Fuzzy Cognitive Maps for Conflict Analysis and Dissolution in Drought Risk Management

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Abstract

Empirical investigations in scientific literature have highlighted the differences between stakeholders' perceptions on the severity of a given drought phenomenon and on results out of scientific – technical evaluations. This means that there can be several perceptions over the phenomenon as well as different scientific models to be used in order to assess the drought's severity which itself does not consider such differences. Facing a drought phenomenon, stakeholders adopt different mental models to assess its severity, taking into account additional elements, other than just water availability and climatic conditions. At turn, this could have a strong negative impact on the effectiveness of strategies for drought mitigation. In fact, if mitigation actions were selected without considering stakeholders' perceptions over the drought, then, the actions themselves would be considered as unsatisfactory by the stakeholders or, even worst, not acceptable at all. If the degree of acceptability was low, then stakeholders would strongly hamper the implementation of mitigation actions. Therefore, an in depth analysis of potential conflicts and the definition of effective negotiation strategies should be useful. By this perspective, we propose a methodology based on a Fuzzy Cognitive Map (FCM) to support the elicitation and the analysis of stakeholders' perceptions over the drought and the analysis of potential conflicts. The method has been applied to a drought management process in the area nearby the Trasimeno Lake (located in the Region of Umbria) in order to analyze potential conflict.

Keyword: Drought risk management; drought perception; Fuzzy Cognitive Map; Conflicts analysis.

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1. Introduction

Drought is a crucial phenomenon amongst those referring to water scarcity.. It is defined as a natural and temporary imbalance of water availability, consisting of a persistent precipitation, lower than average, (Pereira et al., 2009) occurring at uncertain frequency and characterised by severity and duration. Moreover, drought is difficult to predict in terms of its beginning, ending and severity. Therefore, management strategies aimed only at increasing the seasonal availability of water through a merely technological and infrastructural approach are not sufficient. It is widely acknowledged that coping with the problem of drought requires the development of a risk management plan to support the timely implementation of mitigation measures.

Nevertheless, policy making on the issue of drought planning is hindered by the lack of clearly agreed definitions of drought, which makes it difficult to implement urgent measures as well as to apply timely mitigation measures when a drought occurs, or to adequately evaluate drought impact (Pereira et al., 2009b). Ohlsson stated that indicators of water scarcity – and, thus, of drought – are "not fixed stars" (Ohlsson, 2000 – pag. 215), but they show what has been postulated as important throughout the analysis of the phenomena. The prevailing technical dimension of drought management imposes the use of specific indicators for the drought analysis, which are mainly based on the amount of precipitation and water availability.

Empirical investigations in scientific literature have highlighted the differences between different stakeholders' perceptions of drought phenomena and results out of scientific – technical evaluation (Noemdoe et al., 2006). Thus, characterizing "drought" as simply as a point of departure from the normal precipitation and as a reduction of the amount of the water available provides only a one-dimensional definition of drought (Noemdoe et al., 2006). There is no unique definition of the problem, but each individual has his/her own perspective in defining and interpreting it (Lane and Oliva 1998). A distinction is needed between hard and soft system thinking, where the former adopts an "objective" stance which considers problems as independent from individuals' views and beliefs. Soft system thinking, at the other hand, requires a "subjective" stance that recognises the importance of participants' perceptions (Rosenhead and Mingers, 2001). Facing the drought's phenomenon, stakeholders adopt their own mental models to assess its severity, taking into account additional elements other than just water availability and climatic conditions. Mental models influence actors' perceptions about critical situations by influencing both his/her world observation and his/her conclusions based on that observation (Pahl-Wostl 2007). They can be considered as windows through which people view the world (Timmerman and Langaas 2004). Mental models determine what information actors perceive in the real world and what knowledge actors derive from it (Kolkman *et al.* 2005).

The perception of drought is influenced by the main impacts of drought on a stakeholder' s perceived environment (Slegers, 2008) and on activities related to water usage. For these reasons, on the one hand, a farmer quickly recognizes the onset of a drought due to soil water deficit (agricultural drought) because this drought process is the first, amongst the others, to be detected. At the other hand, an urban citizen might ignore the occurrence of a drought as long as water is no longer available for domestic usage (i.e., in the last stage of a drought occurring when the water supplies drought due to a deficit in terms of a surface storage, it is the last drought process to be detected (Pereira et al., 2009b).

Thus, different stakeholders can perceive in a different way the severity of a drought and, moreover, drought can be perceived at different times. These differences result ambiguous in the definition of the problem. Ambiguity implies that a critical situation can be approached and interpreted in different ways (Hommes et al., 2009), leading actors to act in different ways (Checkland, 2001), and, consequently, to judge actions taken by others according to different criteria.

The ambiguity in the definition of drought could have a strong negative impact on the effectiveness of drought mitigation strategies. In fact, if mitigation actions were selected without considering stakeholders' perceptions over droughts, then stakeholders would considers actions as not satisfying or, even worst, not acceptable at all. The latter case would occur when mitigation actions are expected to have a negative impact on the main elements of stakeholders' perceptions.

If the degree of acceptability would be low, then stakeholders would severely hamper the implementation of mitigation actions. This would lead to a reduction in the effectiveness of the mitigation actions, particularly in the case of actions to be implemented by the stakeholders (e.g. a reduction in crop irrigation by farmers). In worse cases, the low level of acceptability would make the implementation of mitigation actions impossible, resulting in the increase of the drought's impact and the cost of drought management. Therefore, sound methodologies to elicit, structure and analyze stakeholders' perceptions of a drought are required to support effective drought management.

In this work, a methodology based on the Problem Structuring Method (PSM), and, in particular, the Fuzzy Cognitive Map (FCM), is applied in order to identify similarities and differences among stakeholders' perceptions over drought phenomena. The methodology has been experimentally implemented by analyzing the perception of drought in the area nearby the Lake Trasimeno, located in the Region of Umbria, Central Italy.

The remaining part of this article is structured as following. Section 2 will summarize the literature's review based on the potential of PSMs in supporting the resolution of complex and unstructured problems. Section 3 will describe the approach adopted and the results that will come out the case study. Section 4 will summarize the lessons learned.

2. Problem Structuring Methods for environmental management: an introduction to literature

Environmental management problems are characterized by the existence of multiple actors, multiple perspectives, conflicting interests and key uncertainties (Mingers and Rosenhead, 2004). These characteristics result in the lack of consensus in terms of values and norms to be considered in the problem analysis and resolution and in an uncertain knowledge basis (Hommes et al., 2009). Therefore, the most demanding and troublesome task in environmental management often consists of defining the nature of the problem, rather than its solutions (Rosenhead and Mingers, 2001).

Problem Structuring Methods (PSMs) start from the basic assumption that problem formulation cannot be separated from problem solutions (Hommes et al, 2009). PSMs support the elicitation of different perceptions over critical situations and is to facilitate the debate where assumptions about the world are teased out, challenged, tested and discussed (Checkland, 2001). During the debate, participants become aware of each other's perspectives and key interests. The objective of this debate is the establishment of a common understanding, which supports information exchange and co-operation.

PSMs do not aim to create a linear process through which an unstructured problem becomes structured. PSMs aim to identify, confront and integrate different views with respect to a given problem situation (Hommes et al., 2009).

Mostly, PSMs have been used to facilitate group work within business organizations. New approaches are attempting to apply these methodologies in more complex shared decision processes such as participatory natural resource management (e.g., Hjorsto, 2004; Ozesmi and Ozesmi, 2003). In fact, PSMs recognize and integrate participants' subjective perspectives, the importance of mutual learning, interactive process design and adaptive decision making. Comparing these characteristics to those proper of environmental management approaches indicates that PSMs may provide a feasible platform for organizing public participation in environmental management (Hjorsto, 2004).

Amongst different PSMs, this work focuses on cognitive mapping methodologies. Two different interpretations seem to emerge in scientific literature about what a cognitive map (CM) represents. On the one hand, it can be seen as a model which is as close as possible to the cognitive representation made by decision makers. Thus, the model can be considered as a "mirror" of causes and effects being inside the mind of decision makers (Montibeller et al., 2001). At the other hand, the constructivist view of knowledge assumes that in order to understand reality, knowledge must change dynamically. According to the constructivist approach, a CM is a construct that can be useful to help the decision maker in the process of reasoning on the on the problem. Thus, the decision maker is involved in the iterative psychological construction of the real world, rather than the perception of an objective world (Eden and Ackermann, 2001).

Fuzzy Cognitive Maps (FCMs) can be included in the first group of CMs. In fact, FCMs can simulate the cause – effect relationships between the main variables in the model. The FCM has been largely used to analyze system dynamics in the business domain (e.g. Xirogiannis and Glycas, 2007; Glykas and Xirogiannis, 2004). Kang et al. (2004) developed a FCM tool to analyze the complex causal relations among conflict, communication, balance of power, shared values, trust, and cooperation in order to enhance the management of relationships among organizational members in airline services. Xirogiannis et al. (2007) developed a decision modelling tool based on FCM' intelligent computing characteristics able to support strategic – level shareholders decisions. The FCM has been increasingly applied in spatial realms while environmental planning is increasing. Ozesmi and Ozesmi (2004) used the FCM to analyze perceptions about an ecosystem held by people in different stakeholder groups. De Kok et al. (2000) adopted a the FCM qualitative approach to integrate social science concepts in a quantitative modelling for the development of water management scenarios. Xirogiannis et al. (2004) proposed an FCM – based approach to model experts' decision mechanisms in the field of urban area management.

Given the aims of this work, the potentialities of FCM to support environmental management are particularly interesting. To this aim, we should consider the two main phases of a decision process, i.e. the divergent and the convergent thinking phases (Montibeller et al., 2001). From the decision's analysis point of view, during the debate among decision makers at the stage of divergent thinking, the issue is disclosed, different views are encouraged and proposed, alternatives are generated, objectives are defined and the boundaries of the problem definition are discussed. Thus, CMs, as Eden and Ackermann (2001) suggest, can be useful during the phase of divergent thinking because the Cognitive Mapping supports creative definition of problems' characteristics and the identification of alternatives. It can be used to clarify what interests are involved in the discussion and to facilitate the debate.

During the convergent thinking phase, instead, criteria are defined to measure the performance of alternatives on objectives, data about performances are gathered, compensations between criteria are stated, alternatives are ranked, and the 'best' alternative is selected and implemented (Montibeller et al., 2001).

FCMs can be used to support the convergent thinking phase given their potentialities to simulate, even qualitatively, the impact of different management actions on the main elements of stakeholders' perceptions.

In this work, a methodology based on the sequential implementation of Cognitive Mapping and Fuzzy Cognitive Mapping is proposed in order to support divergent and convergent thinking for drought management as described in the next sections.

3. The use of FCM to support drought management

The methodology adopted in this work aims to elicit and analyze the different perceptions over drought as well as to investigate the existing links between the ambiguity found in the drought's perception and the emerging of a conflict among actors involved in drought management. To this aim, a multi-step cognitive mapping approach was implemented. The main steps are:

- elicitation of stakeholders' perception over drought;
- assessment of the extent of acceptability of drought management.

The description of results coming out of case study are used here to continue the narration on the methodology that is adopted.

3.1. Description of the case study

The methodology developed has been applied to elicit and analyze drought perceptions in the area of Lake Trasimeno, located in the Region of Umbria, Central Italy. (fig.1).

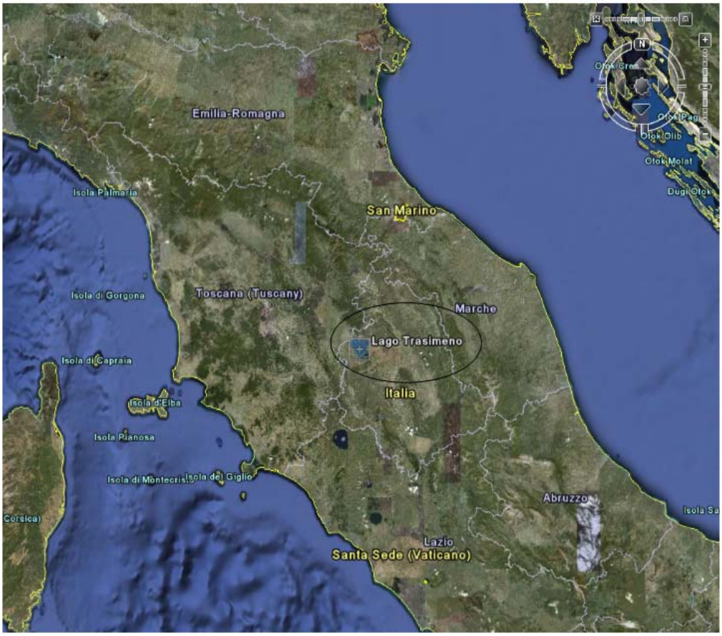

Fig. 1: Trasimeno Lake

The Trasimeno Lake covers a surface area of 128 km^2. The lake has find itself in an unusual hydro-morphological condition which is characterized by the absence of substantial inlet and outlet rivers. The tributary catchments of the lake covers a limited area. Moreover, the depth of the lake is around 4 m, with a maximum of 6 m. These conditions make the lake particularly vulnerable to drought phenomena. Therefore, the amount of water in the lake is strongly influenced by climatic conditions. Evaporation during sunny and windy days, in a normal summer period, can significantly reduce the level of the lake.

Drought increases its normal effects when adverse climatic conditions exist. Drought is quite recursive in this area as shown in fig. 2.

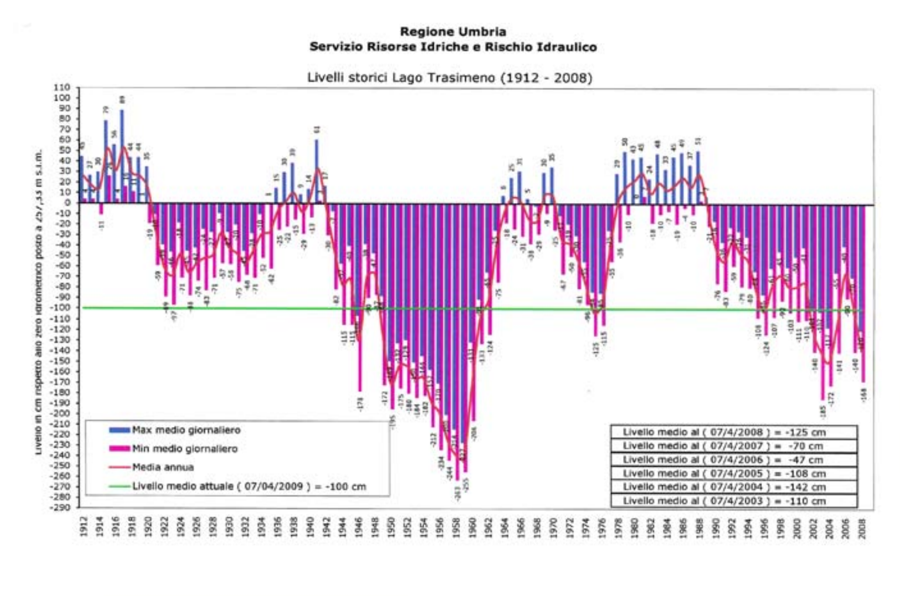

Fig. 2: level of the lake Trasimeno from 1912 to 2008.

The last strong drought phenomenon initiated in year 2002 and ended in 2006. Throughout this period, drought had a strong negative impact on local socio – economic conditions. In fact, most of economic activities were strongly influenced by the state of the lake. Farmers used to withdraw water necessary for irrigation purposes directly from the lake. Therefore, the reduction of the level significantly decreased the water available for irrigation. Moreover, the reduction of the level of the lake had a strong negative impact on the tourist industry of the area.
Drought management strategies adopted in the past were mainly based on limiting the withdrawal of water directly from the lake to be used for irrigation purposes. This led to conflicts between different users and in most of the cases, farmers did not accept such a strategy and continued to use the water of the lake. This

did not only reduced the effectiveness of the drought management strategy, but also increased the perception of the negative role played by farmers in the drought mitigation.
An analysis of conflicts emerged in the past, due to drought phenomena, allowed authors to identify the main stakeholders involved in this study. The list of participants is as follows:

- the Regional Council of Umbria;
- the Local Irrigation System Management (EIUT);
- local Municipalities;
- the Local Development Support Association (GAL);
- the local Farmers Association;
- the Regional Environmental Protection Authority (ARPA);
- the local Tourist Industry Association.

The first three actors play the role of decision makers, while the others can be considered as stakeholders, influenced by the decisions taken by drought managers. Decision makers have been involved in the first step of the process, in order to collect information about potential drought management strategies. The results of this step are described below:

1. **Emergency planning** consists of limiting water withdrawal directly from the lake for irrigation purposes. This is the most common action taken by the Regional Authority in the initial stages of drought phenomena.
2. **Reuse of wastewater**: this action aims at increasing water availability for irrigation purposes by improving the use of treated water. This is a management strategy rather than an emergency decision.
3. **Technical support to farmers**: this action aims at reducing the negative impact of drought on farmers' income by supporting them in the adoption of technical innovations.
4. **Changes in agricultural practice**: this management strategy aims at decreasing the quantity of water-demanding crops grown in the area, in order to reduce their impact on water resources.

5. This information was used as the basis for a conflict analysis for drought management, as described in the next sections.

3.2. Elicitation of drought perceptions

The first step of the approach abovementioned was aimed at eliciting and structuring the mental frames used by each stakeholder to perceive the drought. Any kind of later drought assessment, and thus even stakeholders' perceptual analysis, refer to the initial step of the phenomenon, its termination, or its severity. Since the aim of this work is to support drought management, the focus is on the perception of drought severity.

Therefore, the first step of the Cognitive Mapping process was aimed at eliciting and structuring the stakeholders' perceptions about the severity of a drought and to identify the elements they used to make this assessment. In order to analyze similarities and differences among perceptions, stakeholders were interviewed individually. A round of semi-structured interviews was carried out involving the stakeholders mentioned in the previous section. As stated by Slegers (2008), a stakeholder's perception of a drought is influenced by previous drought experiences. Therefore, interviews were aimed at eliciting stakeholders' understandings about both direct and indirect drought impact on the perceptual environment. In other words, it has been important to consider a sample of the whole environment which is the closest to stakeholders and where they operate and make decisions about how to respond and to behave (Slegers, 2008). Moreover, stakeholders were required to specify elements which can either increase or decrease the negative impact of a drought. Some of the CMs developed from these interviews are shown below:

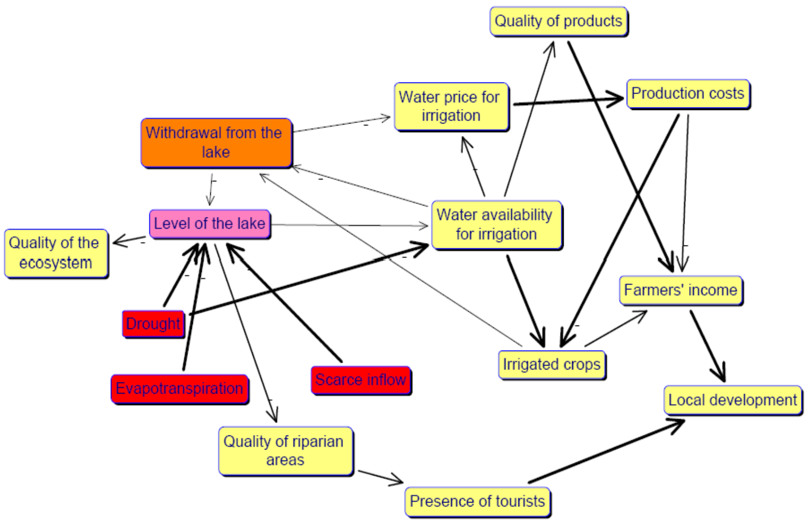

Fig. 3: Cognitive Map of Farmers' Association

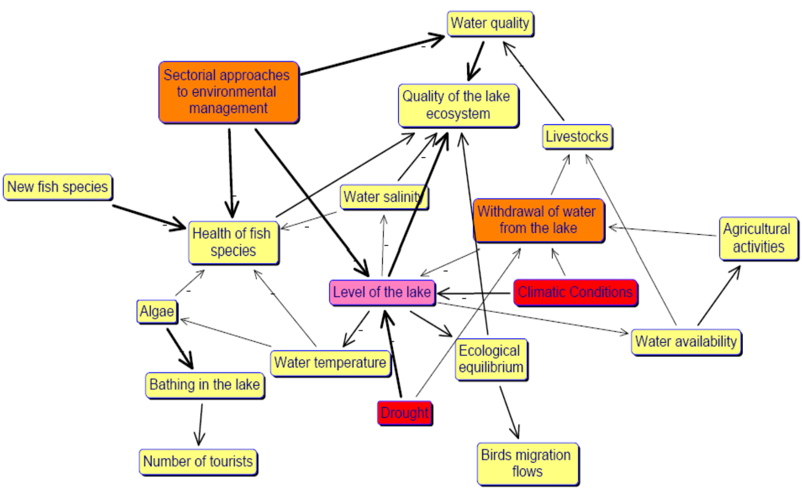

Fig. 4: Cognitive Map of the ARPA.

The developed CMs were used to identify the most important elements found in stakeholders' own perceptions of a drought, that is the "nub of the issue" (Eden, 2004). The basic assumption in assessing the degree of importance of those concepts contained in the CM is that more central is the concept in the CM, more important the concept is in the stakeholder' s perception (Giordano et al., 2007). Taking into account that the meaning of a concept in a CM depends on its explanations and consequences (Eden and Ackermann, 2001), the centrality of each concept can be assessed analyzing the complexity of the surrounding causal chains. Eden (2004) introduced the domain analysis, which calculates the total number of in-arrows and out-arrows from each concept. In this work, the weighted extended domain analysis has been applied. This method extended the domain analysis by adding successive layers of concepts, and giving a decreasing weight to each layer according to a decay weight function (Eden, 2004).

In the present work, authors have used such a method to identify the most important elements of stakeholders' CM. Tab. 3 shows the results of this analysis.

A second round of meetings with stakeholders was organized in order to validate both the CM and the assigned degrees of importance. Stakeholders were quite satisfied with those results obtained and, thus, no changes were required.

Drought perception depends on the impact of a drought on the perceptual environment. Thus, an analysis of stakeholders' CMs allowed the perceptual environment for each stakeholder to be structured. Next, the analysis of a drought perception was completed by assessing and comparing the drought impact on the main elements of each stakeholder' s environment.

To this aim, the CMs were used as a basis for the development of the Fuzzy Cognitive Map (FCM) (Axelrod, 1976; Ozesmi and Ozesmi, 2004; Xirogiannis et al., 2004). Weight and polarity were assigned to each link considering the results coming out of stakeholders' interviews. A positive link between two variables A and B has meant that, according to stakeholders' understanding, an increase in A results as an increase in B. A negative link between the same variables means that a change in A in one direction implies a change in B in the opposite direction. The strength of a link between two concepts indicates the intensity of a relationship between them, that is to say, how strong is the influence of one concept over the other according to the stakeholders' understanding. The strength can assume values in the interval [-1; 1]. The relationships between concepts can be represented in an adjacency matrix. In the FCM, this matrix allows the overall effects of a change on the elements found in the map that have to be inferred qualitatively.

The status of the initial system represents the value of elements located in the FCM at the beginning of the simulation process. Values in the square matrix represent the strength of the impact amongst elements of the FCM. The adjacency matrix allows the propagation of the change in one variable in the FCM to be simulated, thus considering the system as of a causal relationships.

The impact of a drought on the main elements of the FCM was analyzed by comparing the status of variables without drought (the drought value is 0 in the initial state vectors) and the state's system in case of drought (the drought value is changed to 1 to simulate the effects of this phenomenon). In the first state, the "climatic conditions" is the only active variable. In fact, as ARPA said, the drought effects at lake level are added to existing effects of current climatic conditions in the study area.

The comparison amongst the state of the system is done taking into account the stable states, that is the state achieved by the system at the end of the simulation processes.

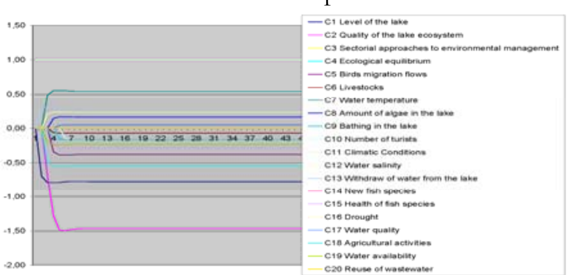

Fig. 5: State of the system before the beginning of a drought according to the Arpa's FCM

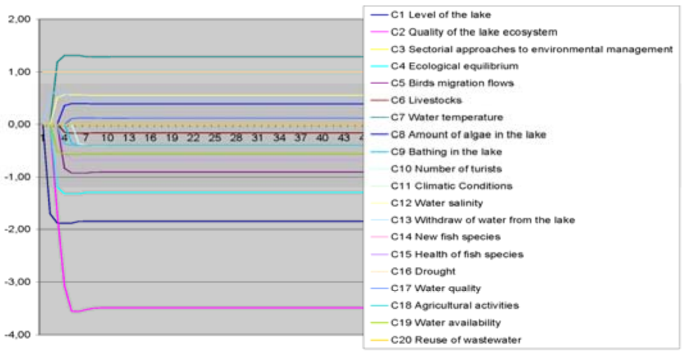

Fig. 6: State of the system after the beginning of a drought according to the Arpa's FCM

The extent of change in each element in the FCM, due to the beginning of the drought phenomenon, has been assessed using the fuzzy linguistic variable shown in fig. 7,

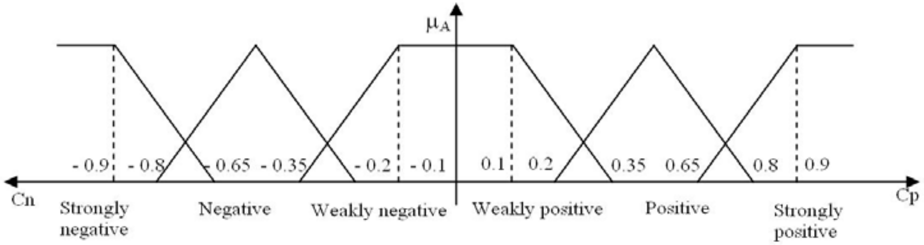

Fig.7: Fuzzy function to describe the degree of change due to drought initiation

where C_n represents negative changes due to drought. A negative change would occur either when a negative element (e.g. water salinity) increases or when a positive element (e.g. quality of the lake ecosystem) decreases. C_p represents positive impacts.

The degree of change was normalized to 1 as a ratio between the change of the i-th element due to the action a, and the maximum change due to the same action. The normalized value is the degree of impact (tab. 1).

Tab. 1: Impact of drought according to the Arpa's perception

Variable	**Degree of Importance**	**Degree of Impact**
Level of the lake	Very important	Negative (decrease)
Quality of the lake ecosystem	Very important	Strongly negative (decrease)
Ecological equilibrium	Very important	Negative (decrease)
Health of fish species	Important	Weakly negative (decrease)
Water quality	Important	Weakly positive (increase)

The aggregation of degrees of importance and degrees of impact has allowed elements with the highest impacts on stakeholders' perception of drought to be identified. The aggregation has been carried out considering that as more important is the element, and as more negative is the drought impact, the stronger is the influence of the element on the stakeholders' perception of the drought. Fuzzy *if...then* rules were defined. The degree of influence on drought perception has been assessed by applying the de-fuzzification method.
Fig. 8 shows the defuzzification process for "quality of the lake ecosystem".

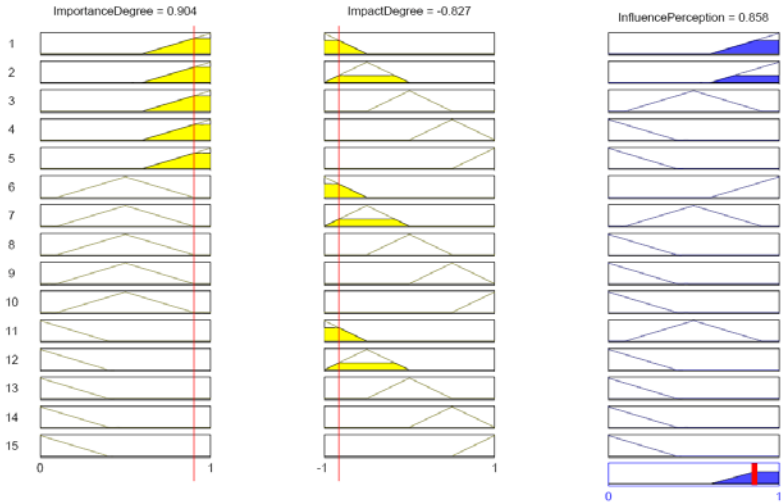

Fig. 8: Impact of "quality of ecosystem" on the stakeholders' perception of drought.

The results of this analysis for the ARPA's perception are shown in Tab. 2.

Tab.2: influence on drought perception of the elements in the ARPA's FCM

Variable	Influence on drought perception
Level of the lake	0,72
Quality of the lake ecosystem	0,86
Ecological equilibrium	0,76
Health of fish species	0,38
Water qualità	0,14

The same analysis was carried out for all the involved stakeholders. Tab. 3 summarizes the results obtained during this first step of the approach.

Stakeholder	Variable	Degree of importance	Degree of impact	Perception of Influence
ARPA	Level of the lake	Very important	Negative	0,72
	Quality of the lake ecosystem	Very important	Strongly negative	0,86
	Ecological equilibrium	Very important	Negative	0,76
	Health of fish species	Important	Weakly negative	0,38
	Water quality	Important	Weakly positive	0,14
Trasimeno National Park	Level of the lake	Very important	Strongly negative	0,92
	Farmers' income	Very important	Negative	0,72
	Local Economic Development	Important	Negative	0,43
	Touristic sector incombe	Important	Strongly negative	0,62
	Quality riparian area	Important	Negative	0,4
GAL	Level of the lake	Very important	Strongly negative	0,82
	Withdrawal of water from the lake	Very important	Strongly negative	0,8

	Touristic sector income	Very important	Negative	0,55
	Local Economic Development	Important	Negative	0,47
	Farmers' income	Important	Strongly negative	0,66
Touristic sector manager	Level of the lake	Very important	Strongly negative	0,91
	Touristic sector income	Very important	Strongly negative	0,9
	Withdrawal of water from the lake	Important	Negative (increase)	0,42
	Water quality	Important	Weakly negative	0,3
Farmers	Level of the lake	Very important	Strongly negative	0,9
	Water availability for irrigation	Very important	Strongly negative	0,9
	Farmers' income	Very important	Strongly negative	0,93
	Irrigation Water price	Important	Negative (increase)	0,48
	Production costs	Important	Negative (increase)	0,46

Tab. 3: results of FCM analysis for all the involved stakeholders

Concerning the indicator "level of the lake", there is a high consensus amongst participants about its importance to assess the impact of a drought phenomenon. In fact, as discussed with stakeholders during the FCM phase of development, the lake level is the first recognizable effect of the drought, and it has the most important impact on local activities.
It is interesting to note that there is no consensus for two elements directly linked to agricultural activities in the area, i.e. "Withdrawal of water from the lake" and "Water availability for irrigation". While some of the stakeholders seemed to consider irrigation as a factor which exacerbates the impact of a drought on the lake, other stakeholders considered the impact of agricultural activities as negligible, if compared with the effects of climatic conditions. A third group, instead, considered the agricultural irrigation as the main victim of drought rather than one of the most important causes.
The "influence on perception" values were used to assess the level of acceptance of potential actions aimed at drought mitigation, as described in the following section.

3.3. Assessment of the extent of acceptance of drought management.

This step of the work is aiming at supporting the identification of the most consensual drought management strategies. The basic assumption is the following: whether the level of consensus was high, then the suggested management action would be considered acceptable by most of the stakeholders. This would facilitate the implementation of the drought management's action.
The acceptance of actions has been assessed while considering their impact on the main elements found in stakeholders' drought perception. In other words, acceptance has been based upon the analysis of impacts per each management action on the stakeholder' s FCM.
To this aim, a third round of meetings with stakeholders was organized in order to analyse the expected impact of the set of potential drought management actions which were defined during the first round of interviews addressed to decision

makers:

- Re-use of wastewater;
- Technical support to farmers;
- Changes in agricultural practices;
- Emergency planning.

At the end this round of interviews, the drought management actions were integrated in the stakeholders' FCM. Fig. 8 shows the expected impact of "re-use of wastewater" on the Arpa's FCM.

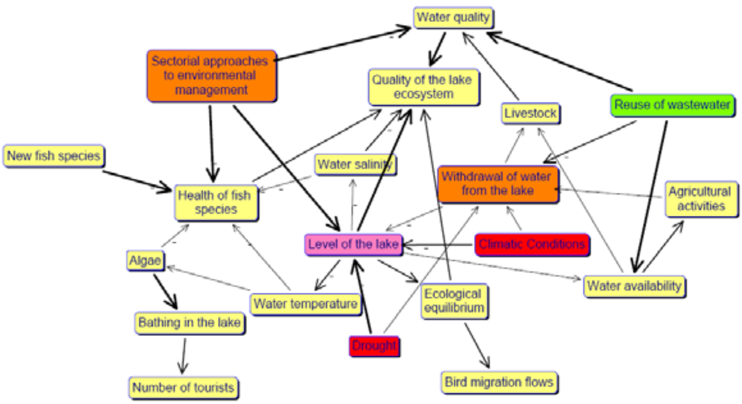

Fig. 9: According to Arpa's opinion, the re-use of wastewater would increase water available for irrigation, would reduce withdrawals from the lake and would have a positive impact on water quality. The adjacency matrix of this FCM let the simulation of the impact of the suggested action on the main elements. (fig. 10).

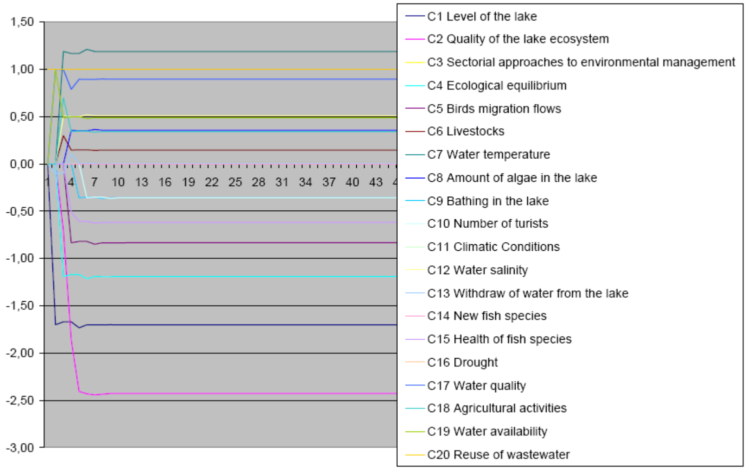

Fig. 10: Simulation of the impact of "re-use of wastewater" on elements of the Arpa's FCM. Although the negative impact of drought cannot be avoided, this action would allow the impact on important elements such as "Quality of the lake ecosystem" to be mitigated.

Tab. 4 summarizes the impact of the recommended action on the main elements of the Arpa's drought perception.The impact has been calculated by comparing the results of the FCM simulation in case of drought and the results of the FCM with the action. In other words, these two elements have been activated (value = 1) in the system state vector. The influence on the stakeholders' perception is reported in brackets. The overall degree of acceptance has been assessed combining the impact on each element and taking into account the influence on perceptions.

Tab.4: impact of "re-use of wastewater" on the main elements of the Arpa's drought perceptions.

Level of the lake (0,72)	**Quality of the lake ecosystem (0,86)**	**Ecological equilibrium (0,76)**	**Health of fish species (0,38)**	**Water quality (0,14)**	**Degree of Acceptance**
Weakly positive	Positive	Positive	Weakly positive	Weakly positive	Acceptable

The suggested action was considered acceptable because it was perceived to have a positive impact on the three elements with the strongest influence on the drought perception. The same action was integrated in the farmers' FCM (Fig.11).

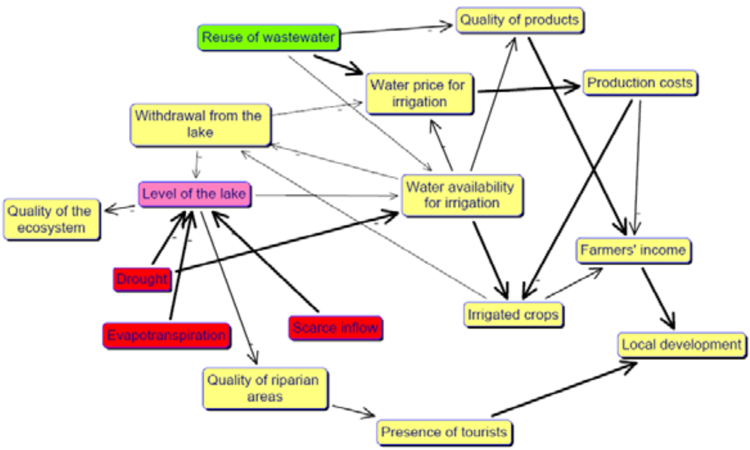

Fig. 11: Farmers' FCM with the introduction of the "reuse of wastewater"

In farmers' opinion, although the suggested action could increase the amount of water available for irrigation, it would greatly increase production costs. The overall impact of the "reuse of wastewater" on the farmers' FCM is shown in Fig. 12.

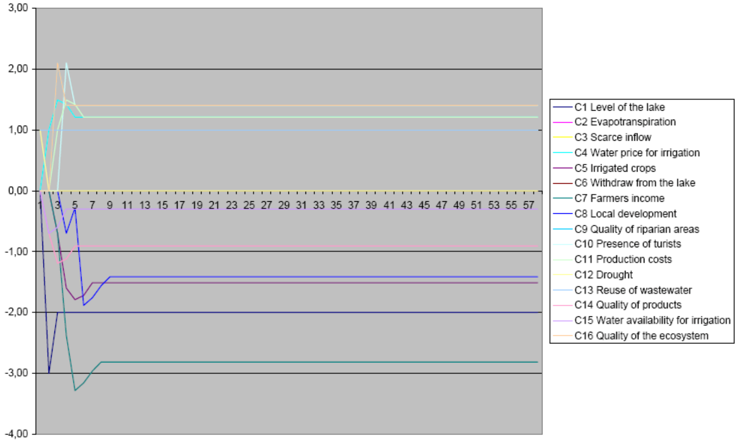

Fig. 12: Simulation of the impact of "reuse of wastewater" on the elements of the farmers' FCM.

Tab. 5: impact on the most important elements of the farmers' perception of drought.

Level of the lake (0,90)	**Water available for irrigation (0,90)**	**Farmers' income (0,93)**	**Irrigation water price (0,48)**	**Production costs (0,46)**	**Degree of Acceptance**
Weakly positive	Positive	Strongly negative	Strongly negative (increase)	Strongly negative (increase)	Not acceptable

The acceptability degree of "reuse of wastewater" is low for farmers because of the strongly negative impact on production costs and, consequently, on farmers' income.

The analysis of the degree of acceptability of this action was carried out for each stakeholder. A similarity measure was then assessed to compare their opinions. To this aim, the degree of similarity between the degrees of acceptability expressed by each stakeholder was assessed using the following formula (Munda, 1994):

$S_d(1, 2, x_i) = 1 - | \mu_1(x_i) - \mu_2(x_i) |$

where, $S_d(1, 2, x_i)$ defines the degree of similarity between stakeholders 1 and 2 on the action x_i (in our case, reuse of wastewater); $\mu_1(x_i)$ expresses the opinion of 1 regarding the acceptability of action x_i and $\mu_2(x_i)$ expresses the opinion of 2 regarding the acceptability of the same action. The results of the degree of similarity assessment were then used to develop the similarity matrix to specify the differences between the actors.

Tab.6: similarity matrix concerning "reuse of wastewater"

	ARPA	Tras. Park	GAL	Tourism	Farmers
ARPA	-	0,83	0,54	0,23	0,16
Tras. Park	0,83	-	0,67	0,33	0,12
GAL	0,54	0,67	-	0,78	0,35
Tourism	0,23	0,33	0,78	-	0,8
Farmers	0,16	0,12	0,35	0,8	-

This table shows that farmers' and tourist operators' opinions are very similar. In fact, none of the two categories accept the suggested action because of the potential negative impact on water quality and, consequently, on the presence of tourists in the area.

The data contained in the similarity matrix were used to assess the degree of consensus among the participants. To this aim, stakeholders have been clustered according to degree of similarity. The procedure to assess the degree of consensus is described in Giordano et al., 2007. This methodology allows the degree of consensus to be assessed using three factors, i.e. the number of clusters created considering the degree of similarity, the distribution of stakeholders in different clusters and semantic distances between the clusters.

Using this methodology, the degree of consensus has been calculated according to each of the suggested drought mitigation actions. Tab. 6 shows the results of this step. The degree of consensus can assume values between 0 and 1. The higher the value, the higher is the consensus among stakeholders.

Tab. 7: degree of consensus for the proposed drought management actions.

Drought management action	**Degree of Consensus**
Reuse of wastewater	0,52
Technical support to farmers	0,96
Changes in agricultural practices	0,88
Emergency planning	0,25

The analysis of the FCM let the definition of expected negative impact of suggested actions on the stakeholders' drought perceptions. Therefore, FCM can be used to identify the main reasons behind conflicts. According to results obtained, the action with the lowest consensus degree is the "emergency planning", that is the decision to reduce the seasonal amount of water available for irrigation in cases of drought. Although this action is currently considered as effective by some of the involved stakeholders – i.e. the tourism sector – this decision seems to be highly controversial due to its negative impact on the local development farmers' and GAL' s FCMs. This could result in a strong opposition between the two stakeholders.
The "reuse of wasterwater" for irrigation purposes has a medium level of conflict. This is due to the potential opposition amongst farmers (expected negative impact on farmers' income and on products' quality) and weak opposition by the tourist industry (expected weak negative impact on water quality).
This information could then be used by water managers to initiate a negotiation process with stakeholders in order to reduce the level of conflict. This step is not discussed in this work.

4. Discussion

The adopted approach has been discussed with stakeholders involved in order to identify benefits and weaknesses. The lessons learned from this analysis are described in this section. Firstly, the strong points of the system are presented,

highlighting the expected positive impact of the system. Secondly, some weaknesses are discussed and suggestions for improvements and future developments are made. The analysis about to what extent if the adopted approach suitable has led to the analysis of different drought perceptions that would support decision makers in dealing with conflict in drought management.
Concerning the first issue, participants stated that one of the positive results of the adopted methodology is its ability to make explicit differences in drought perception. A significant strength of Fuzzy Cognitive Mapping was that the modelling was similar to natural language, which reflected the ways stakeholders were used to talking and thinking about the issues considered. The adoption of a descriptive approach enhanced the comprehensibility of the FCM and, consequently, the sharing of information.

The results of the FCM analysis of the influences on perception were discussed with the stakeholders involved. Thus, they became more aware of the interests and concerns of other participants about drought impact and drought management. In participants' opinion, as expressed at the end of the process, this information allowed them to reflect about divergences and similarities about problem perceptions. The methodology allowed participants to identify, confront different perceptions and starting a debate over the integration of divergent views of the same problems. These are actually the main aim of a Problem Structuring process.

The capabilities of FCM to structure the cause – effects chains of stakeholders' understanding of the problem at hand have an important benefit, compared with other approaches adopted to analyze drought perceptions and to support drought management. As we learned during the feedbacks phase with stakeholders, the FCM analysis – i.e. the assessment of the "perception of influence" – has suggested important elements which have not immediately come up in participants minds but which were acknowledged as important during the discussion about the obtained results. Therefore, FCM supports participants in detaching themselves from their first ideas, as it could happen applying methods based upon the elicitation of

participants memories and experiences in past drought situations (Slegers, 2008; Dagel, 1997).
From decision makers' point of view, as they stated, the main benefits are related to the ability of finding reasons for potential conflict about drought management explicit. This information can be used by them to identify the most consensual management strategies. Moreover, when the implementation of a strategy cannot be avoided, the information obtained can be used to identify and implement "side-measures" together with the identification of strategies able to reduce the level of conflict. For example, the information about farmers' concerns over the negative impact of treated wastewater on the quality of agricultural products suggested decision makers to enhance technical support for farmers as an effective action.
For what concerns the consensus degree of drought mitigation options, the proposed methodology is based on the assumption that the consensus is an iterative process which can be monitored defining a consensus measure. Several methods are described in the scientific literature (e.g. Fedrizzi et al., 1999; Herrera-Viedma et al., 2002; Herrera et al., 1996; Szmidt and Kacprzyk, 2003). These methods are based on the comparison of explicit participants' opinions. The proposed methodology, based on the implementation of FCM, aims at supporting participants to formulate their opinions about drought mitigation actions by simulating their negative or positive impacts on the main participants' concerns and interests.
One of the drawbacks highlighted during the analysis of the results concerns the qualitative nature of results out of FCM simulation. As described previously in the text, FCMs are used to assess also the potential impact of the different actions on the elements of the map. Nevertheless, during the presentation of the results to decision makers, it has been important to highlight the fact that the results should be interpreted as a change in the state of the element rather than as an exact value. This represented a weakness of the system according to decision makers, who are familiar with quantitative assessment. Thus, for them, qualitative results could be considered as not completely reliable. An important improvement in the system could be

made by coupling the FCM with some quantitative models in order to increase the reliability of results for the decision makers. To this aim, research activities are currently in progress to integrate a quantitative analysis of drought and the effects of drought management with qualitative perceptions of the phenomenon.

5. Conclusions and future developments

The complexity and unstructured nature of drought management issues originates from uncertain knowledge about the phenomenon and from the existence of divergent perceptions among local actors. Scientific investigations are trying to enhance the knowledge basis to address these issues. Particularly, many efforts are currently in progress to define an effective monitoring and an early warning system able to make short term drought predictions more reliable.

Nevertheless, dealing with complex and unstructured problems is not only a matter of knowledge production. It is also a problem of ambiguity. The ambiguity in drought perceptions and definition strongly influences the effectiveness of drought management actions. Therefore, methods and tools to support the elicitation and comparison of different perceptions are required.

A Problem Structuring approach based on the use of Fuzzy Cognitive Maps is described in this work. The proposed method was able to identify the main elements of stakeholders' drought perception and to make this information accessible and easily understandable for both decision makers and stakeholders. Thus, it increased the awareness in each actor's interests and concerns over drought management. The sharing of this information has allowed decision makers to become aware of potential conflict due to the implementation of certain drought management actions. Moreover, the availability of information on the reasons for conflict let them to define a negotiation strategy. Currently, the negotiation process has not yet started.

In future research activities, the FCM methodology will be integrated in a Group Decision Support System able to facilitate the collaborative decision making concerning drought management. The capabilities of FCM analysis to identify the main concerns and interests for each participants will lead to the discussion over the selection of those having an interest in the topic. This means that participants will not run the risk of being involved in a discussion far from their interests. This could have a positive impacts on actors' willingness to take part in collaborative decision making.

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