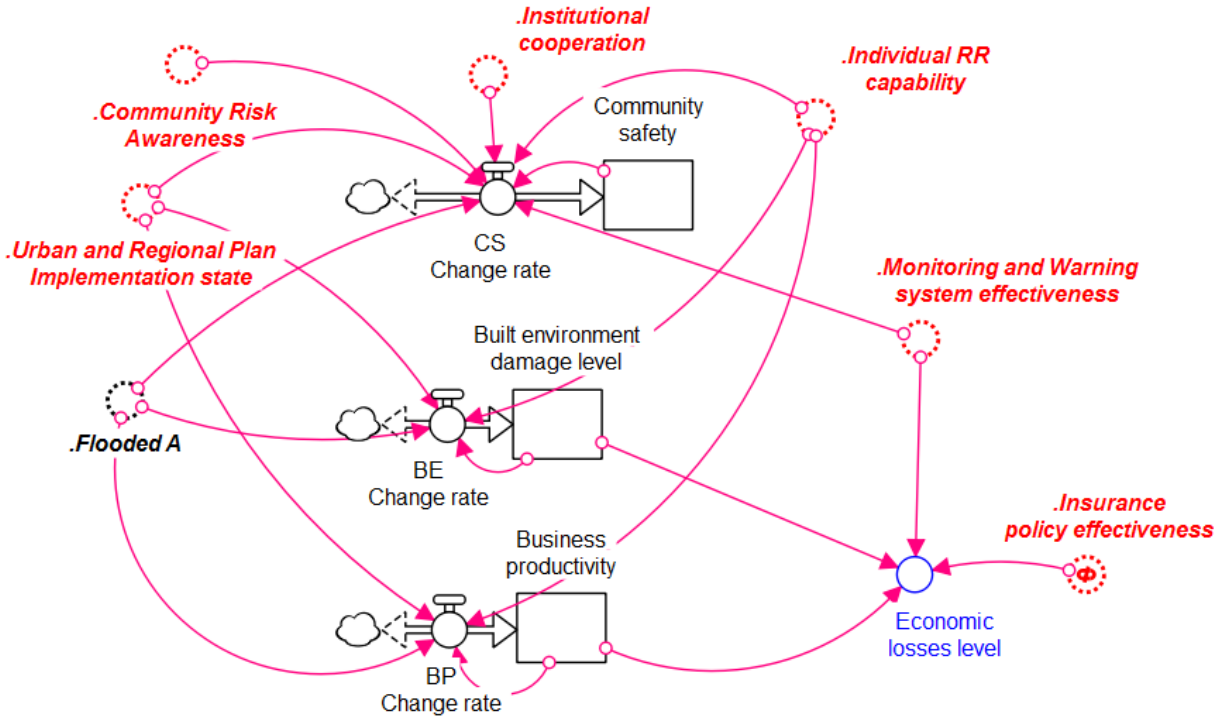

Figure 10. Primary impacts assessment sub-model.

The '*Co-benefits*' assessment sub-model (figure 11) aims at investigating the additional effects that specific risk management measures might have on social, environmental, economic and ecological issues. The structure and the equations of this sub-model are basically built starting from the results of both individual and participatory activities performed with the stakeholders, that provided information on the specific complementary effects that can be guaranteed by the introduction of both NBS and soft measures. More specifically, both NBS and soft measures might have a positive impact on the 'Ecosystem state' (improving the quality of the environment), on the 'Biodiversity' (supporting NBS helps enhancing and conserving the biodiversity in the system), on the 'Agricultural productivity' (the process of watershed renaturation and reduction of urban areas might increase the area available for agricultural activities) and on the 'Social value of ecosystem' (e.g. helping social interaction, education, health and well-being). Clearly, as shown in the figure 11, different measures produce a specific set of co-benefits, and might have a different weight on co-benefits production.

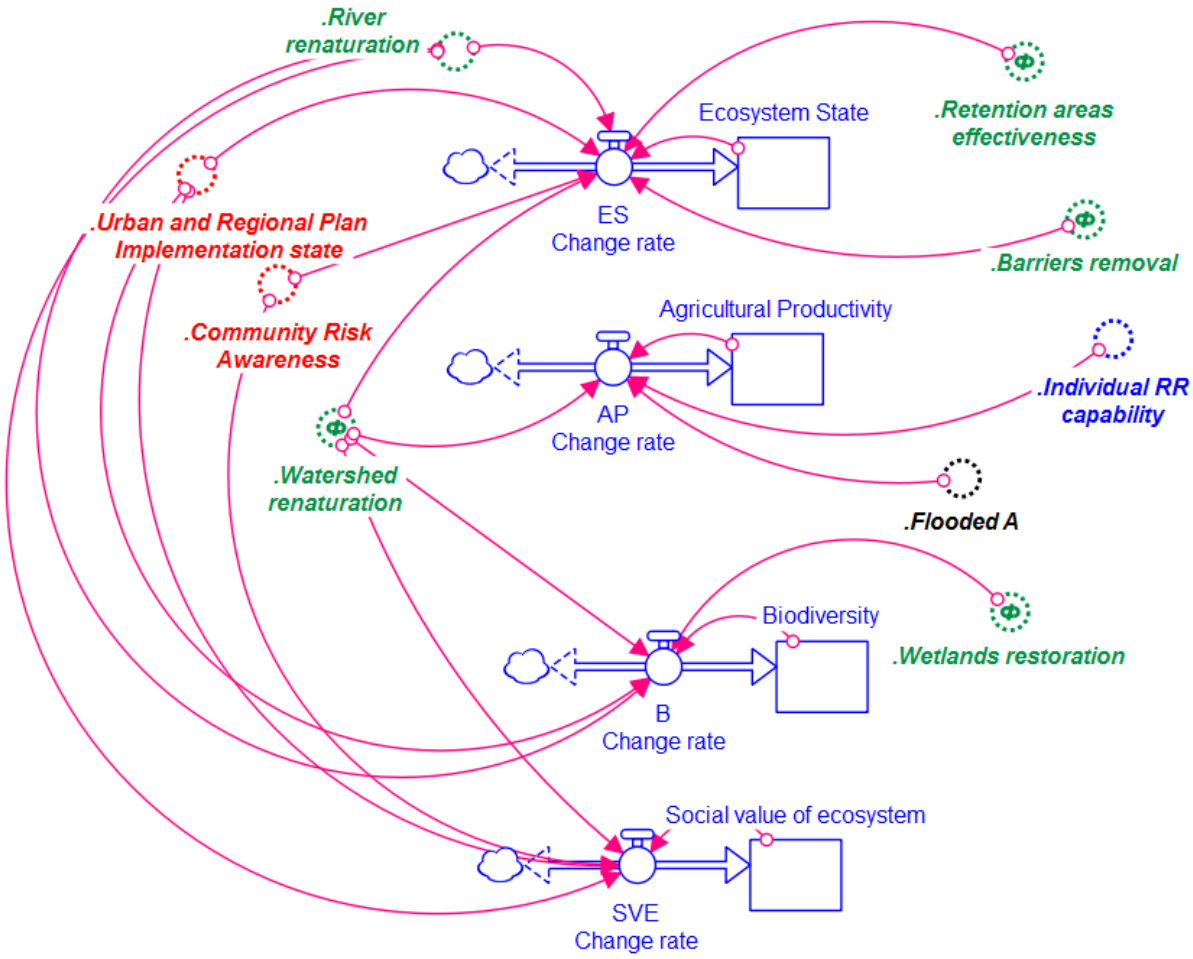

Figure 11. Co-benefits assessment sub-model.

The stock and flow model described above has a strongly quantitative basis, since every flow is associated to a differential equation. It produces, as a result, both graphs and tables with the evolution of the state of the investigated variables with time. The following figure 12 shows, for example, the main results of the model according to the Business-As-Usual (BAU) scenario, i.e. assuming that all the variables keep the current state. It can be easily argued that, according to the stakeholders' risk perception, system conditions are expected to get worse rapidly in the future if nothing is changed in the system. Going further into details, the results shows that:

- The impacts of extreme events are likely to increase in the near future, due to an increased exposure of the main assets and an increased vulnerability of the area to the hazards. This will have also an increasingly negative impact on Community safety and on Economic productivity.
- A significant decrease of all the aspects that can be described as potential co-benefits of the introduction of NBS is likely to occur. Particularly, both the Biodiversity and the Social value of the ecosystem (which also start from a very low state) could be significantly reduced, since currently grey infrastructures are definitely preferred, there is limited attention to the control/planning/protection of the territory and a limited individual and collective awareness.
- The expected evolution of the system in the near future is due both to an increased vulnerability of the area (due to the increase of impervious areas and floodplain occupation) and to a weak socio-institutional framework, characterized by a decreasing individual/collective awareness and by a progressively lower capability to support the implementation of urban planning.

These graphs were:

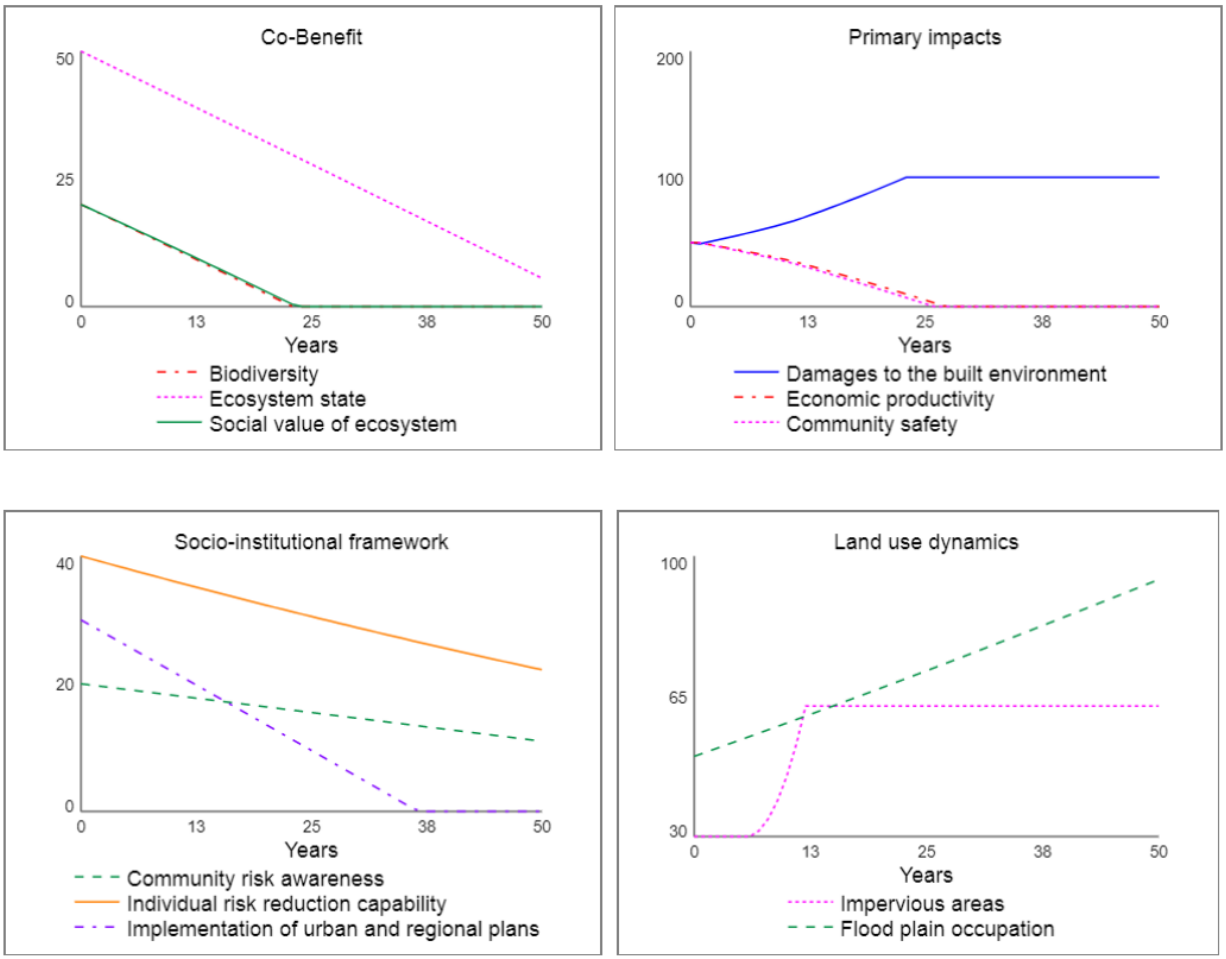

Figure 12. SDM results in the BAU scenario.

Stakeholders' WS for strategy development and scenario analysis

Starting from the results of the ambiguity analysis and the 'divergent' thinking phase, the 'convergent' thinking phase was specifically oriented to the achievement of consensus on the most suitable categories of NBS for both reducing flood risk and producing co-benefits that are relevant for the local stakeholders. To this aim, a *Flood Risk Perception Workshop* was organized.

Starting from the results of the individual interviews, aiming at defining the most important benefits and co-benefits to be produces, the works aimed at co-defining the most suitable NBS for achieving the selected 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. The list of goals to be achieved allowed us to define a set of potentially suitable "socio-institutional" measures, that is, measures to be implemented together with NBS and grey solutions in order to enhance their effectiveness. 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. Table 3 (a) and (b) show the co-defined set of NBS and socio-institutional solutions.

Table 3. List of selected NBS (a) and socio-institutional measures (b).

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

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

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.

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.

The developed SDM model was, hence, used to support the discussion among the different stakeholders concerning the most suitable combination of green (NBS) and soft/institutional measures to produce the already selected benefits and co-befits.

To this aim, the stock and flow model was built using Stella® Architect software, which has a user-friendly interface and, additionally, offers several features that make the model highly useful in participatory activities. Firstly, it offers the possibility to easily and intuitively set the input conditions for the simulations (see figure 13), supporting also a real-time visualization of the results and of the changes originated by the variations in the state of the input variables. Secondly, it supports also a comparative analysis of scenarios and includes several tools for model analysis (e.g. sensitivity analysis). Since this scenario analysis can be directly performed through the interface, the

stakeholders do not necessarily have to deal with the complex structure of the stock and flow model (which is shown and discussed during participatory activities by a facilitator), but could just focus on the effects associated to the changes in input variables. Lastly, it offers also the possibility of sharing the model online for an asynchronous interaction with the stakeholders.

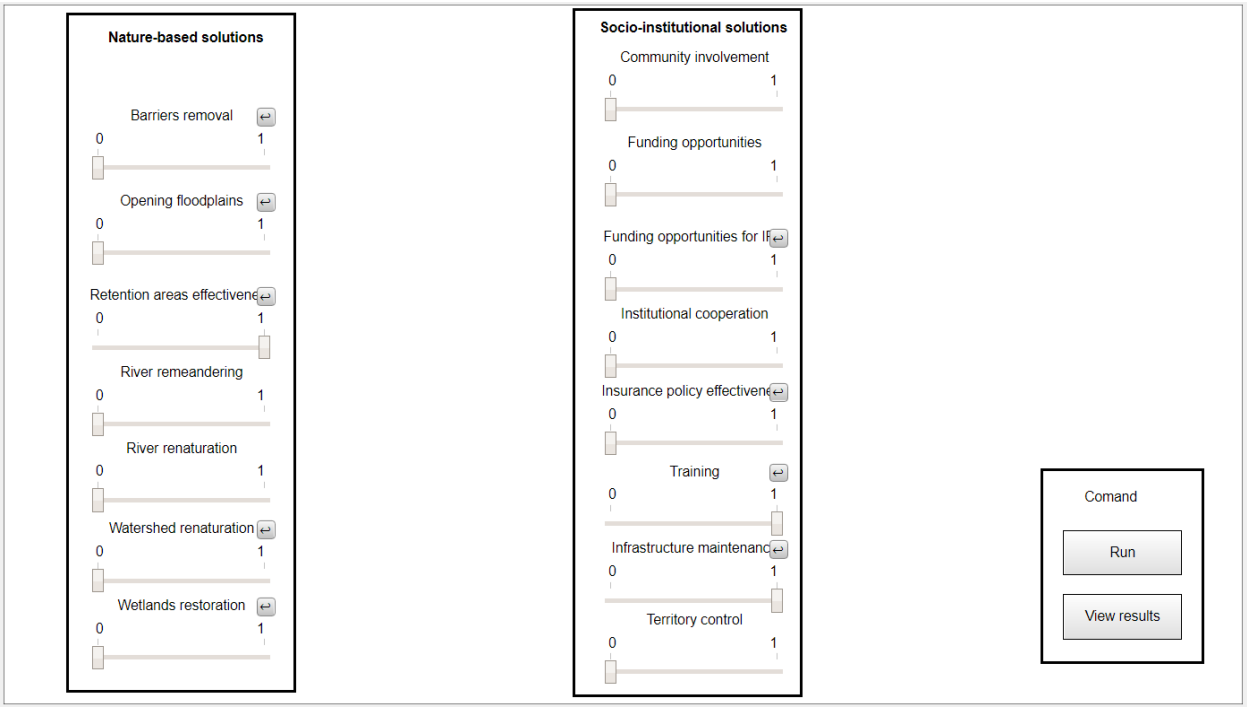

Figure 13. SDM interface in Stella® Architect allowing the stakeholders to define the measures to be implemented.

Several potential scenarios were identified and discussed during the stakeholders' workshop using participatory exercises. The main objective was to identify the most effective combinations of NBS, soft measures and hybrid measures according to the stakeholders' perception. Participants were required to create three different boxes, each of which containing 5 different actions selected among those described in Table 3.

Scenario 1

The Scenario 1, named '**Renaturation'** alias **Glinščica for all** included 3 NBS and 2 soft measures:

- ✓ Retention areas effectiveness (NBS)
- ✓ River renaturation with re-meandering (NBS)

- ✓ Wetlands restoration (NBS)
- ✓ Infrastructure maintenance (soft)
- ✓ Funding opportunities for IRR (soft)

Participants felt that the NBS are the concrete physical measures that would restore the currently degraded stream conditions, increasing flood safety as well as recreational value of the area. In addition, the NBS are easier to maintain and contribute to the ecosystems to the area, ensuring higher biodiversity and more green areas for Ljubljana urban area.

The comparison between the Business-as-usual (BAU) scenario and the graph in Fig. 14 allows to assess the effectiveness of the selected strategy in producing the expected benefits and additional co-benefits. Concerning the reduction of the primary impacts (benefits), the combination of NBS and soft solutions will produce a limited reduction of the effects on the community safety and building damages. The most positive impact regards the state of the ecosystems and the level of biodiversity. Besides, the individual risk management capability will increase.

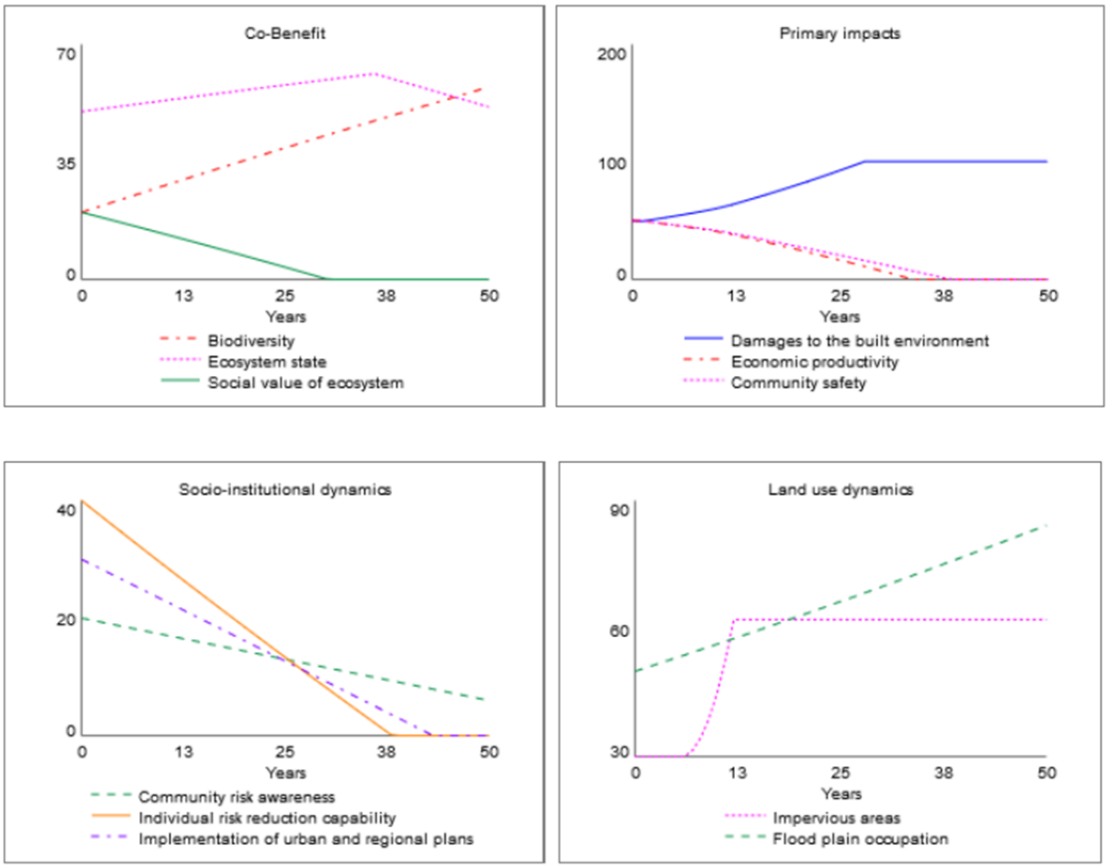

Figure 14. Renaturation (Glinščica for all) scenario simulation results.

Scenario 2

The Scenario 2, named **Bureaucratic** included only 1 NBS and 4 soft measures:

- ✓ Opening floodplains (NBS)
- ✓ Territory control (soft)
- ✓ Community involvement (soft)
- ✓ Monitoring and warning system effectiveness (soft)
- ✓ Insurance policy effectiveness (soft)

The most important benefits associated to the second scenario according to stakeholders are its long-term effectiveness and the enabling effect for implementation of physical restoration measures. On the other hand, stakeholders commented that it is not clear or believable that soft measures without concrete physical changes in the catchment could actually have an effect on flooding damages. It is also remarked that such measures mainly aim at solving future challenges, without important impact on current situation. In addition, some stakeholders underlined that damage reduction significantly benefits from this scenario, since people usually forget about flood events very and these measures could help the local population shifting this attitude. One stakeholder suggested that this scenario is most important due to its effects on people's perceptions, which are believed to be the most important factor of ecosystem/water management.

This scenario is characterized by an increase of the socio-institutional benefits due to the implementation of the selected strategy (Fig. 15). Specifically, the increase of the community risk awareness, due to the increased community involvement, has a positive impact on the implementation of the urban and regional plan as well. Moreover, the positive impacts in the land use dynamics – i.e. flood plain occupation and impervious areas – will lead to a decrease of the building damages. Finally, the social value of ecosystem and the biodiversity will be positively affected.

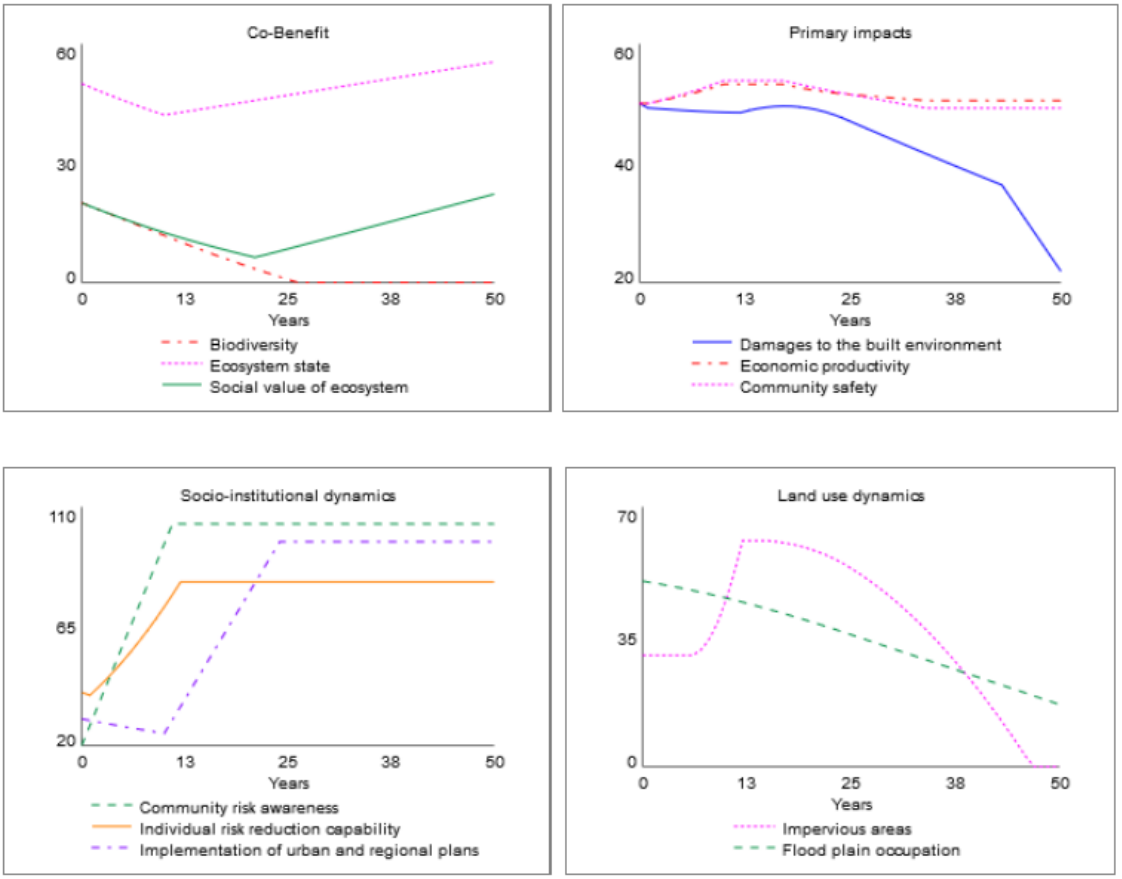

Figure 15. Bureaucratic scenario simulation results.

Scenario 3

The Scenario 3, named **Bottom up** again included only 1 NBS and 4 soft measures:

- ✓ Retention areas effectiveness (NBS)
- ✓ Community involvement (soft)
- ✓ Institutional cooperation (soft)
- ✓ Training (soft)
- ✓ Funding opportunities for IRR (soft)

This scenario is considered effective on the long run due to its enabling effect on implementation of other measures. However, stakeholders suggested also that it might be less effective than the other two scenarios, since it only has indirect impacts on flood safety. The most important measures recognized in this scenario according to stakeholder opinion were financing and awareness raising,

which would lower the pressures/unregulated exploitation of the catchment and thus benefit the environmental and social values both among the general population as well as planners and decision makers. The most important challenge of this scenario is the inefficiency of the national institutions to implement coherent, integrated and holistic processes of spatial planning, which is required for successful environmentally friendly, sustainable spatial management.

This scenario is characterized by very few NBS, therefore the most important impacts are those related to the socio-institutional dynamics (Fig. 16). Nevertheless, those measures have a limited impact on the primary impacts, provoking a reduction of the speed of the damage process, but not an actual reduction.

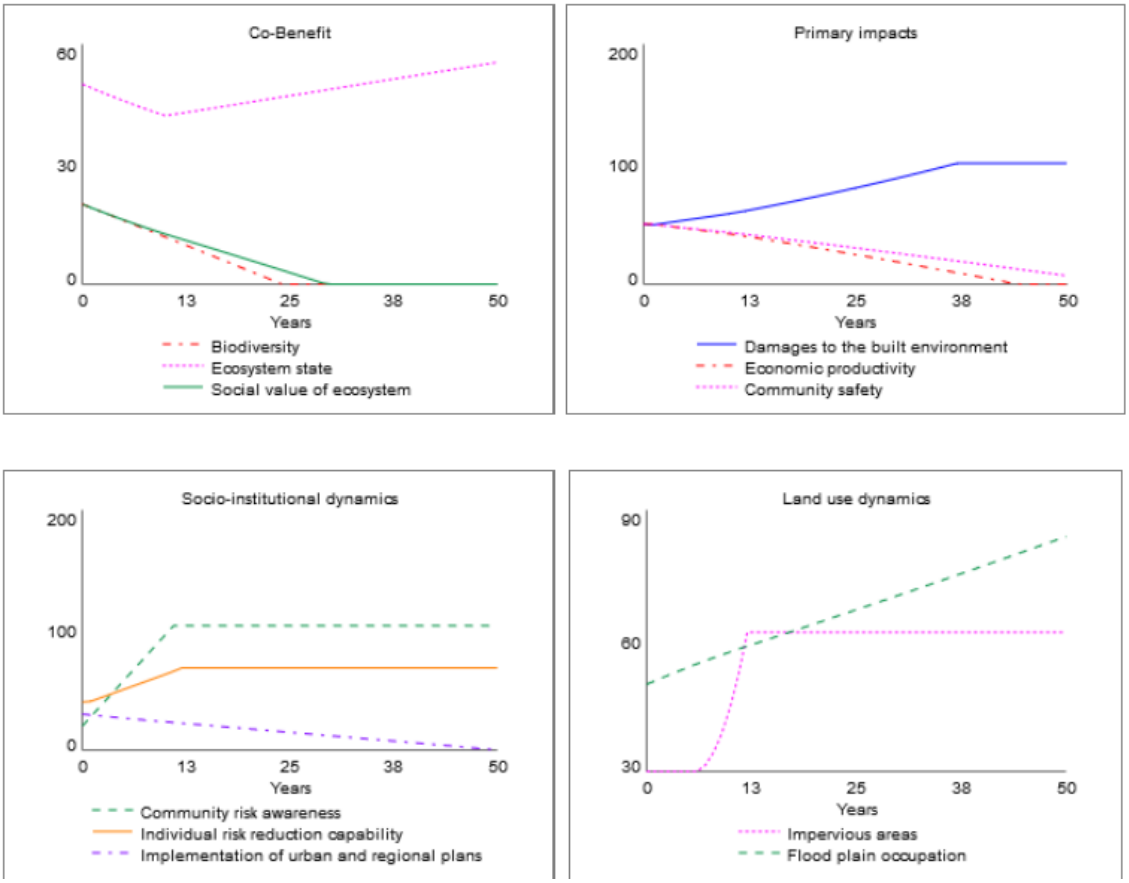

Figure 16. Bureaucratic scenario simulation results.

Scenario 4

Finally, the workshop participants required to further develop, with no constraints on the number of measures, the Scenario 1. Additional soft measures were added, since their simultaneous implementation with the proposed NBS, could help achieve the target benefits and co-benefits in the long term.

The 'Renaturation' scenario was thus expanded with additional soft measures, listed in the following:

- ✓ Territory control
- ✓ Community involvement
- ✓ Institutional cooperation
- ✓ Training
- ✓ Funding opportunities for IRR
- ✓ Insurance policy effectiveness
- ✓ Physical risk assessment infrastructure maintenance
- ✓ Monitoring and warning system effectiveness

As expected, this is the scenario with the most effective impacts on both benefits and co-benefits (Fig. 17). Nevertheless, as already stated by the stakeholders at the end of the WS, a detailed analysis of the costs due to the implementation of these measure is required.

The main results of this phase of the WS is to make the participants aware of the need to integrate different kinds of measures in order to enhance the effectiveness of NBS in producing benefits and co-benefits. Specifically, stakeholders became aware of the role played by the soft/institutional measures capable to enhance the effectiveness of the urban and regional plan implementation. The next phase of the stakeholders' activities in the demo will concern the definition of the costs for the implementation of the selected NBS and soft/institutional measures.

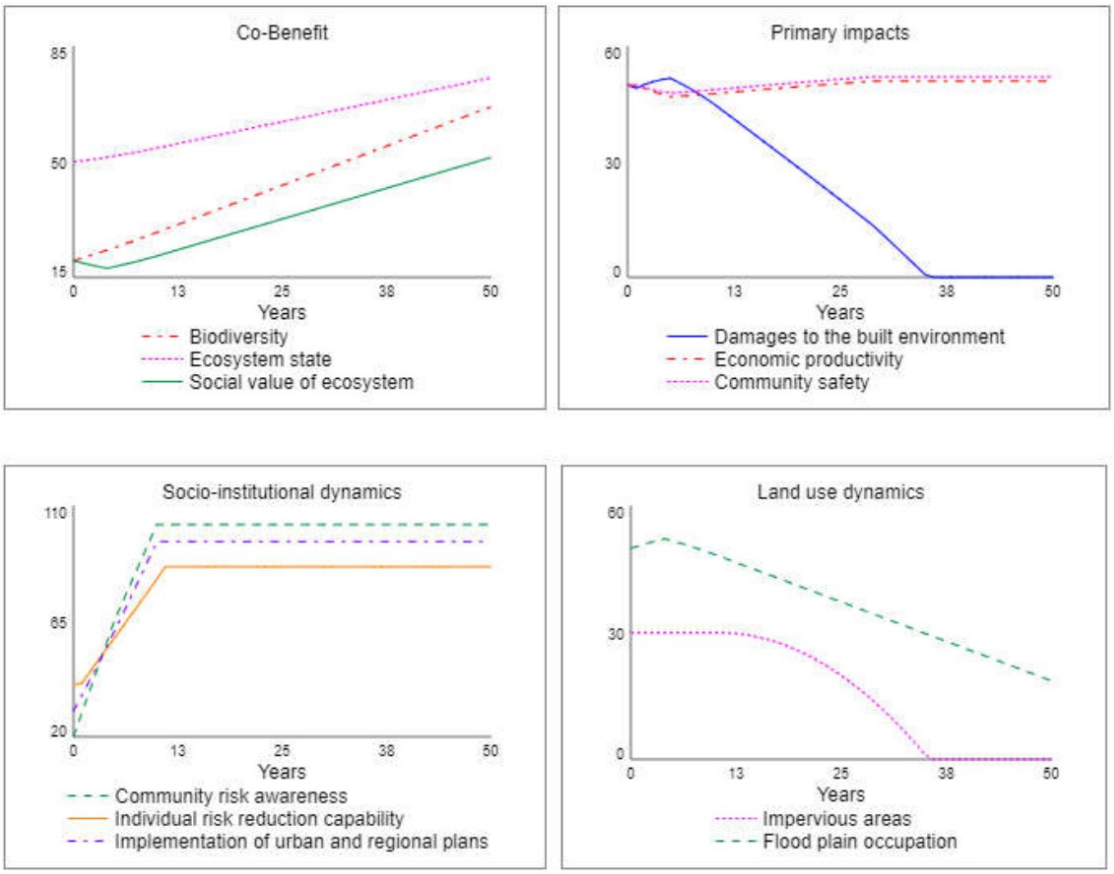

Figure 17. Scenario 4 simulation results.

5.2 LOWER DANUBE CASE STUDY

Co-benefits definition

Two round of interviews and a stakeholders' WS were carried out in order to identify the most important co-benefits, accounting for the stakeholders' understanding. The following table shows the selected co-benefits. Following the methodological approach previously described, the selected co-benefits were the results of the integration between the available scientific literature and the stakeholders' risk perception.

Table 4. Benefits and co-benefits selected in the Lower Danube demo.

Expected benefits and co-benefits	**Awerage score**

Increase biodiversity (Increase Ecosystem State)	10,5
Increase the quality and quantity of green areas	10
Increase water storage	9
Increase rural ecological tourism	9
Increase community wellbeing	8,5
Flood peak reduction	8
Increase fishing productivity	8
Increase water availability for irrigation	7,5
Increase community's awareness and knowledge about the risk management measures	6,5
Increase community risk awareness	6,5
Increase public participation in risk management measures design	6,5
Increase business productivity (industrial + agricultural)	6,5
Increase the population protected by risk management measures	6
Reduce bank erosion	6
Minimize erosion/solid transport in the river	6
Improve coordination of risk management strategies within and across level of governance	5,5
Reduce built environment damages (i.e. building, infrastructures)	5,5
Increase agricultural productivity	4,5
Social justice and social cohesion	4

System Dynamic Model for NBS co-design and evaluation

As explained further in the text, the co-benefits were used to facilitate the debate with the stakeholders during the second stakeholders' WS, held in Craiova. To this aim, a SDM was developed referring to the stakeholders' risk perception. The model is meant to describe the system as perceived by the stakeholders. Moreover, it also integrates a simplified and qualitative (due to the complexity of the case) description of the physical processes which affect the water-related risks.

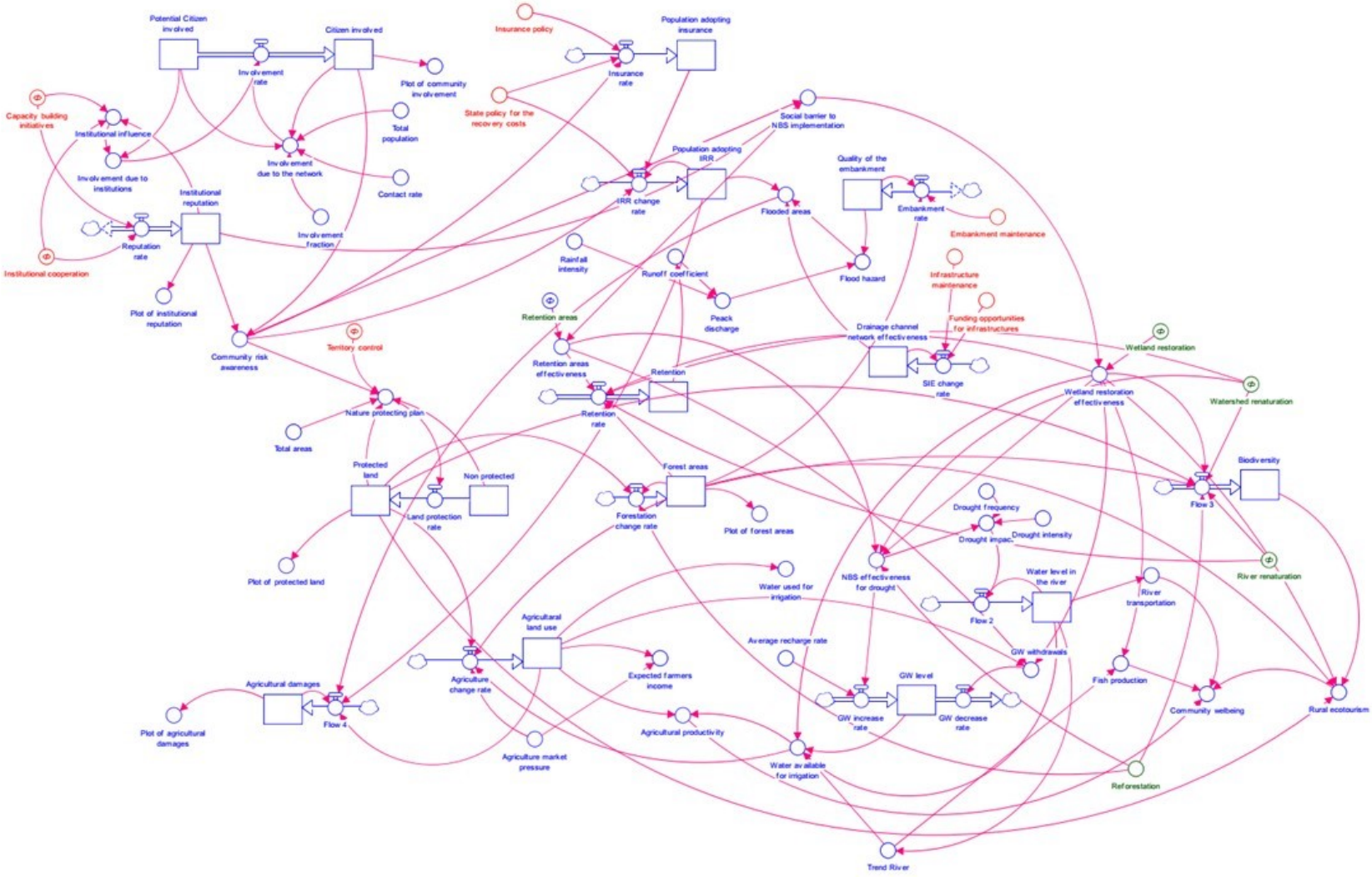

Figure 17. SDM representing the interaction among the different elements affecting NBS effectiveness.

Figure 17 shows the complexity of the issues to be addressed and the different elements that need to be accounted for in order to design effective NBS for reducing water-related risks and producing the expected co-benefits. Specifically, a module related to the socio-institutional dynamics was developed as shown in figure 18.

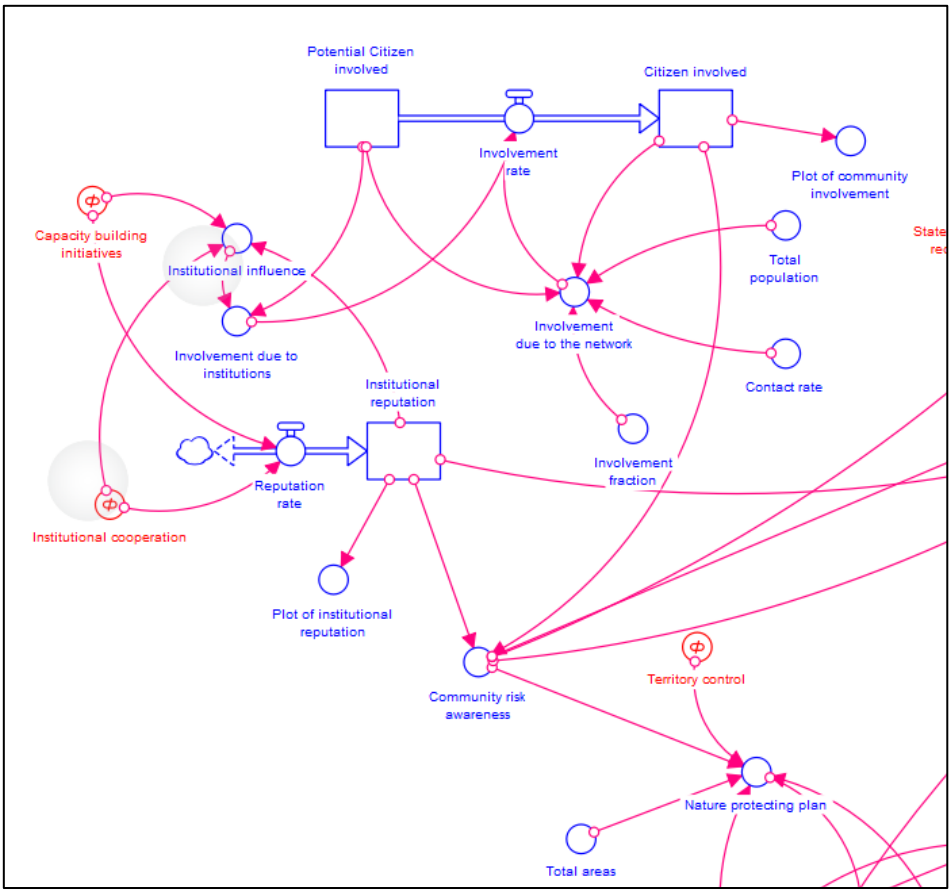

Figure 18. Socio-institutional dynamics affecting the NBS implementation and effectiveness.

As shown in figure 18, there are two elements that played a crucial role in the process, namely the capacity of the local institutions to enhance the involvement of local communities in managing water-related risks, and the reputation of the local institutions as perceived by the local communities. These two dynamics, represented as stocks in the model, are affected by two main measures, i.e. “capacity building initiatives” and “institutional cooperation”. The values of these two stocks affect key variables in the model, such as the community risk awareness and the capability of the institutions to actually control the territory and enhance the effectiveness of the plans for protecting natural areas.

Another important module in the SDM is the one related to elements affecting the risk prevention and insurance measures (figure 19).

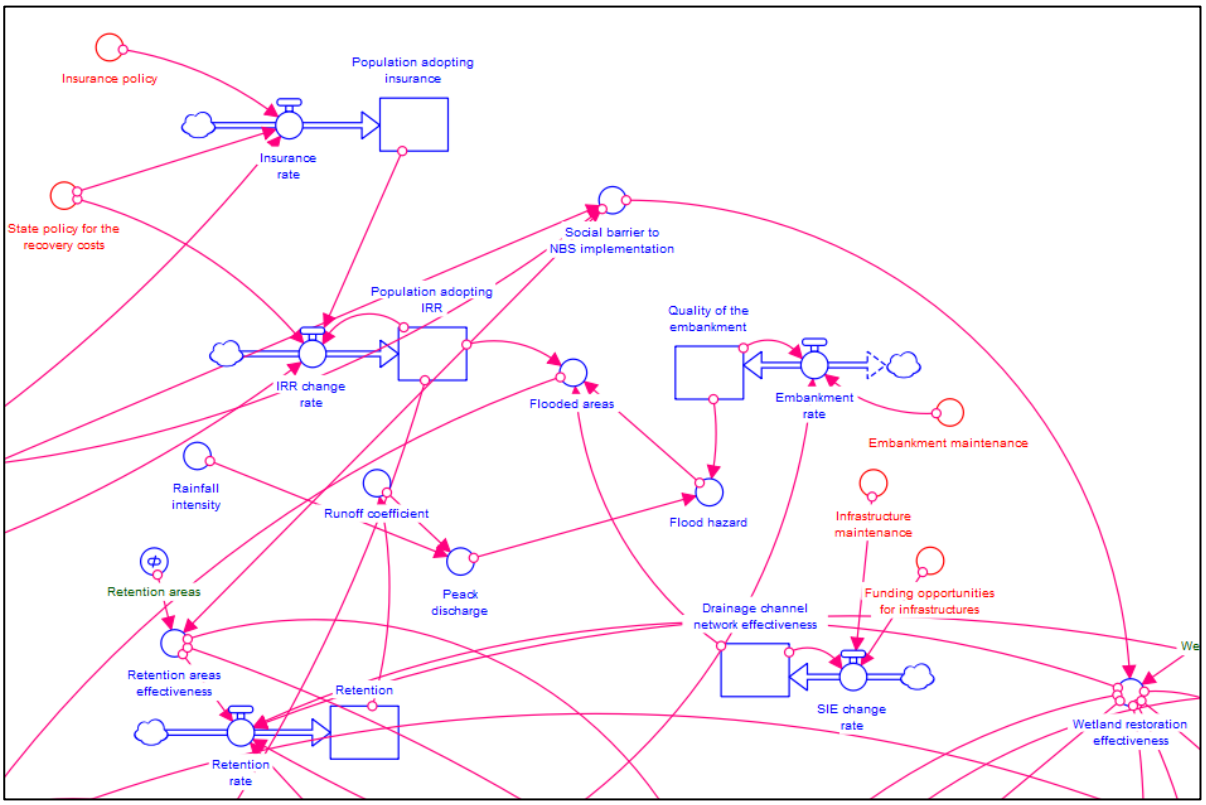

Figure 19. Risk prevention measures and insurance policies affecting the NBS effectiveness.

This module shows the elements affecting the capabilities/willingness of local community to adopt individual risk reduction measures (IRR). According to the knowledge collected in the first phase of NAIAD implementation, the state policies concerning the covering of the recovery costs represent a barriers hampering the adoption of IRR. Local communities tend to rely on the central government, and they prefer to receive the economic support from the state rather than investing economic resources for the individual measures. Thus, they will not adopt IRR, negatively affecting the capability of the system to reduce the flood impacts. Other measures mentioned in this module are those related to the potentially suitable grey infrastructures.

The last module in the model is the one related to the physical assessment of the flood and drought risks and to the land use dynamics, as shown in figure 20.

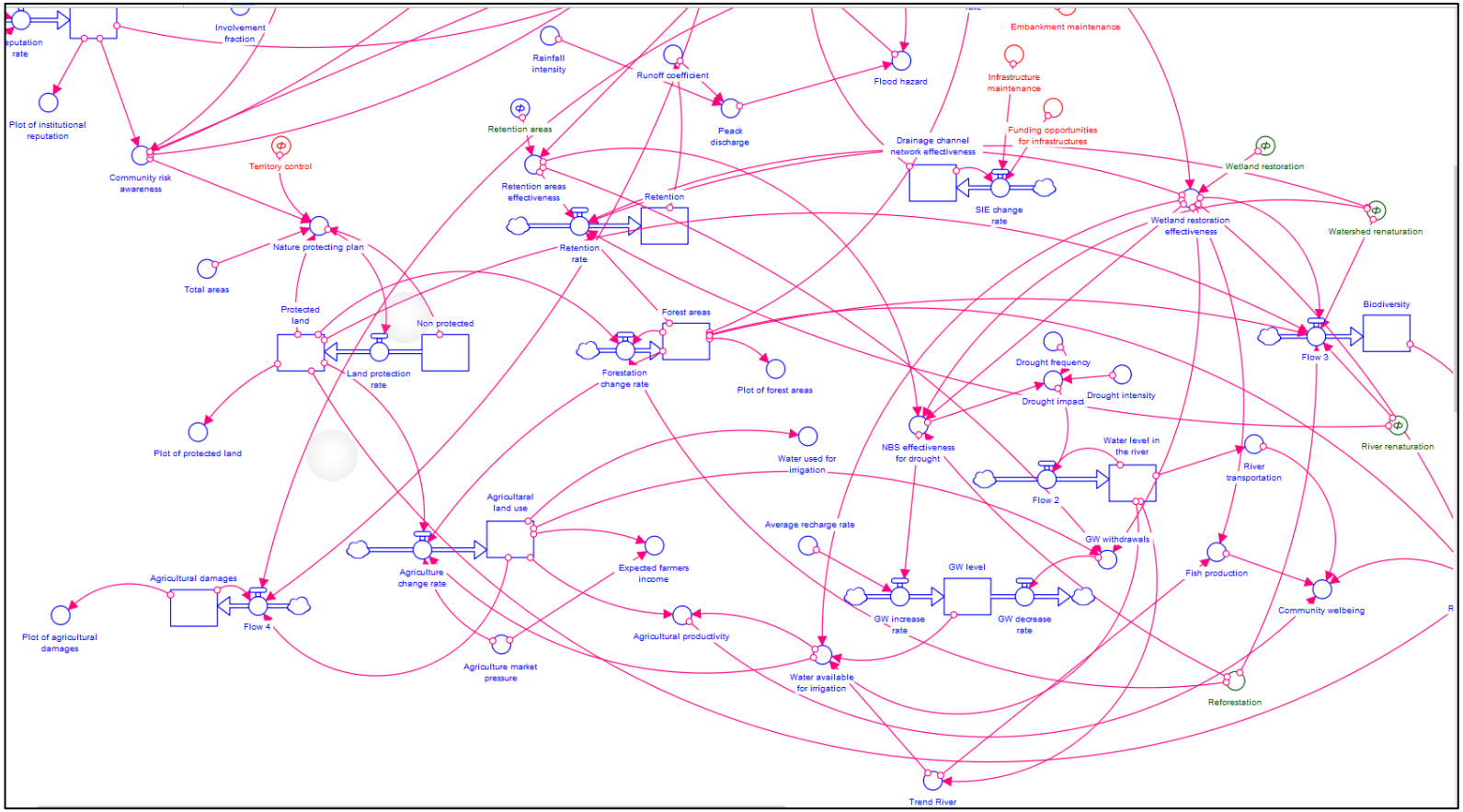

Figure 20. Physical risk assessment and land use dynamics module.

As already stated, the variables, the connections and the equations influencing the dynamic evolution of the variables were defined accounting for the stakeholders' knowledge collected in the previous phases of the project implementation. For what concerns the module of the physical risk assessment, the structure of the model and the equations were defined accounting for the scientific literature and for the knowledge of local experts. We elicited their knowledge about the expected dynamic evolutions of these variables and, then, we validated the obtained model. As soon as the NAIAD models for physical risk assessment will be available (WP2), efforts will be done to integrate these models in the SDM. At this stage of the project implementation, we assumed that a semi-quantitative assessment of the flood and drought risk, based on experts' knowledge, was sufficient for facilitating the interactions with the stakeholders.

The other elements mentioned in this module refer to land use dynamics. Considering that the study area is essentially rural, we did not account for the effects of the impervious surfaces due to the increase of the urban areas. In this module we mainly refer to the ratio between the cultivated lands and the protected territories (e.g. forest, wetland, natural areas, etc.). The lower this ration – that is, the higher is the percentage pf protected territory – and the lower the runoff coefficient. Finally, this module contains the NBS that were selected in the previous phases of the NAIAD implementation in the Lower Danube demo, i.e. wetland restoration, river renaturation, reforestation, watershed renaturation.

Stakeholders workshop for defining suitable strategies to reduce water-related risks

Similarly to the work done in the Slovenian demo, a stakeholders WS was organized in the study area in order to co-developed "strategies" for reducing the water-related risks – i.e. main benefits due to the implementation of the NBS – and the selected co-benefits. In this work, the term "strategy" is used to describe a combination of different kinds of measures, aiming at reducing the water-related risks and to enhance the effectiveness of NBS. Three sets of measures were defined for the Lower Danube demo, namely "Nature-based solutions", "soft-institutional measures", and "grey solutions". The first and the last set of measures are self-explaining. In this work we consider "soft-institutional" measures those actions that, by facilitating innovation in the institutional systems and/or enabling learning processes in the community exposed to risk, could contribute to overcome the barriers hampering the implementation of the NBS and/or reducing their effectiveness.

The WS was held in the Craiova office of the Romanian Water Authority. Around 40 stakeholders attended the meeting, representing the institutions involved at different scale in the management of flood and drought risk.

In order to facilitate the interaction with the stakeholders, an interface to the model was developed using Stella Architect ® functionalities. As shown in figure 21, the interface allowed the participants to activate or de-activate specific measures, changing the values of the variables in the model.

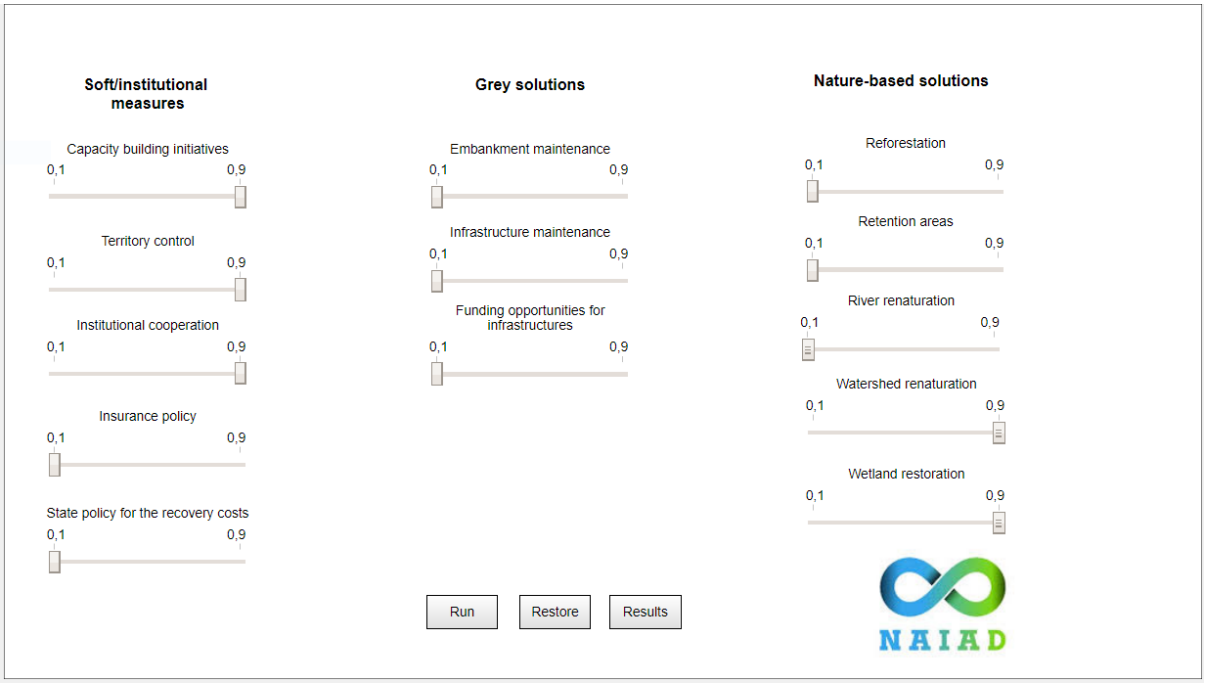

Figure 21: Stella Architect® interface developed for the Lowe Danube demo.

Participants were required to develop three different strategies, combining NBS, soft-institutional and grey infrastructures. The only limits that we asked them to keep in mind while selecting the measures were: i) each strategy had to be composed by no more than five measures (this was because we wanted to observe differences in the strategies' impacts; ii) at least one of the selected measures had to be a NBS. The following table shows the measures selected by the participants. Due to lack of available time during the WS, it was not possible to develop three different strategies, as done during the Ljubljana WS.

Table 5: Measures selected by the stakeholders for defining the strategies for copying with water-related risks.

Strategy 1	
Measures	**Type of measures**
Institutional cooperation	Soft/institutional
Wetland restoration	NBS
River renaturation	NBS
State policy for recovery costs	Soft/institutional
Territory control	Soft/institutional
Strategy 2	
Measures	**Type of measures**
Infrastructure maintenance and development	Grey
Community capacity building	Soft/institutional
Retention areas	NBS
Reforestation	NBS
Insurance policy	Soft/institutional

The model was then used to simulate the impacts of the two strategies. Figure 21 shows the impacts of the first strategy.

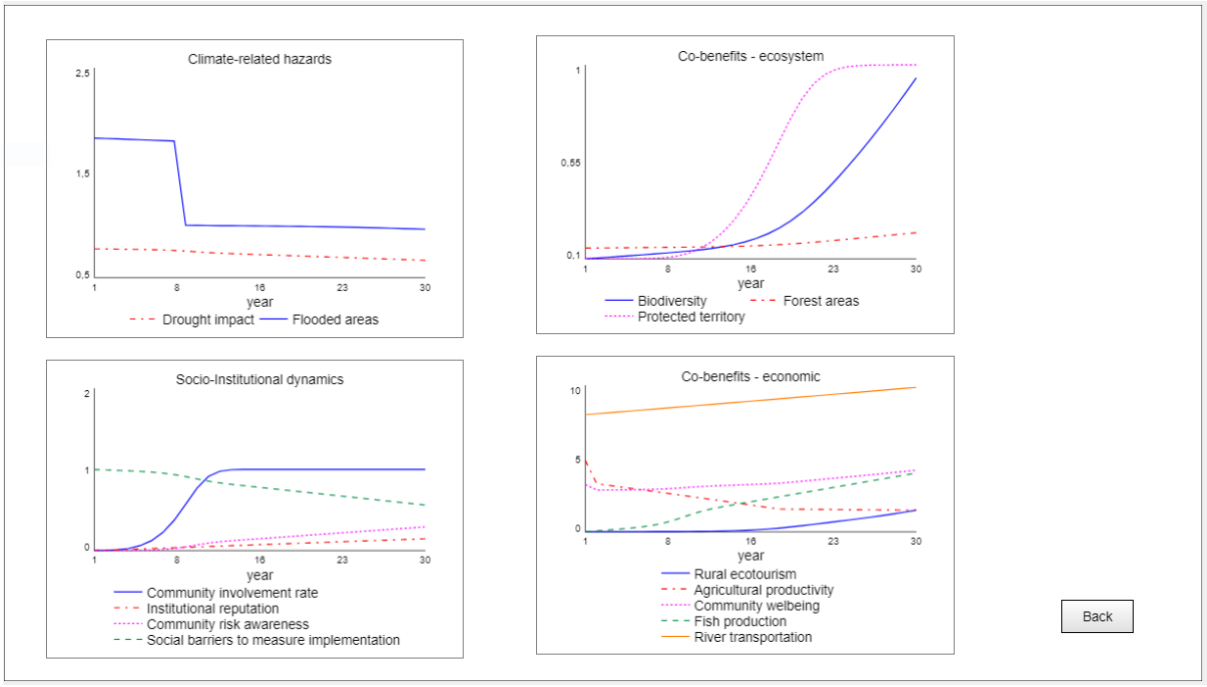

Figure 21. Expected impacts of the strategy 1.

The results of the SDM simulation were clustered accounting for the benefits and co-benefits selected by the stakeholders. As shown in figure 21, the selected measures are expected to provoke an effective reduction of the flooded areas and a slight reduction of the drought risk. Besides, the strategy will provoke a sensible increase of the biodiversity level due to the increase of the protected areas. This is mainly due to the increased capacity of the institutions to control the territory and to guarantee the actual implementation of the plans for protecting the natural areas. For the same reason, the economic co-benefits are largely positive, with the exception of the agricultural production. In the short term, the implementation of the wetland restoration and the increased control of the territory will provoke a reduction of the production. In the medium term, the capability of the wetland restoration to mitigate the drought impacts will lead to a stabilization of the agricultural production. The socio-institutional dynamics are positively affected by the implementation of the strategy. This is mainly due to the increased reputation of the institutions and their capability to involve local communities.

Figure 22 shows the impacts of the strategy 2 on the system variables.

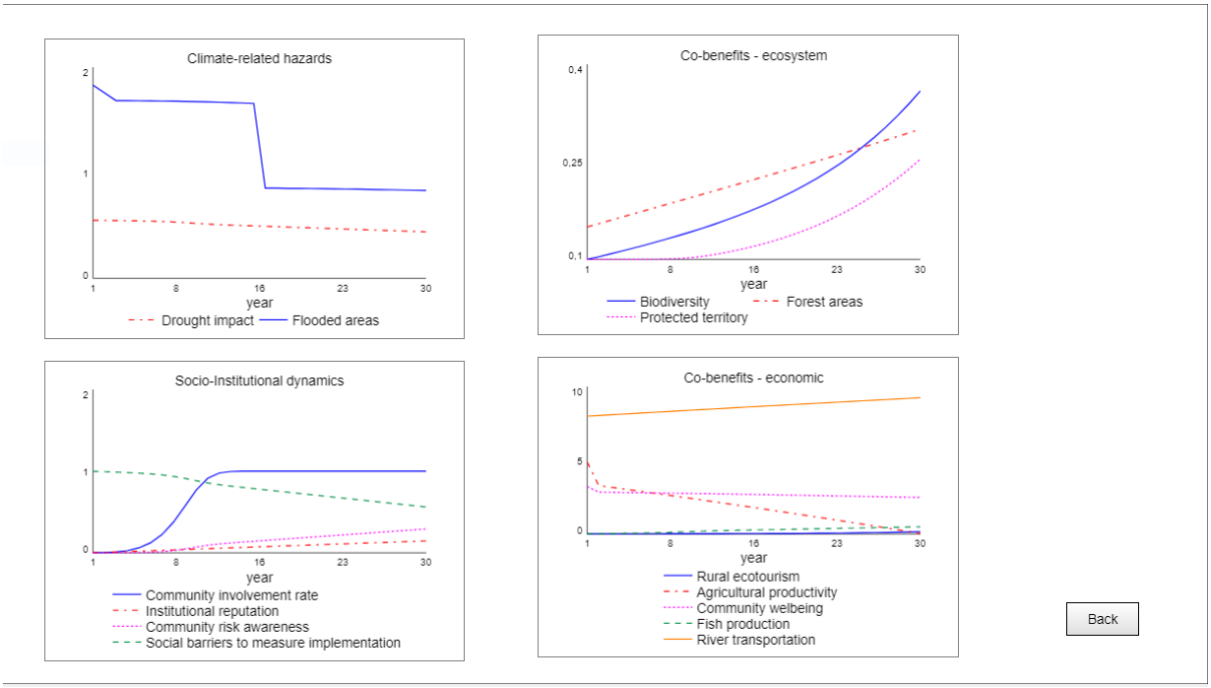

Figure 22. Expected impacts of the strategy 2.

It is worth mentioning that, compared to the strategy 1, this strategy is supposed to have very limited impact on the drought risk. This is because participants did not select effective measures in dealing with drought (e.g. wetland restoration). As consequence, the agricultural productivity will continue decreasing. Other economic co-benefits – i.e. the rural eco-tourism – are not as positive as in the previous scenario. Finally, the socio-institutional dynamics are positively affected by the capacity building measure.

The debate at the end of the workshop allowed to draw some preliminary conclusions concerning the effectiveness of the implemented method. The "take-home" lesson mentioned by most of the participants was that the design of measures for dealing with water-related risk is just one part of the story. The correct and effective implementation of those measures require addressing potential barriers due to the socio-institutional context. Therefore, the integration of soft-institutional measures and NBS is of utmost importance.

5.3 MEDINA DEL CAMPO CASE STUDY

Co-benefits definition

The definition of the most important benefits and co-benefits in the Medina del Campo case study was performed following the methodological approach described in the Section 2. The main difference was that, due also to the high number of stakeholders involved, the activity was not performed through individual interviews, but enhancing the discussion on the issue of benefits and co-benefits during group activities and allowing people to vote individually. The following Table 5 proposes the aggregated results, i.e. the average score for every element.

Table 6. Set of benefits and co-benefits identified in the Medina del Campo case study.

Expected benefits and co-benefits	Average score
Increase water availability in time and space	1.833
Water quality protection	1.5
Groundwater level increase	3.167
River environment improvement & river maintenance	1.667
Increase agriculture efficiency (inc. crop change and efficiency)	2.333
Increase forest areas with adaptive species	1
Increase agricultural productivity	1.667
Increase population well-being	1.667
Increase education and awareness	1.833
Increase institutional cooperation and information sharing	1.333
Reduction of the impacts of climate extremes - Drought	0
Reduction of the impacts of climate extremes - Heat wave	0.167
Reduction of the impacts of climate extremes - Late icing	0

Also in the Medina del Campo case study, besides some key benefits to be achieved (e.g. 'groundwater level increase', 'increase water availability in time and space', ...) the stakeholders perceive the high relevance of additional co-benefits that can be guaranteed by both NBS and soft measures, both on socio-economic (e.g. 'increase education and awareness', 'increase population well-being', 'increase

agriculture efficiency', ...) and on environmental aspects ('water quality protection', 'river environment improvement & river maintenance', ...).

Analysis of the interaction mechanisms and information sharing strategy

As already described in the D3.1, the network of interaction involving the different decision agents in the Medina del Campo demo is pretty complex, as shown in figure 23.

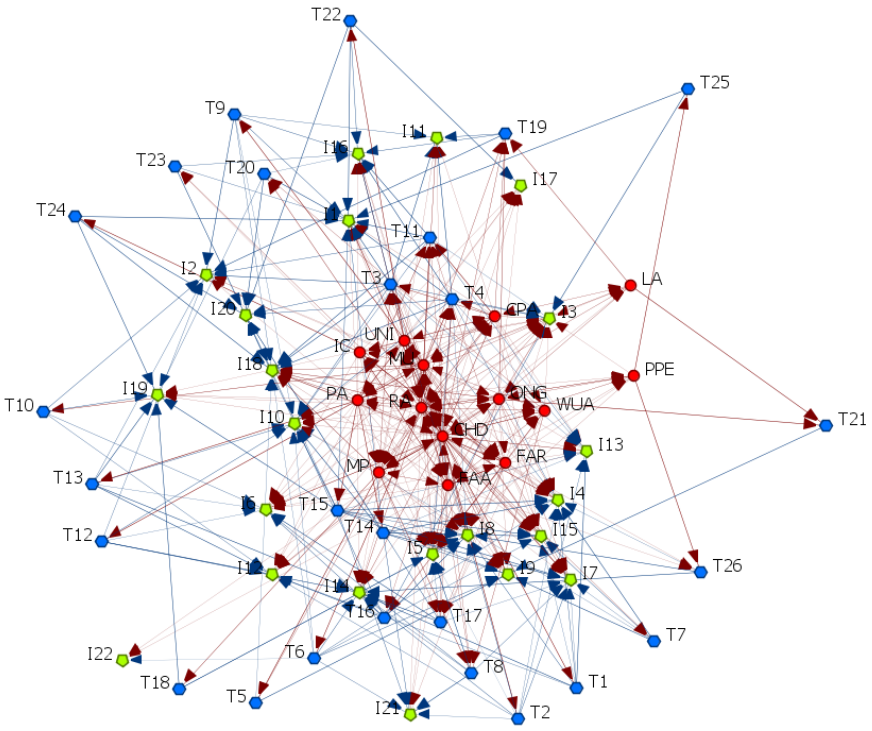

Figure 23. Organizational Map showing the connections among Agents-Information-Tasks.

The analysis carried out allowed us to detect the key vulnerabilities in the network, that is, those elements whose failure could lead to a failure and/or reduction of effectiveness of the whole network of interaction, which, in turn, could affect the effectiveness of the collaborative process for NBS design and implementation. As described in D3.1, several vulnerabilities in the network of interaction were related to farmers' behaviour and the difficulty in introducing innovation in the farming activities. The

SNA showed that this is mainly due to the lack of connections of water users associations, and their incapability to have access to key information. The main scope of this phase is to assess to which extend the vulnerabilities in the interaction network could lead to barriers hampering the implementation of NBS, and to develop policy suggestion for overcoming those barriers.

To this aim, a SDM/SNA integrated model was developed (figure 24). The model is meant to map the connections among the different agents and to simulate the impacts provoked by the flow of information on the decision-makers' decision models. Accounting for the results of the SNA vulnerability analysis, the model focuses on the interactions mechanisms involving the Water Users Association, the CHD and the Regional Authority.

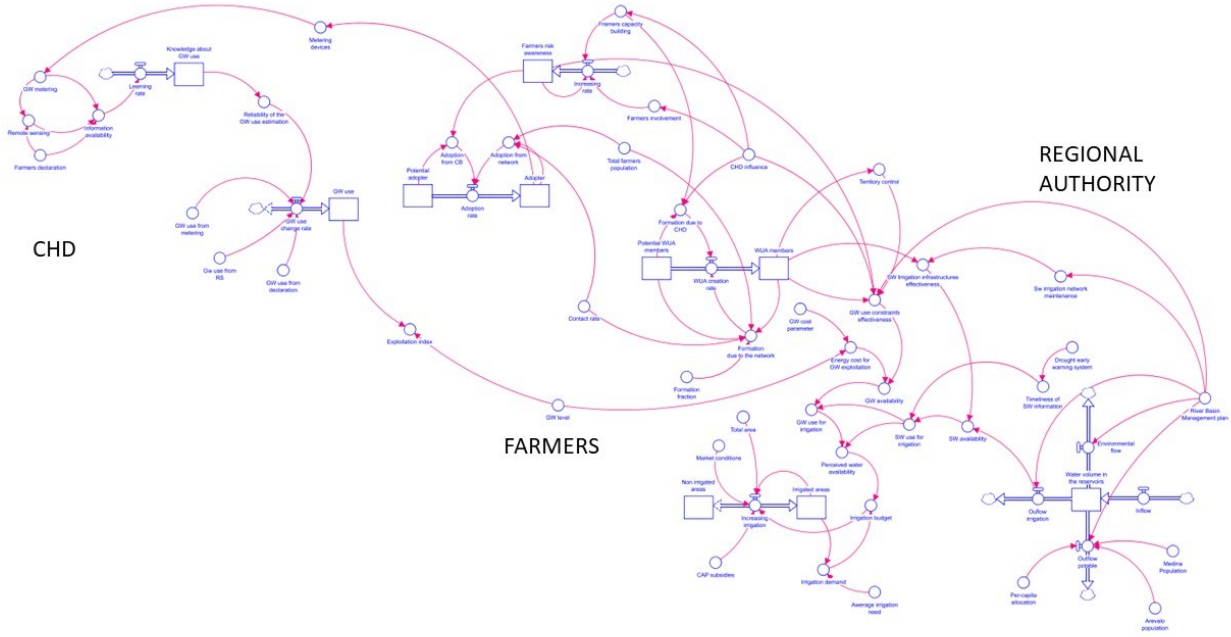

Figure 24. Structure of the SDM/SNA model describing the interactions among farmers/CHD/Regional Authority.

The analysis of the structure of the model – and specifically of the farmers' decision models – combined with the SNA results, allowed us to identify four key issues that need to be addressed prior the implementation of the selected NBS: i) enabling the Water User Association (WUA) formation; ii) providing effective and reliable information for facilitating the shift toward less water-demanding

crops; iii) reducing the level of conflicts over the water right allocations; and iv) raise farmers awareness about the GW state. The model allows us to analyse the mechanisms influencing these issues. Figure 25 shows the module describing the mechanisms of WUA formation.

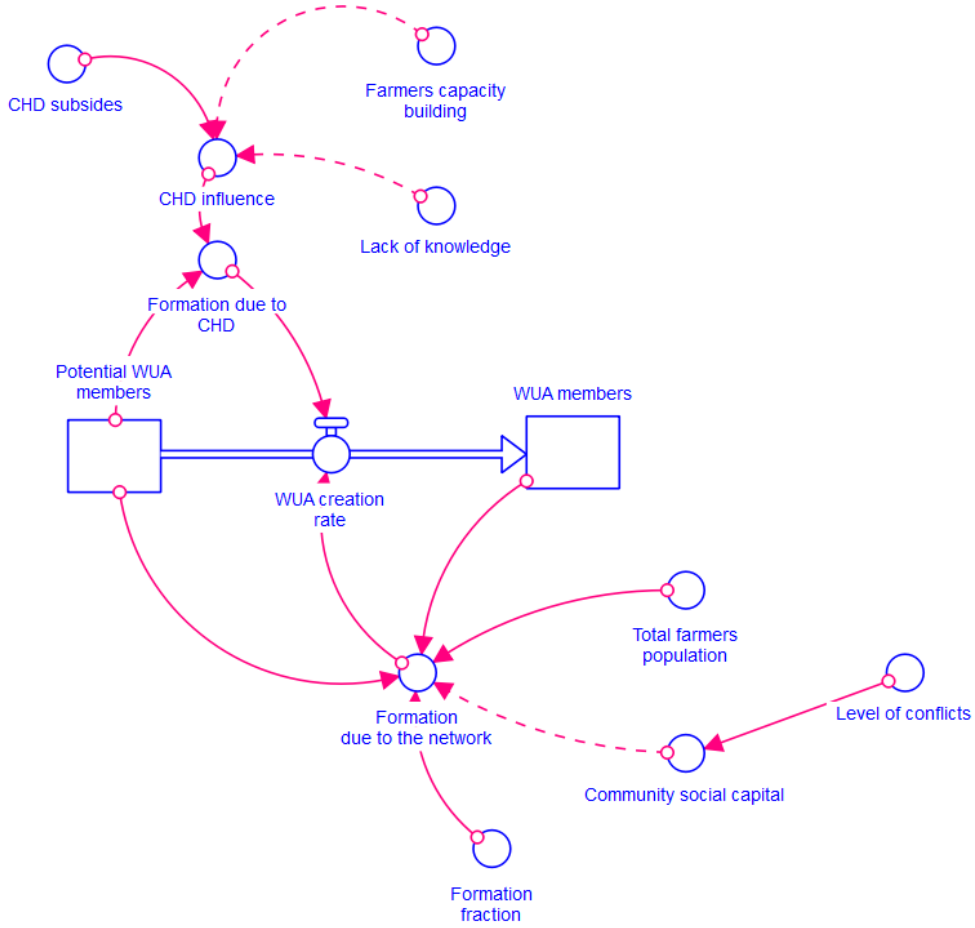

Figure 25. Variables and connections influencing the WUA formation process.

As learned during the knowledge elicitation process, the CHD is trying to speed up the process of WUA formation. This is mainly because CHD considers the WUA formation as facilitating the control of the GW use and the implementation of the GW use constraints. Moreover, the WUA formation would enhance the maintenance of the surface water (SW) irrigation infrastructure. This, in turn, would reduce the pressure on the GW. Figure 18 shows the feedbacks mechanisms influencing the WUA formation. The well-known "potential buyers/buyers" archetype was used to model the WUA formation (Sterman, 2000). That is, at stage 0 the farmers' population is in the "Potential WUA members" stock. The "WUA creation rate", that controls the shift from potential WUA members to

WUA members, is influenced by two main elements, namely, the CHD influence and the network influence. The former describes the role that the CHD could play in influencing the farmers' choice to be part of a WUA. The latter describes the role of the "world of mouth", that is the capability of the farmers to influence each other's decisions through the social interactions. The dotted lines represent the information connections, that is link moving information from one variable to another.

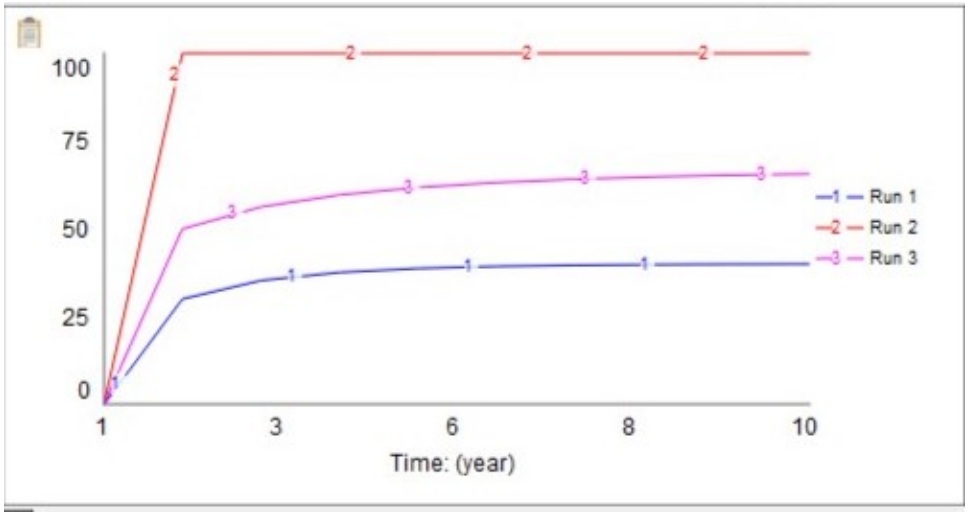

Figure 26. WUA formation process.

Figure 26 shows the dynamic evolution of the WUA formation process according to the value of the variables "CHD influence" and "formation due the network". The different lines refers to state of the WUA member variable according to the different inputs. The line 2 show how fast and effective the process of WUA formation could be in case of the availability of CHD subsides and of the implementation of capacity building initiatives. Line number 3 shows to slow process of WUA formation in case of low level of CHD influence. Finally, line 1 shows that WUA will not be formed if the farmers will still be characterized by high internal conflicts.

Another import elements affecting the GW management and protection in the Medina demo is the effectiveness of the GW use constraints. As learned during the knowledge elicitation phase, CHD can enforce limits to the use of GW if the exploitation index exceeds a certain threshold. Nevertheless, the effectiveness of this measures relies on the farmers' behaviour and on the CHD capability to control the territory. Concerning the first point, the model shows the role of the farmers' risk awareness (figure 27).

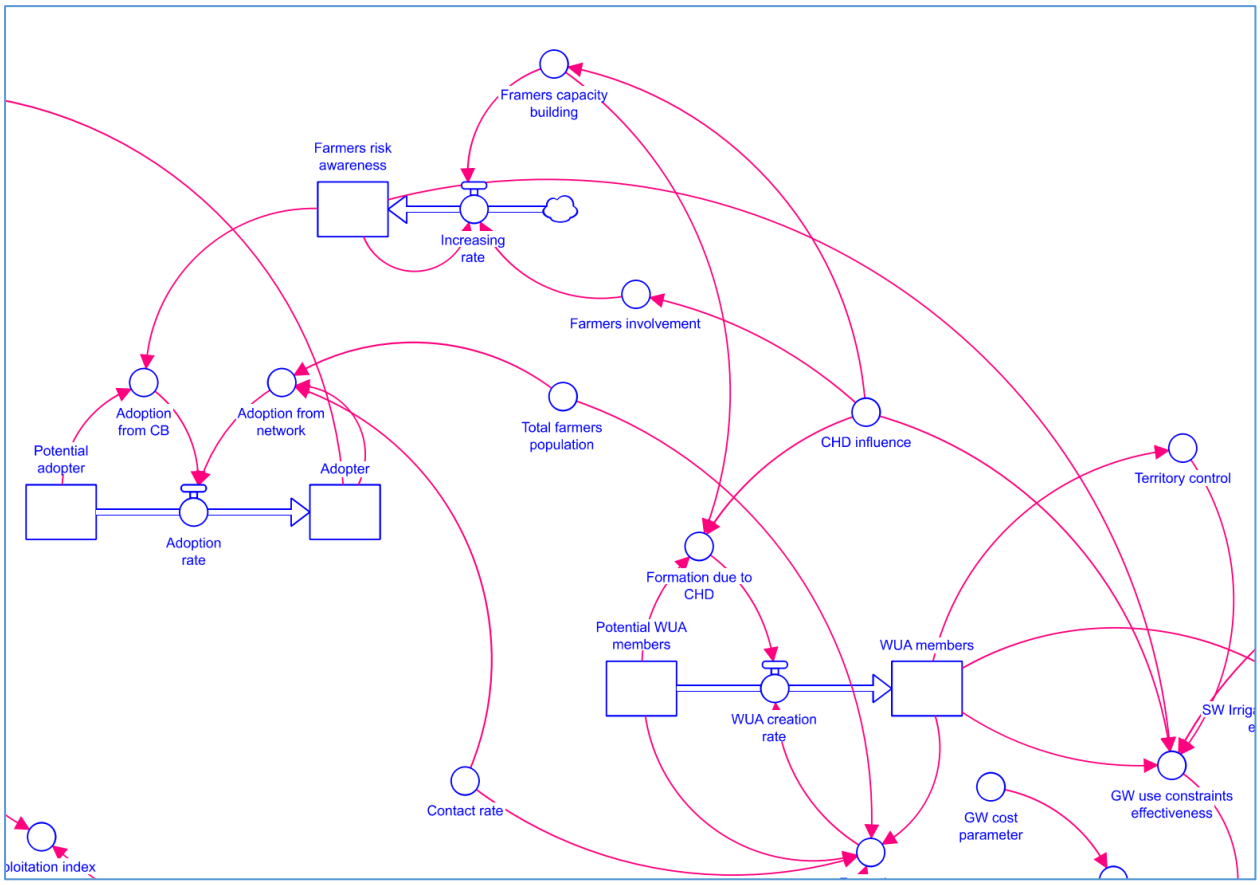

Figure 27. Elements influencing the effectiveness of the GW constraints.

Farmers' risk awareness has a twofold role in affecting the GW use constraints. On the one hand, it reduces the risk of conflicts between farmers and CHD due the enforcement of the GW constraints. On the other hand, raising the farmers' risk awareness could facilitate the diffusion of the GW metering within the farmers' community.

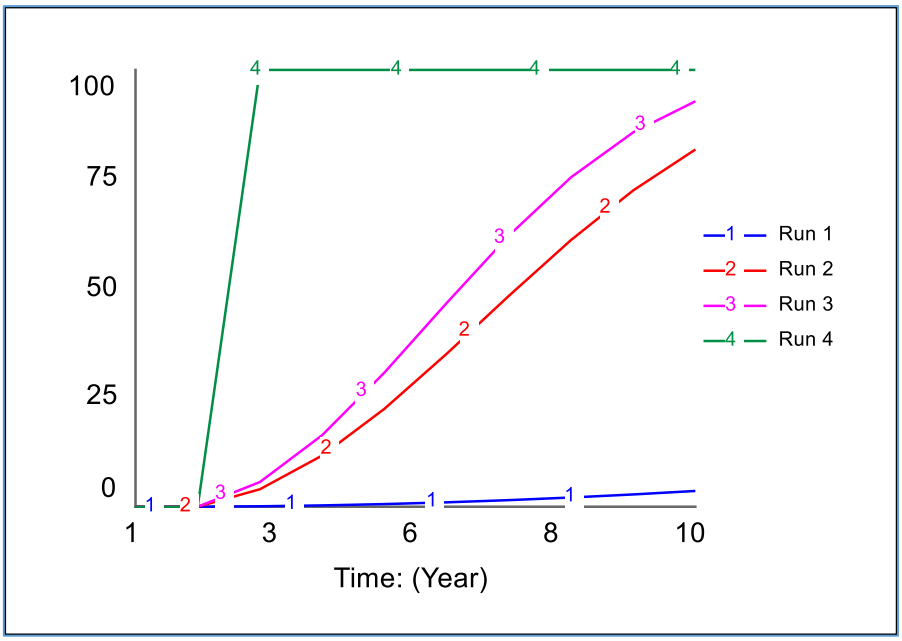

Figure 28. GW metering adoption process.

Figure 28 shows how the process of GW metering adoption becomes faster and more effective in case of increasing farmers' risk awareness. The model shows that an increase of the GW metering would have a positive impact on the CHD knowledge about the state of the GW and, thus, on the legitimacy of the policies concerning the GW protection. Besides, the GW metering diffusion could increase the capability of the CHD to control the territory.

Finally, the role of information in influencing the crop selection process was simulated. Figure 29 shows the module in the SDM.

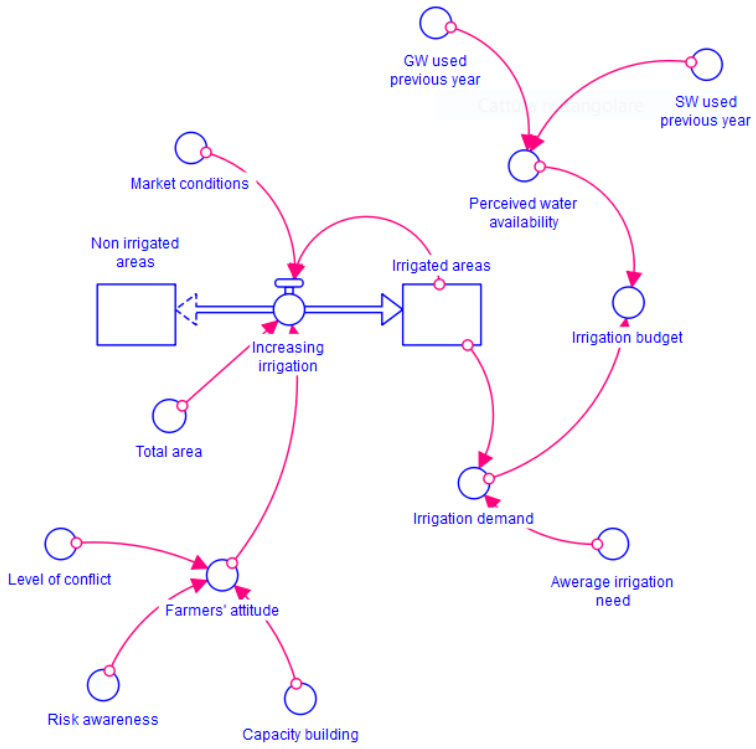

Figure 27. Elements affecting the crop selection.

The module is capable to simulate the farmers' decision-making process concerning the portion of the farm to be irrigated. According to the knowledge collected during the previous phases of the project implementation, the farmers' choice is based on the market conditions, the perceived water availability (based on the water volume used the previous year) and on the farmers' behaviour. The latter variable is affected by the risk awareness and the implementation of capacity building. Besides, the level of conflicts within the farmers' community affected the farmers' behaviour. In this case, farmers tend to act as based of selfish interests. Figure 28 shows the evolution of the "irrigated areas" variable in three different conditions, i.e. unfavourable market conditions (line 4), low level of farmers attitude (line 2), and favourable market conditions.

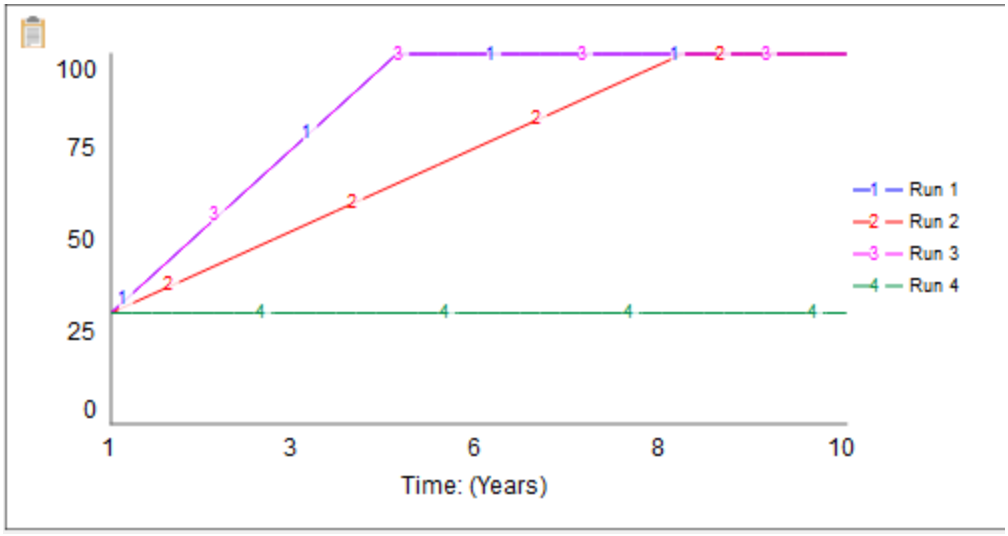

Figure 28. Dynamic evolution of the irrigated areas.

The graph in figure 28 shows that, in case of market conditions favourable to the irrigated crops, implementing capacity building exercises and risk awareness measures could slow down the increase of the irrigated areas.

Summarizing, the developed model allows us to demonstrate that, in order to overcome the barriers detected through the implementation of the SNA, the involvement of the farmers through risk awareness campaign and capacity building exercises could have several benefits on GW protection effectiveness and, thus, on the NBS implementation.

These hypothesis, developed through the SNA/SDM analysis, were at the basis of a stakeholders WS, that was held in Arevalo on the 11th of December. The main scope of this discussion was to co-design innovations in the interaction mechanisms and information sharing processes in order to overcome the above mentioned barrier to the implementation of the NBS in the Medina del Campo demo. Four main questions were asked to the stakeholders:

- What kinds of information should be provided in order to enable the WUA formation? Who should be involved in the information sharing process?
- What kinds of information should be provided to farmers in order to enable the change toward less water-demanding crops? Who should provide this information?
- What kinds of innovation should be introduced in order to reduce the level of conflicts over the distribution of the water rights?

- What kinds of innovations should be introduced in the interaction network in order to raise community awareness on the GW state?

The results of the discussion have still to be analysed. Figure 29 shows the results obtained during the WS.

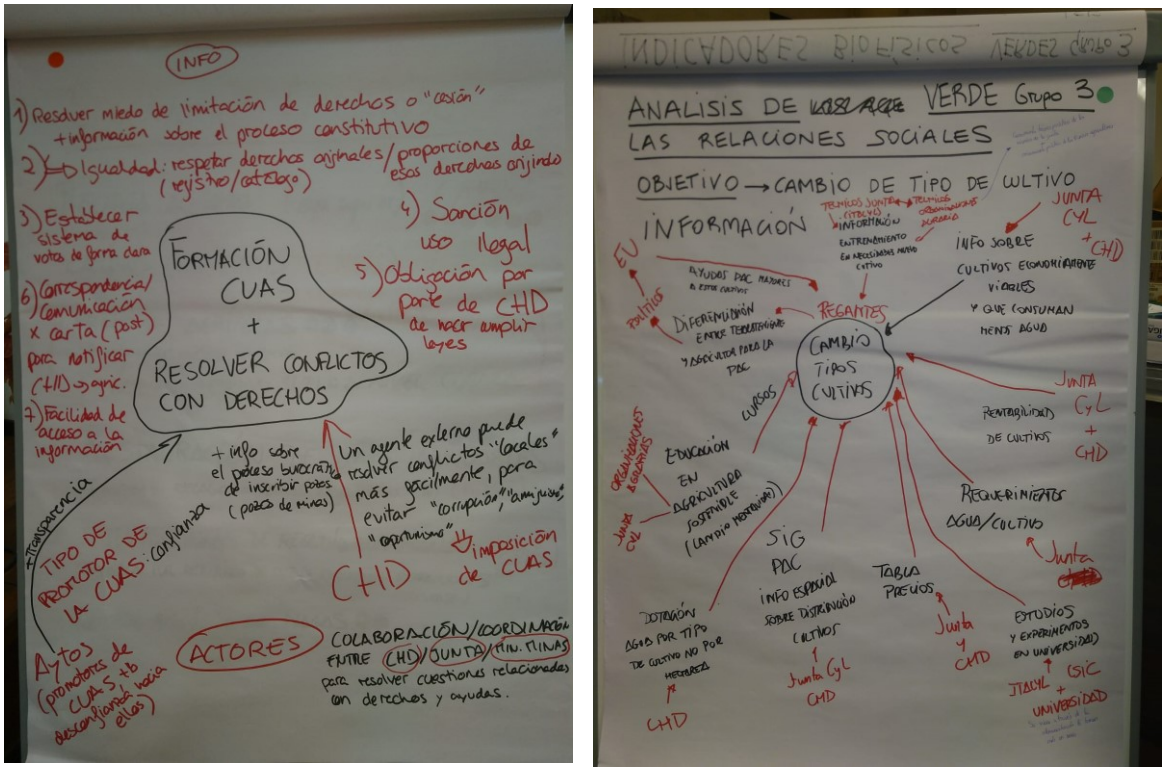

Figure 29. Preliminary results of the Medina del Campo stakeholders WS.

6. CONCLUDING REMARKS

The activities carried out in the NAIAD demos and described in this work demonstrate that, in order to enhance the social acceptance of NBS, effective information sharing and communication strategies need to be developed and implemented. The effectiveness of these strategies depends on two main elements, i.e. the contents of the information sharing and the mechanisms of interaction.

Concerning the first point, the activities carried out in the NAIAD demos demonstrated that involving the stakeholders in the definition of the co-benefits that need to be produced, and connecting those co-benefits to their main concerns – i.e. risk perceptions – is of utmost importance in raising the stakeholders' awareness concerning the NBS effectiveness. Efforts have been made to integrate the

stakeholders' driven co-benefits with those mentioned in the scientific literature. This contributed to fill the gaps between scientists and local communities in NBS design, implementation and evaluation. An interesting results of the activities carried out in the demos concerns the increasing awareness of the need to implement integrated risk management strategies, putting beside NBS and soft/institutional measures, in order to produce the expected benefits and co-benefits.

Concerning the second point, the results of the SNA about the main vulnerabilities of the interaction networks were used to develop a SDM/SNA model capable to simulate the interaction among the decision and actions taken by the different decision-agents. At this stage of the project implementation, the model has been developed for the Medina del Campo demo. In this case, the model shows great potentialities in supporting the definition of policies to enable the information sharing and the learning process for NBS design and implementation process. The results of the SDM/SNA model were used as starting point of the co-creation process, aiming at defining innovative interaction mechanisms for overcoming the main barriers to the NBS implementation.

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