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Three Essays on participatory processes and Integrated Water Resource Management in developing countries

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Tesi di dottorato di LUCIA CECCATO, matricola 955415

Coordinatore del Dottorato
Prof. Fabio Pranovi

Tutor del Dottorato
Prof. Carlo Giupponi
Ca' Foscari University of Venice, IT

Co-tutor
Prof. Yvonilde Dantas Pinto Medeiros
Universidade Federal da Bahia, BR

Om asato mā śad gamaya
Tamaso mā jyotir gamaya
mrityor mā amritam gamaya
Om śānti śānti śāntih
(Brhadāranyaka Upanisad 1.3.28)

From ignorance, lead me to truth;
From darkness, lead me to light;
From death, lead me to immortality
Om peace, peace, peace

Three Essays on participatory processes and Integrated Water Resource Management in Developing Countries

LUCIA CECCATO

PhD Program in Analysis and Governance of Sustainable Development

Ca' Foscari University of Venice & School for Advanced Studies in Venice Foundation

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Short Abstract

The dissertation is a collection of three essays. The first essay is a literature review of participative and IWRM practices in the specific context of the Federal Republic of Brazil, chosen as case study for its modern water management legislation, embracing IWRM paradigms. The essay presents the Brazilian institutional and legislative system, and reviews how different participative approaches have been applied in some states of this country, underlining the criticalities that obstacle an effective development of participatory practices in water management. The second essay presents a methodological proposal aimed at improving the effectiveness of interactions between the scientific community and local actors for decision-making processes in water management, in two case studies, in Europe and Asia: the Upper Danube and the Upper Brahmaputra River Basins. The study explores the utilization of Decision Support System tools and Multi Criteria Decision Analysis to facilitate transparent and robust management of information, and to prioritize problems and solutions in an integrated perspective. The third one focuses on the participatory process to support scientific multidisciplinary research; it explores the utilization of a semi quantitative method to structuralize the cognitive maps of a group of experts. The research utilises the tool of Fuzzy Cognitive Maps to guide the construction of system understanding and to improve the effectiveness of the Building Block methodology for the environmental flow assessment of a river. The application is tested to the Lower Paraguaçu River Basin and Iguape Bay (Bahia, Brazil).

Estratto

La tesi è una raccolta di tre saggi. Il primo saggio è una revisione della letteratura sulle pratiche partecipative e di Gestione Integrata delle Risorse Idriche (IWRM), nello specifico ambito della Repubblica federale del Brasile, scelto come caso di studi per la sua legislazione moderna sulla gestione delle acque, che abbraccia i pradigmi di IWRM. Il saggio presenta il sistema istituzionale e legislativo brasiliano, analizza come i diversi approcci partecipativi

sono stati applicati in alcuni Stati del Paese, sottolineando le criticità che ostacolano un efficace sviluppo delle pratiche partecipative nella gestione dell'acquea. Il secondo saggio presenta una proposta metodologica per migliorare l'efficacia delle interazioni tra la comunità scientifica e gli attori locali nei processi decisionali nella gestione delle acque. Il lavoro é stato sviluppato in due casi di studio, in Europa e in Asia: i bacini idrografici del alto Danubio e dell'alto Brahmaputra. Lo studio si avvale dell'utilizzo di strumenti di supporto decisionale e di analisi muliti-criterial per facilitare una gestione solida e trasparente delle informazioni e individuare le priorità e le possibili soluzioni con una prospettiva integrata. Il terzo saggio si concentra sullo studio del processo partecipativo finalizzato a supportare la ricerca scientifica multi-disciplinare, ed analiza l'utilizzo di un metodo semi quantitativo per struttuare le mappe cognitive di un gruppo di esperti. La ricerca si avvale dello strumento di Mappe Cognitive Fuzzy, come quadro intermedio verso l'attuazione della modellizzazione degli ecosistemi, applicata alla valutazione del flusso idrico di un fiume. L'applicazione è testata per il basso bacino del fiume Paraguaçu e la baia di Iguape (Bahia, Brasile).

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INTRODUCTION TO THE DISSERTATION

The intrinsic complexity of water resource and the multiplicity of physical and social elements depending on it, make water management to be a very difficult and a challenging concern. Water management systems - and natural and socio-economic systems in general - can be described as complex and adaptive systems (CACs), where system components are interacting with each other and with the environment, at multiple temporal and spatial scales, modifying their behaviour to adapt to environment changes (Rammel et al. 2007). CASs are non-linear systems, where the "whole is more than the sum of its components" (Holland, 1995) and where local agents, by interacting with each other, adapting and co-evolving, produce a global behaviour that cannot be foreseen at the local level. This concept is well known in ecology as *emergent property*, that means that when systems components are combined to produce larger functional wholes, new properties emerge which were not present at the level below (Odum and Barrett 2005), and that do not manifest themselves unless the system is examined in its entirety. This implies, in other words, a *non-reducible property*, i.e the property of the whole is not reducible to the sum of the properties of the parts. The integration and interrelation of the individual components of an environment or of a system, create distinct, collective and interactive, properties and functions.

The sustainable management of such systems, therefore, characterized by a high level of complexity, cannot be based upon a static objective but has to be an open process of continue understanding and has to be able to deal with different temporal, spatial and social scales, nested hierarchies, irreducible uncertainty, multidimensional interactions and emergent properties (Rammel et al. 2007). This emphasizes the need of adopting an integrated approach for the analysis of both social-economical agents and the natural components of the ecosystem, and stresses the importance of enhancing participatory stakeholders' processes through greater transparency and a shared contextual understanding (Rammel et al. 2007). Such an integrated approach of analysis is one of the objectives of Integrated Water Resource Management (IWRM).

IWRM was encouraged as an alternative to the sectorial top-down management, and a way of managing increasing degrees of variety (diversity) and variability (dynamics), typical of complex systems. Indeed, the call for a change towards ecological and ecosystems approaches in water resources management led IWRM to turn into a dominant paradigm since the 1990s.

The International Conference on Water and Environment, in Dublin in 1992 (ICWE 1992), gave rise to four principles - known as Dublin Principles - that inspired many water sector reforms and became the foundation of IWRM. Dublin principles recognize fresh water as a finite and vulnerable resource, essential to sustain life, development and environment, and endowed with an economic value, proclaiming the need of participatory approach in water management, involving users, planners and policymakers at all levels.

The term IWRM implies the inclusion of a full array of physical, biological, and socioeconomic variables involved in the development and management of water, land and related resources. The objective of IWRM is to tackle all the dimensions and scales involved when dealing with such a crucial and scarce resource, in relation to environmental and human impacts, recognizing river basins as complex systems. The basin is seen as an integrated ecological system, in which human impacts represent one component of its functioning.

Such a coordinated management should attempt to maximize the economic and social welfare, in an equitable manner without compromising the sustainability of vital ecosystems (GWP, 2000). IWRM approach aspires to find a suitable balance between socio-economic needs and the capacity of the environment to withstand potential or current impacts. This underpins an interdisciplinary and integrated approach, which considers multi-dimensional criteria and objectives (i.e. economical opportunities, ecosystem and biodiversity integrity, social and cultural concerns, equal distribution of cost and benefits, political priorities, etc.), spatial integration of the concerned areas, multi-scale evaluation of drivers (both natural and anthropogenic), and a comprehensive involvement of social actors (Giupponi et al., 2006), through participative processes that promotes partnerships among stakeholders and government agencies.

The use of participatory approaches is one of the fundamental and indispensable elements of IWRM (GWP, 2000). If integration is at the base of the IWRM principles, participation, in turn, is a key component of 'IWRM in practice' (Molle 2008).

Participatory processes can be conceptualized in a variety of forms, they could assume different meaning and could be transformed in practice in several manners, with the involvement of a variegate range of subjects. Even if the idea of dialogue and inclusion of common people in the decision-making is intuitively appealing, the concept embraces a broad array of approaches to public involvement that gives to participants different amounts of control and influence over decisions, as well as different functions according to the involved interests (Goodwin 1998).

The definition of participation has changed over time, according to the development of theories and practice (Conge 1988, Drijver 1991). As Lawrence (2006) mentioned, the word 'participate', from the simple meaning of 'to share or take part', becomes a term loaded with social, ideological, political and methodological meaning. The author recognizes two historical elements in this development: from one side, the growth of public participation in environmental decision-making in industrialized countries; on the other, a more action-oriented approach of community participation, related to the development of poorer countries. The former tends to be used over large areas, and to be mainly consultative. The latter tends to be more site-specific, and oriented to communities involvement and social empowerment.

The concept of public involvement has often a vague definition that allows agencies and governments to interpret individually the extent of and need for it. Indeed, public involvement strategies and techniques are not always grounded by a common philosophy or set of norms.

Public participation can take place in various stages of the decision process, with different structure and timing, regarding different types and levels of decisions and involving - and consequently excluding – a subjective selection of public. Stakeholders involvement can be applied for example in the phase of problem definition, or variables selection and development, data collection and integration, scenario development, interpretation of results, and development of policy alternatives. Moreover, the way and the rules of managing the participation process could differ between approaches and methods.

The literature offers abundant reviews of participation concept and stakeholders' engagement, typologies and instruments or methods for its implementation (Lynam et al. 2007, Reed 2008, Lawrence 2006, Pretty et al 1995, Voinov and Bousquet 2010). Participation typologies have been studied to understand the differences between their application and their associated approaches and methods, and to recognize the contexts in which they are most appropriate (Reed 2008).

The notion of participation can be intended, in general terms, as a process which involves different actors with different perspective or knowledge or interests, without referring necessary to the specific audience of stakeholders. This, for example, is applied in the participatory integrated assessment (PIA) in order to integrate information and interdisciplinary knowledge, broaden points of view, verify information gaps, develop scenarios, and bridging scientific knowledge with the decision-making process (Toth and Vos 2001). PIA methods are usually oriented to stakeholders' inclusion, even so they tend to follow a top-down approach, driven by scientific researchers. The implementation of participatory studies has been described also under the umbrella of participatory action research (PAR) approach (Voinov and Bousquet, 2010). The PAR approach differs somehow from PIA because it is strongly bottom-up oriented, it is driven by community and stakeholders and set off by social activists (Voinov et al. 2004), but the concept of participation is still characterized by the interaction between researchers and informants.

A broader concept of participation is adopted in participative decision making, which is implemented through a bottom-up approach, where the so called stakeholders play a active role in the decision-making process, facilitating – in theory - more democratic and legitimated decisions. Stakeholders' participation is one of IWRM fundamental principle and implies a more specific conception of participation, which in fact seeks to involve all those actors that, directly or indirectly, have their interests involved in the decision/problem. Scholars investigating participatory processes generally recognizes that engaging participants in as many phases as possible and as early as possible, drastically improves the value of the results (Reed 2008), in terms of its usefulness to decision makers, its educational potential for the public, and its credibility within the community.

Some other distinctions in its definition have been made.

Goodwin (1998) distinguishes between an instrumental approach to participation, used as a management tool to accomplish a predetermined product and a transformative participation, where people are a 'local voice' to be heard and not only consulted and where participation is a process in which the objectives are not established in advance, but come out from the act of participation itself.

Pretty et al. (1995) consider the following types of approach:

- Passive participation, in which the objective is just to inform people;
- Extracting participation, which extracts information from people for the scientist who needs data;
- Supportive participation, aimed at supporting the decisions in which stakeholders are used to promote and articulate the chosen decisions;
- Interactive participation, where stakeholders share the diagnostic and analytical methods and tools or results;

- Self organization, where the lessons from the participatory process are transformed into decisions by the stakeholders themselves.

Lynam et al (2007), divide the approaches for involving local views and perspectives into three classes:

- diagnostic and informing methods that extract knowledge, values, or preferences from a target group to understand local issues more effectively and include them in a decision-making process (Extractive use);
- co-learning methods in which the perspectives of all actors change as a result of the process, and the information created is then passed to a decision-making process;
- co-management methods in which all participants are learning and are included in a joint decision-making process.

The extractive type of participation doesn't have exactly the same meaning in Pretty and Lynam definitions. Although in both ones stakeholders are not part of the decision making process, Pretty talks about extraction of information from stakeholders for research structuring, while Lynam is referring to the extraction of results for the decision making process (Voinov and Basquet 2010).

Lawrence (2006) distinguishes between four types of participation:

- consultative and more clearly exploitative type, where the whole power is held by the centre;
- functional approach, where knowledge and labour are shared, but decisions still remain with the centre;
- collaborative approach where knowledge and labour are shared and central and local actors share decisions.
- transformative type where participants control the process.

Taking into consideration the above distinctions in the participation concept, **Table 1** presents a structured synthesis and re-elaboration of the different definitions and key aspects that define participatory processes. The column 'type of participation' reports the terminologies used in literature, while the other ones schematize the aspects characterizing each approach, specifying if the outcome of participation leads to a binding decision or is taken as orientation, the objective, the scale and the type of actors involved in the process and so on..

Informative is defined when participation is used to communicate some decisions. *Extractive-Consultative*, when participation serves to pure information extraction. *Extractive-Functional*, when participation used to extract information in order to structure and influence the study process, even if final decision will be not shared. *Transformative-Co-learning* when, during the participation process, participators, researchers and decision makers can learn one from each other. *Transformative-Co-management*, when participants have the power to control the decision-making process and the final decision.

Level of public engagement	Type of participation		Influence on decisions	Objective (examples)	Actors involved	Scale
	Informative	top-down	Orientation	notification (decision already taken)	Society	Local, Basin, State, Inter-state, National, International
	Extractive-Consultative			consultation	Experts, Key Actors, Specific class of SH, Representatives of all SH, Society	
	Extractive-Functional			problem characterization	Experts, Key Actors, Specific class of SH, Representatives of all SH, Society	
				objective definition		
				variable selection		
				validation of hypothesis		
				scenario development		
	Transformative-Co-learning	Bottom-up		interpretation of results	Experts, Key Actors, Specific class of SH, Representatives of all SH, Society	
				development of policy alternatives		
	Transformative-Co-management		Binding	development of policy alternatives	Representatives of all SH, Society	
				solution elicitation		

Table 1: synthesis of approaches and key aspects that characterize participatory processes

The first column shows that the level of public involvement increases towards the bottom, from a participation dire to provide information towards a more collaborative decision-making. This does mean that one is more important than the other, what is important is to select the proper level of participation for a particular objective. All types of these approaches could potentially be appropriate and useful, depending on the specific context of application. However, participatory methods *per se,* do not guarantee the quality of output and the achievement of the desired objectives.

The success in the use of participative methods depends on the adequacy of the approach and of the methods utilized with respect to the planned objective, the individuals involved in the process, the ability of the facilitator and the context where they are applied. The underpinning philosophy, principles and values could be applied to different contexts, but all other aspects regarding methods must be adapted by practitioners (Pretty et al. 1995). There are various competing requirements that practitioners require in relation to participatory tools, such as standardization vs. flexibility or the often conflicting goals of knowledge or data extraction vs. empowerment researchers attempt to find the most appropriate methods to suit their objectives. Reed (2008) offers a synthesis of experience to guide potential users as to the strengths, weaknesses, and capabilities of these tools despite their widespread use. Voinov and Bousquet (2010) point up some common principles shared by most successful cases of participatory practice and offer practical indications for implementing and managing such a process.

Furthermore, beside the approaches and key features considered above, an extended set of possible methods and tools can be utilized in participatory processes. Participatory methods range from the most simple ones, like Individuals Interviews, Brainstorming, Focus Group, Card Sorting, Community Based Research, to a medium complexity, like Forums, Citizen's Jury, Cognitive Mapping, to more complex ones like Participative Multi Criteria Analysis, Bayesian Belief Networks or Group Model Building or Pariticipatory Ecosytem Modelling. (Evans et al 2006, Lynam et al. 2007, Rao and Velarde 2005, Van Asselt and Rijkens-Klomp 2002).

1.1 IWRM and participation in developing countries

IWRM general principles and values and stakeholder participation have been broadly promoted and shared by the scientific community, scholars and policy-makers worldwide, spreading its practice in a multitude of different contexts and case studies. Its paradigm inspired many national water legislation framework, international agreements, and planning programmes, it oriented international agencies, NGOs, water related associations, and is the object of investigation of an enormous number of scientific publications, and educational courses.

Despite the broadly recognition of IWRM general principles and values by the scientific community in the last decade, it has been produced also an increasing literature questioning several critical aspects in IWRM implementation, especially in the context of developing countries (Biswas, 2004, Lankford et al. 2007, Merrey 2008, Molle 2008, Van der Zaag 2005)

Although the broad, all-embracing IWRM definition appeared remarkable, it was objected to have little practical resonance on the present or on the future water management practices (Biswas, 2004).

The principles underlying IWRM may be commonly applicable, independently of context and socio-economic conditions; however, there is no universal way on how such principles can be put into practice GWP (2000). The differences in the nature, character and intensity of water problems, the availability of resources, the socio-economic needs, the institutional capacities, the relative strengths and characteristics of the public and private sectors, the cultural setting, and natural conditions, are inevitably reflected in the practical implementation of IWRM approaches among countries and regions. Hence, IWRM can take in practice a variety of forms.

In a way, such a great array of possible variations in IWRM application constitutes an important element of flexibility that permits to adapt the process to the specificities of every case study. On the other hand, it gives space to critics and questions about its implementation.

Biswas (2004) doubts whether the good-sounding definition of IWRM gives any contribute in terms of its application and implementation to improve water management. He affirms that it is in reality inapplicable, internally inconsistent and composed by a combination of trendy words which does not help very much to solve real life problems, nor to make the existing water planning, management, and decision-making processes more efficient and equitable. He argues that the objectives of increasing stakeholder participation and decentralization are unlikely to promote integration. Lankford et al. (2007) specifies that Biswas is likely referring to developing countries in his critique - a context in which Biswas had a strong experience.

Merrey (2008), similarly, argues that IWRM represents a theory framework and an intellectual tool, useful to guide to research and scientific understanding, but it “fails as a guide to practical action, at least in developing countries”. Its principles focus on issues that presuppose the existence of water infrastructure. Participation, demand management and cost recovery, for example, are central principles of IWRM practice, but they will always be secondary priorities if a large numbers of people have no access to water for domestic or productive uses, and they will be hardly applicable if the infrastructure to deliver and measure water does not exist and if most of stakeholders do not have a stake yet, are poorly organized, are marginalized and have no political voice.

In the opinion of Merrey et al. (2005), the definitions of IWRM presented by the GWP focuses the attention to second-generation issues and to ecological conservation at the expense of people. In developing countries, this author sees more adequate to focalize the water management to promote the maximization of welfare, the reduction of poverty and the incentive of economic growth. This approach would stress the promotion of water also as a resource of productive processes. Indeed, the author thinks that the considerable attention to the goal of ecological conservation inhibits the use of water for productive goals, which in turn could contribute to reduce poverty.

This concern represents a largely debated dilemma about the use of natural resources in developing countries and it has been at the core of the international debate on the environment governance and sustainable development. Najam (2005) offers an interesting historical overview on the evolution of international environmental governance, showing how the concerns of the southern decision makers remain qualitatively and substantively different from those from the North. Even if both pursue to achieve sustainable development, the northern approach tends to prioritize ecological aspects, while the southern one is inclined to be more concerned about development aspects and equity (Najam 2005).

Another unfavourable assessment of IWRM is given by Molle (2008), who emphasizes that the three desired “E” - Efficiency, Equity and Environmental sustainability – mentioned by GWP definition, appear to be achievable concomitantly, but neglecting that in the real world these three goals are usually antagonistic and thus in contrast one with each other.

The implicit assumption of simultaneous harmonization of several desirable goals, i.e. providing safe drinking water, meeting ecological needs, providing water for productive uses, and reducing poverty, has been described as an example of a ”nirvana concept”, a concept that embodies an ideal picture of what the world should look for, even if the likelihood of achievement is small (Molle 2008). Moreover, such a “comprehensive approach” is too complex to be implemented, and requires financial, human and institutional resources far beyond most developing countries’ capacities.

The idealized IWRM offers a set of principles, tools and practices to be accomplished, many of them simultaneously, which often have been promoted by investment and implementation organizations, as a “comprehensive approach” that operationalises comprehensive normative IWRM programs (Merrey 2008). However, the attempt to implement such a full IWRM normative package diverts attention away from the most serious issues facing people in the basin and sometimes leads to paralysis and indecision in implementing some more complex programs.

Van der Zaag (2005) affirms that the goal of IWRM of reconciling basic human needs, ensuring access and equity, with economic development and ecological preservation is a very ambitious task, requiring, above all, a transparent and inclusive decision-making process. IWRM, in his opinion, is a perspective approach, a way of looking at problems in order to solve them, that however faces many obstacles preventing its realization. According to the author, IWRM is an institutional challenge that requires a strong institutional capacity to integrate, which in fact is not very easily findable. Traditional government departments have to interact with emerging new parallel structures, defined by hydrological boundaries, and the lack of this capacity could lead to misunderstandings, to competition and even to un-coordinated development. Van der Zaag's (2005) argues that the lack of political commitment could be the main obstacle to achieving "nirvana" and that politics is the essence of the problem, not an external factor. He sustains the need of new water managers, able to facilitate the decision process instead of leading it, process that is hindered by the overruled institutional systems and the intertwined managing competences. The decision process, according to the author, has to leave the conventional engineering skill of "predict and provide" aimed at settling the right technical solution. In fact, the right solution does not exist and, on the contrary, it is the result of a negotiation process and consensus achievement. Stakeholders represent local, federal, private and public organizations, as well as individual citizens and interest groups, and have very different and conflicting interests regarding natural resources and systems. The problem emerges because not all needs can be satisfied at the same time and challenging tradeoffs have to be made. Conflicts and trade-offs are unavoidable, and in developing countries they could become more significant, since social and economical differences are stronger.

Similarly to IWRM paradigm, the **participation** concept and its application have been also very much discussed.

The process of stakeholders' participation is a crucial element in water management, and it is subject to all the limitations and criticalities pointed out for IWRM. How the participation process is approached and implemented clearly affect the results and the policy decisions.

Participation tends to reflect power asymmetries, and not necessary to even them. Its practical implementation requires first of all a political commitment towards the democratisation of water management and a more sustainable development; secondly, it presupposes the existence of water infrastructure able to organize and manage the process, with a clear objective, with strong institutional capacity to integrate and the support of a solid technical knowledge.

The implementation of participatory processes demands financial, human and institutional resources and a transparent decision-making process.

It cannot be linked to normative package of tools, but it has to be structuralized as an adaptive and flexible practice.

Moreover, in order to have access to participation, stakeholders must have an explicit stake, have to be organized and must have a political voice or somebody capable to represent it.

All these circumstances are far beyond most developing countries' capacities.

Thus, the absence of such conditions, together with the highly unequal distribution of political and economic power - distinctive of these countries - can lead to an incorrect or superficial implementation of the participatory process. It is not rare, in developing country, the manipulation of the participatory process by the most influencing agents to direct the decision to a self-interested solution, as well as its implementation as a mere formality.

The poor dominance of participatory tools and methods and the rigidity of an old bureaucratic system can also strongly impede participation process in practice. For example, the involvement of a multilateral arena with strong conflicting interests and visions, if not managed appropriately, could lead to an impasse, where consensus is never reached, and bureaucratic procedures are impeding the adaptation of the process, finally paralysing the approval of any decision.

Du Toit and Pollard (2008) make an interesting summary of what are some practical challenges facing public participation in IWRM processes in a developing country.

The main obstacles evidenced by the authors are related to three factors: i) the lack of integration and of an holistic approach in public participation planning; ii) the unequal preparation and capacity of stakeholders; iii) the over-technical, time consuming and complicate procedures.

Here are some examples of possible problems reported by the authors. Overlapping organisms involved in the participatory process can create redundant engagement and confusion. A dense agenda and the repetition of meetings can induce the public to lose interest and commitment. No reporting and feedback associated with meetings can lead to the discontinuity of results and to a loss of engagement. The objectives of the participation processes are not always clearly communicated or understood by the public, with consequent frustration and misunderstanding of people. Participatory processes often follow a project approach, implying that objectives and actions are broken into series of independent projects, consequently producing independent, fragmented and not comparable results. Participative actions are costly in terms of time and resources, and budget and time limitation can imply a cut off of important phases of the process. Stakeholders usually have biased and unfair ability to participate, like unequal language capacity and resources, meaning that poorly resourced participants are disadvantaged in the participation process and, thus, not able to participate equally in the decision-making. Also geographical issues and accessibility can impede or make difficult the involvement of unprivileged public. In addition, dense, lengthy and complicated procedures could represent an impediment for poorest and less educated people and special attention has to be paid to simplify the processes and to invest in capacity building before public engagement.

It is possible to affirm that scientific literature of the last decades sought to investigate and propose principles, guidelines, theoretical manuals, toolkits and methods for implementing IWRM and participation processes. However, it has been noticed that its real implementation still presents serious difficulties and obstacles. Many meaningful works have been realized, but still there is the need to investigate the application of IWRM principles and tools in practice, especially in context-specificity.

Developing countries, in particular, represent a specific socio-economic context where the application of standard

1.2 Research objective and contribution

According to Lankford et al. (2007) the new research challenge has to be focused on more practical aspects, in order "to formulate precise interventions to solve existing or foreseen problems in the pursuit of stated goals". Such a new practical approach has to be directed to identify practical solutions, and to implement them, maintaining in the mean time a critical perspective on the basic principles of IWRM. Lankford et al. (2007) evidences the importance of detecting and prioritizing problems and of finding solutions in an integrated perspective, avoiding the acceptance of principles and the utilization of methods developed without having taken into consideration the specific situations.

This PhD research is based on the conviction that the scientific effort in the field of water management should attempt at re-interpreting the already existing methods and investigate how to adjust them to specific contexts and goals.

For this reason, this research investigates the practical implementation and adjustment of participatory methodologies for supporting Integrated Water Resource Management in the specific framework of developing countries, in order to develop innovative forms of applying and approaching participatory tools.

This study explores how IWRM paradigm - and specifically one of its main instruments that is participation - is practicable in different contexts and, particularly, in developing countries, characterized by local-distinctive social-economical and institutional conditions.

More specifically, it investigates methodologies for supporting integration in multi-disciplinary scientific research teams, in order to:

I. foster local actors participation and overcoming the gap between scientific and not technical knowledge,

II. identify and prioritize problems and solutions in an integrated perspective, as well as

III. facilitate the integration of quantitative and qualitative techniques.

The final sought outcome is to give robustness and effectiveness to qualitative and participative research approaches. Actually, they are fundamental tools of research, especially in developing countries, but at the same time they suffer the risk to be less scientific and volatile.

For this reason, the study investigates public participation in various contexts and stages, within a research context or in a decision process, with different structure and methods, regarding different types and levels of decisions and involving - and consequently excluding – a subjective array of participants.

From a methodological point of view, in order to structure the research and to deep the study on the different features characterizing participation, the thesis is organized in three sections, investigating different application contexts of participatory processes, involving different actors and utilizing different methodologies, as synthesized in **Table 2**.

	Context of participation	*Who participate*	*How*
Art. 1	decision making	Stakeholders	Literature Review
Art. 2	scientific research + decision making	Local Actors	Decision Support System, Multi-criteria Decision Analysis, workshops
Art. 3	scientific research	Experts	Fuzzy Cognitive Map, semi-structured interviews, workshop

Table 2: Where, how and with whom the participation process has been investigated in the thesis.

The first section regards the study of participation at decision-making level, in a specific developing country; it represents a literature review on participation practices in decision-making and management at river basin level, focusing on stakeholders' involvement.

The second explores the implementation of the participatory process in a mixed context, with the integration of experts and local actors; here the scientific research is integrated with the decision making process, in order to support the evaluation of political strategies; the article explores the utilization of decision support system tools and Multi Criteria Decision Analysis at river sub-basin level, with the participation of local actors, i.e all the people involved in the case study activities (not properly stakeholders).

The last one focuses on the participatory process to support scientific multidisciplinary research; it explores the utilization of a semi quantitative method to structuralize the cognitive maps of a group of experts.

In addition to the methodological differences, each section investigates different specific problems regarding integrated water resource management.

The three sections are presented in this thesis under the form of three essays that will be presented in the next chapters.

The First Essay is a literature review of participative and IWRM practices in the specific context of the Federal Republic of Brazil, chosen as case study for its modern water management legislation, embracing IWRM paradigms and being based on the three principles of integration, decentralization, and participation. The essay presents the Brazilian institutional and legislative system, and reviews how different participative approaches and tools have been applied in this country and in some specific state case studies, trying to underline what are the criticalities that obstacles an effective development of water policies.

The second Essay presents a methodological proposal aimed at improving the effectiveness of interactions between the scientific community and local actors for decision-making processes in water management, in two case studies, in Europe and Asia: the Upper Danube (Danube) and Upper Brahmaputra (Brahmaputra) River Basins. A Decision Support System tool is used to facilitate transparent and robust management of the information, to implement a multi criteria decision analysis and to prioritize problems and solutions in an integrated perspective. Here, a broad scale of analysis is adopted, studying the local actors perceptions of expectations on four categories of response strategies, with the aim of orienting and targeting further research activities and policies.

The third Article illustrates the application of participatory methods for IWRM, applied to a specific local case study in Brazil. In particular, the research utilises the tool of Fuzzy Cognitive Maps, as to guide the construction of system understanding and to improve the effectiveness of the Building Block methodology for the environmental flow assessment of a river. The application is tested in a narrower scale, to the Lower Paraguaçu River Basin and Iguape Bay (Bahia, Brazil.). The research offers an operational approach to overcome common research problems of water management in developing countries.

1.3 References

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FIRST ESSAY:
A review of participatory practices in the implementation of IWRM in developing countries: the case of Brazil.

Lucia Ceccato

ABSTRACT

The paper investigates how the practice of participation as a principle of Integrated Water Resource Management is implementable in different contexts with different social-economical conditions in the federal Union of Brazil. Brazil is blessed with abundant water resource, but with an unequal distribution of it. The country is characterized by a large heterogeneity of environmental, cultural, social and economic situations and by the occurrence of strong conflicts in water use, which has differentiated how IWRM and participation processes were implemented. The study investigates how different participative approaches and tools have been applied in Brazil, how participation concepts have been adopted in practice and what are the main obstacles detected. Moreover, the survey attempts to address whether it is possible to record enough transparency and comprehensive documentation on the participatory processes and whether or not common patterns and trends in the Brazilian approaches to water management are recognizable. The investigation has been developed through literature review, with focus on a selection of case studies, represented by different Brazilian state.

KEY WORDS: Integrated Water Resource Management, Participatory Process, Brazilian Water Resource Management System, Decentralization.

2.1. Introduction

Brazil is a challenging and flourishing case study for water management research, in reason of its relative abundance and unequal distribution of water resources, its heterogeneity of environmental, cultural, social and economic situations, the occurrence of strong conflicts in water use, and its advanced and modern water legislative framework, grounded on Integrated Water Resource Management (IWRM) paradigm. The Brazilian Water Resources Policy, indeed, is considered, by many experts in the field, as one of the most advanced in Latin America (Tarqui and Silva 2004).

Brazil is a federative republic, of 8,5 million km2 located in the southern hemisphere, and it is divided in 26 states and a Federal District. The magnitude and volume of water in Brazilian rivers created the idea of abundance of water in this country. In fact, Brazil has the privilege of hosting 12% of all fresh water of the planet. Moreover, in this country there is the world's largest river - the Amazon River - and there is also one of the largest groundwater reservoirs in the world - the Guarani Aquifer System (MMA 2011). However, the impressive average water availability masks an extremely uneven distribution of water resources among regions and population. Per capita availability varies from 1.460 m3/person/year in the semi-arid Northeast to 634.887 m3/ person/year in the Amazon region. About 70% of fresh waters of Brazil are the in the Amazon basin, where only 7% of the country population is located. The remaining 93% of the country's population will depend on the other 30% of the water availability. The north-eastern region, for example, is densely inhabited and has only 3% of the country's fresh water (MMA 2011).

These data explain why conflicts for water in Brazil are not only unavoidable but are extremely strong, underlining the cruciality of an integrated and participatory water management, able to mediate social conflicts. The principles of IWRM, indeed, inspired the formulation of the actual Water Law (*Law 9.433/97)*. Nevertheless, after fourteen years since its promulgation, still several questions on its effective application are often debated.

In general, not only in Brazil, the discussion on critical aspects of IWRM and participatory processes have been investigated by a large number of international scholars, who have emphasized limits and obstacles to its implementation, especially in the context of developing countries.

The absence of an effective economical, institutional and social organization, an institutional and technical capacity, together with the highly unequal distribution of political and economic power, distinctive of these countries, can impede the successful implementation of participatory processes or, even, lead to their voluntary manipulation by the most influencing agents (Van der Zaag 2005, Merrey 2008, Biswas 2004). The poor dominance of participatory tools and methods and the rigidity of an old bureaucratic system can strongly affect the development of a participation process. For example, if not managed appropriately, the involvement of a multilateral arena with strong conflicting interests and visions could lead to an impasse, where consensus is never reached, and bureaucratic procedures are impeding the adaptation of the process, finally paralysing the approval of any decision. Yet, the implementation of integrated and participatory processes demands financial, human and institutional resources (Merrey 2008, Molle 2008) and a transparent decision-making process (Van der Zaag 2005). Moreover, in order to have access to participation, stakeholders must be organized, and hold a political voice, or be represented by somebody capable to do it (Merrey 2008).

All these circumstances are far beyond most developing countries' capacities, making participatory practices a tough challenge in these areas.

Brazil, has been chosen as a case study to evaluate how such critical issues in IWRM are faced and to understand what is the experience of this country in the implementation of participatory practices. This study is focused, in particular, to identify differences, limits and obstacles recorded in different Brazilian states, through the analyses of international and national literature.

The paper is organized as follows. Section 2, describes the Brazilian institutional and legislative system related to water management, in order to contextualize the case study evaluation. Section 3 introduces what are the Brazilian specific criticalities and constraints in the implementation of water management, as detected by scholars. Then, section 4 presents the analyses of the case studies. Finally, section 5 outlines the conclusions.

2.2. Legislative Framework for IWRM in Brazil

Brazil, like many Latin America countries, has been characterized for decades by authoritarian regimes and monopolized decision-making power, where consultation and public involvement were restricted to a small sphere of elite and where civil society organizations were repressed (Abers and Keck 2009). This monopolized power has been overcome through the democratization process in relative recent times. The new democratic environment, then, gave new space for a more free expression of opinion, for new powers and responsibilities, and for the emergence of a wide array of actors attempting to transform the state, although with different "recipes", with a common agenda represented by decentralization and participation progress (Abers and Keck 2009). In this framework, the debate on water resource management has become one of the most questioned issues by national scholars, activists and politicians.

The extension of the country, the regional differences, the inequality in economic development, and the consequent conflicts related to water resources, created the necessity of a reformulation of water normative system oriented to a more integrated and participatory management. Indeed, in the 1980' a comprehensive reform in the Brazilian water resources sector started. The reorganization of water system began with the reform of the Federal Constitution (1988) that introduced an important advance in the management of water resources in Brazil, considering water as a public good and establishing the National Water Resources Management (*Sistema Nacional de Gerenciamento de Recursos Hídricos - SINGREH*). Those measures were later consolidated under the *Law 9.433/97*, known as the *Lei das Águas*, which established the National Water Resources Policy, and its objectives, principles and instruments, and the National Water Resources Management System, creating the institutional arrangement under which the country's water policy were to be implemented.

This reform began the implementation of a new decentralized and participatory water management model that integrated all uses of water and comprises three interconnected levels of decision making: the national system of water management, the state systems of water management, and the river basin organizations. This new model sought to translate into policy the integrated water resources management (IWRM) paradigm. Founded on the Dublin Principles of 1992 (ICWE, 1992), it was inspired by the French water management model (French Water Act, 1992), which introduced the role of Basin Financial Agencies and the River Basin Local Committees in water management system. The Basin Financial Agencies are public institutions in charge for the financial promotion of the basin, and the River Basin Local Committees are intended as forums of negotiation, consultations and orientation for the decision-making process on water resources at the river basin level.

This new Brazilian law recognizes water as a public good, endowed with economic value, and affirms that, in case of it scarcity, human and animal consume has to be privileged, although the management of water resources should always provide multiple use of water. The new National Water Management System takes the river basin as its territorial management unit and adopts three fundamental principles: i) integration, ii) decentralization, iii) participation. The new management model involves a shift from a centralized sectorial administration to a participatory integrated management, decentralized into three interlocking decision levels:

I. the national level,

II. the state level, and

III. the river basin level.

The National Water Resource Management System is composed by the following bodies, (9.433/97, Art. 33), as it is illustrated in Fig.1:

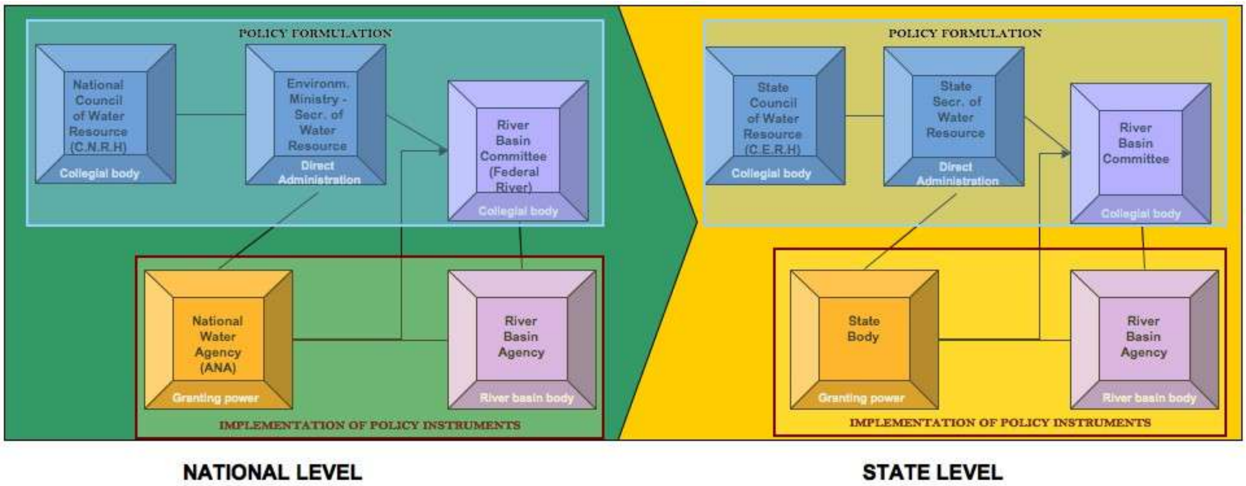

Figure 1: Brazilian National Water Resource Management System. Adapted from MMA – SNGRH (http://www.mma.gov.br/)

The formulation of policy is carried out by collegial bodies (Councils and Committees) and directly administrated by the Ministry and the state Secretariats. The Councils – both at national and state level - assist the formulation of water resources policy and resolve conflicts. The Environmental Ministry (MMA) / Secretary of Water Resource (SRHU) establishes the National Policy of Water Resources and supports the formulation of the budget of the Union.

The implementation and application of management instruments is responsibility of the National Water Agency (ANA) and the respective State Entities. ANA grants and supervises the use of water resources at federal level, while the State bodies (every state determines the name) grant and oversee the use of water resources controlled by the state.

River Basin Committees (*Comitê de Bacia Hidrográfica*) are collegial bodies with consultative and deliberative power. They decide on the Water Resources Plan (when, how and for what to charge for the use of water resources), with the technical and operational support of the the Basin Agencies (*Agências de Água*) (MMA – SNGRH (http://www.mma.gov.br/).

The integrated management is achieved through a set of instruments (9.433/97, Art. 5), like water classification (*enquadramento dos corpos d'água* – 9.433/97, Section II), water resource plans (*planos de recursos hídricos* - 9.433/97, Section I), the granting (*outorga* - 9.433/97, Section III), the pricing of water use rights (*cobrança pelo uso da água* - 9.433/97, Section IV) and water resource information system (9.433/97, Section VI).

The water management may be public or mixed (public and private), depending on the choice of the Federal Union, of the states, municipalities, users and civic organizations. However, water management cannot be totally private, since federal and state powers cannot delegate the regulation and the control of water uses and grant water use rights (9433/97, Art. 29 and 30).

This new organization gives a central role, in coordination with the national and state systems, to River Basin Committees in the policy making process, making them a prosperous context to put participation into practice. The river basin committee is a deliberative institution and the lowest territorial unit for the integrated management of water resources, where choices are oriented with the effective participation of the stakeholders, represented by government (federal, state, and municipal organizations involved in water management), civil society and direct users of water resources (Law 9433/97, Art. 1).

The basin committees have the responsibility, at basin and sub-basin level, to promote the discussion on water resources, to arbitrate in the first administrative instance conflicts related to water resources, to approve the Water Resources Plan for the basin, to monitor the Plan implementation and suggest the actions needed to meet its goals, to establish mechanisms for water pricing and suggest the values to be charges (Law 9433/97, Art. 38), as illustrated in Fig. 2.

Competencies	Deliberative	Arbitrate in the first instance for conflicts in the use of water
		Approve the River Basin Water Plan
	Propositional	Monitor the implementation of the Water Resources Plan for the basin and suggest the steps necessary to meet its goals.
		Indicate the Water Agency to be approved by the Water Resources Council
		Propose to the National and State Water Resources Councils the exemption from granting of use rights of water resources
		Choose the alternative to water classification e propose it to the Water Resources Council
		Establish mechanism for water pricing and suggest the values to be charges
		Establish criteria and promote the sharing of costs of works with multiple use and community interest
		Solicit to Water Resources Council the creation of Water Agencies
	Consultative	Promote the discussion on water resource related issues
		Propose to the Water Resources Council the priorities for the utilisation of resources coming from granting

Figure 2: Competencies of river basin Committees established by the Federal Law 9433/97 (source: ANA).

The duties of river Committees, however, as stated by the law, are vague and generic, resulting in practice in a weak and limited deliberative power. The features of water plan, water classification or water pricing, for example, are often settled at higher decisional levels. In the case of water pricing, the values suggested or proposed by the River Basin Committee are ultimately decided by the State or National Council.

This evidences that, although decentralized, the federal level maintains considerable power over the resolution process of conflicting situations at lower levels, as well as the design and implementation of policies (Garrido, 2000).

Moreover, it has to be considered that, even if the National Water Law confers a common homogeneity throughout the water legislations of Brazilian states, it also permits some degree of freedom to states, in order to deliberate their own water regulation, including basin councils constitution and other governance mechanisms. The Brazilian states, in practice, are implementing different variations of a common basic model. The federal legislation applies directly to federal water courses and provides a general framework for the state legislation on state water resources. The general model established by L. 9433/97 gives principles, the set of policy instruments, and the attribution of competencies between state-level and river basin-level management, while every state decide the specificities of its water regulation, varying for example, in terms of type and extent of participation or decentralization level (Guiterrez 2006b).

The water law, although it has started an important phase of reform in Brazilian water management, is not free from vagueness and contradictions that complicate the articulation between the top national arenas and the river basin organizations (Committees), as well between the national system and the state system (Guiterrez 2006a).

2.3. Criticalities and constraints in the implementation of water management and participatory processes in Brazil

Since the promulgation of the *Water Law 9433/97*, the debate on water resource management in Brazil has intensified especially on the issue of participation in decision-making processes. Yet, the concrete establishment and regulation of the river basin Committees, even if realized in different forms and timing by every state and river basin, has had the common purpose of regulating participation and creating a multistakeholder arena that integrates civil society, public institutions and water users to establish priorities for water use and to solve conflicts related to water resources.

The creation of river basin Committees, established at local level, fostered the expectations of civil society groups to increase their access to decision-making. In practice, however, the state bodies and officers often showed themselves reluctant to give up decision making power and even when the political motivation were oriented to implement participatory decentralization, not always political and technical capacity were able to achieve their objectives (Abers, 2007).

In Brazil, as in other developing countries, a typical problem is the impasse between the creation of laws establishing the guidelines for management and their real application (Tarqui and Silva 2004). In fact, several concerns have been raised on the applicability of the Federal water law and its gaps.

It has been argued that the new water system overlaps with the existing administrative structure (Kettelhut et al. 1999), hurdling the implementation of water management. The structures created by the *Water Law 9433/97* maintains the competencies of the existing bodies and creates new body necessary for the implementation of new activities, which have a territorial basis – the river basin - different from the political-administrative division of the country. Indeed, river basin committees cover territorial units that embrace many municipalities or some fractions of them or several states, and shared the jurisdiction over their competencies among different units and levels of government. The relations between the federal, state, municipal and basin governments are characterized, therefore, by an eternal conflict due to the overlapping domains ad competencies of their bodies, concerning the use of resources water and the related sectors. Kettelhut et al. (1999) argue that the superposition of systems is the result of the fact that the water sector reform did not involve also a deep change in the institutional structure.

According with Tarqui and Silva (2004), this conflict is caused also by the coexistence of different models of water management - the bureaucratic model, financial and economic model participatory model - in the same territory.

Some other authors state that the river basin is an inappropriate unit for water management. Cardoso (2003), for instance, considers the river basin management level as a weakness, justifying that there is no type of social identity that corresponds to the limits of the basin.

The lack of legal powers of Committees is a further weakness of the water system. Committes, although responsible for the definition of river-basin plans, do not have any instrument to force governments to implement their decisions (Abers and Keck 2009).

Also the artificial creation of the Committee can difficulty its functioning. Indeed, if such a forum does not arise from the spontaneous demand of the basin population, it will not be recognized as a legitimate space for addressing society needs (Abers 2007). The adoption of a multi-stakeholder forum does not imply per se a more democratic management (Santos et al. 2006).

Another important criticality related to river basin Committees regards the **representativeness** of its members. Stakeholders' participation involves a process of selection, which can be on the basis of not impartial criteria and could be manipulated by the dominating powers. Warner (2005) noticed that stakeholders usually are not self-selecting and self-motivated, on the contrary, they are invited to participate by external facilitators or institutions, and generally they represent an organised interest group. This gives considerable discretion to the facilitators of the process. If facilitators were not scrupulous and impartial about stakeholder selection, this automatically could disadvantage potentially interested but unorganised parties.

To promote and improve the transformation in water management and to design innovative solutions, Tundisi (2008) sustains the need of an advanced training of water managers and the creation of new management instruments that improve the monitoring capabilities and the management of databases. The author argues that a further transformation is needed to shift from a local, sectorial and responsive management, to an ecosystem-level management, integrating the water cycle of atmospheric, surface and groundwater together with the multiple uses.

Another criticality related to water management, concerns how the negotiation process is implemented in the River Committees context. According with Warner (2005), two types of negotiation exist - distributive and integrative negotiation. Distributive negotiation is antagonistic, and based on self-interests, resulting in an approach of "cutting of the cake". Integrative negotiation, on the other hand, starts from a commonly perceived challenge, involves "baking the cake together" and involves joint social learning. The adoption of one or the other approach cannot be forced, but can be progressively constructed through a process of reciprocal understanding.

All these criticalities concerning the Brazil water management framework find expression in the operation of river basin Committees, which provide a privileged site for examining the political process and states' capacity to operate efficiently and responsively, in response to the ambiguities let by the federal legislative framework (Abers and Keck 2006). Substantive differences remain among Brazilian states, as for example how the principles of decentralization and participation are materialized in such forums (Guiterrez 2007).

From these considerations, emerged the interest of investigating how different Brazilian states have applied the orientation of the Federal framework and how participation is effectively implemented in such different contexts, within the river basin Committee scope.

Thus, some specific research questions oriented this survey:

- Which kind of participation approach is adopted in Brazilian states?
- What are the instruments and methods used to implement participatory processes?
- What are the critical elements that compromise participatory processes in water management of Brazil?
- Are river basin Committees an efficient body able to guarantee stakeholders participation?
- Could we recognize some common model in the Brazilian experience?

In order to address these questions, a revision of literature concerning participative processes in Brazil have been performed and presented in the next section. For the purpose of this research, given the impossibility of analysing all twenty-seven federal units of Brazil, some specific states has been chosen as case studies.

2.4. Brazilian case studies

Brazil has several river basins and a variety of situations in relation to its water resources, which imply also the necessity of different management models. River basin Committees are the entities where water related issues are discussed and managed, and where participation processes are put in practice. In order to coordinate the multiple uses of water resources, these bodies have to evaluate a great complexity of variables related to hydrologic, geomorphologic and ecological processes and have to develop management mechanisms to conciliate different economic sectors (industry, agribusiness, power generation, sanitation, etc.), within different political and administrative sovereignties (municipalities, states and Federal Union).

The reality of each river basin is very different across the country. Each basin or state model responds to the peculiarities of each region and determines the management proposal defined for each river basin. The management models in the south-east region, for example, attend to the problems of heavily urbanized regions. The models such as those concerning the federal rivers crossing several states characterize regions with large areas where conflicts extend beyond the water issue. The management models of semi-arid regions are peculiar for water scarcity problems and consequent strong conflicts in its use.

The selected cases are not intended as a representative sample of all Brazilian realities, since every single state has specific cultural, economic and institutional features and its own history, but rather as a demonstration of the Brazilian variety in the implementation of participatory processes.

From a methodological point of view, each case study has been analysed on the basis of the reviewed literature, and therefore it is also limited to the information and opinion expressed by the author. It has to be stressed that the investigation and its conclusions largely depend on the availability of documentation and on the contents presented by the writers. The research does not aspire to present a comprehensive evaluation of problems and approaches adopted by Brazilian states, but to discuss how such concerns emerge from the scientific analyses.

2.4.1 Ceará

Ceará is a semi-arid region, located in the north-eastern part of the country, characterized by the unequal and irregular - in time and space - occurrence of rainfall. The scarce and unequal distribution of water resources creates conflicts for their allocation among the several users (irrigation, domestic water use, industry, tourism, fishing, etc.), being water the main source of economic and political power in Ceará (Garajulli 2001a). For this reason, a large number of dams have been constructed in the last century in Ceará, in order to store water resources in reservoirs for the dry seasons.

In these areas, the decentralization of decisions and the involvement of users and civil society faced strong difficulties, due to the already established habits in water resources management practice. The State historically adopted a **centralizing** approach, fostering a paternalistic relationship with the society. In turn, the society accommodated itself in the role of "beneficiary" of government social programs (Garajulli 2001a). Nevertheless, Ceará emerged for its advances in promoting decentralized stakeholder models, involving a large number of stakeholders in key water management questions (Formiga-Johnsson and Kemper 2008).

Nevertheless, Ceará is also characterized by a water law that establishes a centralized political and institutional structure. In this country, basin Committees have limited deliberative powers in comparison with other Brazilian states. For instance, the definition of the water pricing system is not a Committee competence, as elsewhere (Formiga-Johnsson and Kemper 2008). The technical support to Committees, usually given by basin water agencies as the federal framework proposes, is provided here by a state management body. Ceará, differently from other States, has not water agencies. Instead, a state Water Resources Management Company (COGERH – Companhia de Gestão dos Recursos Hídricos) was created in 1993, to cover the agency functions and manage the state water resource supply. In practice, Committees must rely on the executive assistance of a centralized agency over which they have no control at all (Guitierrez 2007).

Even if water management is much centralized in Ceará, local mobilization and stakeholder involvement is very intense. Even if under COGERH coordination and with the support of the state governmental water body, several basin and local institutions - different from the river basin Committee - have been gradually created, beyond the Federal law requirements, and they have been orientated towards participatory principles, as mentioned by Garajulli (2001a).

Councils for the management of specific water systems – usually dams - involve representatives of users, civil society organizations, municipal governments and governmental and non-governmental institutions, to reach a negotiated definition of water allocation and the terms of use and preservation of water sources.

Municipal Commissions for Water Management are also composed by representatives of users, civil society and government, but act at a municipal level.

A Committee of Users of Regulated Valleys ("*vales perenizados*"), that is the valleys that have been transformed in perennial through flow regulation, is aimed at deepening the knowledge on water resources situation and at defining joint actions for a more rational use of them.

The most innovative experience in Ceará state (Lemos and Oliveira 2004) concerns the creation and organization of **Users' Commissions** to negotiate water allocation among users of the regulated valleys of the Curu, Jaguaribe and Banabuiú. Within this context it is implemented an annual negotiation process for determining the use of water stored in large reservoirs. Users' Committees analyse the technical information about the supply of available water, and they present the water demand and create simulations on the alternatives of operation. Thus, users and other local stakeholders discuss and negotiate together the annual allocation of water of the reservoir. The users are empowered to decide each year - with monthly adjustments in the summer period - the discharge released from the dams, the rules of use and preservation that have to be respected by all users, and the prioritization of government interventions in these water systems (Garajulli 2001a). This participative management has led in the last few years to an important reduction in water use and has prevented from the serious water shortage which was frequent in the past (Formiga-Johnsson and Kemper, 2005).

However, these Users' Commissions are still only informal institutions that have to co-exist with the formal system of licences, which is not obliged to respect the decisions of users' commissions. The Ceará water system, therefore, is not free from discrepancies and conflicts that appeared especially in the definition and implementation of management instruments (Formiga-Johnsson and Kemper, 2005).

Beside the positive experience of users' Commission, some other factors obstacle the participatory process in Ceará. The sectorial approach of government planning contrasts with the need of water resource management and limits multisectoral actions at basin level; the authoritarian tradition of the Ceará government and the strong centralization and hierarchy of the state apparatus make the active participation of civil society to be more difficult, and this is aggravated by the fact that the role of active citizens is not fully embedded in values of the society (Garjulli, 2001b). In addition, also the conservative attitude of policy-makers tends to inhibit more innovative and inclusionary aspects of decentralization, transparency and stakeholder participation (Lemos and Oliveira 2004).

It is interesting to note that, although the water management approach is centralized in Ceará, at the same time the stakeholders' participation and mobilization are also vey developed in this state (Formiga-Johnsson et al. 2007).

Ceará Case study shows also that the most appropriate level to facilitate decentralized water management is not necessarily the river basin, since the Users' Commissions emerged as a very effective forum for allocation negotiation and conflict resolution (Formiga- Johnsson et al. 2007).

2.4.2. Bahia

The State of Bahia emerged for its significant delay in suiting its water legislation to the Federal one. This state showed the first effort in these sense only in 2005, under the pressure of the National Water Agency (ANA) and some international funding institutions (Pereira 2008), with the institutionalization of river basin Committees (L. 9843/2005). A more complete reformulation of its water law came only in 2009, with the law 11612/2009.

Nevertheless, some authors evidenced that the establishment of the river basin Committee did not mean a step forward in the direction of a more democratic commitment of Bahia State, but only a form of adaptation of its institutional framework to the federal legislation, in attendance o the conditions imposed by funding bodies (Santos et al. 2006). The water reform in the state of Bahia, indeed, has not been translated into a concrete decentralization of the management power, which used to be centralized and controlled at state level. This was also confirmed by some local experiences. The practice of participatory processes in Paraguaçu river basin, for instance, was characterized by strong conflicts between the river Committee and the State, due mainly to the hegemonic attitude of the State in the organizing process of the Committee (Santos et al. 2006).

It has been stated that the participation process within the river Committees in the state of Bahia has been only limited to the respect of the minimum requirements of the water law, due to a weak commitment of the state and also to a low propositional capacity of social organizations (Santos et al. 2006). The role of river Committees concerns only the discussions and proposition of issues relevant for the basin, to the state management body. In this state, the Committee has mostly consultative competencies. It decides, in fact, on a restricted range of issues concerning the river basin, and it does not have the power to enforce its deliberations to the state.

The function of participation in water resources management of Bahia ends up having an advisory role and, secondarily, only a deliberative one, having no great impact on policy formulation. The political and administrative structure is still centralized and centralizing, showing that the decentralization reform, fostered by the Federal water law, has assumed in Bahia only an administrative nature. Santos et al. (2006), moreover, observed a predominance of a pragmatic and instrumental approach of the participatory practices.

Another obstacle to civil society participation in the public water management of Bahia is represented by heterogeneous, fragmented, and little propositional qualities of its population and by the unequal financial condition and information access among regions (Santos et al. 2006). This was confirmed also by other studies.

Ribeiro (2006), from his research on **Itapicuru** river basin, underlines that the scarce participation in the basin was justified by historical and cultural factors, as well by the economic and political features of the population of the area. In particular, the dependence from the public power – local or state – and the difficulty to understand the public policy are mentioned as causes that disfavoured the mobilization processes.

Brannstrom et al. (2004) analyses the participatory process implemented in the **Itapicuru** river basin, one of the poorest regions of Bahia. He reports that participatory organizations and civil society remain fragile and unconsolidated, due to the dependence to public bodies for the organization of public initiatives, and to the "clientelist" political culture. In addition, the lack of resources impedes local users' organization and stabilization with proper infrastructures, and the low education levels inhibits the expression of opinions and the participation at the public meeting.

Also in Bahia state the composition of the river Committee is mentioned as a crucial issue. The representation of the different actors within this body has been reported, in some cases, not to be much balanced. Pereira (2008) studied the particular case of the Paraguaçu river basin Committee and demonstrated that there is a power concentration within the Committee, due to the overrepresentation of irrigators' representatives of the upper part of the river basin, having as a consequence the hegemony of this region in the political and management process. This is particularly relevant for this basin, where the priority of a semi-arid climate and an unequal distribution of water resources causes seasonal water shortages. Indeed, the up-stream position of this dominant group of interest can harm the down-stream areas by controlling – with dams or high water withdrawal – the inflow of the river or by discharging polluting effluents. The composition of the river basin Committee, as regulated by the national law, does not guarantee a share of votes on the base of a geographical distribution Pereira (2008) to minimize the possible dominance of specific powerful regions.

The Committee composition of **Salitre** river basin reflects an unequal representation of actors represented by a restricted expression of civil society who holds only 20% of votes (Gonçalves 2008). The remaining votes, indeed, are equally guarantied to the public sector (40%) and to water users (40%). Gonçalves (2008) studied the experience of the social actors' in this basin and - through interviews - detected also that a large part of Committee members doesn't know the technical words utilized during the participatory meetings by moderators and public officers, showing the necessity of using simplified language and of developing training programs for local actors.

The author reports some of the difficulties faced for developing the desired actions, especially at bureaucratic level, like the obtaining of official documents and data, the establishing of contacts with local governments, the lack of resources to visit the communities and the lack of a logistical support of the state.

In addition, serious difficulties were faced to convince social actors to participate in the management processes, in part due to the lack of organization between government, civil society and users.

2.4.3 São Paulo

The main concern of water management in Sao Paulo state, as in most of the southern and south-eastern states, is related to urban water problems (Abers and Keck 2006).

Sao Paulo Water Law (L. 7633/91) inaugurated the institutionalization of river basin Committees in the state, through the first pilot project in the Piracicaba basin. The river basin Committee of Piracicaba, Capivari, Jundiaí was constituted in 1993, and served as a model for all the other Committees coming afterward (Ribeiro 2006). Sao Paulo water law mandated an equally divided participation in the Committee between municipalities, civil society and state agencies. However, several examples showed that efficiency and equity imperatives in participation processes have only partially been achieved (Brannstrom et al. 2004).

Several Sao Paulo basin Committees achieved a rapid organization due to the creation, in 1993, of a state Water Resources Fund (FEHIDRO), which financed Committees for small projects in their jurisdictions (Abers and Keck 2006). These resources permitted almost all the Committees to design water management plans, and to involve local actors in the implementation of some collective infrastructures. The Sao Paulo participatory practices have been depicted as well organized and structuralized, thanks also to the efforts of a professional and experienced network (Abers and Keck 2006). Even the successful practice of Sao Paulo state was not sufficient to achieve a more complete implementation of water reform. Indeed, political and economical resistance impeded to create the system of water pricing (*cobrança*), showing once again how that the water system does not offer any tools to prevent from the influence of dominating power groups.

2.4.5 Rio Grande do Sul

The main issues related to water management in Rio Grande do Sul, as in most of the southern and south-eastern states, concerns water quality and the management of water resources in the urban areas due to industrial discharge, solid waste and domestic untreated sewage that are polluting rivers draining urban areas (Guitierrez 2006a).

Decentralization and participation principles have been introduced into Rio Grande do Sul water management since 1981, with the creation of the state water resource system. Thus, the actual system resulted from such experiences and from the improvement of the previous state legislative-institutional framework. Rio Grande do Sul has also a long familiarity in managing river basin Committees, which began with the creation of the first river basin Committee of Rio dos Sinos e of Gravataí in 1988 (Ribeiro 2006).

In this state, the issue of representativeness within the Committee has been marked as a delicate concern, affecting the participatory processes of this body. The state Water Law (Lei 10.359/94), similarly to other basins, guarantees 40% of votes to the water users, 40% to the population and civil society and 20% to the representatives of public institutions acting in the basin. However, the law also permits that population could be represented by local legislative bodies and, considering that also users representatives can come from state or local institutions, it is possible in theory to have a river Committee entirely composed by public bodies representatives (Oliveira 2008). This means that, if not handled carefully, the committees' decisions can be taken exclusively by representatives of the executive and legislative powers of the municipalities and the state.

2.4.6 Federal rivers

Some relevant experiences were investigated in relation to river basins that, by crossing different states, belong to the Federal domain by law.

Sao Francisco river passes, from the south to the north-east regions of Brazil, through the states of Minas Gerais, Bahia, Perambuco, Sergipe e Alagoas,. The Committee of Sao Francisco river basin has an undeniable productive participatory experience. The formation of its basin Committee (CBH-SF) and the election of the first directorial board, for example, involved a process of sensitization of public institutions and a large mobilization process of population, users and civil society, involving 39 regional meetings and 6.000 people, as reported by Santo et al. (2006).

Beside the positive and fruitful participatory experience of the CBH-SF, the case became emblematic of the real empowerment of river basin Committees. The limitation in their decisional power clearly emerged with the strongly debated discussion on the project of São Francisco river diversion (Santos et al 2006). The project was supported by the national political power, but found the firm disapproval of a large part of the population and also of the river Committee. However, the final decision was centralized at national level through the intervention of the National Water Resource Council. This is a vivid example of how, in case of strong conflicts in water management, the decision process is not effectively decentralized and the participatory process, through the river Committee body, does not embody any decisional power. Also in this case, participation has been confirmed to have a mere consultative function (Empinotti 2007).

Another case of Federal river is that of the **Rio Paraíba do Sul,** which touches the southern states of São Paulo, Minas Gerais e Rio de Janeiro. Its Committee was the first to be implemented in Brazil, in 1942, with the name of Committee for the integration of the River Basin of the Rio Paraíba do Sul (CEIVAP). According to Engle and Lemos (2010) the Committee was well-developed and it implemented significant changes in the water management of the three states, in part due also to the contribution of the National Water Agency (ANA). It successfully created the first operational water pricing system in Brazil (Formiga-Johnsson et al. 2007), and permitted the inclusion of a broader representation of stakeholders in the decisions; those, before the Committee creation, were traditionally controlled by the hydroelectric sector.

According to Pereira and Formiga-Johnsson (2004), the implementation of such management instruments was possible thanks to the characteristics of this basin, one of the most prepared of the country, in terms of its technical and mobilization capacity. This was achieved through a long process of planning, that allowed a deeper understanding of the real problems of the basin, and on the other hand, through the sequential and progressing attempts of institutional mobilization.

For Kumler and. Lemos. (2008) the successful experience of this Committee is due to the framework of social learning and to the trust that has been established between, allowing local adaptations during the implementation of the reform process.

2.5. Discussion of the results

The analysis of the literature on participatory practices in Brazil revealed, first of all, a variety of approaches in the form of investigating participatory processes. As it was described previously in this thesis, the term 'participation' can assume several different meanings and can be actualized through the application of a large range of methods. Yet, the type of participation processes can involve different levels of public engagement, from an informative and consultative type of participation to a more collaborative participation, oriented toward the co-management of decision-making (Pretty et al 1995, Lynam et al. 2007, Lawrence 2006).

From the analysis of the case studies emerged that, in most of the cases, the implementation of participatory processes within the river basin Committee assumes only a consultative function. Even the most successful cases of participative practices of the Committee, like the case of Sao Francisco basin, evidenced that the Committee has not the power to force its decision.

Only in the case of Ceará Users 'Commissions it is possible to recognize a transformative and co-learning approach of participation process, which results in a joint making of decision to negotiate water allocation among users. However, being such Commissions only informal institutions, their decisions are binding only within the Commission context of that group of users, and are not necessarily respected by the formal bodies.

In relations to tools and methods utilized in Brazil, it was not possible to develop any comparative analyses, due to the lack of published articles and documentation relating on the details of participatory practices. Abundant literature discusses participation, democratization or decentralization in general terms, but still little attention is paid – in written documentations – to inform on the adopted methodological approaches and on the choice of specific participatory tools and mechanisms. As a consequence, the participatory practices in the different states are not detectable. This fact could also be interpreted as a lack of transparency in Brazil, not necessarily voluntary, in relating how participation processes are implemented.

The literature reviewed, on the other hand, helped to identify clearly what are the critical elements in the water management system of Brazil. Even if every state related some different problems, some common concerns and obstacle in the implementation of IWRM and participatory processes are deductible:

- the centralizing attitude of states and centralized political and institutional structures;
- the overlapping competences between the federal, state and basin levels;
- the lack of agility of the system characterized by over-bureaucratic procedures;
- the limited deliberative power of Committee, whose competency is restricted to consultative functions;
- the insufficiency of financial resources and consequent economical dependence on external entities;
- the unequal expression of interests in the Committee composition;
- the low confidence of population and Committee member in relation to institutional actors and actions;
- the lack of integrative negotiation processes that lead to a joint management of water resource;
- the sectorial and fragmented character of politics.

Some of the mentioned criticalities that have been evidenced can lead to the conclusion that the river basin Committee is not yet an efficient body to guarantee stakeholders participation. The gaps in the Federal water management system allow discretionary approaches of stakeholder involvement, both in the process of selection of Committee members, and in the general public mobilization actuated in the Committee initiatives. Moreover, the lack of detailed written relations on the methodological methods adopted in participatory practices does not guarantee a sufficient level of transparency of the processes.

2.6. Conclusions

Similarly to IWRM, the Brazilian Water Reform and the new Federal water management system establish common principles and instruments, having as goals decentralization and participation, along with integration. However, the Federal normative framework leaves an abundant freedom to states in term of regulation and implementation of participatory processes.

The socio-economic context and the specific water problems, like pollution or scarcity, force water policies, but they are not sufficient to explain the development of the water reform and of the management model adopted by each state. Indeed, studying Southern and South-eastern states that share the same level of socio-economic development and similar water problems, we see that the reform has followed a different path in each of them. This is explained because political, cultural and historical factors have marked each sate in different ways (Guitierrez 2007).

However, it is possible to identify some common criticalities and obstacles shared by all the case studies. Such impediments come from the fact that the water reform process was not followed by a large and comprehensive institutional reorganization, which led to the impasse between the creation of laws establishing the guidelines for management and their real application.

The water resource management in Brazil has been implemented until now with a set of bureaucratic-institutional measures that need to be improved and ameliorated. The decentralized water management system in Brazil appears still fragile, and has to be drive by a further change in the mentality, behaviour and attitudes of the public institutions.

A strong institutional reform has to be actuated, since institutional problems are the most urgent and shared by all the states. Unclear or overlapping competencies, as well as over-bureaucratic procedures, are just some examples of very critical issues to be solved.

In addition, given the multiple composition of the Committees, the lack of confidence between public bodies and civil society, the vague and often overlapping definition of competencies, and the complexity of issues that river Committees should face together with public bodies, there emerges the need of implementing some specific participatory workshop, involving civil society, institutions and water users, aimed at facilitating a co-learning process from the reciprocal and different perception of reality. Such occasions could represent a means of constructing confidence relations and of legitimating future decisions.

More transparency is needed in the communication and externalization of participatory processes objectives, methods and phases, paying attention at the use of a simple language during public meetings.

An effective participatory process should involve social actors in an interactive (interaction between actors and decision makers and / or scientists) and iterative (repetitions over time) proposal, where the flow of information is exchanged towards several directions: from social actors to researchers, from public officers to social actors and to researchers back to social actors and public officers etc.

Yet, a further effort is needed from the scientific community. Research on more practical aspects of participatory practices has to be developed and more reports have to be diffused. Investigation should regard both participation of society in the river basin Committee and participation of the river basin Committee into the decision-making process. This could permit comparative studies, and could allow learning from successful experiences, in order to advance in the implementation of water reform.

Last, but not least, a political-institutional re-arrangement at municipal, state and federal level is required to ensure an effective and coordinated, integrated and decentralized, management of water resources. The institutional reform is one of the biggest challenges to be overcome in the design of the Brazilian water management system

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SECOND ESSAY:
Participatory assessment of adaptation strategies to flood risk in the Upper Brahmaputra and Danube river basins

Lucia Ceccato [a], Valentina Giannini [a,b], Carlo Giupponi [a,b]

a Ca' Foscari University, Department of Economics, Venice, Italy

b Fondazione Eni Enrico Mattei (FEEM), Venice, Italy

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ABSTRACT

A methodological proposal aimed at improving the effectiveness of interactions between the scientific community and local actors for decision-making processes in water management was developed and tested to two case studies, in Europe and Asia: the Upper Danube (Danube) and Upper Brahmaputra (Brahmaputra) River Basins. The general objectives of the case studies were about identifying and exploring the potential of adaptation strategies to cope with flood risk in mountain areas. The proposal consists of a sequence of steps including participatory local workshops and the use of a decision support systems (DSS) tool. Workshops allowed for the identification of four categories of possible responses and a set of nine evaluation criteria, three for each of the three pillars of sustainable development: economy, society and the environment. They also led to the ranking of the broad categories of response strategies, according to the expectations and preferences of the workshop participants, with the aim of orienting and targeting further activities by the research consortium. The DSS tool was used to facilitate transparent and robust management of the information, the implementation of multi criteria decision analysis and the communication of the outputs. The outcomes of the implementation of the proposed methods and DSS tool are discussed to assess the potential to support decision-making processes in the field of climate change adaptation (CCA) and integrated water resources management (IWRM).

3.1. Introduction

According to the last assessment report released by IPCC in 2007, the climate has been changing over the last decades and will continue to change even if greenhouse gas emissions are reduced to meet the targets of the Kyoto Protocol (IPCC, 2007a; Mace, 2005). The environmental, social and economic costs of extreme weather events are already rising in both poor and rich countries.

Climate change impacts are expected to be unevenly distributed across the planet and some areas, like mountains covered by glaciers, will be subjected to major stresses. Projected climate change for the 21st century in the mountains of the world is two to three times greater than the change observed in the 20th century: all mountains are expected to warm significantly (Nogue´s-Bravo et al., 2007).

There is evidence based on observations that glaciers have been retreating and decreasing in volume, and that mountain snowpack is also decreasing. As a consequence the water storage capacity of the mountains has been decreasing over time (Nogue´s-Bravo et al., 2007; Stewart, 2009). The hydrologic cycle is thus changing and more dramatic changes are expected (Nogue´s-Bravo et al., 2007), up-stream and down stream, with summer droughts which might be longer (Stewart, 2009), together with decreased water availability (Messerli et al., 2004; Viviroli et al., 2007), especially when lowlands are arid, as is the case of systems like the Himalayas (Viviroli and Weingartner, 2004; Messerli et al., 2004). Though physically distant from each other, the populations of different parts of the world will be facing similar problems.

According to the Stern Review (Stern, 2006), it is no longer possible to prevent the climate change that will take place over the next two to three decades, and adaptation to climate change is therefore essential to protect our societies and economies from its impacts. Poor and developing countries in particular, which are only marginally responsible for anthropogenic climate change, will be the most affected by the expected impacts (Heltberg et al., 2009). Climate change is therefore also an equity issue and adaptation policies should continue to have a role in international negotiations and (Mace, 2005) scientific research.

Adaptation has been on the agenda since the Earth Summit in Rio (1992) and reference to adaptation can also be found in the United Nations Framework Convention on Climate Change (UNFCCC, 1992) and the Kyoto Protocol (1997). According to UNFCCC Annex II, countries that ratified the convention made a legally binding commitment to fund adaptation in developing countries (www.unfccc.int; Mace, 2005). However, it is not until the Marrakech Accords (2001) that adaptation policies and projects have gained importance (Schipper and Lisa, 2006) and in the Fourth Assessment Report of the IPCC (2007a), as well as in the Stern Review (2006), we find reference to a demand for research on adaptation, mitigation, and development.

Adaptation policies, however, can be very challenging, and negating their right importance would imply strengthening inequalities, thus burdening those countries and those sectors that will bear the heaviest impacts of climate change, such as water provisioning in river basins fed by glacier melt (Mace, 2005). Innovative water management approaches are, therefore, urgent and they must involve the study of adaptation to future scenarios (EC, 2009).

Integrated water resources management (IWRM) is the most popular paradigm adopted by legislation and plans in many parts of the world (GWP, 2000). The success of this paradigm is due to the recognition of the need to deal with the impacts of climate change on water resources in a holistic manner. Generally speaking, in fact, when dealing with the social-ecological system, it is often impossible to cope with one impact without affecting the other elements of the system: therefore the solutions are best sought in a holistic framework (Folke et al., 2002). Moreover, since the impacts are felt in a variety of sectors, and the result is bigger than the mere sum of the single impacts, responses can be developed in an integrated manner (Heltberg et al., 2009). Considering specifically water the IPCC acknowledges the fact that climate change will impact water availability, for example because of a reduced flow in watersheds fed by glaciers or snowmelt, which is the situation of the case studies presented in this article (IPCC, 2007b). Water scarcity sparks conflicts, which some think might be better addressed in an IWRM setting, where conflicting uses can find a compromise solution (WWC, 2006).

Participatory processes are one of the prerequisites of IWRM plans and projects. They further mutual learning between scientists and stakeholders, new opinions can be expressed, problems can be addressed, technical expertise shared, agreements reached, and compromise solutions found if all vested interests are voiced (Renn, 2006). Stakeholders' involvement is essential, because stakeholders hold the necessary information that could facilitate the exploitation of scientific knowledge with high social relevance (de la Vega-Leinert et al., 2008; Griffin, 2007; Reed, 2008).

In parallel to the increasing emphasis on public participation in IWRM, there is also an increasing attention to the need for efficient tools to support the management of those processes and to the role that could be played by information and communication technologies (ICT), mathematical simulation models and decision support system (DSS) tools, in particular. In the context of climate change research the first category of tools may provide scientifically-based scenarios and projections – prerequisites for any planning activity – while DSS tools may provide the ground for bridging the scientific contributions (i.e. by further elaborating model outcomes) and decision/policy-making processes, including managing the participation of different actors (e.g. policy makers, local experts, dwellers, etc.) in a scientifically sound and transparent way. Despite the theoretical potential, traditional modelling techniques have shown limited impacts on policy-making, especially with respect to complex systems such as those involved in natural resource management. DSS tools have quite often performed similarly. One of the problems most often mentioned is the limited or late involvement of stakeholders and potential users (Geurts and Joldersma, 2001), which contributes significantly to the limited uptake of modelling tools and outcomes. The conventional division of roles between the academy and 'outsiders', where scientists supply conceptual frameworks, theories, methods which are then available for use by various actors in society, such as politicians, civil society, etc., is not accepted anymore (Scott Cato, 2009) and new relationships between science, politics and society are necessary.

One of the main challenges in attempting to bridge the gap between science and policy in the water management sector nowadays lies in the development of new tools combining the potentials of advanced ICT tools and robust participatory approaches (Mysiak et al., 2005). Such instruments could be identified as decision support methods and tools providing participatory modelling functionality, in which the exploration of the problem and the formulation of a conceptual model and its formalisation are carried out by disciplinary experts with the direct involvement of stakeholders in a way that is coherent with the so-called "hard science" modelling approaches to be adopted (Sgobbi and Giupponi, 2007). The computer-based tool is surely one important component, but, as recently pointed out in a comprehensive review and survey on this topic (Giupponi et al., 2011) the future of DSS should envisage a broader and more robust combination of the tool(s) and the process of structuring problems and aiding decisions, including adequate instruments for dissemination and training. In an idealized view DSS should thus act as mediators between science and policy/decision making and as catalysts of trans-disciplinary research.

This article illustrates some of the methods and findings of the Brahmatwinn Project,[1] with a specific focus on the approach developed for demonstrating the potentials of innovative decision support processes and tools.[2] They are presented for their potential as a methodological and operational reference for the management of decision processes in a participatory context for the development of IWRM plans, including climate change perspectives and adaptation needs.

The project was carried out through the collaboration of an international research consortium of European and Asian institutions and it focused on two – "twinned" – river basins in the two continents: the Danube and the Brahmaputra. The choice of these study areas stemmed from the idea, later confirmed by the research results, that the two upper river basins, even if very distant from geographical and socioeconomic viewpoints, would have commonalities, since they are both fed by glaciers potentially impacted by climate change. This hypothesis was confirmed during the project, which showed how climate change (CC) scenarios downscaled for the case studies (Dobler et al., 2011), point out how intensified weather events in both areas are expected to cause an increase in rainfall in the wet season and of droughts during the dry periods. Climate change could thus exacerbate the uncertainty of water availability and quality, and the occurrence of extreme events, as Brahmatwinn climatologists have suggested.

For the purposes of the project, five case studies have been analysed: two in the Upper Danube River Basin (Danube) – the Lech RB and the Salzach RB (Austria and Germany) – and three in the Upper Brahmaputra River Basin (Brahmaputra) – the Assam State of India, the Wang Chu RB (Bhutan) and the Lhasa RB (Tibet, China).

The FEEM[3] research group – to which the authors of this paper belong – developed a methodological proposal aimed at strengthening the communication and collaboration within the research consortium and with local communities of the end users of project outcomes. The proposal enabled exchange of knowledge and feedbacks between the twinned river basins, and among scientists and local actors[4] (LAs). A programme of local workshops in the two river basins was thus defined in parallel to the other research activities in various disciplinary fields (dynamic climatology, hydrology, sociology, economics, etc.) relevant for the integrated assessment of climate change impacts and the development of adaptation strategies.

The paper is organized as follows: Section 2 describes the methodological framework adopted, the information base and the DSS design. Section 3 presents the results of the application to the Brahmatwinn project. Section 4 discusses the outcomes achieved and draws some conclusive remarks.

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[1] Project title: Twinning European and South Asian river basins to enhance capacity and implement adaptive management approaches. (Brahmatwinn). Project no: GOCE -036952. Research funded by the European Community, SUSTDEV-2005-3.II.3.6: Twinning European/third countries river basins.

[2] A comprehensive and concise presentation of the results of the whole Brahmatwinn project is presented in a recent issue of Advances in Science & Research Open Access Proceeding at www.adv-sci-res.net/7/1/2011/.

[3] Fondazione Eni Enrico Mattei.

[4] We use the term local actor (LA) to identify all the people involved in the case study activities instead of the more commonly used term stakeholder, to emphasise the fact that they were local experts or policy makers, without the ambition to assess their representativeness with robust procedures, such as social network analysis.

3.2. Methods

3.2.1 The methodological framework

The approach adopted for the analysis of alternative adaptation responses is developed upon the NetSyMoD[5] methodological framework (Giupponi et al., 2008) for the management of participatory modelling and decision processes in the field of environmental management.

NetSyMoD is organised in six main phases. The first three (Actors' Analysis, Problem Analysis, Creative System Modelling) were implemented in the initial activities of the project and are not described here. They provided the Brahmatwinn research with (a) a list of the local actors to be involved in the participatory activities; (b) an in-depth analysis of general problems related to water resources management in the two upper river basins, with the participation of the communities of parties interested in the case study areas; (c) mental model representations of the problems, i.e. qualitative descriptions of the causal links among the various components of the local socio-ecosystems by means of cognitive maps clustered in order to be consistent with the DPSIR framework (EEA, 1999); and (d) extensive data sets deriving from hard science modelling activities, consisting mainly in spatial and temporal data sets describing climate change scenarios and their expected consequences in the study areas.

This NetSyMoD methodology relies on the DPSIR framework (driving forces, pressures, state, impacts, and responses), as a comprehensive and simplified conceptual framework for the formalisation of man-environment problems. An extended version of DPSIR is adopted to overcome some of its recognised weaknesses, responding to the necessity, remarked by Svarstad et al. (2008) of expanding the DPSIR framework to incorporate social and economic concerns. In the proposed approach Exogenous Drivers are added, to consider all those driving forces that act as external forcing variables to the system representing the study case: for example climate change, or international markets or policies, which are beyond the sphere of the potential effects of the decisions in question. The extended DPSIR framework is used as a communication interface, categorising the various components of the projects (in particular multiple kinds of information and knowledge) and facilitating the identification of the main causal relationships, thus framing the need for data processing procedures and modelling capabilities.

The fourth and fifth phases, DSS Design and Analysis of Options, are aimed at involving the actors and disciplinary experts in the design and evaluation of a set of alternative responses, in this case four broad categories of flood risk mitigation strategies, and are those reported in this paper. The last phase, Actions and Monitoring, is beyond the scope of the research project and it refers to the implementation of the decision taken by the competent administrations.

In particular, the DSS Design phase develops upon the conceptual models provided by the previous Creative System Modelling phase and consists of specifications in terms of elaboration and management procedures at the interface between the scientific outcomes of the project and the preferences and expectations of local actors. The Analysis of Options implements the results of those elaborations and consists in a series of participatory events supported by an ad hoc decision support system software (mDSS; Giupponi, 2007). The mDSS tool provides the framework for decision analysis at the interface between scientific

[5] NetSyMoD (www.netsymod.eu/) stands for network analysis, creative system modeling and decision support.

outcomes and the preferences of the involved actors, with a set of techniques aiming at the elicitation and aggregation of decision preferences and through the implementation of multi criteria decision analysis (MCDA; Figueira et al., 2005). MCDA techniques are adopted to assist a decision maker, or a group of decision makers, in identifying the preferred alternative out of a range of alternatives in an environment of diverging and competing criteria and interests (Belton and Stewart, 2002).

In order to implement those two phases, the participation of local actors (LAs) in the two case studies was achieved through a series of workshops, in which brainstorming techniques were initially used to elicit the most relevant local issues and the most promising responses – potential or in place – to cope with flood risk in a climate change perspective.

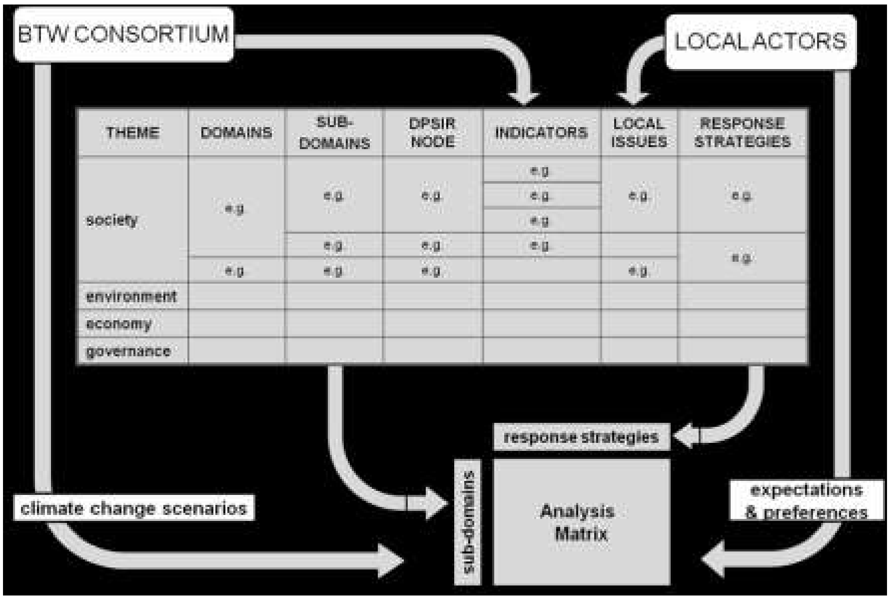
In parallel, disciplinary experts of the project were involved in an exercise to develop a catalogue of indicators, categorising the widest collection of data provided through analyses and modelling of various kinds and facilitating the communication of the expected outcomes in advance to the interested parties. Local issues raised by the involved actors express the demand of knowledge, while the delivery of information planned by the researchers represents the planned supply of knowledge. The two should in theory match to allow for an effective transfer of knowledge and local impact of the project. This aspect is unfortunately, quite often either neglected in many international research efforts, or considered only in the final phases of the activities, thus dramatically limiting the potential research outcomes. An innovative solution designed to cope with this problem was the implementation of a series of activities carried out in parallel with both the researchers and the local actors belonging to the two case study areas, culminating with the delivery of an extensive integrated indicator table (IIT).

The IIT represented the main interface to the knowledge base developed by the Brahmatwinn Project allowing the combination and comparison of the supply and demand of information (see Fig. 1 for the IIT structure and functions and Supplementary on-line Materials for details). On the left side of the table a hierarchical classification of the information relevant to the whole research project is reported, starting with the level of greatest aggregation, i.e. the four ‘‘Themes’’ (Environment, Economy, Society and Governance). The ‘‘Themes’’ are sub-divided into ‘‘Domains’’, which are further segmented into ‘‘Sub-domains’’. Such a categorisation of relevant information for the project was developed with a Delphi technique in a series of steps, in which all the project partners were involved. At the highest level of detail ‘‘Indicators’’ were identified by partners (one or more per Sub-domain) as the means of providing a quantitative assessment of the various typologies of information dealt with by the project. The left hand side of the IIT thus represents a comprehensive catalogue of the information provided in the project and intended to be useful for supporting the identification of response strategies at local level.

On the right hand side of the IIT, the issues identified by local actors during the workshops dedicated to the NetSyMoD phases of Problem Analysis and Creative System Modelling are assigned to related ‘‘Sub-domains’’, thus providing an interface between the potential supply of information from project activities, and the demand from potential beneficiaries. In general it was possible to create such correspondence, but in some cases, as exemplified in Fig. 1, it appeared that either the consortium was ready to provide information not immediately relevant to local issues or the local actors were raising issues not dealt with by the project, thus identifying the existence of knowledge gaps. As described below – and depicted in Fig.

1, information categorised within the IIT was at the basis of the organisation of workshops aimed at analysing the expectations and the preferences of LAs in terms of future strategies, to orient the final steps of analysis of the project, with the help of the mDSS software.

Fig. 1. The interactions between local actors and the consortium of researchers of the Brahmatwinn (BTW) Project: interfaces and fluxes of information in support to participatory workshop conducted for the analysis of options in terms of strategies to cope with evolving flood risks within climatic change scenarios.



Therefore, sub-domains were also assigned to the five nodes of the DPSIR framework, for maintaining the coherence with such conceptual framework and preparing for the utilisation of the mDSS tool (see Fig. 2).

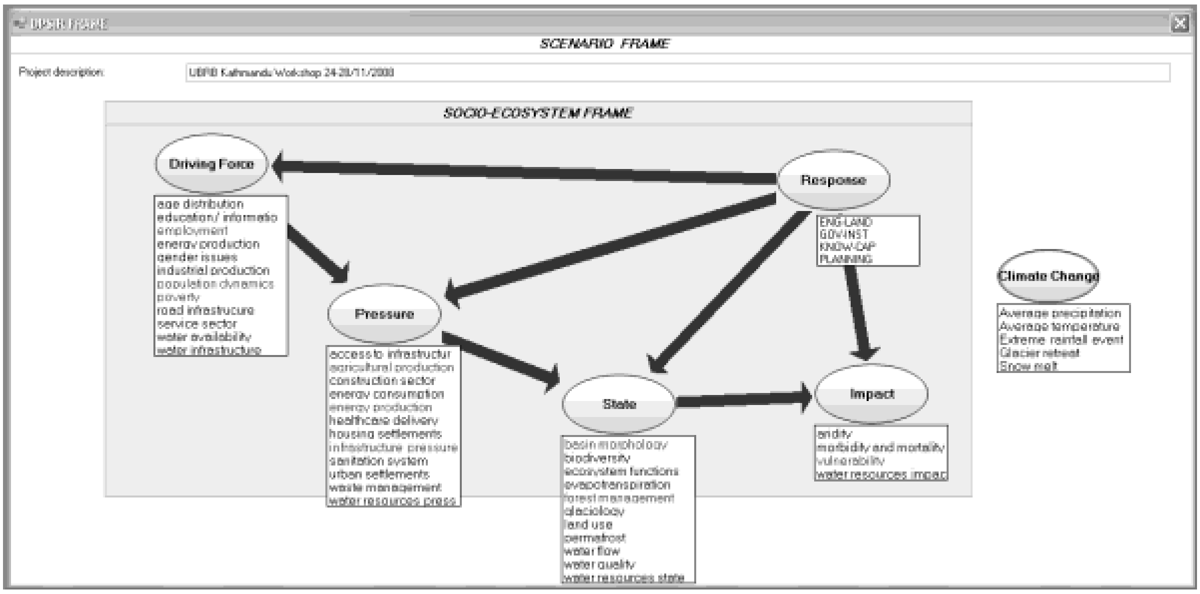


Fig. 2. The conceptualisation of the information base stored in the IIT within the extended DPSIR framework (screenshot of the mDSS software).

In collaboration with project partners the possible IWRM strategies to cope with flood risks in future climate change scenarios in the two areas were categorised into four broad categories of Responses (according to the DPSIR definition), in order to involve LAs in the process of targeting and finalising the remaining project activities:

1. ENG-LAND: Engineering Solutions and Land Management (e.g. dam construction, river network maintenance, soil conservation practices, etc.);
2. GOV-INST: Investments in Governance and Institutional Strength (e.g. accountability and transparency in government actions, enforcement of existing regulations, flood insurance, etc.);
3. KNOW-CAP: Knowledge Improvement and Capacity Building (e.g. awareness-raising activities, dissemination of scientific knowledge, training of public employees, etc.);
4. PLANNING: Solution based on planning instruments (e.g. design and implementation of relief and rehabilitation plans, hazard zoning, etc.).

3.2.2 The DSS design and analysis of options

Building upon the information acquired in the participatory activities carried out in the first two years of the project and referred to in the first three NetSyMoD phases, two workshops were organised, one in Salzburg, Austria (Danube) and one in Kathmandu, Nepal (Brahmaputra), with the aim of testing the proposed methodology. In order to guarantee the comparability of the results of the two river basins, both workshops were structured using the same procedure, designed with the purpose of building a common language and understanding of the problems within the groups of LAs, and between them and the research consortium. The workshops were organised in two half-day phases (afternoon of day 1 and morning of day 2) and their outline is briefly described below.

The workshops started with the **presentation** of the goals and of the preliminary results of the downscaling of climate change (CC) scenarios, by means of storylines developed by the project climatologists (Institute for Atmospheric and Environmental Sciences of Johann-Wolfgang Goethe University, Germany), focusing on the possible effects of CC on local water resources over the coming 40 years.[6]

Having introduced the problem and the scenarios, a brainstorming session was conducted to elicit and consolidate the sets of possible responses within the four main categories that had been defined during the previous project meetings. This section created the basis for the correct implementation of the ensuing steps, and led to the identification of sub-categories and specific actions, within the proposed four major categories of responses.

Having consolidated the identification of responses, participants were asked to select the criteria for the evaluation of responses, from the sub-domains listed in the IIT. Each participant was asked to rank the three most important, within three separate lists for the

[6] Climate change scenarios provided climate simulations using three IPCC-SRES scenarios (A1B, A2 and B1; IPCC, 2000) and the COMMIT scenario (i.e. the consequence of committing world economies to limit GHG concentrations at 2000 levels), five data sets (GPCC, UDEL, CRU, EAD, F&S) and four models (ERA40, CLM-ERA40, ECHAM5, ECHAM5-Γ).

economic, social and environmental domains, in terms of relevance for evaluating the responses (40 criteria in total were listed in the IIT).

Once identified the nine most important evaluation criteria (three per each sustainability theme considered), participants were asked to provide weights expressing their relative relevance. The criteria-weighting procedure was based on the method proposed by Simos (1990) and revised by Figueira and Roy (2002), which involves the aid of sets of cards. This method was very appropriate for these workshops, because it supports the planned application of the Electre III method (Belton and Stewart, 2002) and because it provided a simple and effective approach for weighting, without the need of a computer lab, which was not always available.

Criteria and responses defined the entries of the Analysis Matrix (9 rows and 4 columns for criteria and response categories, respectively) and, together with the weight vectors, they were used for the subsequent evaluation exercise, by means of the MCDA methods provided by the mDSS software. Participants were asked to fill in the matrix, responding to the question "What is the potential effectiveness of the responses (columns) in coping with the issues expressed by the criteria (rows)?". In practice, they evaluated the potential effectiveness of each response (columns) in coping with the issues expressed by the criteria (rows) by means of a Likert scale (from 1 to 5 ranging from "very high expected effectiveness" to "very low expected effectiveness").

A second Likert scale was added in every cell to analyse the degree of confidence and uncertainty related to LAs opinion (IPCC, 2005), i.e. a rough idea about the uncertainty related to the judgement provided for every combination of response category and assessment criterion. In the forms distributed to workshop participants, the concept of uncertainty was specifically related here to their perceptions of the limits in the predictability of the effectiveness of the responses.

The compilation of the AM concluded the first part of the NetSyMoD workshop. All the data collected were coded with a spreadsheet software and then passed to the mDSS tool, for Multi-Criteria Analysis (MCA) and Group Decision-Making (GDM). The mDSS software allowed for the comparison of the alternative options using MCA techniques, by operating parallel evaluation processes, representing the preferences of each participant. In practice, the qualitative evaluations contained in the Analysis Matrix were transformed into normalized scores that expressed the performances of the responses in real numbers ranging between 0 and 1, and subsequently processed by means of the ELECTRE III decision rule (Belton and Stewart, 2002), allowing the aggregation of partial preferences describing individual criteria into a global preference and the ranking of the alternative strategy categories. ELECTRE adopts a pairwise comparison of the alternatives, so it is computationally rather demanding, but very simple to be applied by practitioners. The preference (P) and indifference thresholds (Q) were parameters defined by the research team as an input, while no veto threshold (T) was introduced in the analysis, because not pertinent to the selected indicators and analytical context.

Results of individual outranking procedures were subsequently combined in a Group Decision-Making procedure by means of the Borda rule (de Borda, 1953).

All the results of the data processing were reported to the participants in a final plenary session of the NetSyMoD workshop.

3.3. Results

The two workshops in the Danube and Brahmaputra were conducted in parallel without exchanges of information between the two communities of LAs. Even so, five out of nine selected criteria are common to the two cases revealing that in the two river basins, though characterised by different geographical locations, ecological, social and economic dimensions, LAs approach decisions about future strategies in a similar way, i.e. by basing the decision upon a similar set of criteria.

A valuable outcome of the twinning approach, therefore, has been the delineation of some crucial aspects related to flood risk and climate change adaptation strategies in the two river basins. Vulnerability was one of the highest weighted criteria, demonstrating the relevance of the issue and, in general, the concern on the two basins' ability to cope with the adverse effects of climate change in the future. Vulnerability is a hotly debated concept, but according to the IPCC (2007b), vulnerability is determined by the exposure to climate change, by the physical setting and sensitivity of the impacted system, and by its ability to adapt to change. Following this definition, an interpretation of LAs' opinions expressed during the workshops can be provided.

The exposure to climate change risks is clearly related to *Basin Morphology*, that is the physical characteristics of the drainage area, which could appear an obvious consideration, but, on the contrary, it highlights here that the design of actions and strategies lacks careful consideration of the specificity of the area. *Population Dynamics* is contemplated as one of the most important driving forces to be studied to cope with flood risk. Population size and growth, the distribution across urban and rural areas, population concentration, the distance between settlements and riverbanks, are examples of some of the aspects to be evaluated in the strategy design. Also the role of *Agriculture Production* has to be carefully considered by policy makers. Critical issues are related to irrigation infrastructure and extension, ratio of commercial agricultural land per household, household agriculture dependence as a primary source and cropping patterns and diversity. Finally, the pressure caused on *Infrastructure*, according to the LAs, has to become one of the central points of flood risk reduction strategies. Attention has to be paid to the extent of potential damages caused by floods to human infrastructures, like dams and reservoirs; aspects like the probability of dam break, the reservoir-induced seismicity, the downstream stream bed retrogression, the upstream reservoir sedimentation volume and submergence area have to be studied and integrated in the policy focus.

Table 1: Criteria selected by LAs from the Integrated Indicators Table (IIT) and their weights

	Criteria selected at the UDRB WS	Weight	Criteria selected at the UBRB WS	Weight
SOC.1	Housing settlements	0.138	Poverty	0.125
SOC.2	Population dynamics	0.097	Population dynamics	0.132
SOC.3	Infrastructure pressures	0.133	Infrastructure pressures	0.100
ENV.1	Vulnerability	0.144	Vulnerability	0.145
ENV.2	Basin morphology	0.091	Basin morphology	0.125
ENV.3	Ecosystem functions	0.143	Forest management	0.113
ECO.1	Agricultural production	0.111	Agricultural production	0.103
ECO.2	Construction sector	0.099	Energy production	0.101
ECO.3	Energy consumption	0.043	Employment	0.056

Besides the emergence of such similarities, the exercise of criteria selection also evidenced the significantly different relevance attributed to a series of proposed criteria out of the lists of proposed sub-domains. In the Brahmaputra, to which mainly low-income countries belong, "*Poverty*" was picked as the most relevant criterion, highlighting how the poverty level and low life standards strongly affect the significance of flooding damages in the area.

It is, indeed, recognized that poverty is directly related to vulnerability to climate change, since it is a determinant of adaptive capacity. Countries with limited economic resources are likely to have also poor infrastructure, fragile institutions, low levels of technology, reduced skills, limited access to information and to resources, and consequently little capacity to adapt. Poverty is both an important determinant of endogenous environmental risk, and hence indirectly of socioeconomic vulnerability, and an important constraint of adaptive capacity (Brouwer et al., 2007). Hence, poverty reduction policies would indirectly reduce the exposure to flood risk.

It is also interesting to notice that "*Forest management*" was selected in the top-3 environmental sub-domains only in the Brahmaputra. In the Danube, instead, LAs concentrated their votes on "*Housing settlements*", showing a different perspective in the European area when considering flood risk. According to LAs, the flood risk in the Danube seems to be affected mostly by housing concentration, high population density and the concentration of residential constructions in areas exposed to flood risk. With respect to the economic criteria, "*Agriculture production*" was considered as one of the most relevant in both river basins. This confirms that, according to the LAs' opinion, agricultural systems, irrigation infrastructures and land use in general are crucial and can contribute to either aggravate or reduce the risk of flooding.

Having identified the set of nine evaluation criteria, workshop participants then defined their relative importance by attributing criteria weights (**Table 1**), providing information about the relative relevance to be given to the criteria in the final ranking of alternatives. Besides the difference in the relative importance of each criterion, it is interesting to observe that in both river basins LAs tend to hold environmental and social criteria in greater regard than economic ones. We can easily see this by summing up criteria weights for each dimension: the environmental dimension was considered the most important, accounting for 38% of the total weights, followed by the social (36–37%) and lastly by the economic one (25–26%).

The calculation of weights by means of average aggregation, however, can homogenise and flatten the values. Aggregate values can therefore hide important information, such as divergence and convergence of participants' opinions. The discordance in the weight evaluations clearly reflects the different perceptions and objectives of LAs, and reveals the presence of possible conflicting interests among them. The elicitation of weights is therefore a very crucial phase, because weights can strongly influence the results (Belton and Stewart, 2002). In fact, in theory, an equal representation and integration of all the issues at stake should be guaranteed in participative exercises. In our case, after analysing the distribution and the spread of individual preferences for each criteria weight using Box and Whisker plots (see **Fig. 3**), we were able to verify that in general, among the Danube participants, there was a reasonable concordance in weight attribution, while, on the contrary, among Brahmaputra respondents we observed high discordance in weight evaluations.

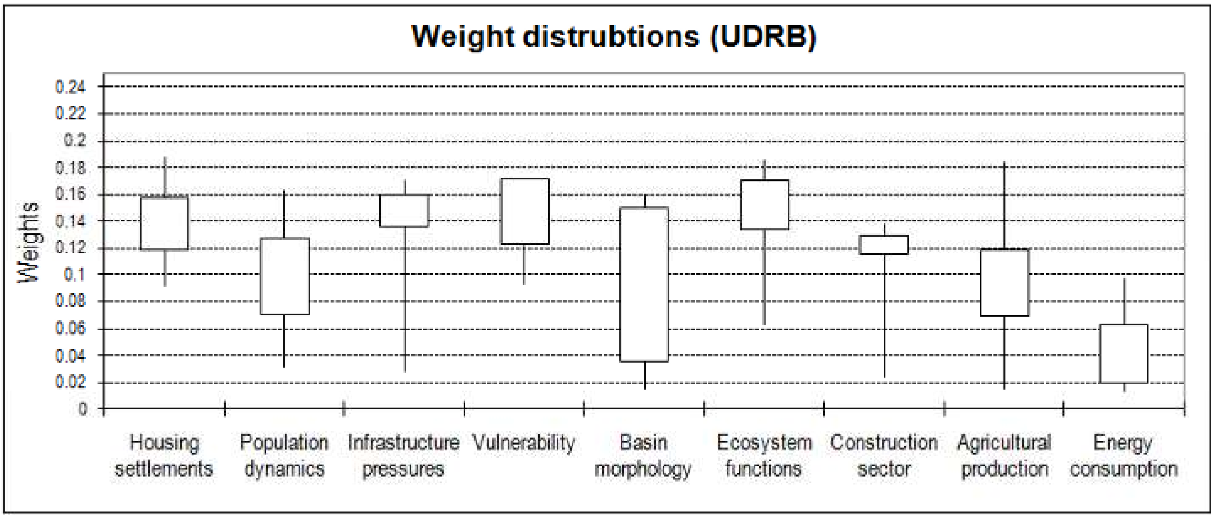


Figure 3: Box and whiskers plots of the dispersion of weights provided by local actors of the UDRB (a) and UBRB (b).

This result pointed out the need for a sensitivity analysis, for the Brahmaputra case, to monitor how changes in the weight sets could influence the final ranking. Sensitivity analysis, indeed, is necessary to improve the quality of environmental decisions and verify the robustness of the results (French and Geldermann, 2005 and Cloquell-Ballester et al., 2007), and it should, therefore, be recommended in all the cases of implementation of the proposed approach in the practice of decision making. In this exercise the sensitivity analysis of weights was performed by exploring the effects of incrementing and diminishing one weight at a time by 25%, 50% and 75%, and rescaling all the others while maintaining the original proportions among them. The sensitivity analysis results are discussed further on in the article.

The following step was the elaboration of the Analysis Matrix (AM) for each river basin, aggregating and averaging the information collected from each individual AM of participants. Two average AMs resulted (Table 2).

Table 2 – Analysis Matrix – average values of LAs' evaluations on the potential effectiveness of each response in coping with the issues expressed by the criteria (rows) by means of a Likert scale ranging from 1 "Very high effectiveness" to 5 "Very low effectiveness"."

Analysis Matrix (Average values) **Upper Danube RB**		PLANNING	KNOW-CAP	GOV-INST	ENG-LAND	**Average**
SOC.1	Housing settlements	2,00	2,43	2,57	2,71	2,43
SOC.2	Population dynamics	2,86	3,00	2,29	3,29	2,86
SOC.3	Infrastructure pressures	2,43	2,14	2,57	2,00	2,29
ENV.1	Vulnerability	2,33	2,67	2,50	2,67	2,54
ENV.2	Basin morphology	2,71	2,57	3,43	3,29	3,00
ENV.3	Ecosystem functions	2,86	2,43	2,29	3,43	2,75
ECO.1	Construction sector	2,14	3,29	2,57	2,43	2,61
ECO.2	Agricultural production	2,86	3,14	2,71	2,57	2,82
ECO.3	Energy consumption	2,86	2,43	2,57	2,86	2,68
	Average	2,56	2,68	2,61	2,80	

Analysis Matrix (Average values) **Upper Brahmaputra RB**		PLANNING	KNOW-CAP	GOV-INST	ENG-LAND	**Average**
SOC.1	Poverty	2,43	2,62	2,00	3,33	2,60
SOC.2	Population dynamics	1,76	2,52	2,33	3,19	2,45
SOC.3	Infrastructure pressures	2,00	2,86	2,67	2,19	2,43
ENV.1	Vulnerability	1,71	2,43	2,24	1,95	2,08
ENV.2	Basin morphology	2,38	2,67	3,10	2,43	2,64
ENV.3	Forest management	1,86	2,10	2,10	1,95	2,00
ECO.1	Agricultural production	2,15	2,50	2,48	2,29	2,35
ECO.2	Energy production	2,19	3,00	2,43	2,10	2,43
ECO.3	Employment	2,43	2,57	2,43	3,52	2,74
	Average	2,10	2,58	2,42	2,55	

From the observation of preliminary data, the results in both the Danube and Brahmaputra showed that none of the categories of strategies clearly dominates the others. All the average criterion scores (bottom rows) or responses (columns farthest to the left) are in a range between "very high effectiveness" and "medium effectiveness", meaning that all the responses are considered to be potentially effective to cope with flood risk and important to deal with the selected environmental, social and economic criteria.

This result is not too surprising. Indeed, throughout the participatory process developed along the entire project, LAs gradually shared their knowledge and perceptions of the various aspects discussed around adaptation strategies to climate change. This process enhanced a shift in LAs views of the problem, from a more individualistic perspective to a common understanding of the interdependence of its multiple dimensions and, thus, of the related policies to cope with. This emphasizes the role of scientists in supplying such a communication platform and confirms the great potential of this methodology to boost knowledge sharing and mutual learning between scholars and LAs.

A supplementary validation of these results is given by the analysis of confidence scores attributed by LAs to their evaluations. The LAs were asked, indeed, to indicate the degree of confidence related to their answer (normalised scale of confidence ranging between 1 "Very high confidence" and 0 "Very low confidence"). All the answers were given with a confidence above the normalised value of 0.5 and very close to the highest one (i.e. 1.0).

The last part of the analysis consisted in calculating the ranking of alternative responses by applying the MCA capabilities of the mDSS software. The partial scores describing the performance of each alternative response with respect to each single criterion were thus aggregated, considering the elicited weights and following the decision rule adopted (i.e. ELECTRE III). On average, LAs of both river basins evaluated the PLANNING solution as the most effective one. The remaining categories show different preferences and ranking in the two basins: in the Brahmaputra the second ranked category is ENG-LAND (e.g. dam construction, river network maintenance, soil conservation practices, etc.), there is no preference between investments in GOV-INST (e.g. accountability and transparency in government actions, enforcement of existing regulations, flood insurance, etc.) and KNOW-CAP (e.g. awareness-raising activities, dissemination of scientific knowledge, training of public employees, etc.). The LAs of the Danube instead ranked ENG-LAND as strictly dominated (not preferred) by all the other alternatives, with GOV-INST and KNOW-CAP ranked third and fourth, respectively.

Given the broad meaning of the categories of strategies considered and the exploratory context of the exercise with a relatively high number of stakeholders involved, dramatic differences in the performances were not expected and the differences of the performances were not of great interest. The robustness of the ranking was instead a main issue, because the following steps of the project went into a more detailed analysis of possible strategies within the preferred category identified at this stage.

The robustness of the results was explored and confirmed firstly with a sensitivity analysis of weights, which showed an overall stable performance. In the Brahmaputra basin, all the verified variations of weights (from ±25%, and ±50%) did not induce an overturning of the ranking, confirming PLANNING as the preferred option and ENG-LAND as the second ranked category. In the Danube basin the ranking was confirmed with variations of weights by ±25%, while it was observed that a variation by +50% of the criterion *Population Dynamics,* or of the criterion *Infrastructure Pressure* by −50% would determine a change of the ranking. These variations are indeed very high, so that the results can still be considered robust enough, nevertheless it should be mentioned that in those cases the GOV-INST became the preferred category, thus pointing out a slightly different perspective of the Danube stakeholders.

Moreover, in order to explore the possible effects of averaging the preferences of multiple actors in terms of both analysis matrices and weight vectors, the data collected from each LA were also processed separately thus obtaining multiple final rankings of options. All the rankings obtained were subsequently processed in mDSS using the Group Decision-Making (GDM) capabilities, by means of the Borda Rule. The Borda rule counts how many times each category of responses is preferred to each of the other options by interviewed LAs, and sums up the so called "votes in favour"[7]. According to Borda mark (Table 3), we observed that the PLANNING category is the dominating solution (most preferred one) in both basins, with 10 votes in the Danube and 38 in the Brahmaputra, respectively.

Table 3: Group Decision Making marks. The first number refers to the N. of votes in favour, while "I" refers to the votes of indifference.

UDRB	PLANNING	ENG-LAND	KNOW-CAP	GOV-INST	**sum of votes in favour**	**BORDA Mark**
PLANNING	---------	3 (I=0)	4 (I=0)	3 (I=2)	**10**	**1°**
ENG-LAND	4 (I=0)	---------	1 (I=0)	2 (I=0)	**7**	**3°**
KNOW-CAP	3 (I=0)	5 (I=1)	---------	1 (I=3)	**9**	**2°**
GOV-INST	2 (I=2)	5 (I=0)	3 (I=3)	---------	**10**	**1°**
UBRB						
PLANNING	---------	10 (I=6)	16 (I=3)	12 (I=5)	**38**	**1°**
ENG-LAND	5 (I=6)	---------	9 (I=4)	8 (I=6)	**22**	**2°**
KNOW-CAP	2 (I=3)	8 (I=4)	---------	8 (I=6)	**18**	**3°**
GOV-INST	4 (I=5)	7 (I=6)	7 (I=6)	---------	**18**	**3°**

[7] The votes in favour, in Borda mark, consider strictly preferences and do not count indifference.

For the purposes of the exercise within the activities of the Brahmatwinn Project, the results were robust enough to orient the attention of the researchers toward analysing in greater detail the strategies for mitigating flood risks in a climate change perspective within the broad category of PLANNING. Discussions with LAs were useful to better define strategies and actions which should be considered within the preferred category of PLANNING measures, and assessed in a more detailed second round of analysis supported by mDSS (not reported in this paper).

In both basins the attention was driven to: improving the implementation of existing land use plans; establishing protected areas along rivers; designing new catchment development plans; coordinating regional and community level planning; evaluating and harmonizing existing hazard plans; restricting the construction in risk areas; realizing flood risk mapping and zoning and vulnerability mapping. In the Danube river basin LAs also pointed out strategies oriented toward designing and implementing IWRM plans, underlining the need for a common government platform of the basin, and strategies focused on the planning of retention areas and urbanisation processes. In the Brahmaputra basin, LAs also focused their attention on strategies related to disaster risk management act and plan, for an earlier intervention and community preparation to flood occurrence.

3.4. Discussion and conclusions

The NetSyMoD methodological framework developed for the integrated participative activities of the Brahmatwinn Project, with the involvement of both researchers and local actors, facilitated in general communication and exchanges of experiences between the twinned river basins, and among scientists of different disciplines and local actors, through a continuous interaction and feedback process. In particular, the participative process proposed contributed significantly to ensuring that the scientific knowledge and approaches offered could meet the perceptions and needs of local people and decision makers, who would ultimately be the end-users of the project's outputs. The process also enabled the management of the different roles needed according to French and Geldermann (2005): researchers giving insights on how the future might unfold, with local actors providing judgements on the expected feasibility and effectiveness of the responses to cope with flood risk. In this case adaptation responses to climate change have, therefore, been evaluated by those adapting, i.e. local actors as suggested by de França Doria et al. (2009).

These findings show great potential for addressing further research efforts more effectively. In the case of the Brahmatwinn Project the results reported herein allowed for more targeted final activities, including a subsequent round of Analysis of the options focused on a set of possible strategies within the broader category of “Planning” approaches.

Looking at LAs’ contributions during the brainstorming phase of the workshops, we can interpret the preference given to “Planning” in a general way: there needs to be some kind of response developed a priori, so that when flooding occurs local authorities and communities know how to behave during and after the emergency, e.g. the design of relief and rehabilitation plans and disaster risk management. Also, in a stricter sense, LAs referred to the need of physically identifying and mapping hazard areas, such as flood risk zoning, and, more generally, land-use planning. The emergence of “Planning” as the most promising response in both basins might therefore mean that not only do LAs think that “Planning” is most needed in absolute terms, but also that it is currently the most deficient of the four categories presented. In the Danube, LAs acknowledged that change in land-use planning after major flooding events – even if partial – had been a key factor for the prevention of damage in more recent flood events.

Examples of change are the projects implemented for the renaturation of the river banks, which, according to some LAs, should be extended to other areas. However, LAs have also expressed the need to evaluate, harmonize, and implement existing plans. On the other hand, in the Brahmaputra the importance given to population density and poverty (i.e. second and third most important criteria) is related to the fact that many settlements are found in high risk areas, which are sometimes the only place where poor people can afford to live. The concern for encroachment on Brahmaputra's banks as one of the factors limiting the possibility of risk reduction voiced in the workshop confirms this hypothesis. LAs of the Brahmaputra have expressed the need for land-use planning to deal with concerns for urbanisation processes along the river banks, which should be prohibited and people already living there should be resettled.

The results were also circulated within the research consortium to direct the attention of modellers to the subsequent phases of the project, with the idea of providing a quantitative assessment of the strategies within the assessment framework described here. However, the ambition to substitute LAs’ expectations elicited through the Likert scale at the workshops, with quantitative assessments provided by models proved to be beyond the capabilities of the project, mainly because of time constraints. It should therefore be recommended that when approaches deriving from the one proposed here are adopted, the work plan be carefully defined with adequate time length and with the possibilities of (re)orienting hard science modelling according to the issues and the expectations elicited from the stakeholders.

Besides the methodological framework, also the mDSS software raised great interest among the participants, who were involved in the project activities since its initial phases, exposed to preliminary results and asked to contribute to orient the final phases of the project. Several participants appreciated the use of public domain software in particular, because it allowed the reuse of the approach proposed in local decision problems. In the scientific literature elements such as the timely involvement of stakeholders and the free availability of tools for reuse in local cases and elsewhere have been quite often proposed, but rarely applied in practice.

In this regard the results of this research are encouraging, because they advance our understanding of adaptation to climate change in river basins, and in particular they demonstrate how strategic planning can be implemented in practice, with the support of freely available tools. Starting with the brainstorming in each workshop we were able to elicit and develop a number of responses, needed or in place, to cope with flood risk and future scenarios. LAs of both basins were able to identify responses based on their knowledge and understanding, but also based on other responses identified in previous workshops, either in the same or in the other basin. This was possible thanks to the fact that besides the two workshops described in this article five others were held, i.e. a total of seven workshops took place according to the sequential and iterative process envisaged by the NetSyMoD framework.

In general, the experimental application of the NetSyMoD approach to the study areas provided a means to concretely carry out the twinning of the two river basins, shedding light on the commonalities and distinct features. This study approach led to structured and very effective discussions concerning adaptation responses to flooding in those areas, and allowed for the collection of a significant amount of insights and lessons, drawn from the involvement of local actors. From the evaluation questionnaires collected at the end of the events, we had no evidence of problems concerning the opportunities to freely and equally express opinions, possible biases, or about the process being guided by a dominant discourse, which may delegitimize some of the stakeholders only because they do not subscribe to a preliminarily defined agenda (Griffin, 2007).

As a final remark it should be remembered that the participatory processes described above were at least to some extent, academic simulations of social processes, since they were carried out within the activities of a research project; this implies that the results must be considered mainly for their role in methodological test and demonstration. For this reason, crucial aspects of real world applications were not dealt with by the project, such as the statistically sound identification of representative local actors. Having clarified this at the outset with the participants involved, these activities provided at least two very important opportunities and one caveat: (1) testing and refining methods and tools to be applied in real world decision processes, and (2) disseminating information about scientific developments and the availability of methods and tools to potential users of the project results. Regarding the caveat, it should be remembered that participatory activities should be carefully planned, designed and managed and that methods and tools are not enough – skilled professionals are needed too. This points to the need for future training efforts specifically targeted to provisioning the participatory processes to be implemented in IWRM and climate change adaptation processes with professionals of adequate capabilities.

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THIRD ESSAY:
Using participatory Fuzzy Cognitive Maps for structuring the Environmental Flow Assessment process in the Lower Paraguaçu Basin.

Lucia Ceccato

ABSTRACT

The paper illustrates the application of participatory methods for IWRM applied to a specific study case in Brazil. In particular, the research utilises the tool of Fuzzy Cognitive Maps to guide the construction of system understanding and to improve the effectiveness of the Building Block methodology for the environmental flow assessment of a river. The innovative integration of such methodologies was explored in order to externalize and structuralize experts' knowledge progressively, allowing the identification of synergies and interconnections among individual research methods. FCMs showed to be an excellent informal tool for knowledge construction, as well as a simple and clear way to represent causal relationships visually. The use of FCMs contributed to guaranty a higher integration of the disciplinary studies, which stimulated the construction of a system approach of research also in a situation where information was mostly qualitative and incomplete. In addition, the running of the final model consented to realize some prediction on the interactive and cumulative effects of relations between variables and the possible consequences related to environmental modifications. The application was performed to the Lower Paraguaçu River Basin and Iguape Bay (Bahia, Brazil). The research offered an operational approach to overcome common research problems of water management in developing countries.

4.1. Introduction

The increasing pressure and exploitation of water resources have led to significant degradation of the freshwater biodiversity and of the services that rivers provide. The socio-economic impacts of freshwater systems alteration and corruption are generally intense, because people are much more dependent on natural riverine services than they could perceive it, and they become aware only when the river is seriously degraded (O'Keeffee and Le Quesne 2009). People use rivers, lakes and wetlands for drinking, irrigating, fishing, as well as for recreation and cultural activities and for a variety of industrial finalities. Every modification in hydrological and environmental conditions of a river imply, indeed, a modification in the multi-functional use of its water resources, making indispensable and very challenging an integrated approach to river basin management (Das Gupta 2008). It is well known that dams (Renöfält et al. 2010), for example, modify the natural flood regime, limiting the water flow in the river, modifying the ecosystem and its natural dynamics and affecting the local communities living and depending on the river natural resources. The control of water discharge by dams usually causes an increase of the minimum flow and a reduction of the maximum flow - flattening the annual average in-flow curve – as well as an alteration of the natural seasonality of water flow (Porto, 1998).

In response to this, the concept of Environmental Flows has been introduced during recent decades. As the state of river systems is deteriorating all over the world, the study on environmental flows has become the centre of attention of scientific researchers, national and international political agendas, turning, in some cases, into a legislative requirement for water management (King et al. 2008). The science of environmental (or instream) flow assessments (EFAs) has evolved during the last five decades, as a means to facilitate the control and the recovery of such river degradation.

Environmental flows are flows that are left in a river system, or released into it, in order to maintain the river in a desired environmental state (King et al 2008), capable to keep healthy conditions for river ecosystems and for those people depending on the river. Environmental flows are aimed at the preservation of some of the natural flow patterns along the whole length of a river, so that people, animals and plants downstream can continue surviving and using the river's resources. Yet, the assessment of environmental flows goes far beyond determining a 'minimum' flow level for rivers, since all of the elements of a natural flow regime - as for example seasonal floods and droughts - are important in controlling the characteristics and natural communities in a river (O'Keeffee and Le Quesne 2009).

Environmental flows are determined in accordance with the goal of the river management, and greatly depend on the specific physical situation and the expected status of the ecosystem (Artinghton 2006). An ecosystem objective or status can be defined as a desired future state of an ecosystem that can be used to guide management. The determination of such a desired future state requires a deep understanding of how the ecosystems respond to management actions (Hobbs et al. 2002).

The assessment of the desirable environmental flow regime is strictly linked with the concept of ecological niche, that, as proposed by Hutchinson in 1957, addresses the ways in which tolerances and requirements interact, to define the conditions and resources needed by individuals or species, in order to practice their way of life (Begon et al., 2006). In order to establish a target status and the hydrological requirements that could maintain the river in a healthy or desirable condition, it is necessary to study and understand which are the organisms, populations and communities living in such a system, how their environment is, where they live and how individuals are affected by their environment and how they affect it. This understanding creates the basis for attempting a prediction of what will happen to an organism - or population or community or ecosystem - under a particular set of circumstances, which are consequence of possible scenarios of a water flow regime. The understanding of such a complex system and of the interactions that determine the distribution and abundance of its organisms and of all those factors and phenomena that influence their living - whether these are physical and chemical (abiotic) or other organisms (biotic) - is undoubtedly a challenging issue.

A wide array of methodologies has been developed in the last decades for the environmental flow assessment, including for example the hydrology-based approaches, the hydraulic rating methodologies and the habitat simulation methodologies (Tharme 1996, Tharme 2003). The so-called holistic methodologies (Arthington and Zalucki 1998) permit an ecological and ecosystem approaching to river systems. The holistic approaches to the environmental flow assessment try to create an understanding of the functional links between all the aspects of the hydrology and the ecology of a river system ((O'Keeffee and Le Quesne 2009), adding also the human component as an integrated part of the river system. They incorporate biological, geo-morphological and hydrological data, and consider all the aspects of the flow regime, such as the magnitude and the timing of both, base flow and flood events (Tharme 2008).

Some of the environmental flow assessment methods use *ecosystem dynamics models* as tools to attempt to predict a system's response to an external factor. These models are usually used to simplify the reality, to understand it and to predict its behaviour under changing conditions (Voinov 2008). In general, validated quantitative models of physical, chemical and biological processes are the best way to project such impacts; however, time, data, and model limitations often make these approaches not applicable (Hobbs et al. 2002), especially in the specific context of developing countries.

In developing countries, indeed, research studies very often have to deal with the scarcity or unavailability of information, in part due to inefficient and not integrated information systems, in part to hidden competitions among scientists and in part to the lack of historical quantitative data. Moreover, an over-bureaucratic institutional system can cause interruptions in the collection of information and in the disposal of financial resources. In this context, qualitative information become a precious but hardly usable resource, if they remain disorganized and unstructured.

One of the first holistic approaches designed for the specific context of a developing country was developed in South Africa in the '90s. It was named **Building Block Methodology (BBM)** (King and Tharme 1994). It consists in an approach intended to determine complex of different flow events – called blocks - capable of preserving a river in a predetermined condition (King and Louw 1998, King et al. 2000). This method is an interactive, scenario-based approach and involves also a socio-economic component, related to the use of river resources by traditional communities (Tharme 2003). The Building Block Methodology has been used mostly in developing countries, due to the fact that, being founded on experts knowledge and experience, permits to overcome the typical scarcity or fragmentation of data at disposal. The use of expert systems are frequently adopted in order to construct the ecological understanding, since they give strong and flexible means for finding solutions to a variety of problems that cannot be dealt by other, more traditional and conventional methods (Shu-Hsien 2005).

The BBM was designed as a process for guiding, organising and using, in a holistic way, a disparate array of knowledge and data, in order to provide the final output – the flow regime - quantified in space and time, needed for the desired future condition of a specific river (King et al. 2008). The BBM methodology involves a multidisciplinary team of research, in a series of converging phases, which end in a final 'BBM workshop', where the specialists determine the desired flow (Pollard 2000). In the BBM process, however, a wide degree of freedom is given to each specialist, who chooses the most appropriate methods for his/her discipline, to produce data in the required form and nature to be used in the BBM. The output, therefore, relies to a considerable extent on the professional judgment of the experts, and thus, depends on the care that is devoted to apply the process in a rigorous, well structured manner (Tharme 2008) and on the capacity of the coordinator of organizing and coordinating all activities and specialists. In addition, since the final results are discussed and negotiated by specialists during a participatory workshop, the output highly depends also on experts' capacity of integrating one with the others, on their use of an understandable language, and on the individual power and the dialectic skills of participants.

As a consequence, the BBM process does not necessary guaranty an effective integration among specialists' studies, nor the adoption of a system approach of investigation, as required by holistic methodologies.

This can be exacerbated by the fact that in developing countries it is still diffused a disciplinary approach of research, even when it is developed under an "interdisciplinary" framework. Scientific studies are often organized through disciplinary segmentations of reality, accustoming the specialists to a disciplinary approach of research, which represents an obstacle to the understanding of the socio-ecosystem as a whole.

The lack of a careful orientation of specialist's studies to incentive their communication and integration along the entire research process can be considered a strong weakness of the BBM methodology. For this reason, there emerges the need of incorporating in the BBM process an operational method, to structuralise and support the knowledge integration, to facilitate the communication of researchers and to frame the participatory processes along the research.

For this reason, this research investigates and tests the use of **Fuzzy Cognitive Maps** (FCM), as a participatory methodology able to alleviate some of the mentioned obstacles frequent in developing countries, and capable to improve the BBM process.

The implementation of FCMs can be effectively combined with the expert systems (Peña et al.. 2008) and so it represents a very good alternative to system quantitative models. Actually, this tool is able to transform qualitative information into predictions of the effect of possible modifications in the ecosystem (Hobbs et al. 2002). Fuzzy Cognitive Maps, being a semi-quantitative approach, are a very flexible and effective instrument that can support the construction of system understanding in situations where information source is mostly qualitative and where research segments do not follow an integrated approach (Özesmi, and Özesmi, 2004).

The construction of FCM can be carried out through individual interviews with the experts or through a participatory process of all of them. The use of a semi-quantitative method like FCM allows to incorporate system thinking in the participatory process, to aid a social learning process between stakeholders and modellers (Van Vliet et al. 2010), to facilitate the creation of consensus, to increase the stakeholders input in the quantification of their products (Van Vliet et al 2010) and, finally, to create the bases for a further development of the quantitative system modelling.

Here, the adoption of a participatory methodology refers to the participation of experts, and not to the participation of stakeholders or societies. However, this method could be extended also to these types of participatory processes.

The use of Fuzzy Cognitive Maps has been judged as a promising tool, capable of facilitating the identification of the environmental flows during the application of the Building Block Methodology.

Thus, this paper has investigated the utilization of Fuzzy Cognitive Maps with the following objectives:

- To simplify the description of the ecological functioning of a river system
- To identify the interconnections between inflow and downstream socio-environmental components.
- To orient the construction of expert understanding.
- To facilitate the organization of experts' knowledge or perceptions.
- To integrate disciplinary results.

- To overcome the problems related to incomplete quantitative information.

The application of this methodology has been performed for the Lower Paraguaçu River Basin and Iguape Bay (Bahia, Brazil.) case study, within the context study "*Estudo do Regime de Vazões Ambientais a jusante da UHE de Pedra do Cavalo – Baía do Iguape*".

The paper has been organized as follows. The next section presents the case study of Paraguaçu river and it is then followed by the description of the methodological framework. Afterwards, the results concerning the conceptual models of experts and those coming from the running of the FCM model are illustrated. Finally, the conclusions are discussed.

4.2. The Case study

The investigation activities have been developed in parallel with the research activities of the "*Estudo do Regime de Vazões Ambientais a jusante da UHE de Pedra do Cavalo - Baía do Iguape*"[8], a research project financed by the governmental Water and Climate Management Institute (INGÁ), actual Environment and Water Management Institute (INEMA), and developed by the Federal University of Bahia[9]. However, it has to be underlined that results and methods carried out by this paper are totally independent from the activities of the mentioned project.

The general objective of the research project was to identify the environmental flow that attends to the environmental requirements and social need of down-stream populations, in response to the negative effects generated by hydropower plant of Pedra do Cavalo, installed in the low segment of Paraguaçu river (UFBA-INGA 2009).

The determination of environmental flows in Brazil has been regulated by the legislation at boh state and federal levels, mainly in relation to the administrative procedures for environment licensing, and to water right granting. The federal and state water resources legislations, indeed, do not explicitly mention who should have the competence to define the environmental flow requirements (Sarmento 2007).

Actually, in Brazil there is no specific regulation with regard to environmental flow assessment. The Brazilian MMA (Ministry of the Environment) in the Normative Instruction 4/2000 concerning the administrative procedures to water right concession in federal water bodies, defines "environmental flow" as the minimum flow necessary to guarantee the preservation of the aquatic natural ecosystems equilibrium and sustainability. The CNRH (The National Water Resources Council), with the Resolution 16/2001, similarly, establishes that the "minimum flow" is the flow necessary to prevent environment degradation, to maintain aquatic ecosystems and adequate conditions to the fluvial transportation (Sarmento 2007). In the State of Bahia, the water law 11612/09 and the state Decree n. 6.296/97 establish the flow requirements on the base of hydrologic methodologies that utilize hydrologic data - time series of diary or monthly flows - to fix a minimum flow requirement as a percentage or proportion of the natural flow.

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[8] For simplicity, this project will be called later in the text as *Vazão Ambiental Project.*

[9] The *Estudo do Regime de Vazões Ambientais a jusante da UHE de Pedra do Cavalo - Baía do Iguape* is part of the scope of the contract No. 012/09 signed on July 29, 2009, between the Water and Climate Management Institute (INGÁ) and the Federal University of Bahia (UFBA).

The minimum flow is, therefore, the only requirement mentioned in the Brazilian water regulation. However, the establishment of a minimum flow – unique fixed value - has been recognized to be an inappropriate requirement for protecting biodiversity and ecosystem services (Arthington et al. 2009), and to be an insufficient reference for all years and for all annual seasons, leading to numerous social and environmental concerns. Environmental flow requirements should constitute a regime of flows that take into consideration seasonal flow variations, necessary to maintain the biodiversity and the dynamic environmental equilibrium of the river.

The dam of Pedra do Cavalo thwas constructed by the Bahia government in 1985 to control the flooding of Paraguaçu river and to supply water to the city of Salvador and its metropolitan Region. On the Pedra do Calavo dam, the Votorantim Group installed, in 2005, a hydroelectric power plant, with an installed power of 160 MW, divided into two generating units of 80 MW each one.

In accordance with the state and federal orientation, the Pedro do Cavalo dam is obliged to maintain only a minimum flow of $10m^3/s$ – mean diary value -, requirement that has emerged to be insufficient to maintain the ecological equilibrium downstream. In fact, in recent years, especially after the installation of the power plant, several problems have appeared down-stream of the dam, especially denounced by the local populations who complain about the alteration of the environmental conditions and about the strong decrease in the fishery production, seriously affecting their livelihood.

Figure 1: Pedra do Cavalo dam

The dam directly affects the amount of water that flows into the river, as well as its timing and its chemical quality. The hydroelectric plant operation, indeed, tends to dampen the magnitude of the inflow and to reduce its variations and the modulation of seasonality (Alber 2002). Every change in the freshwater discharge has profound effects on the downstream conditions. The relation between discharged flow and relative ecological and social consequences is the objective of study of the Building Block Methodology.

However, this specific study case represents a special context of application of environmental flow assessment methods due to the fact that the here studied river segment is very close to the estuary and, as a result, suffers its influence.

Usually, the applications of environmental flow assessment methodologies regard freshwaters of rivers. Nevertheless, in the low Paraguaçu river, the inflow control carried out by the *Pedra de Cavalo* dam resulted in a decrease of the discharged flows, permitting salt water to intrude farther up-stream.

The alteration of the freshwater inflow changes the hydrodynamic regime of the river. A decrease in discharge results in an increase of the tide influence on circulation patterns (Alber 2002). The traditional hydrological variables, like water flow (m^3/s) and velocity (m/s) are in this context affected also by the force of the sea tide. As a consequence, traditional hydrologic methods for river flow measurement are not applicable in this context.

Changes in the inflow lead to the alteration of down-stream geomorphology, since freshwater is also a source of sediment. An increase in the inflow enhances the contribution of sediments, but at the same time the dam operation can have the opposite effect of trapping them. The reduction of water discharge reduces the velocity and the erosion capacity, facilitating the accumulation of sediments transported from the estuary.

Changes in the freshwater inflow greatly affect the concentration of nutrients, the dissolved materials and in general all water quality parameters. In addition, the downstream water quality is influenced by the intrusion of salt water, especially altering its salinity, which is a critical determinant of the habitat characteristics. Frequent salinity fluctuations result in an increase of physiological stress (Alber 2002). All these circumstances affect the downstream ecosystems functioning.

The interactions of freshwater and saltwater make the study of the lower Paraguaçu river ecosystems very challenging, and the potential benefit from the use of Fuzzy Cognitive Maps even stronger.

The research project constitutes the first attempt, in Brazil, of evaluating environmental flows in a not pure freshwater system. Even FCM have never been applied to such a context.

From a methodological point of view, the *Vazão Ambiental Project* has developed its studies, considering five specific sample "points" of the river (**Fig 2**), called "study sites". These points are the focus of the analysis and of the collection of information provided by experts.

These points were selected by researchers in order to be representative of the different conditions of the river (UFBA-INGAa 2011). For each of them, the research team collects empiric data and develops studies on the environmental conditions of the ecosystem, considering hydraulic and hydrological aspects, geomorphology, water quality, the biota and the traditional communities.

The specialists studies constitute the informative basis for the developing of experts´ cognitive maps, while the development of the FCM was applied only to the study site number 1, which is the most up-stream point and the most close to the dam, as explained in detail in the methodological section.

Figure 2: The study sites in the lower Paraguaçu river, Bahia, Brazil

4.3. The methodological framework

4.3.1. The Building Block Methodology

Within the various holistic methodologies, Building Block Methodology (BBM) was considered by the *Vazão Ambiental Project* to be the best method for achieving the objectives of this study. BBM provides a structure for collection, analysis and data integration to give an estimate of the effects of flow changes and can be applied to rivers that have limited data, but an experienced team of experts.

The Building Block Methodology is based on the involvement of various specialists in different fields to afford a consensus view on the appropriate flows to meet a pre-defined set of environmental objectives (O'Keeffee and Le Quesne 2009). Indeed, there is no unique 'correct' environmental flow for any given river, and the output strongly depends on what are the objectives to be achieved through the river management.

The method, usually, involves an hydrologist and a hydraulics engineer to provide the baseline data on flows and hydraulic conditions; freshwater biologists for fish, invertebrates, and riparian vegetation to characterize the requirements of the biotic communities; a geo-morphologist to foresee the changes in sediment transport related to different flows; a water quality specialist to understand the chemical conditions of the water; a socio-economist for the study of traditional communities necessities.

The BBM is developed in three main phases, which include the preparations and collections of data for the BBM Workshop, the running of BBM Workshop, and the follow-up activities:

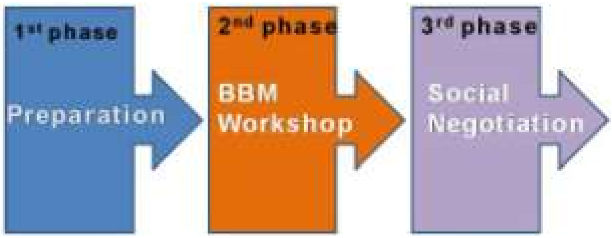

Figure 3: Three phases of BBM

The **first phase** regards the process of preparation for the BBM workshop. A structured set of activities is implemented to collect and display the best available information on the river, in order to support the specialist evaluations during the BBM. This phase regards the scientific, ecological and physical understanding of the river system and it is aimed at studying and predicting the dynamics of river ecosystems diversity.

The **second phase** is the BBM Workshop, which involves all scientists engaged in the first phase of the methodology in a participatory meeting, under the guidance of a chairperson and facilitators. The identification and description of the environmental flow requirements is realized for each site; each specialist identifies, month by month, the required flows that would facilitate the maintenance of the proposed environmental objectives. Throughout the process, the hydraulic specialist transforms, by the support of a hydraulic model, the implications of the described flows in terms of depth, wetted perimeter, velocity and converts the proposed flows into flow discharge values. The flows are described in term of timing, frequency and duration and are justified with relevant motivation by each specialist. Finally a consensus between specialists is reached on the monthly environmental flow requirements for each BBM site, and the final annual hydrograph is constructed.

The **third phase** occurs after the BBM Workshop and is aimed at verifying whether or not the proposed flow regime can be met without conflicts with the stakeholders. This phase consists in a participatory negotiation process where all the rivers users and institutions analyse and discuss the proposed annual hydrograph. Specialist can present scenarios showing the consequences for the river of not meeting the proposed environmental flow requirements; they can also advise on the least damaging way of managing the remaining flows in the river. The desired environmental objectives are re-discussed among the involved actors and groups of interest.

The interest of this research concerns the first phase of the BBM, when specialists construct their understanding with regards to the link between flows and social, physical and ecological consequences.

The first part of the BBM is developed throughout a set of activities as schematized in **Figure 4**.

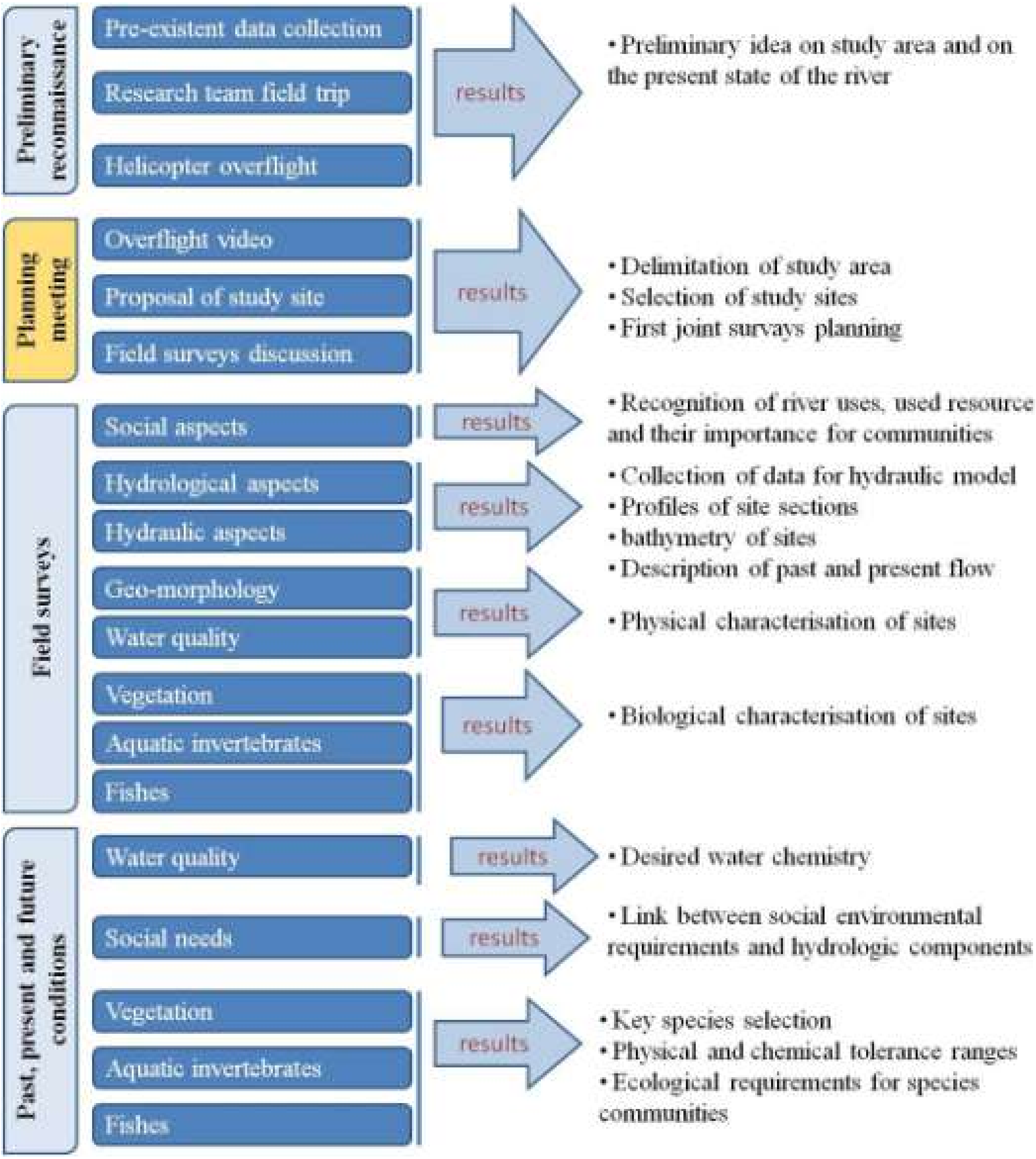

Figure 4: BBM phase 1 – flowchart of activities and related results

The initial activities of the BBM permit to create the first preliminary appraisal of the study area and of the river conditions. The pre-existing materials are collected, a reconnaissance field trip along the river is realised by the specialist and an overflight by helicopter is performed in order to record an aerial video of the study area.

During the first planning meeting, the specialists meet together for the first time, the aerial video is projected and commented, the study area is formally delineated, the present relevant knowledge on the river is assessed, and the specialists select the representative sites. These BBM sites are the research focus for all the studies and the data collection.

The following activities regard the collection of primary data during several field surveys. The specialists go on the field concurrently, in order to take comparable and synchronized information of each site. The field surveys permit to progressively delineate the present conditions of the river, of different components of the ecosystem (fishes, invertebrates, riparian vegetation, water quality, geomorphology, social uses) and of the ecosystem as a whole. The hydrological historical and recorded data, together with the measurement of the channel morphology of each site (bathymetry and section profiles) will serve as input for the hydraulic model, which will permit to link ecological and physical recommendations with the discharge flow parameters.

The next phase of activities concerns the analysis of the past and present conditions and the determination of the desired environmental objectives. The water quality conditions to be adhered to are discussed considering the ecosystem perspective and the human use needs. The biological surveys, realized for each site, give an assessment of species abundance and distributions from which the experts could establish the physical and chemical tolerance ranges, specific flow-related requirements, vulnerable lifecycle stages, and some key species to be used as indicators. Similarly, the social specialists analyse the environmental requirements needed by the population for maintaining a good welfare. These activities lead to the determination of the environmental objectives for each site and for each components of the ecosystem, which will be discussed during the BBM workshop.

4.3.2. The Fuzzy Cognitive Maps

Fuzzy Cognitive Maps (FCM) are a type of cognitive maps used to outline the relations among the variables of a system, but extended by the adding of a fuzzy logic, which is used to incorporate ‘‘vague and qualitative knowledge” (Kosko 1986) on the causal relations among concepts.

Cognitive maps were introduced by Axelrod (1976) for representing social scientific knowledge. Similarly, FCM are constituted by several variables, related by many relation and feedback loops (Özesmi, and Özesmi, 2004). FCM represent the knowledge in a symbolic manner, relating states, variables, outputs and inputs through a causality approach. Variables can be quantitative and measurable notions or abstract concepts and are chosen by the modeller or by the interviewed people. Indeed, FCMs reflect the perception of the person who is making them, in relation with the most important variable affecting the system (Özesmi, and Özesmi, 2004).

They are easy to construct, allow users to rapidly compare their mental model of a system with the real world, and, thanks to their fuzzy logic elements, they tolerate also uncertain information. FCMs are excellent informal tools for knowledge construction, as well as a simple and clear way to visually represent causal relationships.

A FCM consists of a number of **nodes** (or concepts, C, being the variables) with connections, depicted with weighted arrows between them, which represent the causal relationships between the concepts.

Each connection (arrow) is associated with a weight e_{ij} (between 1 and 0) that reflects the strength of the corresponding causal relationship between the concepts C_i (source concept) and C_j (destination concept) that it is connecting, in the absence of other influences.

FCM has a graphical illustration but also a mathematical representation in the form of a vector matrix calculation (Jetter and Schweinfort 2011). According to graph theory, cognitive maps can be transformed into **adjacency matrices** in the form

$$A(D) = [e_{ij}]$$

Where $e_{ij} = e(C_i, C_j)$ is the causal relationship function value. C_i causally increase C_j if $e_{ij} = 1$ or it casually decrease if $e_{ij} = -1$ and imparts no causality if $e_{ij} = 0$.

When two variables are connected, the value is reported in the square matrix, assuming a value between (−1, 1). The effect of C_i to C_j is not necessary the same as C_j to C_i. The matrix is therefore, asymmetric and square.

A FCM works in discrete steps. When a strong correlation exists between a concept's state and another concept's state in the preceding step, we say that the former concept positively influences the latter one and we draw a positively **weighted arrow** from the causing concept to the influenced concept (Kok 2009). When a strong negative correlation exists, there is a negative causal influence, and we draw an arrow with a negative weight. Positive values describe promoting effect, while negative ones describe inhibiting effect. The value of −1 represents full negative, +1 full positive and 0 denotes neutral relation. Other values correspond to different intermediate levels of the causal effect.

The realization of cognitive maps can be obtained from questionnaire, written texts, deducing them from data showing casual relationship or through the direct interview of individuals or group o f people (Özesmi, and Özesmi, 2004). FCMs can be derived by **experts or by stakeholders**, who often have a deep understanding of the (local) system (Khan et al. 2004).

However, selecting the weighting factors for the semi-quantification of relationships has been questioned as one of the weakest points in this approach.

The most frequent approach found in literature is either to combine multiple Fuzzy Cognitive Maps from individual stakeholders, or to develop one version in a participatory workshop (Papageorgiou et al. 2009). In both cases, the product is a consensus of various opinions.

Once the relations and adjacency matrix are determined, it is possible to calculate some indices to analyze and compare different cognitive maps (Özesmi, and Özesmi, 2004).

The **Density** of FCM is an index of connectivity, which shows how connected or sparse the map is.

$D = C/N(N-1)$, where

C= connections

N= n. of variables

If the density of the map is high, it means that the map has a large number of causal relationship among the variables.

The **type of variables** in a map is important because it shows how the variables act in relation to the other variables. In addition, the number of different types of variables in a cognitive map facilitates an understanding of its structure.

The three types of possible variables are: 1) transmitter, 2) receiver 3) ordinary. The total number of receivers can be considered as an index of map complexity. These variables are also defined by their outdegree and indegree.

Outdegree is the row sum of the absolute values of a variable in the adjacency matrix. It shows the cumulative strengths of connections exiting the variable.

Indegree is the column sum of the absolute values of a variable in the adjacency matrix. It shows the cumulative strengths of connections entering the variable

Centrality or total degree, is the summation of its indegree and outdegree. It expresses the contribution of the variable in the cognitive map, showing how the variable is connected to other variables and what is the cumulative strength of these connections.

After the analyses of the adjacency matrix and of the relationship between variables, it is possible to **run the model** to see where the system will go if no modification will be introduced and consequently to determine the so called **steady state** of the system (Özesmi, and Özesmi, 2004). These calculations are made using a method originated in neural network approaches, and are calculated iteratively.

Concept nodes possess a numeric state, which denotes a qualitative measure of the concepts presence in the conceptual domain. To each concept a weight is given consisting with the current weight in the system, which forms the **state vector**. The vector of initial states of variables (*In*) is multiplied with the adjacency matrix A of the cognitive map. The next state of the system can then be calculated via a vector matrix calculation. The state of conceptual node A, at time step *n*, is computed by taking the sum of the inputs, i.e., the state values at step $n - 1$ of nodes with edges coming into A multiplied by the corresponding edge weights.

Usually, the state values are normalized through a threshold function. In this study, the logistic function $1/(1+e^{-x})$ was used to transform the results into the interval (0,1).

The threshold functions force fuzzy state vectors to non-fuzzy values. FCMs using the logistic signal threshold function may become nonlinear under some conditions of feedback. In this case, chaotic attractors may exist. Since the state vector of the map at time n is completely determined by the state vector at time n-1, equilibrium states may be easily detected during FCM simulation by comparing two successive state vectors. If they are identical, the map has reached equilibrium.

This equilibrium, is called also the **steady state** of the system. Concepts, having reached their equilibrium values, show whether or not they will increase or decrease. All outcomes are however relative. They show that one concept will become bigger than the other, but it is not possible to quantify such an increase (Kok 2009).

Once relations are set and model rum, it is possible to simulate also different scenarios (Jetter and Schweinfort 2011, Alcamo 2008, Kok 2009). That means that it is possible to change one variable each time and see what happen at the rest of the system – forecasting or explorative scenarios – or, differently, it is possible set a desired status and change the values until reach the desired objective – backcasting scenarios (van Vliet et al 2010, Kok 2009).

4.3.3. The integration of BBM and FCMs

For the purpose of this research, FCM were used to externalize and to structure experts' knowledge progressively and to integrate their conceptual model into an integrated inter-disciplinary framework.

Such a 'constructive' approach starts with the study of single components of the system, then it consider the ways in which they interact one with each other, and lastly it investigate how different environmental conditions influence their co-existence.

The development of conceptual maps has proceeded in parallel to the *Vazão Ambiental Project* activities and in coordination with the evolution of knowledge acquisition by the experts. During the research time, experts have been involved in several trips on the field and in the collection of empirical data from the river that allowed improving expert understanding of the system.

Since the *Vazão Ambiental Project* adopted a disciplinary approach of study, the same structure has been respected in the application of FCM methodology. The river system has been divided in four main disciplinary areas, to which the different experts belong (**Fig 5**).

1. The **hydrological characteristics** of **the river flow:** involve variables expressing the hydrological modification of the river inflow. The exogenous variable, here, is represented by the *Flow Discharged*, since it is controlled by the dam operation. All the remaining variables vary in function of the exogenous one. However, it was also considered that hydrological variables are affected by the fact to be close to the estuarine area. Indeed, the sea tide manifests its influence on velocity, water volume and height of water column. The experts on hydraulic and hydrology of *Vazão Ambiental Project* will try to model the physic combination of those river and estuarine effects.
2. **Abiotic environment** is studied in term of geomorphology and chemical characteristics in each study site. It constitutes the environment where biota lives and affects the elements that determine ecological habitats.
3. **Biota living in the system** is further divided into the aquatic invertebrate, vegetation and fish systems.
4. **Social System** is intended to be constituted by the traditional communities living along the river, who depend on its resources for their livelihood. The benefit from the river and cause a pressure extracting resources.

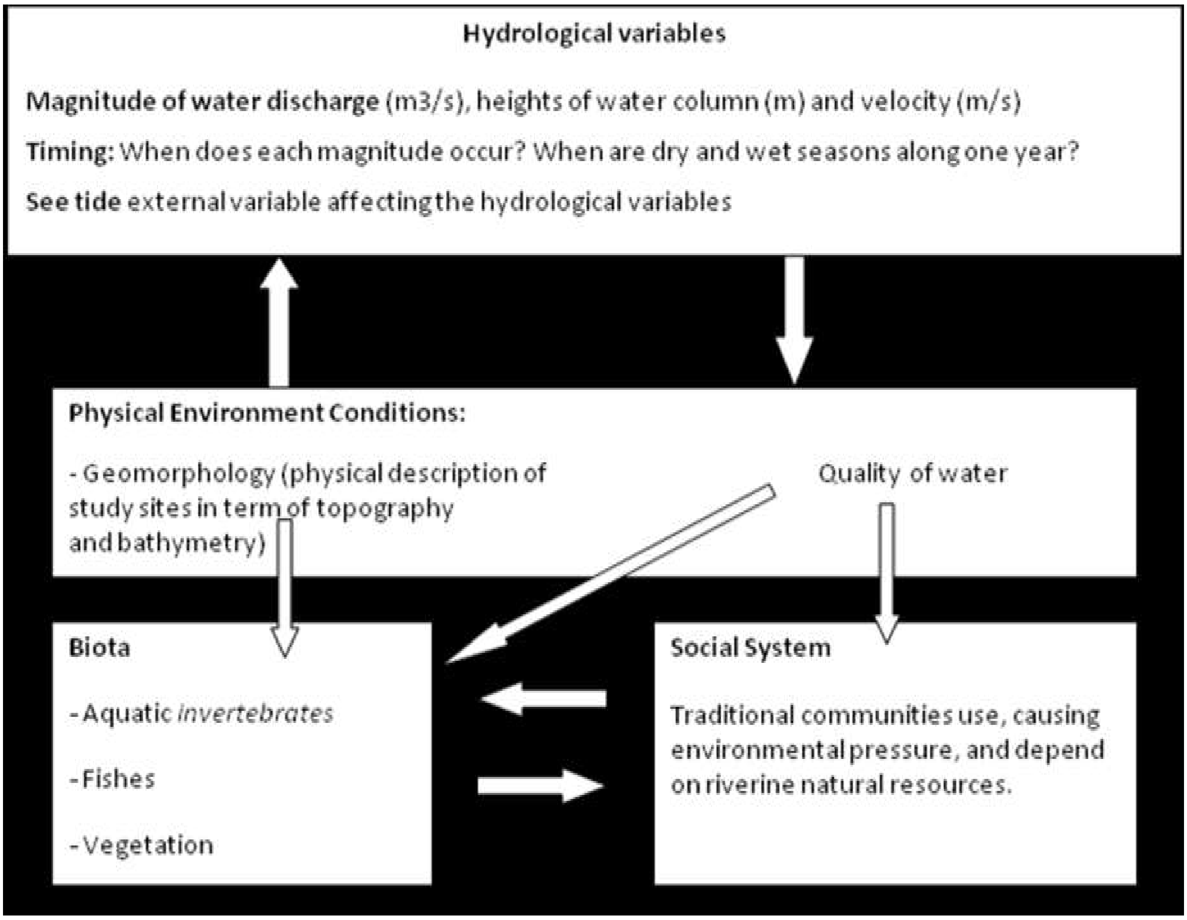

Figure 5: The system under study is divided into 4 causal sub-groups. The first contains those variables that are the input for the rest of the model. Every part is analysed individually for facilitating the comprehension, but then the interconnections and the feed-back relations between its elements are established.

The process of expert involvement and of FCMs elicitation was designed to be implemented in sub sequential and progressive steps:

Step 1) After the first planning meeting of BBM method, experts, under the modeller orientation, are individually interviewed and induced to the compilation of questionnaires (SEE ANNEX 2). This is the first step to structuralize their ecological understanding of the studied system, and it is realized *ex-ante*, before any data collection. The complexity of the river system is simplified by the elicitation of key variables to be studied and the relations that link them. In this phase, relations are expressed only as a positive or negative type.

- *This step lead to the selection of NODES (concepts) and ARROWES (casual relations)*

Step 2) After the realization of the field surveys, the conceptual models of every expert is revised during a second-round of individually interviews and then integrated into a common framework which is presented in a participatory meeting. Experts are encouraged to present the respective component of the system to the rest of the team, evidencing the relations with the variables of the other system components. The integrated model is adjusted, if necessary, and thus validated by the specialists. Communalities and synergies, as well as problems are discussed and a conjoined working plan is elaborated.

- *This step leads to the elaboration and validation of a conjoined conceptual model and to the first progress towards the knowledge integration.*

Steps 3) On the basis of the knowledge acquired during the field surveys and of the analysis of present river conditions, during a second participatory meeting, experts are asked to further describe the relationships among concepts, inferring the strength of each interconnection between variables. Every expert describes each interconnection with a fuzzy rule, expressing the intensity of such a relation. A Likert scale is used to describe the relationship between the two concepts and to establish the grade of causality between them. They are also oriented to make deductions about how was the 'initial state' of variables. The exercise is implemented separately for each study site, since they constitute different segments of the river and, thus, characterized by different casual relations.

- *This step leads to the elicitation of connections intensity (fuzzy weights) expressed by a qualitative scale.*

Step 4) The modeller re-aggregates the inferred fuzzy weights suggested by experts and an overall linguistic weight is produced, which is then transformed into a numerical weight w_{ji}, belonging to the interval [-1,1] and representing the overall suggestion of experts (Papageorgiou and Groumpos 2005). The model is then run and results analysed.

- *The modeller alone performs this step but results are then discussed in a plenary section.*

Step 5) During a workshop, the model is presented and possible scenarios are investigated together. The variation of water discharge is simulated and the consequences detected. Depending from the results and to the specific objectives, the research group will propose how to explore different scenarios, in order to establish the environmental desired status and the flow regime.

- *Environmental objectives are identified for each system component*

The implementation of such progressive modelling process is expected to deepen the understanding of variables interrelations, to enlarge experts' vision of the system and to integrate the disciplinary results into a unique and interdisciplinary framework understood by all the experts. The final FCM model would permit to simulate forecasting or explorative scenarios and backcasting scenarios, which would guide the experts in the final choice of environmental objectives and the definition of desired flow discharged. This result will lead to the final phase of the Building Block Methodology – the BBM workshop - with a stronger knowledge background and clearer justifications of the desired environmental objectives. This in turn, will be reflected in a more robust decision on the proposed flow regime.

The research investigation and the application of the described method, as already mentioned, was designed to be interconnected and coordinated with the activities of *Vazão Ambiental Project.*

Unfortunately, the project, started in the middle of 2010, and having an expected duration of 1 year, had suffered several impediments that compromised the correct evolution of actions. The *Vazão Ambiental Project,* indeed, has been interrupted and prorogued three times due to bureaucratic impasses and inconstant flux of resources. At current time, the project has not yet completed its activities and it is still in progress. Some empirical analyses and field surveys have been performed, but complete results on river present status – for example, on water quality parameters and hydrological data - are not yet available. Also some members of the research team are not part of the group any more – the expert of geomorphology for instance – and they have not be replaced yet, due to the current lack of resources. Due to this delay, the original methodological plan for the implementation of FCM had to be reformulated. Even so, thanks to the flexible applicability of FCM, it was possible to re-adapt the research objective and the methodological phases progressively, according to the evolving of the project. In this way, it has been possible to the test the potential contribution of FCM in environmental flow assessment with the data and information at disposal at current time, nevertheless, the outputs resulted to be less ambitious then desired.

The group of experts who participated at the elaboration of cognitive maps was composed by two hydrologists, one hydraulic modeller, one expert in water quality, one expert in aquatic invertebrate, one in fishes, one in vegetation and two in social dimension[10].

Hence, the research process was reorganized as follows:

Step 1) After the first planning meeting of BBM method, experts, under the modeller orientation, were individually interviewed and induced to the compilation of questionnaires. This was the first step to structuralize their ecological understanding of the studied system, and it was realized before any data collection. As a result of this phase, the components (nodes) of each system war identified, as well as the casual relations (arches) linking the nodes. Arches were expresses in term of positive or negative casual relations, but in some cases it was not possible to establish the sign of such relations, due to the lack of knowledge regarding the area.

Step 2) During the activities of field surveys, some level of empirical knowledge was acquired on the environmental conditions of each site. The individual maps created by experts and re-composed by the modeller, were therefore validated through individual discussion with the experts.

Step 3) One of the conceptual models developed by the experts – vegetation - was chosen as a representative example and it was further developed through a new individual interview section. A specific study site was chosen and analysed, the relationships among concepts are further described, inferring the strength of each interconnection between variables. Arches were associated to a ”strength” evaluation expressed by a Likert scale, which was used to describe the relationship between two concepts and to establish the intensity of causality, through a linguistic description from *very weak* to *very strong* intensity.

Step 4) The modeller transformed the cognitive maps into the adjacency matrix and the model was finally run. At this purpose, the *FCMapper Software Solution* was used to facilitate the processing of data **(**www.fcmappers.net**).** FCMapper is a FCM analysis tool based on MS Excel and freely accessible for non-commercial use. The Steady States of the system was calculated and then compared with the results coming from the simulation of some scenarios.

The occurrence of such unexpected events have evidenced the importance, when working in developing countries contexts, of adopting versatile instruments of research, and assuming a flexible attitude in order to adapt its goals and objectives according to the needs.

In practice, the readapted research process lead to the elaboration of the cognitive maps of five system components (water quality, aquatic invertebrates, fishes, vegetation, social system) and to

[10] The group of experts was composed by: Yvonilde Medeiros, Andrea Fontes, Tiago Rosario, Marlene Peso, Vânia Campos , Alexandre Clistenes, Fernando Esteves, Golde Stiefelmann and Lucia Ceccato.

the development of a FCM for the specific case of vegetation system, which was run to simulate some scenarios for a specific study site.

4.4. Conceptual models results

The next sections presents the results coming from the first step of the process that involved all the experts through individually interviews and led to the identification of the perceived most relevant variables, being affected by a variation in the water flow. The relations (arches) between variables have been described only in term of positive or negative relations.

It has to be notice that one of the most important factors altering the entire natural system is related to the modification of the freshwater ecosystems towards more saline environments. The freshwater environment has been affected by the river fragmentation, originated by the presence of the dam, which was not provided with any connectivity mechanism linking the two parts of the river. The dam represents therefore a physical barrier that interrupts the natural biological and physical dynamics of freshwater flow.

On the other side, the river segment under analysis, situated in proximity of the coastal areas, suffer a strong influence of the estuary, caused by the cycling variations of tide and consequent fluctuation of sea water level. Two opposite forces therefore characterize the system, the freshwater discharge coming from up-stream and the sea tide coming from downstream. The hydrodynamic combination of these forces is under study by the hydrologist and hydraulic experts. However, the strength of the resulting casual relations have not been yet identified. To overcome this problem it has been considered the variation of hydrological variables (velocity, height of water column and water volume) without concerning what the original cause of their modification is. The models, therefore, do not permit to directly link the variations in the freshwater discharge to the modifications of the other system components.

The variable *water volume* is one of the strongest elements of perturbation of the system. The terms *water volume* and *water discharge* have been distinguished to underline that, even if the water discharged is controlled by the dam operation, the resulting volume of water in a specific point of the river depends on the cumulative effect of freshwater flow and of sea water flow coming from the estuary.

The *discharge flo*w negatively affects the tide entrance, but the final effect depends on the force of the discharge and on the type of tide (spring and neap tides). Usually with no estuarine effect, *discharge flo*w positively influences the *flow velocity* and the height of *water column* and consequently increases the *volume* of water in the channel. However the cumulative effect of water discharge and tide on water volume has not been quantified yet.

In the next section, the cognitive maps related on the sub-systems water quality, aquatic invertebrates, fishes, vegetation and social system are presented, as they were charted by experts.

It has to be noticed that, even if experts in a plenary section validated the maps, they usually modify nodes and relations along the entire process, especially in the phase of evaluating the strength of relations. Since it was not possible to realize the integration of individual maps into a common framework, nor to determine the intensity of relations, the following maps have to be considered only as preliminary results of the participatory process, and not as the ultimate representation of experts' perceptions. The objective of the FCM methodology is to model and perform a simplified simulation of reality, but even more important is to induce experts to a deeper and detailed reasoning on the system functioning and to lead them to evaluate how each discipline of study is related to the others.

4.4.1 Water quality

All variables in the area of water quality are, according to the expert, highly related to the three main mechanical components: *velocity*, *height of water column* and *water volume* **(Fig. 6).** This relationship facilitates a physical–chemical interaction of biotic and abiotic parameters, which in turn affect indirectly all the remaining parameters. The modulation of water quality parameters shapes the habitat of the different categories and groups of biota, influencing their quality of life.

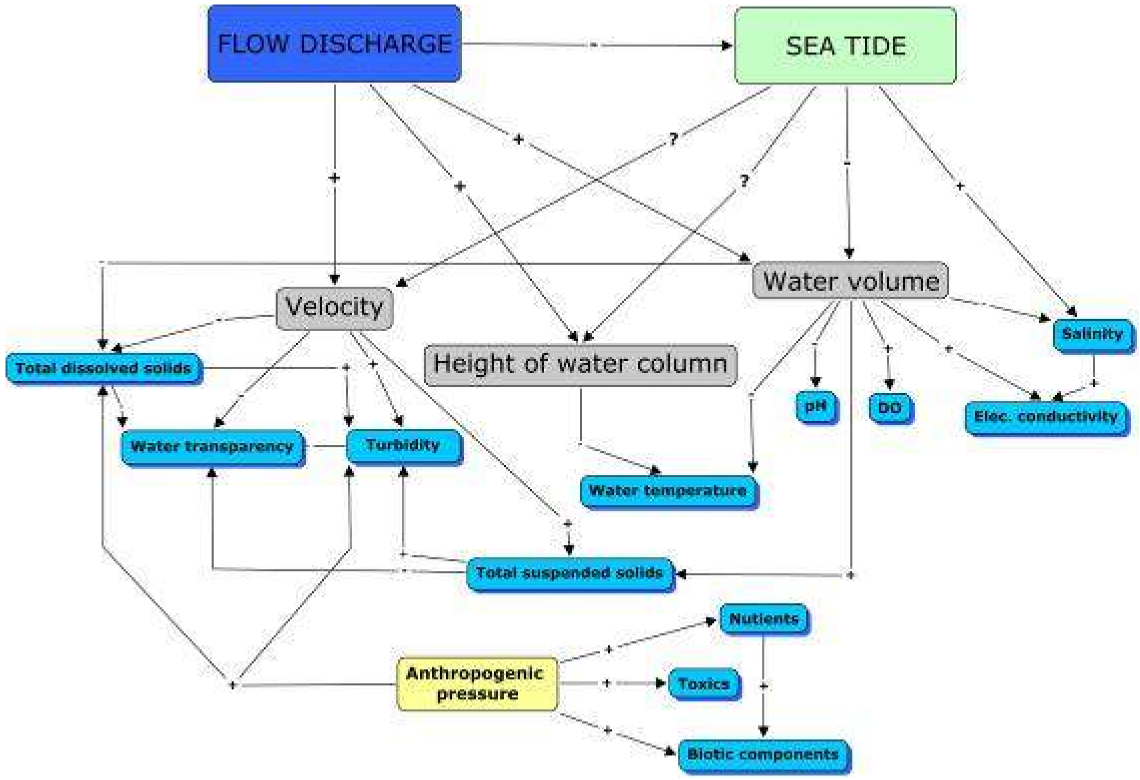

Figure 6: The conceptual map for water quality

The parameters such as *salinity*, *pH* and *temperature* can suffer a negative variation with an increase of freshwater discharge, simply due to the phenomenon of dilution. In the studied system the *salinity* variable behaves as one of the most disturbing factors. This parameter is influenced by levels of salts dissolved in upstream waters and by the amount of water coming from the tide and from the penetration of the saline wedge.

The expert considered that water *temperature* has not significant influence on the system. The expression and influence of *pH* on the system is not determined yet, because it depends also on the –unknown - physicochemical characteristics of water coming from upstream.

The *velocity* of the water in the channel was underlined as a mechanical factor of great importance for the entire system. This variable influences the turbidity, the water transparency and the total *dissolved* solids. The water flowing with great amount of kinetic energy has the power of increasing the sediment, suspending it and transporting it through the channel. This phenomenon can be measured by the *turbidity,* that has a negative influence on the variable *transparency* of the water. This, in turn, reduces the incidence of light on the system, affecting the trophic level and harming producers (photosynthetic organisms) and the dependent food chains consuming invertebrates and fishes.

The components *dissolved solids* and *suspended solids* are influenced by an increase in the flow rate, with different characteristics, but the type of relation depends on the condition of the water coming from upstream, which, in turn, is influenced by natural conditions and anthropogenic pressures.

Human activities can introduce pollutants into the water positively contributing to increase solids and hence turbidity. Human activities also influence the supply of nutrients in the environment and consequently increase the values of biological parameters. Part of the nutrients are also naturally contained in the water, coming from the biomass cycle in the environment, however the great contribution of nutrients in the system comes from the emission of untreated sewage and agricultural activities close to water bodies.

The *biological parameters* associated with nutrient parameters are mainly related to the leakage of untreated sewage into the system and to the dynamics of nutrients in the sediment. One indicator of this nutritional intake in the water is the presence of *macrophytes vegetatio*n and of plants strongly depending on water. These organizations benefit from the release of nitrogen and phosphorus, contained in the sewage generated by *human activities*. These *nutrients* can also be deposited into the *sediment* or be suspended by the increase of river flow. The availability of nutrients in the system can generate the explosion of microorganisms which contaminate the water. Nutrient parameter could also be negatively influenced from an increase of *water volume,* through a dilution factor. The final effect therefore depends on the characteristics of the water coming from upstream and downstream (tide).

The expert noticed that agricultural activities are the most determinant factors responsible for the introduction of *toxic agents* in the system. Although data on concentrations of pesticides and toxins were not available yet, big agricultural areas have not been identified in the nearby areas. It has to be noticed, that the results on water quality parameters of the samples taken during field trips were not yet available in this phase of the project, and the relations between variables are in some case based upon the expert previous knowledge of the area or, in other cases, not evaluable yet. Once this information will be available, the conceptual map will be validated and adjusted.

4.4.2 Aquatic invertebrates

Aquatic invertebrates have different adaptive capacities and each species needs specific ecological requirements. For this reason, they are commonly used to characterize and monitor the condition of the river. Invertebrates play an important role in the functioning of the river. They are responsible for the retention and breakdown of organic matter, they recycle nutrients and minerals, and contribute to the transformation of energy in the river at different trophic levels. The variation of the environmental components is reflected in the organization of this group. The fluctuation of physico-chemical and biotic variable influences the homeostasis of this group. Invertebrates have a close relationship also with riparian vegetation and fish communities (**Fig. 7**).

It has been observed by the expert, that in this specific study area – the low segment of Paraguaçu river - invertebrates are extremely sensitive to changes in their habitat. In particular, the variation in salinity is one of the components that greatly influence most of the variables considered in the system.

The invertebrate groups occupy specific environments with specific properties that if altered cause a perturbation of invertebrate communities, with the risk of destructuralization of the entire associated ecosystem.

Physical, chemical and biotic relationships were identified between invertebrates and hydrologic variables, characterizing the river flowing.

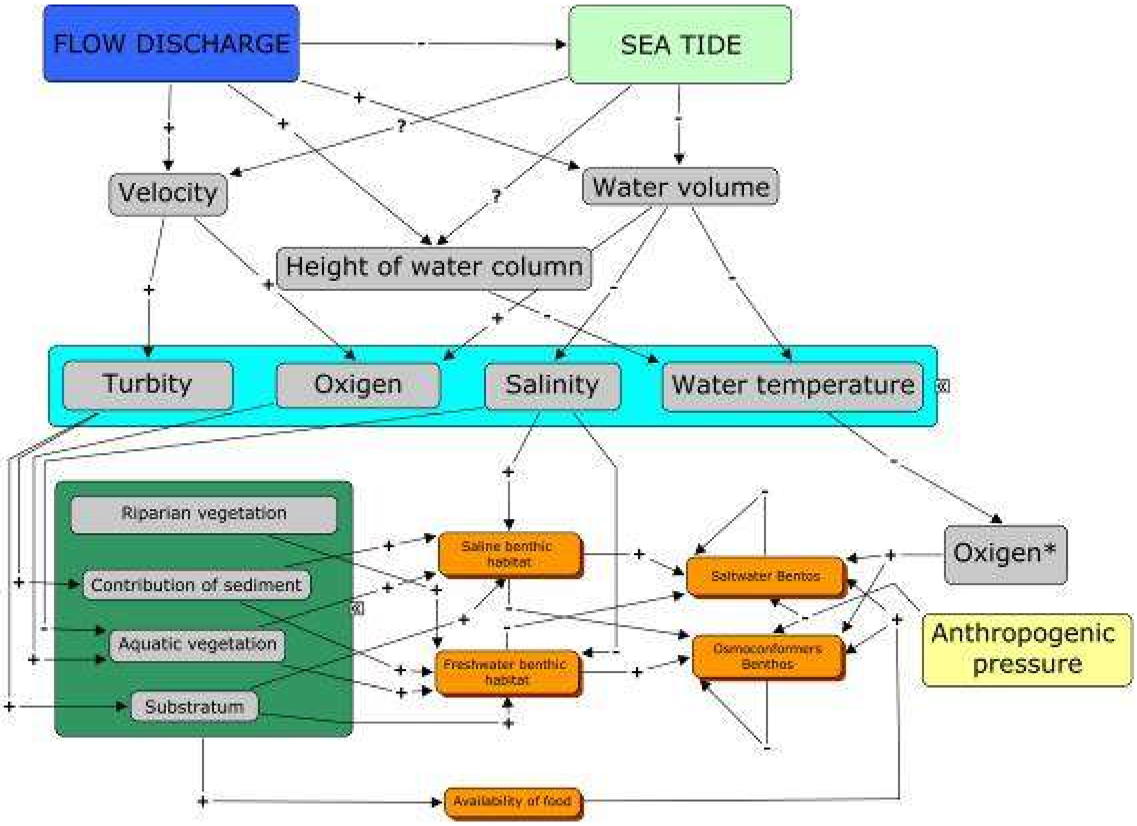

Figure 7: The conceptual map for aquatic invertebrates

The flow components represented by *velocity, height of water column* and *volume of water* directly affect the habitat of invertebrates and can limit their occupation in the environment. The oscillation of the water *velocity* selects the groups of invertebrates that are established in a given environment. High speeds move sediment that impedes the establishment of larvae in the substrate (either sediment or rock). The *height of water column* indirectly influences the establishment of this group. The distance between the substrate of the river and the water level diminishes light incidence in the deeper areas due to the turbidity of water (caused by natural or human action). This condition prevents the establishment of producers' organisms photosynthesising), essential for the development of invertebrate primary consumers.

The oscillation of the water *temperature* was detected as another determining factor in the biological cycle of invertebrate individuals. This variable influences on sexual maturation of the organisms and the availability of water oxygen. *Salinity* fluctuation alters habitats and thus changes the characteristics of the environment, consequently selecting the communities that tolerate the new condition. After the dam creation, many freshwater organisms were replaced by osmoconformers communities (supporting salinity fluctuation). Despite the tolerance, each group of organisms prefers specific ranges of salinity. So invertebrates are distributed along the channel looking for environments with optimal salinity for the performance of its metabolic functions.

The *pH* of the water also determines the establishment and development of communities. Naturally, a saline environment has an alkaline characteristic (pH above 7.0) that is tolerated only by a certain group of organisms. A river has naturally acidic pH due to the presence of humic acids from degradation of organic matter.

Besides the environmental factors, also the ecological dynamics influence population dynamics of benthic invertebrates. There are different trophic levels within a community, that relates other groups through the food web, for example fishes, shellfishes, mammals and man (due to the commercial interest of particular species).

4.4.3 Fishes

In a balanced river we can usually find a variety of fishes. Fishes have trophic variety and different food habits (omnivores, herbivores, insectivores, piscivores). The alteration in the availability and in the variety of food is reflected in the abundance, variety, and compositions of fish communities. The sensitivity of fishes and their capacity of rapidly dislocate, make fishes a good indicator expressing the integrity of the environment under study.

The water quality and the hydrodynamics of the river are also important factors for the maintenance of fish communities. In addition to these, variables are important components of habitat, as illustrated in the **Figure 8**.

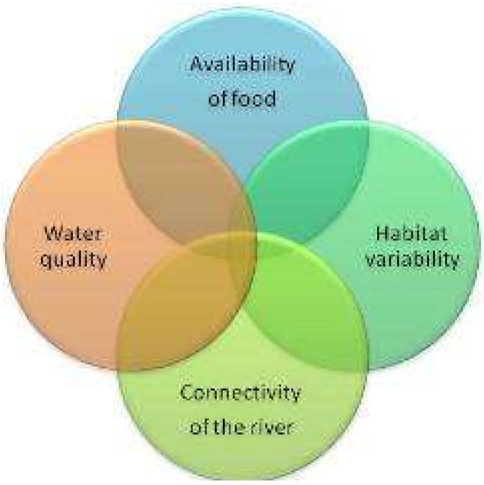

Figure 8: Variables that contribute to compose habitats

The variability of habitats is linked to water dynamics and water quality. The *quality of water* in turn is influenced by the freshwater inflow and the tide flow. The availability of food will depend on other ecological mechanisms that convert biomass into energy, from the producer to the consumer.

In the studied system, however, it has been underlined that a single water flow is not sufficient to maintain the balance of a complex ecosystem, but it is necessary to evaluate a regime of flows, that would consider the seasonal dynamics of the river and the interconnection with the sea tide.

The *riparian and aquatic vegetation* have great influence on the *food availability* and *variability of habitat,* producing biomass (through complexation of solar energy with the nutrients available in the water) and providing nutrients (autochthonous and allochthonous) to herbivores organisms. The latter, in turn are preyed by individuals of higher trophic levels. The vegetation also acts as a *refuge* and area where to deposit eggs during the reproduction season. The branches and trunks that fall into the river act as diversifiers of the habitat (**Fig. 9**).

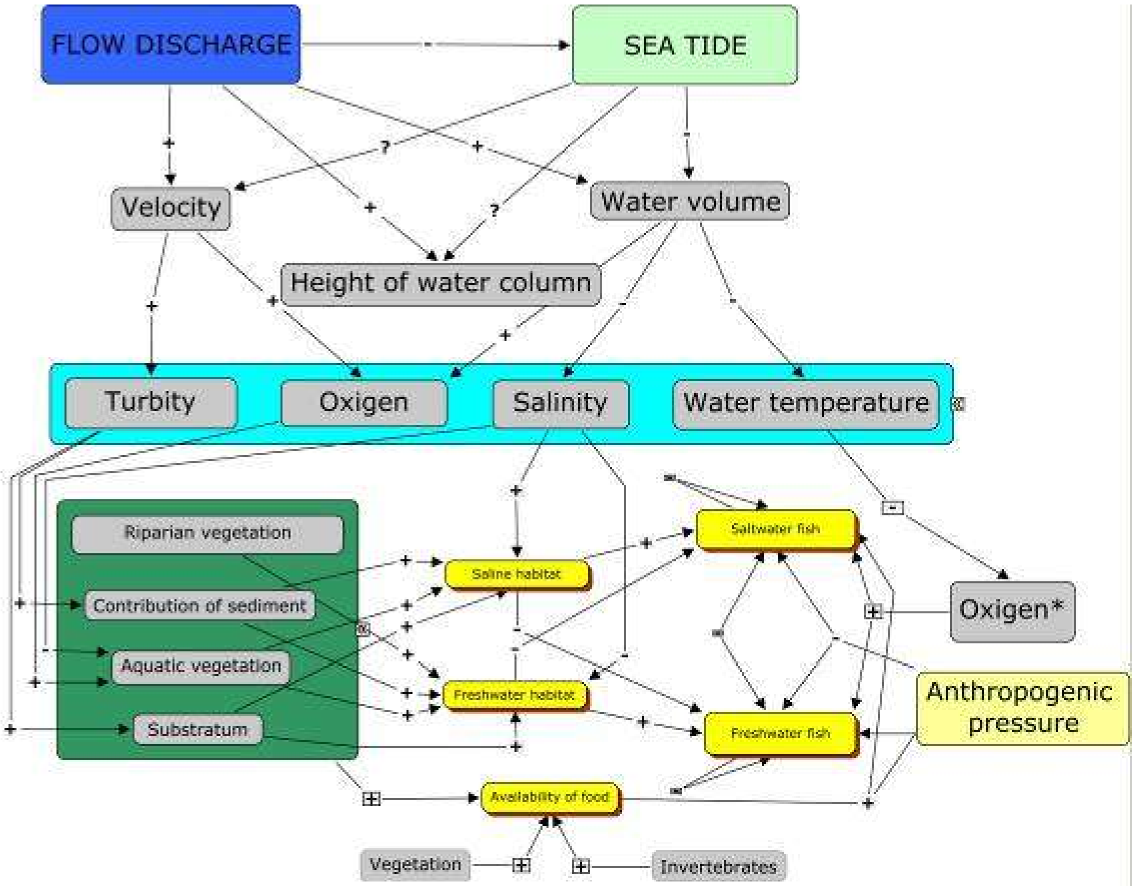

Figure 9: The conceptual map for aquatic invertebrates

In the system, the physico-chemical variable *salinity* acts as a strong modulator of the habitat. Species may have a different tolerance to salinity. Usually freshwater species have little tolerance and resist only low salinity. Once the parameter of salinity and its variation according to the flow fluctuations will be know, it will be possible to establish the impact on the fishes present on the area. The parameters *oxygen*, *temperature* and *turbidity* were cited as relevant for the maintenance of species but their influence also depends on the fish species.

The *anthropic action* was cited as being of great importance for the balance of groups of fish, since fishing activities can compromise the abundance and diversity of fish. Modifying the environment - such as removing vegetation from the banks, supply of nutrients, toxicants release - may also influence the balance of fish species by modifying their habitats.

4.4.4 Vegetation

The upper and lower photosynthetic organisms influence the input of energy in a system. They have the property of converting light energy and nutrients into biomass dispersed in the environment - protein, lipids, among others - and this is exploited by consumers in the form of food, jointly with other nutritional components. The vegetation associated with a body of water also has a mechanical function to stabilize the river banks, bars and floodplains. In addition, riparian vegetation influences the equilibrium of the water temperature, the physical and chemical quality of the water body and the alleviation of flooding effects. The vegetation is also important because of its ability to provide shelter, habitat and because it acts as a complete migration corridors for aquatic and terrestrial fauna.

V*egetation* is influenced by the dynamics related to water discharge and sea tide, however, since it was not possible to distinguish their specific and individual effects, the model considers the variable *height of water column* as the initial input. Clearly, also other variables, like *velocity,* have an influence on vegetation, however, they were excluded from the model in order to be able to establish a more complete framework of relations. The variation of *height of water column* is reflected in the modification of the *wetted perimeter*, which in turn influences the soil characteristics and its content and concentration of humidity and salts. From this dynamic, the expert has distinguished three categories of soil that in turn will favour or unfavour the presence of some types of vegetation. In order to establish this casual relation, the expert classified vegetation by an ecological classification (Cavalcante et al. 2005) expressing their dependence on water, as **Table 1** shows.

Vegetation Group	Characteristic
Hydrophilic	Amphibious or aquatic plants that live in water or in flooded soils. They are plants that live on the banks where flooding or tides regularly flood the soil. They represent the transition between aquatic plants and mesophilic plants. Their entire reproductive cycle takes place into the water.
Hygrophytes	Terrestrial plants living in moist and shady environments they live in a humid environment. They can support even prolonged dry period, restarting their growth after rehydration.
Mesophilic	Plants growing in a well drained and in places of great variation of relative humidity. They are plants that live on the wet ground and in the shade.
Xerophytes	They live in environments where water is scarce. These plants have mechanisms for drought resistance.

Table 1: Ecological classification of plants

The model was therefore designed as follows. The vegetation model is here fragmented in several figures; the complete conceptual model will be presented in the next section of this study.

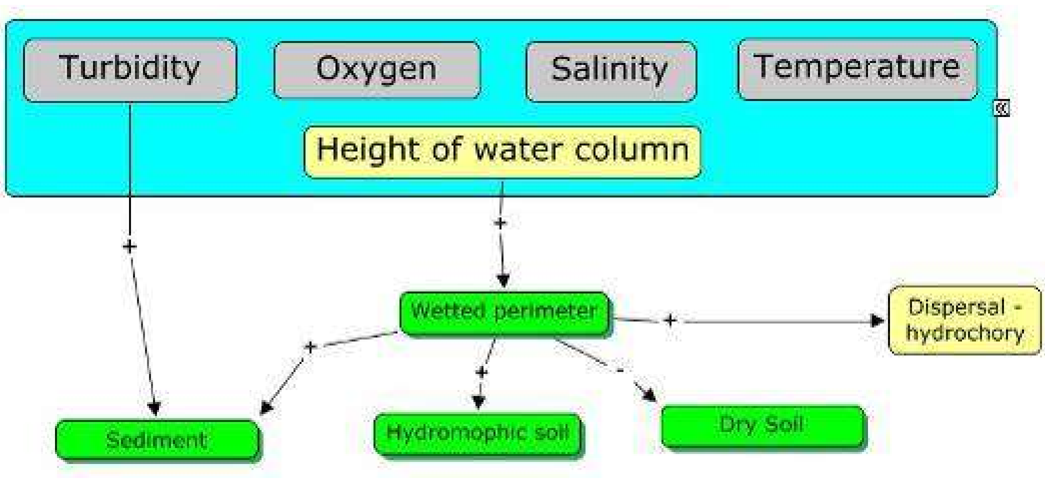

Figure 10: The conceptual map of vegetation – part 1.

An increase of the *height of the water column* amplifies the amplitude of the *wetted perimeter* (**Fig 11**), but the intensity of such increase will depend on the morphology of each site. Also positive relationships are observed in relation to the effect on *sediment* and *hydromorphic soils*, while a negative relationship is observed with the disposal of *dry soils*.

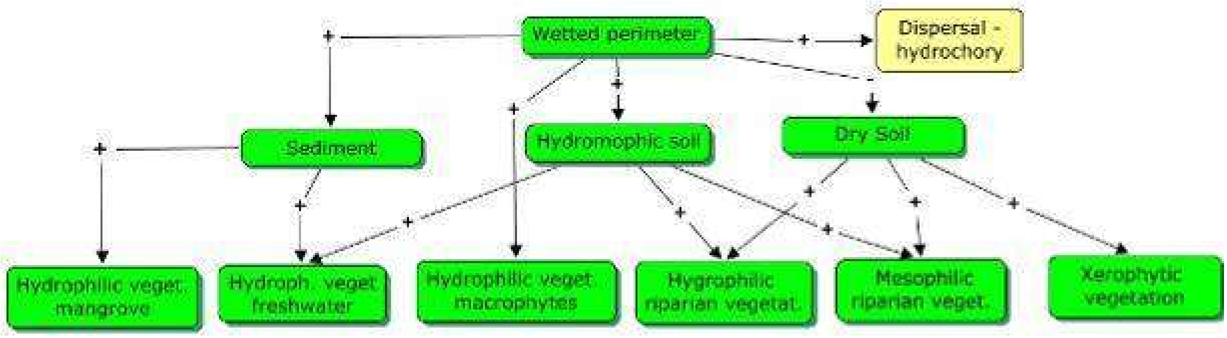

Figure 11: The conceptual map of vegetation – part 2.

The plant groups are influenced by the sediment deposited in the water and the three layers of soil where they are distributed. *Sediment* is permanently wet and varies with the alternation of floods. This is deposited with the increase of the wet perimeter. The availability of soil and sediment determines the occupation and distribution of vegetation species. The *sediment* component, in the expert opinion, has a positive influence on the communities of hydrophilic vegetation, both in environments with less and higher salinity. In freshwater environments (less salinity) the sediment acts as a substrate for macrophytes plants and for other hydrotolerant vegetation. In saline environments, sediment contributes to introduce nutrients to the wetlands occupied by mangroves. The *hydromorphic soil* is a zone located in an intermediate range (sometimes dry, sometimes wet). The *dry zone* of the stratum is called *dry soil* or drained soil. The *hydromorphic soil* favours the occupation of vegetation with water affinity (Hydrophilic vegetation, hygrophilic riparian vegetation, and mesophilic riparian vegetation). *Dry soils* favours the establishment of hygrophilic riparian vegetation, mesophilic riparian vegetation and xerophytic vegetation.

In relation to water quality parameter, the expert argued that *salinity* is the variable that most influence the vegetation system (**Fig. 12**). The latter positively benefits only the vegetation adapted to environments of great marine influence (mangroves). In all the other cases, it has been judged to have a negative effect.

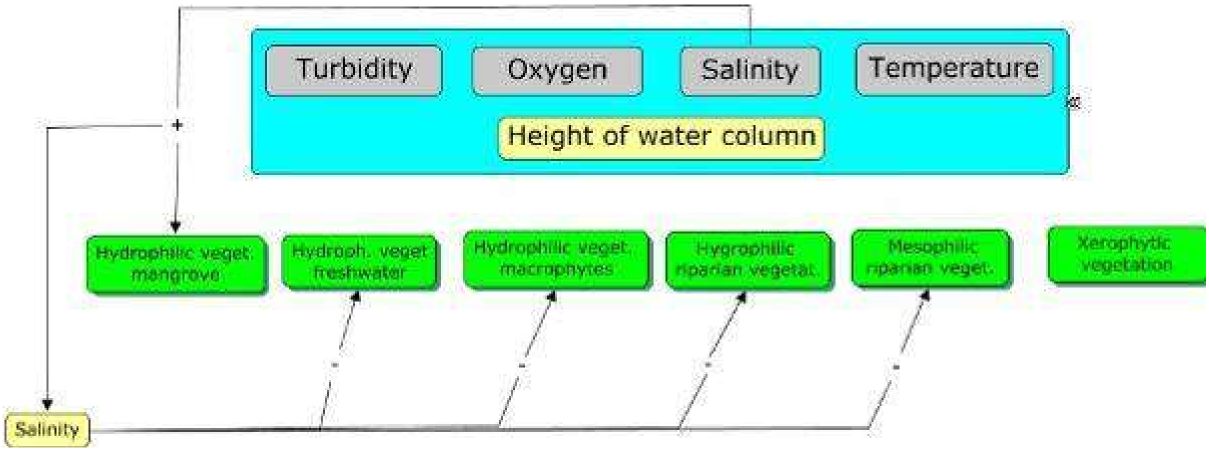

Figure 12: The conceptual map of vegetation – part 3.

4.4.5 Social System

The map of the social system represents the interconnections of the traditional communities located down-stream along the river with the river ecosystems. Such communities live on the extraction of natural resources from the river and are most affected by the alterations of the ecological equilibrium. The experts related to the socio-economic area realized a survey on the filed involving the population of the local communities through interviews and focus groups (UFBA-INGA 2011b). This investigation allowed understanding how the population used the river natural resources, what was the level of their dependence from and how much they suffered from river ecosystem alterations.

The conceptual map related to the social system is presented in **Fig. 13**.

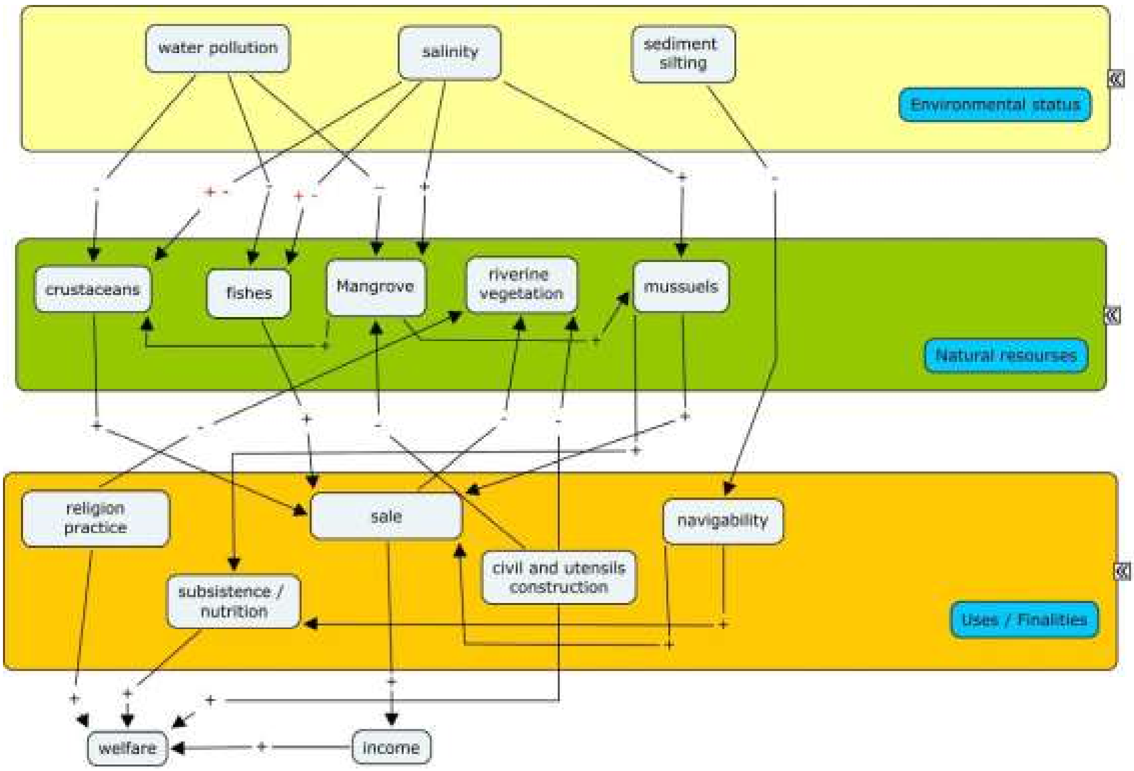

Figure 13: Cognitive map for the social system

The most important natural resources for the population are *fishes*, *mussels* and *crustaceans*. Indeed, these communities catch fishes, both from freshwater and saline water, shrimps and crabs and bivalves mostly of saline water. The fishing activity is the primary source of alimentation and directly influences the *nutrition* level and the *welfare* of these people. These resources are also sold, at markets or directly on the streets, and represent the primary source of *income* for the majority of the population. According with the communities' opinion, the water quality - here considered simply as polluted water or not polluted water - has a poitive effect on the abundance of these species. These populations are much connected also to the presence of mangroves, where they catch certain types of mussels and crabs. The entrance of *saline* water, according to people, benefits the mangroves and, consequently, also mussels and crabs. It has to be noticed, however, that the presence of mangroves is detected mostly in the river segment close to the estuary. Most up-stream population living closer to the dam rarely catches saltwater species. Traditional communities extract *vegetation* from the river banks with different uses and finalities. The principal uses are related to the *religious rituals*, to the *construction of houses* and to the creation of *utensils* for fishing. All these activities influence, even if with different intensity, the population *welfare*. Another important factor mentioned by the communities concerns the *navigability* along the river. The silting caused by sediment accumulation, indeed, has strongly impacted the navigability of the river, modifying the fishing places and creating obstacles to people mobility. They, indeed, use boats not only for fishing, but also for diary transportation. Boats are used for transporting goods to the market, merchandise to the villages, people to the hospital or, simply, as a leisure transportation.

Traditional communities depend on natural resources and benefit of them and, at the same time, cause a negative pressure to them. In fact, occasionally they extract from nature with improper tools or practices: for example, they practice fishing with bombs or poisons; they wash dishes and clothes in the waters of the river, and drain their sewages directly to the river.

4.5. FCmaps results

As it was already mentioned in the methodology, the vegetation model was selected to develop the Fuzzy Cognitive Map, in reason of the fact that it was considered the system less affected by water quality variable. The indeterminacy of such parameters, indeed, impeded to establish and quantify most of the relations linking the variable of the other models. Invertebrates and fishes were perceived to have a high dependence from water quality parameters.

In order to determine the strength of relations, the exercise has been applied to the study site 1 (**Fig.1**), considering two scenario of tide.

Thus, the FCM outputs regard two situations: a) site 1 with neap tide, b) site 1, with spring tide.

The strength relations have been expressed by the expert through a Likert scale with linguistic expression and the transformed by the modeller in number between (-1,1), as indicated in the next table.

no relation	very weak	weak	moderate	strong	Very strong
0	0,2	0,4	0,6	0,8	1

Finally, to facilitate the visualization of results in the map, the "strength" of relations are reported together in each arch, indicating in order, the neap tide scenario and the spring tide scenario (**Fig. 14).**

The quantification of relation has been determined on the base of the expert knowledge of the site morphological characteristic and on the base of the actual vegetation present in the place and verified during the field trip.

The site was assumed not to be affected by the intrusion of salinity. This assumption was confirmed by local fishers and by empirical analysis, even with no objective chemical result. Nevertheless, this does not imply the absence of tide influence. The volume of water and the height of water level in site 1 vary in accordance with the tide and of course with the water discharge.

The graphical representation of the Fuzzy Cognitive map of vegetation is illustrated in **Figure 14**.

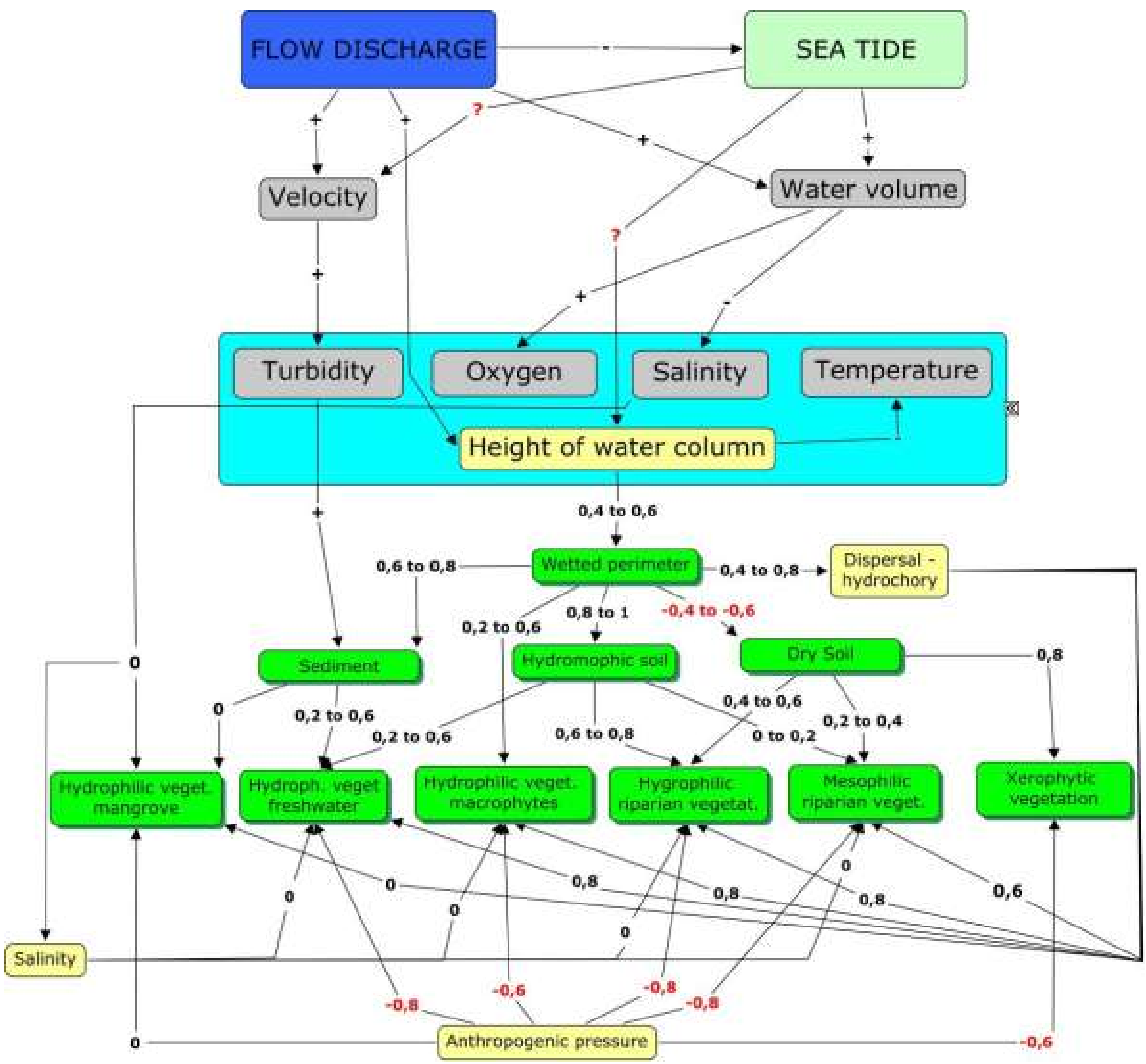

Figure 14: the FCM for vegetation

The map is composed by 12 nodes (variables) and 22 arches (connections). Within the variables only *Height of water column* and *Human pressure* are transmitter variables, while the other 5 are receiver and the lasting 5 are ordinary. The map is characterized by a quite low Density index equal to 0,153, showing a low rate of connectivity of the variables. This is justified by the voluntary simplification of the conceptual map in order to allow the running of the FCM.

4.5.1. Neap tide

Under the scenario of neap tide, the relations are specified and it is possible to calculate some other indices that could help in understanding the model, and then in comparing it with other scenarios.

The graphical representation of the map can be expressed also through the Adjacency matrix (**Tab. 2**).

	Height of water column	Wetted perimeter	Seed dispersal - hydrochory	Sediment	Hydromorphic soil	Dry Soil	Hydrophilic freshwater veg.	Hydrophilic veg. Macrophytes	Hygrophilic riparian veg.	Mesophilic riparian veg.	Xerophytic veg.	Human pressure
Height of water column	0,00	0,60	0,00	0,00	0,00	0,00	0,00	0,60	0,00	0,00	0,00	0,00
Wetted perimeter	0,00	0,00	0,80	0,80	1,00	-0,60	0,00	0,00	0,00	0,00	0,00	0,00
Seed dispersal - hydrochory	0,00	0,00	0,00	0,00	0,00	0,00	0,80	0,80	0,80	0,60	0,00	0,00
Sediment	0,00	0,00	0,00	0,00	0,00	0,00	0,60	0,00	0,00	0,00	0,00	0,00
Hydromorphic soil	0,00	0,00	0,00	0,00	0,00	0,00	0,60	0,00	0,80	0,20	0,00	0,00
Dry Soil	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,60	0,40	0,80	0,00
Hydrophilic freshwater veg.	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Hydrophilic veg. Macrophytes	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Hygrophilic riparian veg.	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Mesophilic riparian veg.	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Xerophytic veg.	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Human pressure	0,00	0,00	0,00	0,00	0,00	0,00	-0,80	-0,60	-0,80	-0,80	-0,60	0,00

Table 2: Adjacency matrix for vegetation, under neap tide scenario

The Outdegree is calculated through the row sum of the absolute values of one variable and it expresses the cumulative strengths of connections **exiting** the variable (**Fig.15**).

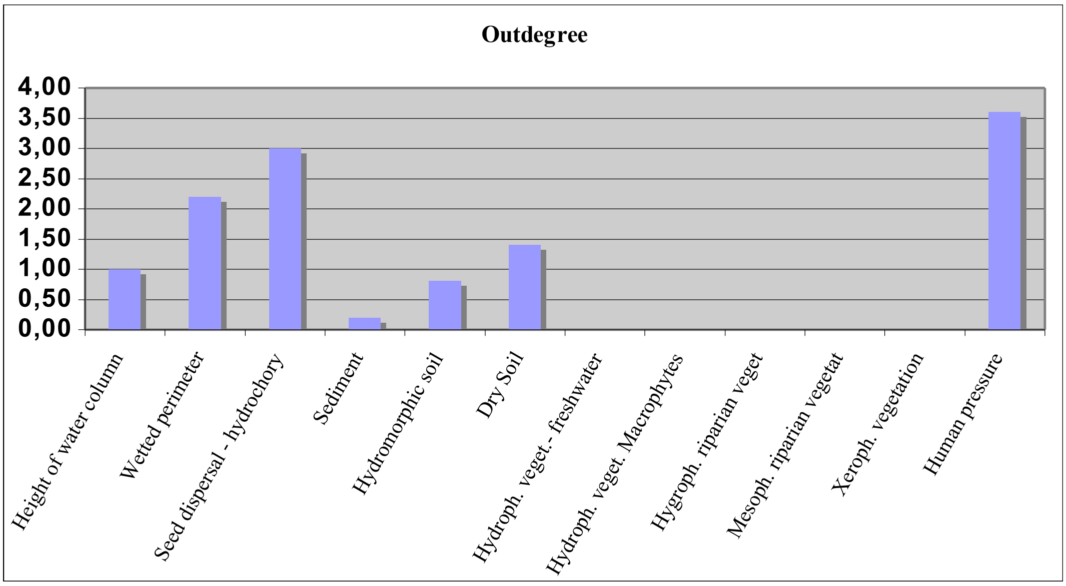

Figure 15: Outdegree index, under neap tide scenario

From the figure we can see that *Human pressure* and *Sediment dispersal* have the highest cumulative strength, meaning that the external variables most influence the model.

The Indegree is calculated through the column sum of absolute values of a variable and it expresses the cumulative strengths of connections **entering** the variable (**Fig. 16**).

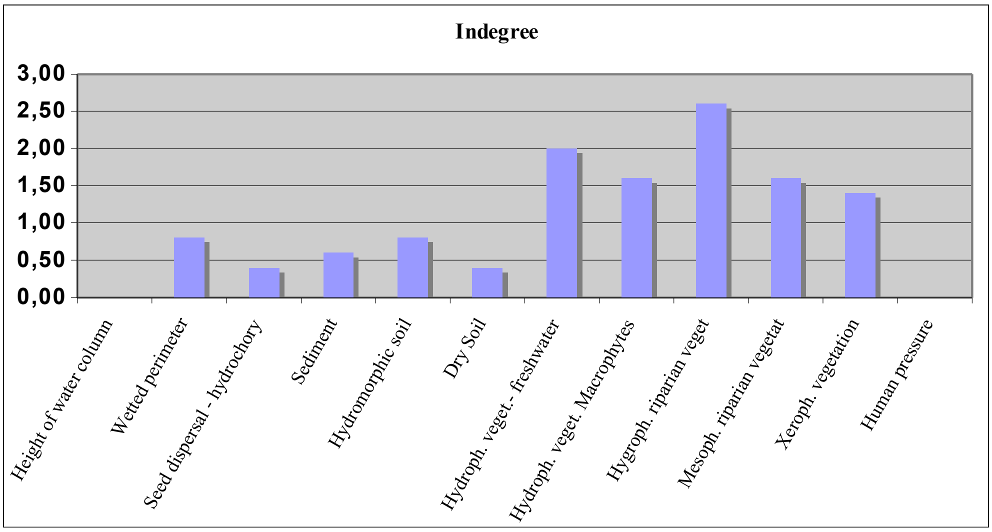

Figure 13: Outdegree index, under neap tide scenario

From the figure it is possible to notice that the hygrophilic plants are the one that most suffer from the cumulative effect coming from the variation of height of water column, followed by the hydrophilic ones.

The Centrality index, or total degree, is the sum of the indegree and the outdegree of a variable and it expresses the contribution of the variable in the cognitive map (**Fig.17**).

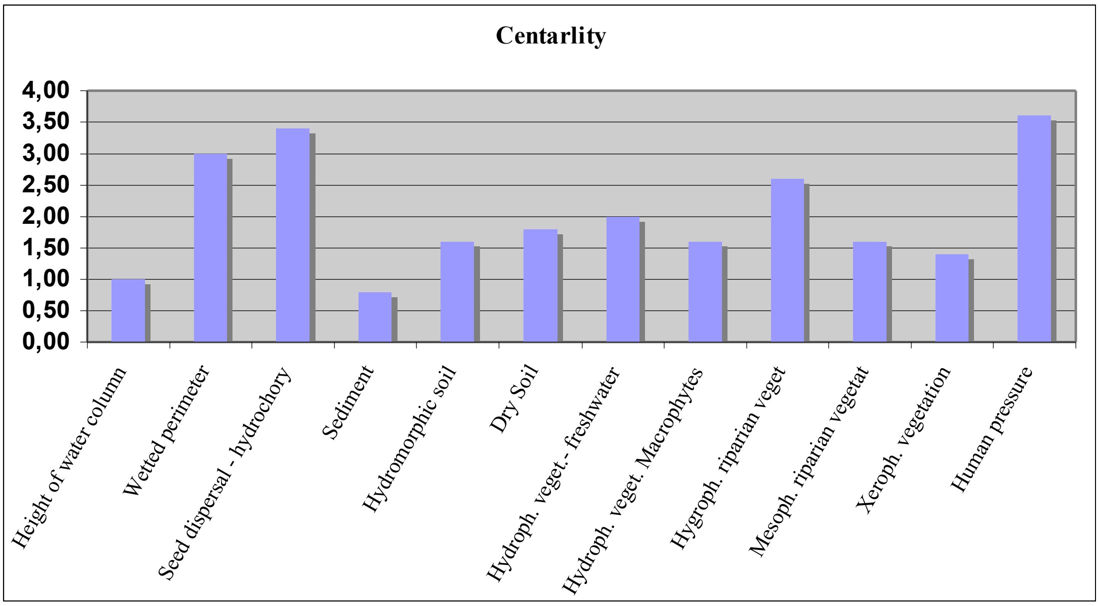

Figure 17: Centrality index, under neap tide scenario

The Centrality index shows that the most interconnected and expressive variables, are *Human pressure* and *Sediment dispersal,* strong transmitter variables, together with *Wetted perimeter*. This information can also orient water policy-maker, evidencing that beside the effects derived from the water level variation, attention should be paid to the human anthropogenic pressure.

The last phase regards the **model running**. Through the Software *FCMapper* the Steady State of the model is calculated. The steady state describes the state of the variables when the cumulative effect of variation ends, or in other words, where the system will go if thing continue as they were at the initial state. For doing so, the initial state vector is set equal to 1 for the variables and then it is multiplied with the adjacency matrix, several times until the steady state is reached (**Tab 3**). The logistic function $1/(1+e^{-x})$ was used to transform the results into the interval (0,1).

	Height of water column	Wetted perimeter	Seed dispersal - hydrochory	Sediment	Hydromorphic soil	Dry Soil	Hydroph. veget.- freshwater	Hydroph. veget. Macrophytes	Hygroph. riparian veget	Mesoph. riparian vegetat	Xeroph. vegetation	Human pressure
Initial state vector	1	1	1	1	1	1	1	1	1	1	1	1
	0,500	0,690	0,599	0,646	0,690	0,401	0,599	0,599	0,731	0,500	0,550	0,500
	0,500	0,599	0,569	0,602	0,635	0,431	0,586	0,569	0,658	0,510	0,505	0,500
	0,500	0,599	0,560	0,589	0,617	0,440	0,575	0,563	0,648	0,507	0,511	0,500
	0,500	0,599	0,560	0,589	0,617	0,440	0,572	0,562	0,644	0,506	0,513	0,500
	0,500	0,599	0,560	0,589	0,617	0,440	0,572	0,562	0,644	0,506	0,513	0,500
Steady State	**0,500**	**0,599**	**0,560**	**0,589**	**0,617**	**0,440**	**0,572**	**0,562**	**0,644**	**0,506**	**0,513**	**0,500**

Table 3: calculation of steady state for the FCM of vegetation, under neap scenario

From the steady state calculation we can get an idea of the ranking of the variables in relationship to each other according to interviewed perception.

The used of the logistic function transformed the results in the interval (0,1), thus the values 0,5 means no change, and the values >0,5 detect an increase in the variable state. We can see that *Height of Water column* and *Human pressure* don't vary, since they are transmitters variable. At the steady s tate on *Dry soil* have suffered a diminution, while *Mesophilic* and *Xerophilic* riparian vegetation almost don't change. The most affected variables are *Hygrophilic* riparian vegetation and *Hydromorphic soil*.

In addition, the comparison of the values of the steady state of the model, run for different sites or scenarios can contribute to facilitate the understanding of the possible effects of a variation in water level. In the next section the results from spring tide scenario are presented.

4.5.1. Spring tide

The same procedure is applied for the analysis of the other scenarios. To facilitate the reading the results have been described in a more synthetic manner. The Adjacency matrix of the FCM under spring scenario is presented in **Table 4**.

	Height of water column	Wetted perimeter	Seed dispersal - hydrochory	Sediment	Hydromorphic soil	Dry Soil	Hydroph. veget.- freshwater	Hydroph. veget. Macrophytes	Hygroph. riparian veget	Mesoph. riparian vegetat	Xeroph. vegetation	Human pressure
Height of water column	0,00	0,80	0,00	0,00	0,00	0,00	0,00	0,20	0,00	0,00	0,00	0,00
Wetted perimeter	0,00	0,00	0,40	0,60	0,80	-0,40	0,00	0,00	0,00	0,00	0,00	0,00
Seed dispersal - hydrochory	0,00	0,00	0,00	0,00	0,00	0,00	0,80	0,80	0,80	0,60	0,00	0,00
Sediment	0,00	0,00	0,00	0,00	0,00	0,00	0,20	0,00	0,00	0,00	0,00	0,00
Hydromorphic soil	0,00	0,00	0,00	0,00	0,00	0,00	0,20	0,00	0,60	0,00	0,00	0,00
Dry Soil	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,40	0,20	0,80	0,00
Hydroph. veget.- freshwater	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Hydroph. veget. Macrophytes	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Hygroph. riparian veget	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Mesoph. riparian vegetat	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Xeroph. vegetation	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Human pressure	0,00	0,00	0,00	0,00	0,00	0,00	-0,80	-0,60	-0,80	-0,80	-0,60	0,00

Table 4: Adjacency matrix for vegetation, under spring tide scenario

From the Adjacency matrix it is possible to calculate the other indicators, as the oudegree and the indegree **(Fig. 18**).

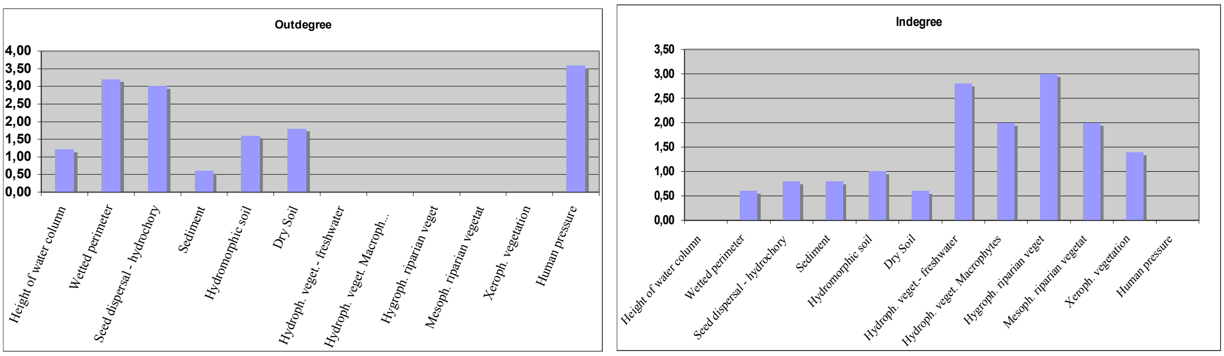

Figure 18: Outdegree and Indegree indexes, under spring tide scenario

In term of outdegree and indegree we see that the variables that most suffer from or influence the variation of the model remain the same, however, the intensity of such strengths has been intensified for all the variables under springs.

From the analysis of the Centrality index (**Fig 19**) we can see that *Wetted perimeter* and *Seed dispersion* strongly intensified their expression, which means that during spring tide the effect on these variables will be higher. All the types of plant suffer a more intense effect during spring tide, with exception only for the *Mesophilic riparian vegetation* and for the *Xerophilic vegetation* that does not seam to suffer from the spring tide.

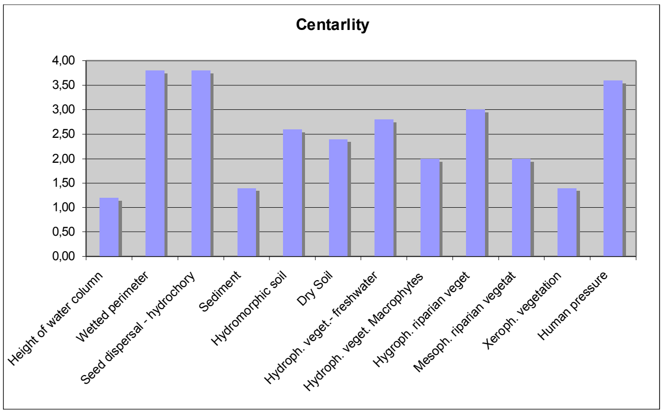

Figure 19: Centrality index, under spring tide scenario

Finally, the FCM model is run in order to analyze the steady state of the model under spring scenario (**Tab 5**).

	Height of water column	Wetted perimeter	Seed dispersal - hydrochory	Sediment	Hydromorphic soil	Dry Soil	Hydroph. veget.- freshwater	Hydroph. veget. Macrophytes	Hygroph. riparian veget	Mesoph. riparian vegetat	Xeroph. vegetation	Human pressure
Initial state vector	1	1	1	1	1	1	1	1	1	1	1	1
	0,500	0,646	0,690	0,690	0,731	0,354	0,769	0,690	0,802	0,599	0,550	0,500
	0,500	0,574	0,626	0,626	0,656	0,404	0,732	0,635	0,721	0,575	0,496	0,500
	0,500	0,574	0,613	0,613	0,640	0,415	0,705	0,623	0,704	0,567	0,506	0,500
	0,500	0,574	0,613	0,613	0,640	0,415	0,699	0,620	0,701	0,565	0,508	0,500
	0,500	0,574	0,613	0,613	0,640	0,415	0,699	0,620	0,701	0,565	0,508	0,500

Steady State	**0,500**	**0,574**	**0,613**	**0,613**	**0,640**	**0,415**	**0,699**	**0,620**	**0,701**	**0,565**	**0,508**	**0,500**

Table 5: calculation of steady state for the FCM of vegetation, under spring scenario

The model reaches the steady state in a relatively reduced number of steps, meaning that the feedback relations are not so significant and there are not cause/effects cycles.

We can notice from the steady state analysis that most of the variables suffer an ampler variation.

For a better comprehension of the steady step meaning it is worth to compare them through visual representation, as illustrated in the following paragraph.

4.5.1. Comparison of scenarios

The values of the steady state reached in the two scenarios of neap and spring are compared through the following graph.

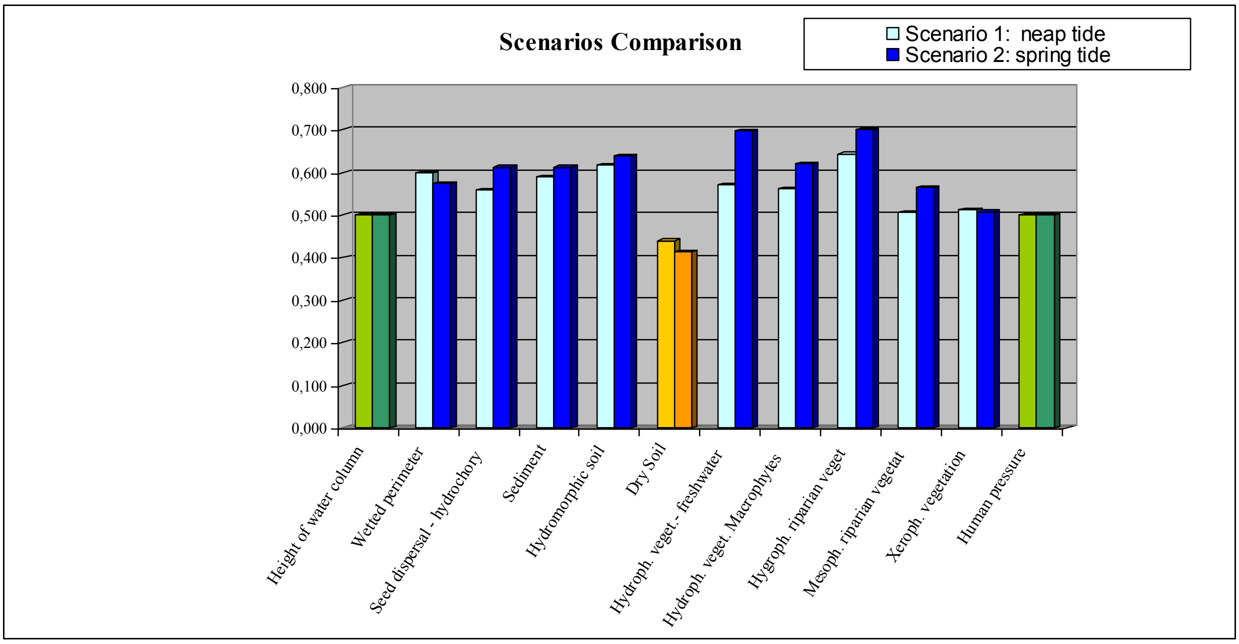

Figure 20: Comparison of steady states under neap and spring scenarios

First we can notice that the relative "ranking" of the variable does not vary depending on the tide. From the results coming from running the model, we can see that a variation in *Height of water level* implies a reduction of Dry *soil*, while the effect on the other variable is positively diffuse.

On the other hand, we can notice that, under the scenario of spring tide, most of the effects are intensified. The variable *Dry soil* suffers a higher decline than during neap tide. The variable more sensible to spring tide are the *Hydrophilic vegetation*, while the less sensible is *Xerophilic vegetation*. Results sound quite logic.

As it was already noticed, the transmitter variables, like *Human Pressure* for example, don't vary according to the scenario. Indeed, by definition, in this model they do not receive any entering relation.

The model simulates the cumulative causal effects related to height of water volume and vegetation, if no changes were introduces. Applying the same model it is possible to test further different scenarios. For example, it is possible to simulate a variation in one variable - *Height of water level* for instance - and see what happens to the others. Similarly, it is possible to modify the value of some variables until reaching a desired status. These simulations can support in the selection of water flow blocks, with a more consciousness on the possible consequences.

It has to be remembered, however, that maps represent the system in accordance with the perception and experience of the interviewed person, who can emphasize some parts of the system instead of others. A formal validation of the maps is consequently not possible, because they are qualitative results representing the understanding of a person, and thus, it is not possible to affirm that some maps are better then others (Özesmi, and Özesmi, 2004).

Qualitative map validation could be performed analyzing whether or not the model behaviour is consistent with empirically established relationships (Hobbs, et al. 2002).

4.6. Conclusions

Despite the impediments that occurred during the study period and the consequent adaptation of the research objectives, it has been possible to test the use of Fuzzy Cognitive Map as a participatory research tool, functional to the specific characteristic of developing countries and to the Building Block Methodology objectives.

The flexible nature of FCM allowed the adaptation and reformulation of its application, in order to overcome the obstacles and impediments intervening in the meantime. This quality is particularly significant in the context of developing countries. Indeed, interruptions or modifications in the research network are quite frequent and the adaptation of the research to the new circumstances is often necessary. The delay in project activities has forced to adjust the targeted output to an intermediate result; nevertheless some important results have been obtained.

This research contributed to innovate the development of environmental flows assessment and, in particular, the application of the Building Block Methodology with the incorporation of FCM into the research process. This constituted the first attempt of integrating together these two methodologies. The application of FCM demonstrated to be congruently integrable with the Building Block Methodology and to contribute for a more robust development of its activities.

Moreover, the case study of lower Paraguaçu river constituted the first attempt, in Brazil, of evaluating environmental flows in a hybrid freshwater-saline system. Such a particular and more complex situation made the implementation of the BBM even more challenging and, hence, the use of FCM more valuable. In fact, the participatory elaboration of cognitive maps in the first phase of BBM activities helped the specialists to focalize better their research goals, facilitating feedback observations, and to verify whether or not the individual methods of research meet the overall final objective and the expectations of the other specialists.

Through the construction of cognitive maps the experts' knowledge was externalized and structuralized progressively, allowing the identification of synergies and interconnections among individual research methods. FCMs showed to be an excellent informal tool for knowledge construction, as well as a simple and clear way to represent causal relationships visually.

Such a process contributed to guaranty a higher integration of the disciplinary studies, which stimulated the construction of a system understanding even in a situation where information were mostly qualitative and incomplete. Indeed, during the study process, the individual experts' outputs were presented to the entire research team, explaining how every single model was related to the others. It was recognized by participants that such an instrument could effectively help the understanding the system functioning as a whole, contributing to carry out more organic and integrated interdisciplinary results.

The elaboration of the FCM applied to the vegetation system component served as an experiment to test the potential contribution of this tool. The model facilitated the visualisation of variables and the analysis of how they are related with the others. It permitted to understand the contribution of each variable in the cognitive map and the cumulative strengths caused by the connections entering or exiting each variable. This allowed a more robust and deeper study of the system as a whole. In addition, even if only simple scenarios were run, the calculation of the steady state of the system consented to predict the interactive and cumulative effects of relations offering important insights about the possible consequences related to environmental modifications.

The model developed for the vegetation system represents, however, only a limited simulation of the possible applications of FCM due to the restricted information availability. The model indeed, was applied only to one system component and to one study site, under the assumption of no salinity effect. Auspiciously, the research will continue and the data collection will be completed. The conclusion of the biological and physical field surveys, realized for each site, will consent to assess the ecological requirements and the physical and chemical tolerance ranges of the present species communities. This information will permit to clarify the relations among variables for all the systems components and for each study site. Then, the integrated model will be constructed letting a further and more complete utilization of the FCM tool. Such a comprehensive framework will permit to run the model according to different discharge scenarios and to each study site, and thus to understand how individuals and communities are affected by environment and flow modification. These scenarios offer a prediction of what will happen to an organism - or population or community or ecosystem - under a particular set of circumstances, which are consequence of possible water flow regime.

A further application of FCM can be expanded to a participatory process involving also the population and other actors. The same exercise, developed in this study with experts, can be reproduced with stakeholders, stimulating in this way the social learning process between stakeholders and academic scholars, and leading to more legitimated outcomes. Alternatively, the opinion of experts can be combined also and with those of local actors and the different perceptions compared.

The involvement of stakeholders can diminish the risk of misconceptions or biases and give more accuracy to the map. Stakeholder involvement, however, has to be carefully planned, since it is a time and resource consuming process. Moreover, the comparison of cognitive maps among different stakeholders has to be taken with caution, because the map composition depends on the capacity of the facilitator and on the duration of interviews.

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5. CONCLUSIONS TO THE DISSERTATION

The complexity of water resource systems emphasizes the need of adopting an integrated approach for the analysis of both the social-economical agents and the natural components of the ecosystem. Integrated Water Resource Management tries to find a suitable balance between socio-economic needs and the capacity of the environment to withstand potential or current impacts. This underpins the involvement of interdisciplinary and integrated processes of study, which consider multi-dimensional criteria and objectives, different scale levels of analysis and the involvement of social actors, stakeholders and policy makers.

Participation has been recognized as a fundamental element for environmental and water management, because it allows a better definition of the problems of research and the incorporation of unknown or underestimated points of view, and permits the validation of the study approach along the process. In addition, participation can facilitate the relation between scientific research and decision-making and it can contribute in setting priorities and makeing the decision process more transparent. Participation can be used for building knowledge, establishing co-learning processes and finally stimulating consensus leading to the identification of compromise agreements. Furthermore, it helps to avoid narrow or partial examinations, and helps not to exclude any of the stakeholders that, even if with a very little role, may hold legitimate interests and objectives.

Nevertheless, it has also been evidenced that participation could be a vague concept if not clearly structuralized and properly framed. Different aspects and elements of participation imply completely different participation processes; consequently, it is important to clarify: i) *who is participating*: participation could refer to the involvement of experts, civil society, stakeholders or decision makers; ii) *what is the context*: participation could be applied within research projects or in decision making processes; iii) *what is the* t*ype of process and objective*: depending on its objectives, participation could consist in an informative process, an extractive process, a transformative process, a learning process, a co-management process, or some mixed compositions of them; iv) *what is the participatory method or tool utilized*: different types of participatory methods can be applied.

This thesis has been organized in three sections, each of them approaching participation in a different way, while different tools and methods have been tested. The first section has focused on participation practices in decision-making and management at river basin level, with regards to stakeholders' involvement. The second section has involved the participation of experts and local actors and has investigated how scientific research can be integrated with the decision-making process, utilizing decision support system tools and multi criteria decision analysis. The third one has concerned the participation process within a group of experts and under the scope of a scientific research project, involving the utilization of fuzzy cognitive maps.

Another crossing element of the thesis regards the study of integration processes. IWRM indeed involves interdisciplinary analysis, inter-sectorial policies and multiple actors' involvement, making integration a complex task. In addition, the focus of the thesis has been restricted to the specific context of developing countries, since in these areas a large number of obstacles still impede the effective implementation of IWRM and further research is needed overcome such critical issues.

This PhD research has been constructed with the aim of progressively: a) deepening the understanding of the reality of water management in developing countries, b) circumstantiating the specific issues and problems with relation to participation and integration processes in this countries and, b) proposing possible solutions.

This research, as a whole, has contributed in developing and designing innovative forms, through the application of participatory tools, to lead with the IWRM impediments present in developing countries, to facilitate the detection and prioritization of problems, to integrate and coordinate research efforts, to increase the transparency of decision processes, to overcome the lack of quantitative data, and, after all, to give robustness and effectiveness to participative processes in the development of water management policies.

The first article has contributed to give a theoretical presentation of IWRM limitations in the specific context of developing countries as described by international scholars. Such criticalities have been contextualized to the specific case of Brazil, permitting to evolve the analysis from a theoretical point of view to a more practical one. It has emerged that several obstacles still exist in order to implement IWRM and participatory processes, mostly due to restrictions in the institutional, political, economic and educational systems. Some of the criticalities that have emerged regard the difficult integration of research and policies, the lack of transparency, the fragmentation of actions, and the lack of resources and data. The review on the implementation of water resource management in Brazil has consented to evaluate how this country leads in practice with the challenges caused by an inefficient institutional framework, the unequal distribution of natural and financial resources.

From these insights, the research has evolved towards two different contexts and problems: first, the effort has been directed to improve the integration between scientific scholars and decision makers in order to select and orient effective policy options to cope with flood risk – the case of Danube and Brahmaputra basins -; then, the attention has been directed to advance the process of experts' knowledge integration to establish the appropriate environmental flows to maintain the ecosystem in a desired status – the case of Paraguaçu.

The study on Brahamaputra and Danube basins presents a new methodological proposal for decision support, aimed at improving the effectiveness of interactions between the scientific community and the local actors, applied to respond to the urgency of developing Climate Change adaptive strategies. The study explored the utilization of Decision Support System tools and Multi Criteria Decision Analysis to facilitate transparent and robust management of information, and to prioritize problems and solutions in an integrated perspective. The proposed participative process has contributed significantly to ensure that the scientific research approaches could meet the perceptions and needs of local people and decision makers, who would ultimately be the end-users of the project's outputs.

The results of this research demonstrate how strategic planning could be implemented in practice, with the support of freely available tools. Starting with the brainstorming in each workshop and utilizing of participatory multi criteria analysis, it has been possible to elicit and develop a number of responses to cope with flood risk and future scenarios.

The experimental application of the NetSyMoD approach to the study areas has provided a means to carry out concretely the twinning of the two river basins, evidencing the commonalities and distinct features. The study has led to structured and very effective discussions concerning adaptation responses to flooding in those areas.

The method has allowed prioritizing strategies and policy options, and thus has permitted to orient and to target research activities to more effective objectives, coherent with the expectations and needs of stakeholders.

The study implemented in the Paraguaçu basin has tested the utilization of Fuzzy Cognitive Maps to structuralize and orient the research process for the assessment of environmental flows. The innovative utilization of such a method has permitted to improve the application of the Building Block Methodology (BBM). The BBM, as a holistic approach, involves different disciplines that develop their studies in parallel one with the other, converging their results at the end of the process, in a participatory workshop. This implies that, since the beginning, individual-disciplinary works do not share common specific objectives and methodologies of research, and, moreover, that they don't have any tools to verify and thus adjust their work along the research process, in accordance with the findings of the other specialists. This represents a weakness of the BBM methodology that has been overcome by the utilization of FCM. This method, applied for the first time within the process of the BBM, has allowed to incorporate a system understanding even in a situation where information were mostly qualitative and incomplete and experts were used to adopt disciplinary research approaches: experts progressively externalized and structuralized their knowledge and the identified possible synergies and interconnections among individual research methods.

Moreover, the elaboration of the FCM applied to the vegetation system component has served as an experiment to test the potential contribution of this tool. The vegetation FCM model has consented to analyse how the variables – related to the vegetation component - were related with the others, and to demonstrate what were their individual contribution into the cognitive map. The model simulate the cumulative causal effects between variables and consente to transform qualitative information into predictions of the effect of possible modifications in the ecosystem. Applying the same model it is possible to test also further different scenarios. For example, it would be possible to simulate a variation in one variable and see what happens to the others – forecasting scenario. Similarly, it would be possible to modify the value of some variables until a desired status is reached – backcasting scenario. The research has shown that the use of FCM can add important insights to the description of the ecosystems dynamics and that it can assist experts in the final decisions related to the flow regime to be proposed.

The further construction of the integrated model that links the individual systems in a unique framework will give a more complete and deeper understanding of the ecological and physical interrelations within the system. Hence, comparative studies will be extended to all study sites and further scenarios will be developed simulating the effect of variations in the freshwater discharge. The exploration of different scenarios will guide the experts in the choice of the environmental desired status and in the definition of the required monthly and seasonal freshwater discharges.

This result will lead to the final phase of the Building Block Methodology – the BBM workshop - with a stronger knowledge background and clearer justifications of the desired environmental objectives. This, in turn, will be reflected in a more robust decision on the proposed flow regime, which will be more easily defendable during the next negotiation phase of BBM.

It has to be noticed, however, that even if fuzzy cognitive maps do perform a kind of prediction of ecosystem dynamics, they cannot be used as predictive tools and have to be considered with caution, since they constitute a simulation of reality and could incorporate the errors, misconceptions and biases of the modeller (Kosko 1992). The maps complexity depend on time available when making the interviews; they cannot deal with co-occurrence of multiple causes and do not permit to understand the reason of the numerical results. It has to be underlined that FCM, as well as quantitative dynamics models, are “wrong” by definition, because they are always simpler than the reality (Voinov 2008).

In relation to the BBM process, it has to be remembered that the scientific research constitutes only one part of the entire process, which is followed by the important phase of negotiation. The scientific output dos not have any efficacy until stakeholders accept the assessment, and the water starts flowing back naturally into the river. Even the best assessment of flow needs will not be implemented unless people and users understand why the flows should be left in the river, or restored to a more natural condition. Such an understanding can be facilitated by the use of FCM during the negotiation process, offering an interesting further possible application of this tool. Further research could be developed on the potential use of FCMs to construct scenarios during the environmental flow assessment negotiation process.

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Participatory assessment of adaptation strategies to flood risk in the Upper Brahmaputra and Danube river basins

Lucia Ceccato [a,b], *Valentina Giannini* [a,c], *Carlo Giupponi* [a,c,*]

[a] *Ca' Foscari University, Department of Economics, Cannaregio 873, I-30121 Venice, Italy*
[b] *Universidade Federal da Bahia (UFBA), Grupo Recursos Hídricos (GRH), Rua Aristides Novis, 02, Federação, Salvador, BA, Brazil*
[c] *Fondazione Eni Enrico Mattei (FEEM), Isola di San Giorgio, I-30124 Venice, Italy*

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A B S T R A C T

A methodological proposal aimed at improving the effectiveness of interactions between the scientific community and local actors for decision-making processes in water management was developed and tested to two case studies, in Europe and Asia: the Upper Danube (Danube) and Upper Brahmaputra (Brahmaputra) River Basins. The general objectives of the case studies were about identifying and exploring the potential of adaptation strategies to cope with flood risk in mountain areas. The proposal consists of a sequence of steps including participatory local workshops and the use of a decision support systems (DSS) tool. Workshops allowed for the identification of four categories of possible responses and a set of nine evaluation criteria, three for each of the three pillars of sustainable development: economy, society and the environment. They also led to the ranking of the broad categories of response strategies, according to the expectations and preferences of the workshop participants, with the aim of orienting and targeting further activities by the research consortium. The DSS tool was used to facilitate transparent and robust management of the information, the implementation of multi criteria decision analysis and the communication of the outputs. The outcomes of the implementation of the proposed methods and DSS tool are discussed to assess the potential to support decision-making processes in the field of climate change adaptation (CCA) and integrated water resources management (IWRM).

1. Introduction

According to the last assessment report released by IPCC in 2007, the climate has been changing over the last decades and will continue to change even if greenhouse gas emissions are reduced to meet the targets of the Kyoto Protocol (IPCC, 2007a; Mace, 2005). The environmental, social and economic costs of extreme weather events are already rising in both poor and rich countries.

Climate change impacts are expected to be unevenly distributed across the planet and some areas, like mountains covered by glaciers, will be subjected to major stresses. Projected climate change for the 21st century in the mountains of the world is two to three times greater than the change observed in the 20th century: all mountains are expected to warm significantly (Nogués-Bravo et al., 2007).

There is evidence based on observations that glaciers have been retreating and decreasing in volume, and that mountain snowpack is also decreasing. As a consequence the water storage capacity of the mountains has been decreasing over time (Nogués-Bravo et al., 2007; Stewart, 2009). The hydrologic cycle is thus changing and more dramatic changes are expected (Nogués-Bravo et al., 2007), up-stream and down-

* *Corresponding author at*: Ca' Foscari University, Department of Economics, Cannaregio 873, I-30121 Venice, Italy. Tel.: +39 041 234 9126; fax: +39 041 234 9176.
E-mail addresses: luciaceccato@yahoo.it (L. Ceccato), valentina.giannini@feem.it (V. Giannini), cgiupponi@unive.it (C. Giupponi).
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stream, with summer droughts which might be longer (Stewart, 2009), together with decreased water availability (Messerli et al., 2004; Viviroli et al., 2007), especially when lowlands are arid, as is the case of systems like the Himalayas (Viviroli and Weingartner, 2004; Messerli et al., 2004). Though physically distant from each other, the populations of different parts of the world will be facing similar problems.

According to the Stern Review (Stern, 2006), it is no longer possible to prevent the climate change that will take place over the next two to three decades, and adaptation to climate change is therefore essential to protect our societies and economies from its impacts. Poor and developing countries in particular, which are only marginally responsible for anthropogenic climate change, will be the most affected by the expected impacts (Heltberg et al., 2009). Climate change is therefore also an equity issue and adaptation policies should continue to have a role in international negotiations and (Mace, 2005) scientific research.

Adaptation has been on the agenda since the Earth Summit in Rio (1992) and reference to adaptation can also be found in the United Nations Framework Convention on Climate Change (UNFCCC, 1992) and the Kyoto Protocol (1997). According to UNFCCC Annex II, countries that ratified the convention made a legally binding commitment to fund adaptation in developing countries (www.unfccc.int; Mace, 2005). However, it is not until the Marrakech Accords (2001) that adaptation policies and projects have gained importance (Schipper and Lisa, 2006) and in the Fourth Assessment Report of the IPCC (2007a), as well as in the Stern Review (2006), we find reference to a demand for research on adaptation, mitigation, and development.

Adaptation policies, however, can be very challenging, and negating their right importance would imply strengthening inequalities, thus burdening those countries and those sectors that will bear the heaviest impacts of climate change, such as water provisioning in river basins fed by glacier melt (Mace, 2005). Innovative water management approaches are, therefore, urgent and they must involve the study of adaptation to future scenarios (EC, 2009).

Integrated water resources management (IWRM) is the most popular paradigm adopted by legislation and plans in many parts of the world (GWP, 2000). The success of this paradigm is due to the recognition of the need to deal with the impacts of climate change on water resources in a holistic manner. Generally speaking, in fact, when dealing with the social-ecological system, it is often impossible to cope with one impact without affecting the other elements of the system: therefore the solutions are best sought in a holistic framework (Folke et al., 2002). Moreover, since the impacts are felt in a variety of sectors, and the result is bigger than the mere sum of the single impacts, responses can be developed in an integrated manner (Heltberg et al., 2009). Considering specifically water the IPCC acknowledges the fact that climate change will impact water availability, for example because of a reduced flow in watersheds fed by glaciers or snowmelt, which is the situation of the case studies presented in this article (IPCC, 2007b). Water scarcity sparks conflicts, which some think might be better addressed in an IWRM setting, where conflicting uses can find a compromise solution (WWC, 2006).

Participatory processes are one of the prerequisites of IWRM plans and projects. They further mutual learning between scientists and stakeholders, new opinions can be expressed, problems can be addressed, technical expertise shared, agreements reached, and compromise solutions found if all vested interests are voiced (Renn, 2006). Stakeholders' involvement is essential, because stakeholders hold the necessary information that could facilitate the exploitation of scientific knowledge with high social relevance (de la Vega-Leinert et al., 2008; Griffin, 2007; Reed, 2008).

In parallel to the increasing emphasis on public participation in IWRM, there is also an increasing attention to the need for efficient tools to support the management of those processes and to the role that could be played by information and communication technologies (ICT), mathematical simulation models and decision support system (DSS) tools, in particular. In the context of climate change research the first category of tools may provide scientifically-based scenarios and projections – prerequisites for any planning activity – while DSS tools may provide the ground for bridging the scientific contributions (i.e. by further elaborating model outcomes) and decision/policy-making processes, including managing the participation of different actors (e.g. policy makers, local experts, dwellers, etc.) in a scientifically sound and transparent way. Despite the theoretical potential, traditional modelling techniques have shown limited impacts on policy-making, especially with respect to complex systems such as those involved in natural resource management. DSS tools have quite often performed similarly. One of the problems most often mentioned is the limited or late involvement of stakeholders and potential users (Geurts and Joldersma, 2001), which contributes significantly to the limited uptake of modelling tools and outcomes. The conventional division of roles between the academy and 'outsiders', where scientists supply conceptual frameworks, theories, methods which are then available for use by various actors in society, such as politicians, civil society, etc., is not accepted anymore (Scott Cato, 2009) and new relationships between science, politics and society are necessary.

One of the main challenges in attempting to bridge the gap between science and policy in the water management sector nowadays lies in the development of new tools combining the potentials of advanced ICT tools and robust participatory approaches (Mysiak et al., 2005). Such instruments could be identified as decision support methods and tools providing participatory modelling functionality, in which the exploration of the problem and the formulation of a conceptual model and its formalisation are carried out by disciplinary experts with the direct involvement of stakeholders in a way that is coherent with the so-called "hard science" modelling approaches to be adopted (Sgobbi and Giupponi, 2007). The computer-based tool is surely one important component, but, as recently pointed out in a comprehensive review and survey on this topic (Giupponi et al., 2011) the future of DSS should envisage a broader and more robust combination of the tool(s) and the process of structuring problems and aiding decisions, including adequate instruments for dissemination and training. In an idealized view DSS should thus act as mediators between science and policy/decision making and as catalysts of trans-disciplinary research.

This article illustrates some of the methods and findings of the Brahmatwinn Project,[1] with a specific focus on the approach developed for demonstrating the potentials of innovative decision support processes and tools.[2] They are presented for their potential as a methodological and operational reference for the management of decision processes in a participatory context for the development of IWRM plans, including climate change perspectives and adaptation needs.

The project was carried out through the collaboration of an international research consortium of European and Asian institutions and it focused on two – "twinned" – river basins in the two continents: the Danube and the Brahmaputra. The choice of these study areas stemmed from the idea, later confirmed by the research results, that the two upper river basins, even if very distant from geographical and socio-economic viewpoints, would have commonalities, since they are both fed by glaciers potentially impacted by climate change. This hypothesis was confirmed during the project, which showed how climate change (CC) scenarios downscaled for the case studies (Dobler et al., 2011), point out how intensified weather events in both areas are expected to cause an increase in rainfall in the wet season and of droughts during the dry periods. Climate change could thus exacerbate the uncertainty of water availability and quality, and the occurrence of extreme events, as Brahmatwinn climatologists have suggested.

For the purposes of the project, five case studies have been analysed: two in the Upper Danube River Basin (Danube) – the Lech RB and the Salzach RB (Austria and Germany) – and three in the Upper Brahmaputra River Basin (Brahmaputra) – the Assam State of India, the Wang Chu RB (Bhutan) and the Lhasa RB (Tibet, China).

The FEEM[3] research group – to which the authors of this paper belong – developed a methodological proposal aimed at strengthening the communication and collaboration within the research consortium and with local communities of the end users of project outcomes. The proposal enabled exchange of knowledge and feedbacks between the twinned river basins, and among scientists and local actors[4] (LAs). A programme of local workshops in the two river basins was thus defined in parallel to the other research activities in various disciplinary fields (dynamic climatology, hydrology, sociology, economics, etc.) relevant for the integrated assessment of climate change impacts and the development of adaptation strategies.

The paper is organized as follows: Section 2 describes the methodological framework adopted, the information base and the DSS design. Section 3 presents the results of the application to the Brahmatwinn project. Section 4 discusses the outcomes achieved and draws some conclusive remarks.

2. Methods

2.1. *The methodological framework*

The approach adopted for the analysis of alternative adaptation responses is developed upon the NetSyMoD[5] methodological framework (Giupponi et al., 2008) for the management of participatory modelling and decision processes in the field of environmental management.

NetSyMoD is organised in six main phases. The first three (*Actors' Analysis, Problem Analysis, Creative System Modelling*) were implemented in the initial activities of the project and are not described here. They provided the Brahmatwinn research with (a) a list of the local actors to be involved in the participatory activities; (b) an in-depth analysis of general problems related to water resources management in the two upper river basins, with the participation of the communities of parties interested in the case study areas; (c) mental model representations of the problems, i.e. qualitative descriptions of the causal links among the various components of the local socio-ecosystems by means of cognitive maps clustered in order to be consistent with the DPSIR framework (EEA, 1999); and (d) extensive data sets deriving from hard science modelling activities, consisting mainly in spatial and temporal data sets describing climate change scenarios and their expected consequences in the study areas.

This NetSyMoD methodology relies on the DPSIR framework (driving forces, pressures, state, impacts, and responses), as a comprehensive and simplified conceptual framework for the formalisation of man-environment problems. An extended version of DPSIR is adopted to overcome some of its recognised weaknesses, responding to the necessity, remarked by Svarstad et al. (2008) of expanding the DPSIR framework to incorporate social and economic concerns. In the proposed approach Exogenous Drivers are added, to consider all those driving forces that act as external forcing variables to the system representing the study case: for example climate change, or international markets or policies, which are beyond the sphere of the potential effects of the decisions in question. The extended DPSIR framework is used as a communication interface, categorising the various components of the projects (in particular multiple kinds of information and knowledge) and facilitating the identification of the main causal relationships, thus framing the need for data processing procedures and modelling capabilities.

The fourth and fifth phases, *DSS Design* and *Analysis of Options*, are aimed at involving the actors and disciplinary experts in the design and evaluation of a set of alternative

[1] Project title: Twinning European and South Asian river basins to enhance capacity and implement adaptive management approaches. (Brahmatwinn). Project no: GOCE -036952. Research funded by the European Community, SUSTDEV-2005-3.II.3.6: Twinning European/third countries river basins.

[2] A comprehensive and concise presentation of the results of the whole Brahmatwinn project is presented in a recent issue of Advances in Science & Research Open Access Proceeding at www.adv-sci-res.net/7/1/2011/.

[3] Fondazione Eni Enrico Mattei.

[4] We use the term local actor (LA) to identify all the people involved in the case study activities instead of the more commonly used term stakeholder, to emphasise the fact that they were local experts or policy makers, without the ambition to assess their representativeness with robust procedures, such as social network analysis.

[5] NetSyMoD (www.netsymod.eu/) stands for network analysis, creative system modeling and decision support.

responses, in this case four broad categories of flood risk mitigation strategies, and are those reported in this paper. The last phase, *Actions and Monitoring*, is beyond the scope of the research project and it refers to the implementation of the decision taken by the competent administrations.

In particular, the *DSS Design* phase develops upon the conceptual models provided by the previous *Creative System Modelling* phase and consists of specifications in terms of elaboration and management procedures at the interface between the scientific outcomes of the project and the preferences and expectations of local actors. The *Analysis of Options* implements the results of those elaborations and consists in a series of participatory events supported by an *ad hoc* decision support system software (mDSS; Giupponi, 2007). The mDSS tool provides the framework for decision analysis at the interface between scientific outcomes and the preferences of the involved actors, with a set of techniques aiming at the elicitation and aggregation of decision preferences and through the implementation of multi criteria decision analysis (MCDA; Figueira et al., 2005). MCDA techniques are adopted to assist a decision maker, or a group of decision makers, in identifying the preferred alternative out of a range of alternatives in an environment of diverging and competing criteria and interests (Belton and Stewart, 2002).

In order to implement those two phases, the participation of local actors (LAs) in the two case studies was achieved through a series of workshops, in which brainstorming techniques were initially used to elicit the most relevant local issues and the most promising responses – potential or in place – to cope with flood risk in a climate change perspective.

In parallel, disciplinary experts of the project were involved in an exercise to develop a catalogue of indicators, categorising the widest collection of data provided through analyses and modelling of various kinds and facilitating the communication of the expected outcomes in advance to the interested parties. Local issues raised by the involved actors express the demand of knowledge, while the delivery of information planned by the researchers represents the planned supply of knowledge. The two should in theory match to allow for an effective transfer of knowledge and local impact of the project. This aspect is unfortunately, quite often either neglected in many international research efforts, or considered only in the final phases of the activities, thus dramatically limiting the potential research outcomes. An innovative solution designed to cope with this problem was the implementation of a series of activities carried out in parallel with both the researchers and the local actors belonging to the two case study areas, culminating with the delivery of an extensive integrated indicator table (IIT).

The IIT represented the main interface to the knowledge base developed by the Brahmatwinn Project allowing the combination and comparison of the supply and demand of information (see Fig. 1 for the IIT structure and functions and Supplementary on-line Materials for details). On the left side of the table a hierarchical classification of the information relevant to the whole research project is reported, starting with the level of greatest aggregation, i.e. the four "Themes" (Environment, Economy, Society and Governance). The "Themes" are sub-divided into "Domains", which are further segmented into "Sub-domains". Such a categorisation of

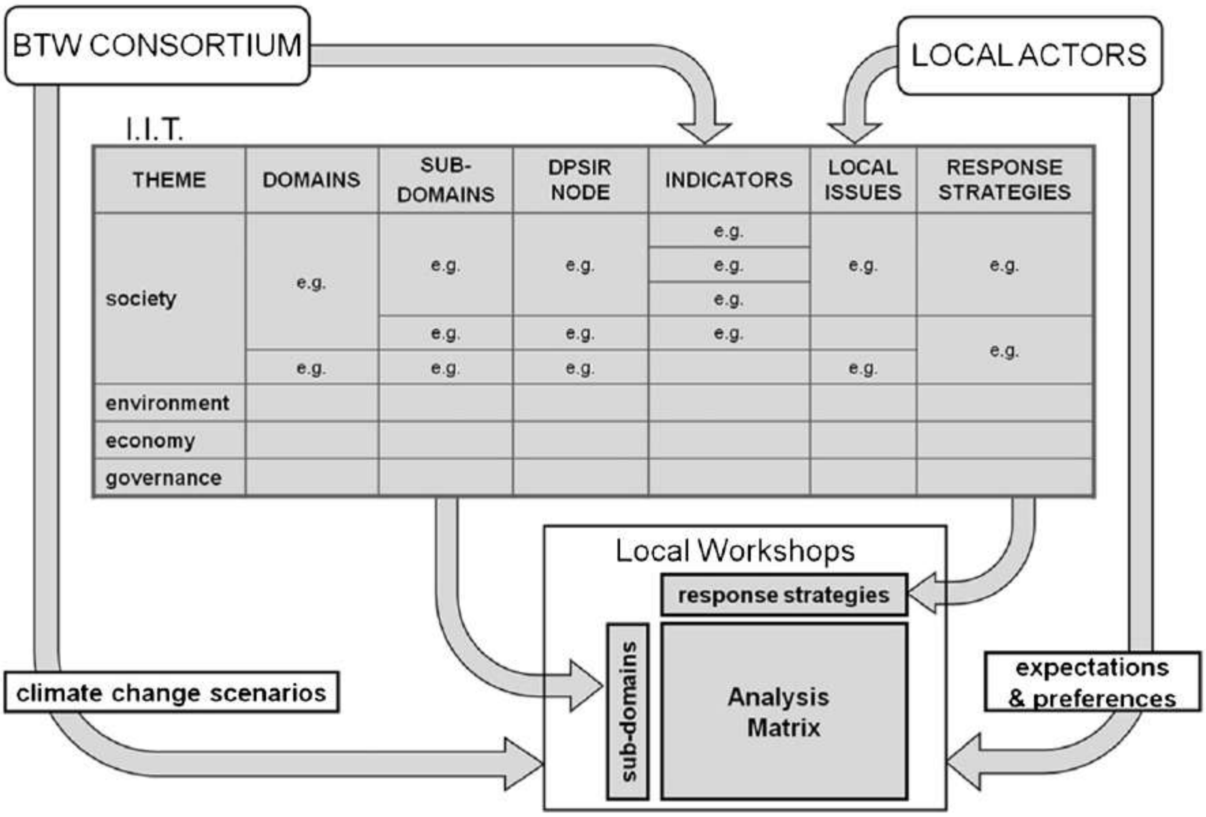

Fig. 1 – The interactions between local actors and the consortium of researchers of the Brahmatwinn (BTW) Project: interfaces and fluxes of information in support to participatory workshop conducted for the analysis of options in terms of strategies to cope with evolving flood risks within climatic change scenarios.

relevant information for the project was developed with a Delphi technique in a series of steps, in which all the project partners were involved. At the highest level of detail "Indicators" were identified by partners (one or more per Sub-domain) as the means of providing a quantitative assessment of the various typologies of information dealt with by the project. The left hand side of the IIT thus represents a comprehensive catalogue of the information provided in the project and intended to be useful for supporting the identification of response strategies at local level.

On the right hand side of the IIT, the issues identified by local actors during the workshops dedicated to the NetSyMoD phases of *Problem Analysis* and *Creative System Modelling* are assigned to related "Sub-domains", thus providing an interface between the potential supply of information from project activities, and the demand from potential beneficiaries. In general it was possible to create such correspondence, but in some cases, as exemplified in Fig. 1, it appeared that either the consortium was ready to provide information not immediately relevant to local issues or the local actors were raising issues not dealt with by the project, thus identifying the existence of knowledge gaps.

As described below – and depicted in Fig. 1, information categorised within the IIT was at the basis of the organisation of workshops aimed at analysing the expectations and the preferences of LAs in terms of future strategies, to orient the final steps of analysis of the project, with the help of the mDSS software. Therefore, sub-domains were also assigned to the five nodes of the DPSIR framework, for maintaining the coherence with such conceptual framework and preparing for the utilisation of the mDSS tool (see Fig. 2).

In collaboration with project partners the possible IWRM strategies to cope with flood risks in future climate change scenarios in the two areas were categorised into four broad categories of Responses (according to the DPSIR definition), in order to involve LAs in the process of targeting and finalising the remaining project activities:

1. ENG-LAND: Engineering Solutions and Land Management (e.g. dam construction, river network maintenance, soil conservation practices, etc.);
2. GOV-INST: Investments in Governance and Institutional Strength (e.g. accountability and transparency in government actions, enforcement of existing regulations, flood insurance, etc.);
3. KNOW-CAP: Knowledge Improvement and Capacity Building (e.g. awareness-raising activities, dissemination of scientific knowledge, training of public employees, etc.);
4. PLANNING: Solution based on planning instruments (e.g. design and implementation of relief and rehabilitation plans, hazard zoning, etc.).

2.2. *The DSS design and analysis of options*

Building upon the information acquired in the participatory activities carried out in the first two years of the project and referred to in the first three NetSyMoD phases, two workshops were organised, one in Salzburg, Austria (Danube) and one in Kathmandu, Nepal (Brahmaputra), with the aim of testing the proposed methodology. In order to guarantee the comparability of the results of the two river basins, both workshops were structured using the same procedure, designed with the purpose of building a common language and understanding of the problems within the groups of LAs, and between them and the research consortium. The workshops were organised in two half-day phases (afternoon of day 1 and morning of day 2) and their outline is briefly described below.

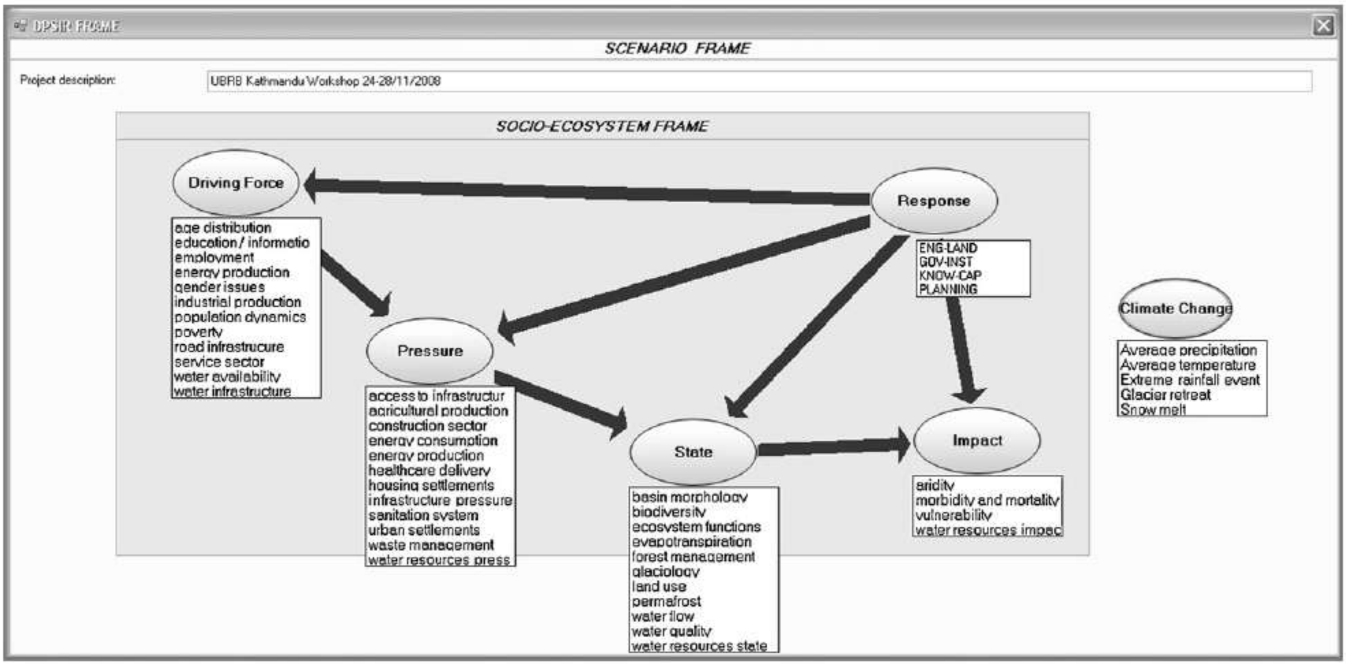

Fig. 2 – The conceptualisation of the information base stored in the IIT within the extended DPSIR framework (screenshot of the mDSS software).

The workshops started with the **presentation** of the goals and of the preliminary results of the downscaling of climate change (CC) scenarios, by means of storylines developed by the project climatologists (Institute for Atmospheric and Environmental Sciences of Johann-Wolfgang Goethe University, Germany), focusing on the possible effects of CC on local water resources over the coming 40 years.[6]

Having introduced the problem and the scenarios, a **brainstorming** session was conducted to elicit and consolidate the sets of possible responses within the four main categories that had been defined during the previous project meetings. This section created the basis for the correct implementation of the ensuing steps, and led to the identification of subcategories and specific actions, within the proposed four major categories of responses.

Having consolidated the identification of responses, participants were asked to select the **criteria** for the evaluation of responses, from the sub-domains listed in the IIT. Each participant was asked to rank the three most important, within three separate lists for the economic, social and environmental domains, in terms of relevance for evaluating the responses (40 criteria in total were listed in the IIT).

Once identified the nine most important evaluation criteria (three per each sustainability theme considered), participants were asked to provide **weights** expressing their relative relevance. The criteria-weighting procedure was based on the method proposed by Simos (1990) and revised by Figueira and Roy (2002), which involves the aid of sets of cards. This method was very appropriate for these workshops, because it supports the planned application of the Electre III method (Belton and Stewart, 2002) and because it provided a simple and effective approach for weighting, without the need of a computer lab, which was not always available.

Criteria and responses defined the entries of the **Analysis Matrix** (9 rows and 4 columns for criteria and response categories, respectively) and, together with the weight vectors, they were used for the subsequent evaluation exercise, by means of the MCDA methods provided by the mDSS software. Participants were asked to fill in the matrix, responding to the question "What is the potential effectiveness of the responses (columns) in coping with the issues expressed by the criteria (rows)?". In practice, they evaluated the potential effectiveness of each response (columns) in coping with the issues expressed by the criteria (rows) by means of a Likert scale (from 1 to 5 ranging from "very high expected effectiveness" to "very low expected effectiveness").

A second Likert scale was added in every cell to analyse the degree of confidence and **uncertainty** related to LAs opinion (IPCC, 2005), i.e. a rough idea about the uncertainty related to the judgement provided for every combination of response category and assessment criterion. In the forms distributed to workshop participants, the concept of uncertainty was specifically related here to their perceptions of the limits in the predictability of the effectiveness of the responses.

The compilation of the AM concluded the first part of the NetSyMoD workshop. All the data collected were coded with a spreadsheet software and then passed to the mDSS tool, for Multi-Criteria Analysis (MCA) and Group Decision-Making (GDM). The mDSS software allowed for the comparison of the alternative options using MCA techniques, by operating parallel evaluation processes, representing the preferences of each participant. In practice, the qualitative evaluations contained in the Analysis Matrix were transformed into normalized scores that expressed the performances of the responses in real numbers ranging between 0 and 1, and subsequently processed by means of the ELECTRE III **decision rule** (Belton and Stewart, 2002), allowing the aggregation of partial preferences describing individual criteria into a global preference and the ranking of the alternative strategy categories. ELECTRE adopts a pairwise comparison of the alternatives, so it is computationally rather demanding, but very simple to be applied by practitioners. The preference (P) and indifference thresholds (Q) were parameters defined by the research team as an input, while no veto threshold (T) was introduced in the analysis, because not pertinent to the selected indicators and analytical context.

Results of individual outranking procedures were subsequently combined in a **Group Decision-Making** procedure by means of the Borda rule (de Borda, 1953).

All the results of the data processing were reported to the participants in a final plenary session of the NetSyMoD workshop.

3. Results

The two workshops in the Danube and Brahmaputra were conducted in parallel without exchanges of information between the two communities of LAs. Even so, five out of nine selected criteria are common to the two cases revealing that in the two river basins, though characterised by different geographical locations, ecological, social and economic dimensions, LAs approach decisions about future strategies in a similar way, i.e. by basing the decision upon a similar set of criteria.

A valuable outcome of the twinning approach, therefore, has been the delineation of some crucial aspects related to flood risk and climate change adaptation strategies in the two river basins. Vulnerability was one of the highest weighted criteria, demonstrating the relevance of the issue and, in general, the concern on the two basins' ability to cope with the adverse effects of climate change in the future. Vulnerability is a hotly debated concept, but according to the IPCC (2007b), vulnerability is determined by the exposure to climate change, by the physical setting and sensitivity of the impacted system, and by its ability to adapt to change. Following this definition, an interpretation of LAs' opinions expressed during the workshops can be provided.

The exposure to climate change risks is clearly related to *Basin Morphology*, that is the physical characteristics of the drainage area, which could appear an obvious consideration, but, on the contrary, it highlights here that the design of

[6] Climate change scenarios provided climate simulations using three IPCC-SRES scenarios (A1B, A2 and B1; IPCC, 2000) and the COMMIT scenario (i.e. the consequence of committing world economies to limit GHG concentrations at 2000 levels), five data sets (GPCC, UDEL, CRU, EAD, F&S) and four models (ERA40, CLM-ERA40, ECHAM5, ECHAM5-Γ).

Table 1 – Criteria selected by LAs from the Integrated Indicators Table (IIT) and their weights.

	Criteria selected at the Danube WS	Weight	Criteria selected at the Brahmaputra WS	Weight
SOC.1	Housing settlements	0.138	Poverty	0.125
SOC.2	Population dynamics	0.097	Population dynamics	0.132
SOC.3	Infrastructure pressures	0.133	Infrastructure pressures	0.100
ENV.1	Vulnerability	0.144	Vulnerability	0.145
ENV.2	Basin morphology	0.091	Basin morphology	0.125
ENV.3	Ecosystem functions	0.143	Forest management	0.113
ECO.1	Agricultural production	0. 099	Agricultural production	0.103
ECO.2	Construction sector	0.111	Energy production	0.101
ECO.3	Energy consumption	0.043	Employment	0.056

actions and strategies lacks careful consideration of the specificity of the area. *Population Dynamics* is contemplated as one of the most important driving forces to be studied to cope with flood risk. Population size and growth, the distribution across urban and rural areas, population concentration, the distance between settlements and riverbanks, are examples of some of the aspects to be evaluated in the strategy design. Also the role of *Agriculture Production* has to be carefully considered by policy makers. Critical issues are related to irrigation infrastructure and extension, ratio of commercial agricultural land per household, household agriculture dependence as a primary source and cropping patterns and diversity. Finally, the pressure caused on *Infrastructure*, according to the LAs, has to become one of the central points of flood risk reduction strategies. Attention has to be paid to the extent of potential damages caused by floods to human infrastructures, like dams and reservoirs; aspects like the probability of dam break, the reservoir-induced seismicity, the downstream stream bed retrogression, the upstream reservoir sedimentation volume and submergence area have to be studied and integrated in the policy focus.

Besides the emergence of such similarities, the exercise of criteria selection also evidenced the significantly different relevance attributed to a series of proposed criteria out of the lists of proposed sub-domains. In the Brahmaputra, to which mainly low-income countries belong, "*Poverty*" was picked as the most relevant criterion, highlighting how the poverty level and low life standards strongly affect the significance of flooding damages in the area.

It is, indeed, recognized that poverty is directly related to vulnerability to climate change, since it is a determinant of adaptive capacity. Countries with limited economic resources are likely to have also poor infrastructure, fragile institutions, low levels of technology, reduced skills, limited access to information and to resources, and consequently little capacity to adapt. Poverty is both an important determinant of endogenous environmental risk, and hence indirectly of socioeconomic vulnerability, and an important constraint of adaptive capacity (Brouwer et al., 2007). Hence, poverty reduction policies would indirectly reduce the exposure to flood risk.

It is also interesting to notice that "*Forest management*" was selected in the top-3 environmental sub-domains only in the Brahmaputra. In the Danube, instead, LAs concentrated their votes on "*Housing settlements*", showing a different perspective in the European area when considering flood risk. According to LAs, the flood risk in the Danube seems to be affected mostly by housing concentration, high population density and the concentration of residential constructions in areas exposed to flood risk. With respect to the economic criteria, "*Agriculture production*" was considered as one of the most relevant in both river basins. This confirms that, according to the LAs' opinion, agricultural systems, irrigation infrastructures and land use in general are crucial and can contribute to either aggravate or reduce the risk of flooding.

Having identified the set of nine evaluation criteria, workshop participants then defined their relative importance by attributing criteria weights (Table 1), providing information about the relative relevance to be given to the criteria in the final ranking of alternatives. Besides the difference in the relative importance of each criterion, it is interesting to observe that in both river basins LAs tend to hold environmental and social criteria in greater regard than economic ones. We can easily see this by summing up criteria weights for each dimension: the environmental dimension was considered the most important, accounting for 38% of the total weights, followed by the social (36–37%) and lastly by the economic one (25–26%).

The calculation of weights by means of average aggregation, however, can homogenise and flatten the values. Aggregate values can therefore hide important information, such as divergence and convergence of participants' opinions. The discordance in the weight evaluations clearly reflects the different perceptions and objectives of LAs, and reveals the presence of possible conflicting interests among them. The elicitation of weights is therefore a very crucial phase, because weights can strongly influence the results (Belton and Stewart, 2002). In fact, in theory, an equal representation and integration of all the issues at stake should be guaranteed in participative exercises. In our case, after analysing the distribution and the spread of individual preferences for each criteria weight using Box and Whisker plots (see Fig. 3), we were able to verify that in general, among the Danube participants, there was a reasonable concordance in weight attribution, while, on the contrary, among Brahmaputra respondents we observed high discordance in weight evaluations.

This result pointed out the need for a sensitivity analysis, for the Brahmaputra case, to monitor how changes in the weight sets could influence the final ranking. Sensitivity analysis, indeed, is necessary to improve the quality of

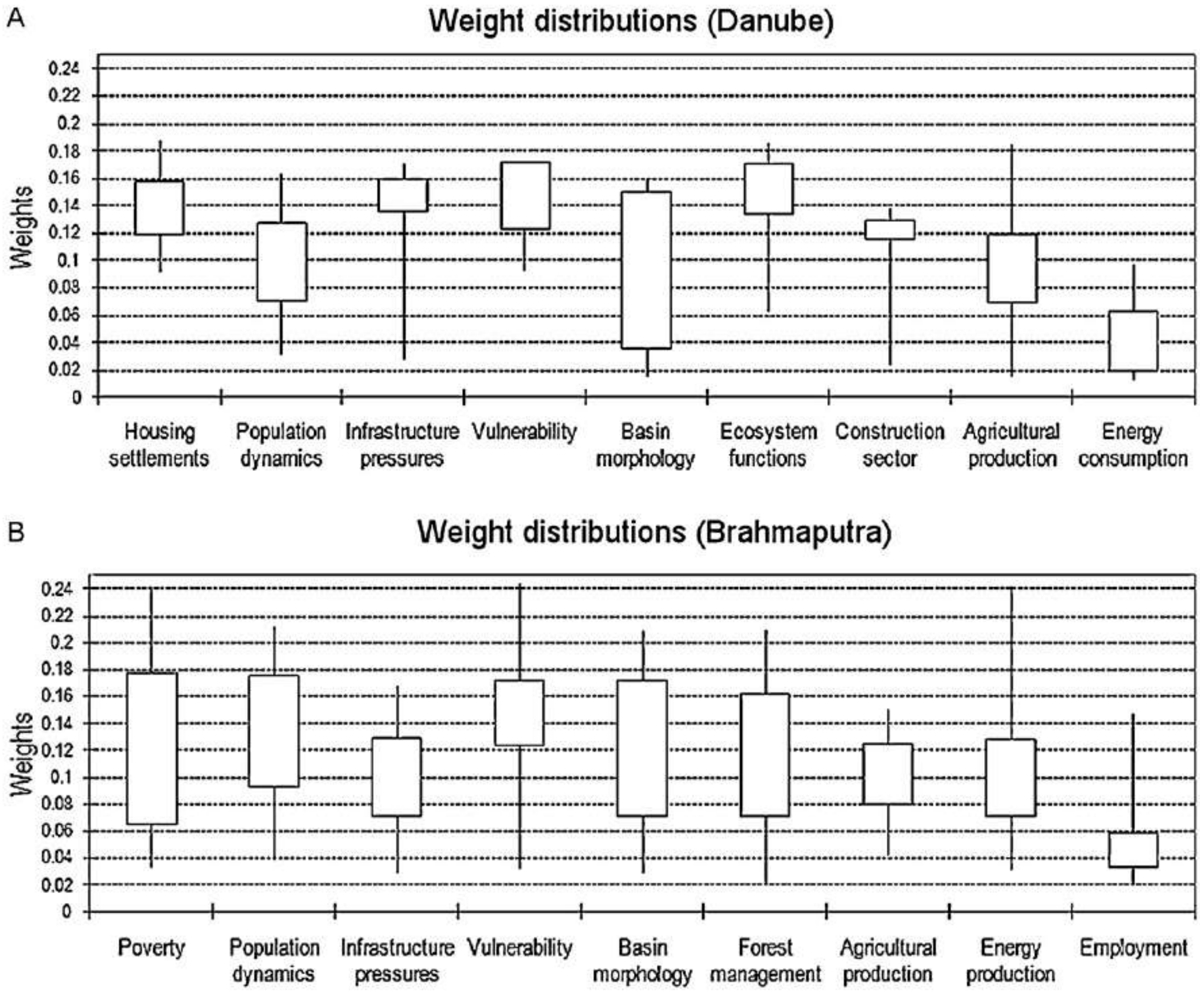

Fig. 3 – Box and whiskers plots of the dispersion of weights provided by local actors of the UDRB (a) and UBRB (b).

environmental decisions and verify the robustness of the results (French and Geldermann, 2005; Cloquell-Ballester et al., 2007), and it should, therefore, be recommended in all the cases of implementation of the proposed approach in the practice of decision making. In this exercise the sensitivity analysis of weights was performed by exploring the effects of incrementing and diminishing one weight at a time by 25%, 50% and 75%, and rescaling all the others while maintaining the original proportions among them. The sensitivity analysis results are discussed further on in the article.

The following step was the elaboration of the Analysis Matrix (AM) for each river basin, aggregating and averaging the information collected from each individual AM of participants. Two average AMs resulted (Table 2).

From the observation of preliminary data, the results in both the Danube and Brahmaputra showed that none of the categories of strategies clearly dominates the others. All the average criterion scores (bottom rows) or responses (columns farthest to the left) are in a range between "very high effectiveness" and "medium effectiveness", meaning that all the responses are considered to be potentially effective to cope with flood risk and important to deal with the selected environmental, social and economic criteria.

This result is not too surprising. Indeed, throughout the participatory process developed along the entire project, LAs gradually shared their knowledge and perceptions of the various aspects discussed around adaptation strategies to climate change. This process enhanced a shift in LAs views of the problem, from a more individualistic perspective to a common understanding of the interdependence of its multiple dimensions and, thus, of the related policies to cope with. This emphasizes the role of scientists in supplying such a communication platform and confirms the great potential of this methodology to boost knowledge sharing and mutual learning between scholars and LAs.

A supplementary validation of these results is given by the analysis of confidence scores attributed by LAs to their evaluations. The LAs were asked, indeed, to indicate the degree of confidence related to their answer (normalised scale of confidence ranging between 1 "Very high confidence" and 0 "Very low confidence"). All the answers were given with a confidence above the normalised value of 0.5 and very close to the highest one (i.e. 1.0).

The last part of the analysis consisted in calculating the ranking of alternative responses by applying the MCA capabilities of the mDSS software. The partial scores describing the performance of each alternative response with respect to each single criterion were thus aggregated, considering the elicited weights and following the decision rule adopted (i.e. ELECTRE III). On average, LAs of both river basins evaluated the

Table 2 – Analysis Matrix – average values of LAs' evaluations on the potential effectiveness of each response in coping with the issues expressed by the criteria (rows) by means of a Likert scale ranging from 1 "Very high effectiveness" to 5 "Very low effectiveness".

Analysis Matrix (Average values)		PLANNING	KNOW-CAP	GOV-INST	ENG-LAND	Average
Danube RB						
SOC.1	Housing settlements	2.00	2.43	2.57	2.71	**2.43**
SOC.2	Population dynamics	2.86	3.00	2.29	3.29	**2.86**
SOC.3	Infrastructure pressures	2.43	2.14	2.57	2.00	**2.29**
ENV.1	Vulnerability	2.33	2.67	2.50	2.67	**2.54**
ENV.2	Basin morphology	2.71	2.57	3.43	3.29	**3.00**
ENV.3	Ecosystem functions	2.86	2.43	2.29	3.43	**2.75**
ECO.1	Construction sector	2.14	3.29	2.57	2.43	**2.61**
ECO.2	Agricultural production	2.86	3.14	2.71	2.57	**2.82**
ECO.3	Energy consumption	2.86	2.43	2.57	2.86	**2.68**
	Average	**2.56**	**2.68**	**2.61**	**2.80**	
Brahmaputra RB						
SOC.1	Poverty	2.43	2.62	2.00	3.33	**2.60**
SOC.2	Population dynamics	1.76	2.52	2.33	3.19	**2.45**
SOC.3	Infrastructure pressures	2.00	2.86	2.67	2.19	**2.43**
ENV.1	Vulnerability	1.71	2.43	2.24	1.95	**2.08**
ENV.2	Basin morphology	2.38	2.67	3.10	2.43	**2.64**
ENV.3	Forest management	1.86	2.10	2.10	1.95	**2.00**
ECO.1	Agricultural production	2.15	2.50	2.48	2.29	**2.35**
ECO.2	Energy production	2.19	3.00	2.43	2.10	**2.43**
ECO.3	Employment	2.43	2.57	2.43	3.52	**2.74**
	Average	**2.10**	**2.58**	**2.42**	**2.55**	

PLANNING solution as the most effective one. The remaining categories show different preferences and ranking in the two basins: in the Brahmaputra the second ranked category is ENG-LAND (e.g. dam construction, river network maintenance, soil conservation practices, etc.), there is no preference between investments in GOV-INST (e.g. accountability and transparency in government actions, enforcement of existing regulations, flood insurance, etc.) and KNOW-CAP (e.g. awareness-raising activities, dissemination of scientific knowledge, training of public employees, etc.). The LAs of the Danube instead ranked ENG-LAND as strictly dominated (not preferred) by all the other alternatives, with GOV-INST and KNOW-CAP ranked third and fourth, respectively.

Given the broad meaning of the categories of strategies considered and the exploratory context of the exercise with a relatively high number of stakeholders involved, dramatic differences in the performances were not expected and the differences of the performances were not of great interest. The robustness of the ranking was instead a main issue, because the following steps of the project went into a more detailed analysis of possible strategies within the preferred category identified at this stage.

The robustness of the results was explored and confirmed firstly with a sensitivity analysis of weights, which showed an overall stable performance. In the Brahmaputra basin, all the verified variations of weights (from ±25%, and ±50%) did not induce an overturning of the ranking, confirming PLANNING as the preferred option and ENG-LAND as the second ranked category. In the Danube basin the ranking was confirmed with variations of weights by ±25%, while it was observed that a variation by +50% of the criterion *Population Dynamics*, or of the criterion *Infrastructure Pressure* by −50% would determine a change of the ranking. These variations are indeed very high, so that the results can still be considered robust enough, nevertheless it should be mentioned that in those cases the GOV-INST became the preferred category, thus pointing out a slightly different perspective of the Danube stakeholders.

Moreover, in order to explore the possible effects of averaging the preferences of multiple actors in terms of both analysis matrices and weight vectors, the data collected from each LA were also processed separately thus obtaining multiple final rankings of options. All the rankings obtained were subsequently processed in mDSS using the Group Decision-Making (GDM) capabilities, by means of the Borda Rule. The Borda rule counts how many times each category of responses is preferred to each of the other options by interviewed LAs, and sums up the so called "votes in favour".[7] According to Borda mark (Table 3), we observed that the PLANNING category is the dominating solution (most preferred one) in both basins, with 10 votes in the Danube and 38 in the Brahmaputra, respectively.

For the purposes of the exercise within the activities of the Brahmatwinn Project, the results were robust enough to orient the attention of the researchers toward analysing in greater detail the strategies for mitigating flood risks in a climate change perspective within the broad category of PLANNING. Discussions with LAs were useful to better define strategies and actions which should be considered within the preferred category of PLANNING measures, and assessed in a more detailed second round of analysis supported by mDSS (not reported in this paper).

In both basins the attention was driven to: improving the implementation of existing land use plans; establishing protected areas along rivers; designing new catchment development plans; coordinating regional and community

[7] The votes in favour, in Borda mark, consider strictly preferences and do not count indifference.

Table 3 – Group Decision Making marks. The first number refers to the N. of votes in favour, while "I" refers to the votes of indifference.

	PLANNING	ENG-LAND	KNOW-CAP	GOV-INST	Sum of votes in favour	BORDA Mark
Danube						
PLANNING	–	3 (I = 0)	4 (I = 0)	3 (I = 2)	10	1°
ENG-LAND	4 (I = 0)	–	1 (I = 0)	2 (I = 0)	7	3°
KNOW-CAP	3 (I = 0)	5 (I = 1)	–	1 (I = 3)	9	2°
GOV-INST	2 (I = 2)	5 (I = 0)	3 (I = 3)	–	10	1°
Brahmaputra						
PLANNING	–	10 (I = 6)	16 (I = 3)	12 (I = 5)	38	1°
ENG-LAND	5 (I = 6)	–	9 (I = 4)	8 (I = 6)	22	2°
KNOW-CAP	2 (I = 3)	8 (I = 4)	–	8 (I = 6)	18	3°
GOV-INST	4 (I = 5)	7 (I = 6)	7 (I = 6)	–	18	3°

level planning; evaluating and harmonizing existing hazard plans; restricting the construction in risk areas; realizing flood risk mapping and zoning and vulnerability mapping. In the Danube river basin LAs also pointed out strategies oriented toward designing and implementing IWRM plans, underlining the need for a common government platform of the basin, and strategies focused on the planning of retention areas and urbanisation processes. In the Brahmaputra basin, LAs also focused their attention on strategies related to disaster risk management act and plan, for an earlier intervention and community preparation to flood occurrence.

4. Discussion and conclusions

The NetSyMoD methodological framework developed for the integrated participative activities of the Brahmatwinn Project, with the involvement of both researchers and local actors, facilitated in general communication and exchanges of experiences between the twinned river basins, and among scientists of different disciplines and local actors, through a continuous interaction and feedback process. In particular, the participative process proposed contributed significantly to ensuring that the scientific knowledge and approaches offered could meet the perceptions and needs of local people and decision makers, who would ultimately be the end-users of the project's outputs. The process also enabled the management of the different roles needed according to French and Geldermann (2005): researchers giving insights on how the future might unfold, with local actors providing judgements on the expected feasibility and effectiveness of the responses to cope with flood risk. In this case adaptation responses to climate change have, therefore, been evaluated by those adapting, i.e. local actors as suggested by de França Doria et al. (2009).

These findings show great potential for addressing further research efforts more effectively. In the case of the Brahmatwinn Project the results reported herein allowed for more targeted final activities, including a subsequent round of Analysis of the options focused on a set of possible strategies within the broader category of "Planning" approaches.

Looking at LAs' contributions during the brainstorming phase of the workshops, we can interpret the preference given to "Planning" in a general way: there needs to be some kind of response developed a priori, so that when flooding occurs local authorities and communities know how to behave during and after the emergency, e.g. the design of relief and rehabilitation plans and disaster risk management. Also, in a stricter sense, LAs referred to the need of physically identifying and mapping hazard areas, such as flood risk zoning, and, more generally, land-use planning. The emergence of "Planning" as the most promising response in both basins might therefore mean that not only do LAs think that "Planning" is most needed in absolute terms, but also that it is currently the most deficient of the four categories presented. In the Danube, LAs acknowledged that change in land-use planning after major flooding events – even if partial – had been a key factor for the prevention of damage in more recent flood events.

Examples of change are the projects implemented for the renaturation of the river banks, which, according to some LAs, should be extended to other areas. However, LAs have also expressed the need to evaluate, harmonize, and implement existing plans. On the other hand, in the Brahmaputra the importance given to population density and poverty (i.e. second and third most important criteria) is related to the fact that many settlements are found in high risk areas, which are sometimes the only place where poor people can afford to live. The concern for encroachment on Brahmaputra's banks as one of the factors limiting the possibility of risk reduction voiced in the workshop confirms this hypothesis. LAs of the Brahmaputra have expressed the need for land-use planning to deal with concerns for urbanisation processes along the river banks, which should be prohibited and people already living there should be resettled.

The results were also circulated within the research consortium to direct the attention of modellers to the subsequent phases of the project, with the idea of providing a quantitative assessment of the strategies within the assessment framework described here. However, the ambition to substitute LAs' expectations elicited through the Likert scale at the workshops, with quantitative assessments provided by models proved to be beyond the capabilities of the project, mainly because of time constraints. It should therefore be recommended that when approaches deriving from the one proposed here are adopted, the work plan be carefully defined with adequate time length and with the possibilities of (re)orienting hard science modelling according to the issues and the expectations elicited from the stakeholders.

Besides the methodological framework, also the mDSS software raised great interest among the participants, who were involved in the project activities since its initial phases, exposed to preliminary results and asked to contribute to orient the final phases of the project. Several participants appreciated the use of public domain software in particular, because it allowed the reuse of the approach proposed in local decision problems. In the scientific literature elements such as the timely involvement of stakeholders and the free availability of tools for reuse in local cases and elsewhere have been quite often proposed, but rarely applied in practice.

In this regard the results of this research are encouraging, because they advance our understanding of adaptation to climate change in river basins, and in particular they demonstrate how strategic planning can be implemented in practice, with the support of freely available tools. Starting with the brainstorming in each workshop we were able to elicit and develop a number of responses, needed or in place, to cope with flood risk and future scenarios. LAs of both basins were able to identify responses based on their knowledge and understanding, but also based on other responses identified in previous workshops, either in the same or in the other basin. This was possible thanks to the fact that besides the two workshops described in this article five others were held, i.e. a total of seven workshops took place according to the sequential and iterative process envisaged by the NetSyMoD framework.

In general, the experimental application of the NetSyMoD approach to the study areas provided a means to concretely carry out the twinning of the two river basins, shedding light on the commonalities and distinct features. This study approach led to structured and very effective discussions concerning adaptation responses to flooding in those areas, and allowed for the collection of a significant amount of insights and lessons, drawn from the involvement of local actors. From the evaluation questionnaires collected at the end of the events, we had no evidence of problems concerning the opportunities to freely and equally express opinions, possible biases, or about the process being guided by a dominant discourse, which may delegitimize some of the stakeholders only because they do not subscribe to a preliminarily defined agenda (Griffin, 2007).

As a final remark it should be remembered that the participatory processes described above were at least to some extent, academic simulations of social processes, since they were carried out within the activities of a research project; this implies that the results must be considered mainly for their role in methodological test and demonstration. For this reason, crucial aspects of real world applications were not dealt with by the project, such as the statistically sound identification of representative local actors. Having clarified this at the outset with the participants involved, these activities provided at least two very important opportunities and one caveat: (1) testing and refining methods and tools to be applied in real world decision processes, and (2) disseminating information about scientific developments and the availability of methods and tools to potential users of the project results. Regarding the caveat, it should be remembered that participatory activities should be carefully planned, designed and managed and that methods and tools are not enough – skilled professionals are needed too. This points to the need for future training efforts specifically targeted to provisioning the participatory processes to be implemented in IWRM and climate change adaptation processes with professionals of adequate capabilities.

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Appendix A Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.envsci.2011.05.016.

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Lucia Ceccato is a PhD candidate in the program of ''Analysis and Governance of Sustainable Development'' at the Ca' Foscari University of Venice (Italy) and researcher in the field of water management at the Federal University of Bahia (UFBA), Department of Environmental Engineering (Brasil). She holds a Master degree in "Non-profit Economics, Cooperation and Development'' and a degree in Economics from Ca' Foscari University of Venice.

Valentina Giannini is a PhD candidate at the University of Venice (Italy) in ''Science and Management of Climate Change''. She holds a Masters of Environmental Management from the Yale University, School of Forestry and Environmental Studies (USA), and a MSc in Architecture & Planning from the Politecnico di Milano (Italy). She is a researcher at FEEM in the field of Natural Resources Management.

Carlo Giupponi is an associate professor at the Department of Economics and is the Director of the Inter-university Doctoral School ChangeS on Global Change Science and Policy of the University of Venice (Italy). He is an affiliate scientist at the Euro-Mediterranean Centre for Climate Change (CMCC), and at the Fondazione Eni Enrico Mattei (FEEM), Water topic leader. He has coordinated research activities at FEEM over the 3.5 years of the Brahmatwinn project.

ANNEX 2: Questionnaires applied for the elaboration of the 3rd Essay

QUESTIONNAIRE
USING PARTICIPATORY FUZZY COGNITIVE MAPS FOR STRUCTURING THE BUILDING BLOCK METHOD (BBM) PROCESS IN THE LOWER PARAGUAÇU BASIN

This survey aims to support the construction of **Fuzzy Cognitive Maps**, to facilitate the integration and organization of experts' knowledge related to the ecological functioning of Low Paraguaçu river system (Bahia-Brasil), and its modification due to variation of its water flow.

The Objective of FCM: the development of the FCM exercise is used to progressively externalize and structure experts' knowledge and integrate their conceptual model into an integrated inter-disciplinary framework.

- Experts first are induced, trough the compilation of questionnaires under modeller orientation, to structuralize their ecological understanding of the limnological system. The complexity of the river system is simplified by the elicitation of key variables to be studied. (Key elements and variables, casual relations, intensity or relations and determination of current and natural status of every variable).
- The conceptual models of every expert is then integrated into a common framework, where experts are encouraged to present their knowledge and research objectives to the rest of the team. The integrated framework is then discussed within the research team, communalities and synergies are discovered and a conjoined working plan elaborated.
- the integrated model is run, and possible scenarios investigated.

Fuzzy Cognitive Maps are a form of cognitive maps used to map the relations among the variables of a system, but extended by adding fuzzy logic, which is used to incorporate ''vague and qualitative knowledge' (Kosko 1986). A FCM consists of a number of **nodes** (or **concepts**), connected by arrows (arches), which represent the causal relationships between the concepts. Each connection (arch) is then associated with a weight e_{ij} (between 1 and 0) that reflects the strength of the such a relationship between nodes. Two conceptual nodes without a direct link are independent. Positive values describe promoting effect, while negative ones describe inhibiting effect.

The value of −1 represents full negative, +1 full positive and 0 denotes neutral relation. Other values correspond to different intermediate levels of the causal effect.

FCM has the capability to incorporate feedback processes and it can be used to simulate the changes of a system over time and address "what if" questions.

STEPS

Step 1 – Elicitation of CONCEPTS (NODES) and CONNECTIONS (ARROWS). Purpose: to select the ELEMENTS of the system (nodes), their casual relations and determine their state.

First round of interviews with experts, realized individually. The interviews regarding the physical aspects of the system are preceding those on biota.

A revision and synthesis of the conceptual map realized with the interviews is performed by the modeller. A Cmap representation of the entire system is constructed. During a common section the synthesised system is presented and validated.

Step 2 – STRENGTH of CONNECTIONS and VECTOR STATE. Purpose: to find out the intensity of relations between nodes and to set the parameters for the nodes (initial and target state).

Second round of interviews, aimed at validating the conceptual model and determining the intensity of relations. It could be implemented again, with personal and individual interviews or during a participatory workshop with all the experts.

Expert are oriented to make deductions about how was the INITIAL STATE of variables, that is the natural state of the river system, when dam war not present.

The exercise focus on the construction of qualitative scales that could indicate the status and range of variation of variables.

Step 3. **SCENARIO**. Purpose: to establish the initial and final state of the system and investigate scenarios, comparing different study sites.

Running the model and analysis of scenarios. The modeller alone executes this step and presents the results to experts for discussion. The analysis of scenarios can induce experts to review and adjust the model. Participatory processes are cycle processes.

Experts and areas of study to be investigated

The system under study refers to the river system (in-stream and riparian zone) functioning of Rio Paraguaçu, specifically to the lower part of the river, downstream from Pedra do Cavalo dam, which regulates the flux of the stream.

In order to structuralize the model and the conceptual knowledge, the elements under study are divided in 4 categories:

5. The **hydrologic characteristics** of **the river flow**, which are the exogenous variables that will impact the other components of the system. This part helps to understand the hydrologic functioning of the river, through the study of historical data and hydraulic modelling.
6. **Biota living in the system**, is represented in this study (BBM manual) by vegetation, aquatic invertebrates, and fishes. Experts study the conditions (tolerances and requirements) and resources needed, by an individuals or a species, in order to live
7. **Abiotic environment,** in term of geomorphology and chemical characteristics, which constitute the environment where biota live and are fundamental element that determine the ecological habitats.
8. **Social System** is intended here the traditional communities living along the river and depending on its resources for their livelihood.

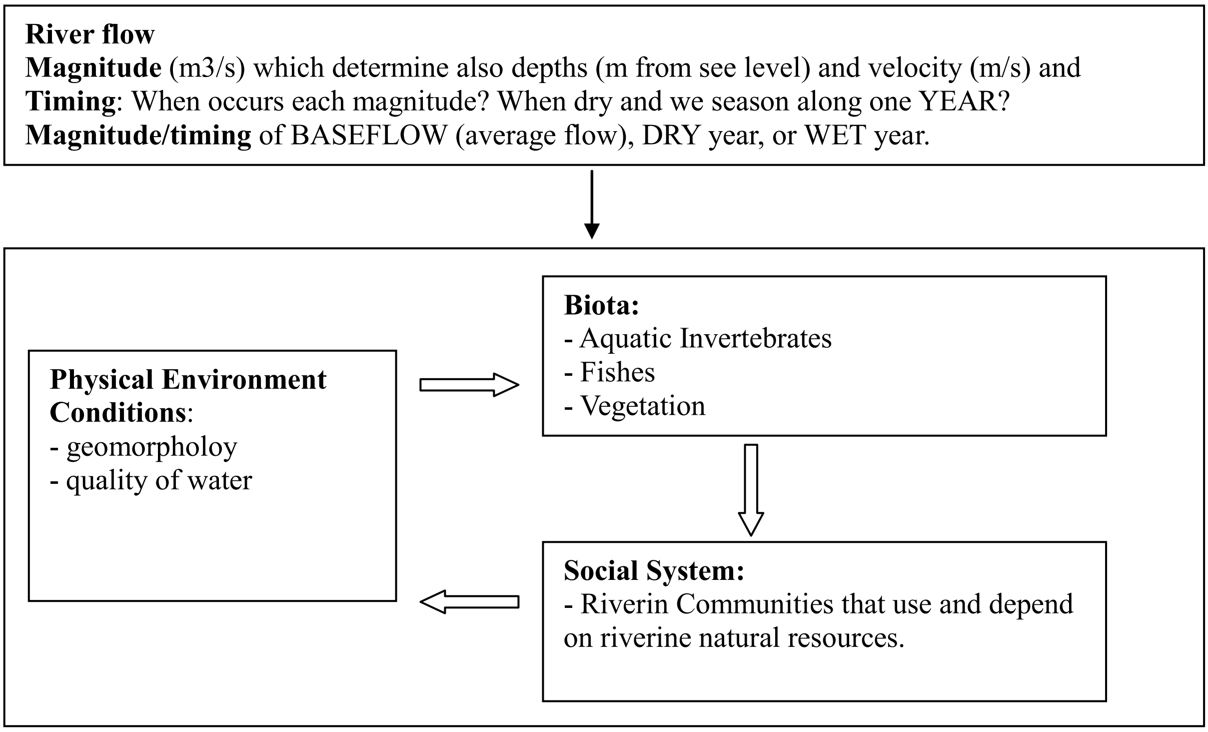

Figure 1: The system under study is divided in 4 causal sub-groups. The first represent the exogenous variable, that give the input for the study of the rest of the model. Every part is analysed individually for facilitating the compression, but we clearly don't ignore the interconnection and the feed-back relations between its elements.

STEP 1 – INDIVIDUAL INTERVIEWS

Elicitation of CONCEPTS (NODES) and CONNECTIONS (ARROWS)

NOTE: Try to answer to the question, according with your former (ex-ante) knowledge, as a experienced observer, relative to the effects of a modification of the flow regimes. An **intuitive evaluation** of a site is expected! Think at the ecological specificities of the low Paraguaçu river and IGUAPE area. Consider all your previous knowledge and experience on the study area and on similar ecosystems.

Question 1: Which are the most important variables (concepts) that you are going to study in order to assess how river flow variation could affect the _________[11] of low Paraguaçu river? Try to distinguish them between biotic and physical variables.

ATTENTION: all the further questions are referring to the list here proposed. Please think carefully about what are the most important issues to be considered. During the interview, feel free to come back and modify this list.

List

VARIABLES	Description the variable and its unit of measure (qualitative scale are also possible)

PHYSICAL VARIABLES

BIOTIC VARIABLES	

[11] This is the general questionaire that was applied to the discipline or experts related to the areas of Water Quality, Hidrology, Vegetation, Aquatic Invertebrate, Fisches and Sociology. The blank was completed then according to the aerea.

Question 2. How it is affected:

i) For each element of the list, explain how river flow variation (quantity, elevation, velocity or seasonality) or physical environmental condition (geomorphological and chemical) could affect the variable? Briefly explain how.

ii) For each element of this list, say what other factors (not cited yet) could affect the variable (natural and human pressures). What the element is affected by?

Copy and paste the elements column of question 1

VARIABLES	**Element X is sensitive to river flow characteristics? How flow quantity, elevation, velocity or seasonality could influence this element?**	**What other factor could affect this element?**

Question 3. What is affecting:

i) Can the elements you mentioned (list) affect one to each other? How?

ii) For each element of this list, say what is the ecological function and how this element can influence/affect other system components (ex. Other physical characteristics, Biota, or humans, etc).

Copy and paste the elements column of question 1

VARIABLES	Element X is affected by the status of other elements (of the list)? Which one and how?	Can element X influence other system components (other discipline of study)?

Question 4. Are there possible feedback loop effects between elements?

Explain.

Question 5. What is the range of variation of every variable? Use specific scale and measure units for each element.

VARIABLES	Measure Unit	STATUS RANGE

STEP 2 – Individual interview

STRENGTH of CONNECTIONS and VECTOR STATE

Consider the following chart, elaborated on the basis of the previous interviews:

INSERT CHART

Question 1: Do you agree with the chart here presented? Do you think some important issue/factor is missing? If yes, please say what.

Yes **No. I suggest the inclusion of the following element: ________________________**

STUDY AREA
Consider that the ecosystem being modelled is the lower part of Paraguaçu River, downstream from the Pedro de Cavalo dam, until the Iguape Bay. The study segment has been divided in 5 STUDY SITES and you are asked to answer to the questions referring at ONE specific SITE each time, on the base of your acquired knowledge of the area.

Question 2: Look at the symbols "+" and "-" on the arrows linking the elements of the chart.

The "+" and "-" symbols indicate the type of causality that the arrow represents. The "+" symbol represents positive causality and the symbol "-" indicates negative causality. For example: the "+" arrow that goes from *XXX* to *YYY* indicates that an increase in the extension of *XXX* will cause an increase in the population of *YYY*. Conversely, a drop in the extension of *XXX* will cause a reduction in the population of *YYY*. Make an example!

We'll try now to determine the **intensity and type** of effect that other factors play on the elements being edited.

INITIAL CONDITIONS
The area of study has a length of 25 km, and we want to analyze the effects of a variation on river flow, in each STUDY SITE, but one at each time. Consider as INITIAL condition, a pre-impact situation, where the dam does not regulate the flow.

Consider the Conceptual Map chart and its + and – relations. Each causality relationship in the fuzzy cognitive map has an associated intensity of effect, that may take any value between 0 and 1, where 0 means that the cause has no effect on the factor being edited, and 1 means that the effect is as intense as possible. If the effect on factor is *none* the intensity of effect plays no role.

Question 2: Attach a value between 0-1 to every pairwise relation (arch) between variables.

<u>INSERT CHART WITH BLANK CELLS FOR INSERTING THE VALUES</u>

Question 5. What is the status of the environment today?

Considering the Variation Range of the element, describe the actual status of each element. Use classes if you consider useful but specify the range of each class.

(try to answer based on your knowledge of the area. If you don't have date or elements to evaluate, answer and attribute a degree of confidence on your answer: 0 very low, 1 low, 2 medium, 3 quite sure, 4 sure)

Describe the status of each element today:

Element	Measure Unit	Variation Range	ACTUAL STATUS	Each of confidence (from 0 to 4)