Fuzzy Cognitive Map to Support Conflict Analysis in Drought Management

R. Giordano and M. Vurro

Abstract. Empirical investigations in scientific literature have highlighted the differences between the stakeholders' perceptions of a given drought phenomenon's severity and the results of scientific – technical evaluation. This means that there can be several perceptions of the phenomenon, and the scientific models used to assess the drought's severity do not consider these 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. This, in turn, could have a strong negative impact on the effectiveness of drought mitigation strategies. In fact, if the mitigation actions are selected without considering the stakeholders' perceptions of the drought, then the actions themselves could be considered as unsatisfactory by the stakeholders or, even worst, not acceptable at all. If the degree of acceptability is low, then the implementation of the mitigation actions could be hampered by strong opposition from the stakeholders. Therefore, an in depth analysis of the potential conflicts and the definition of effective negotiation strategies could be really useful. In this perspective, we propose a methodology based on a Fuzzy Cognitive Map (FCM) to support the elicitation and the analysis of stakeholders' perceptions of drought, and the analysis of potential conflicts. The method was applied to a drought management process in the Trasimeno Lake area (Umbria Region) in order to analyze potential conflict.

Keywords: Drought management, drought perception, Fuzzy Cognitive Map, Conflicts analysis.

1 Introduction

Drought is considered as one of the water scarcity phenomena. It is defined as a natural and temporary imbalance of water availability, consisting of a persistent

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lower than average precipitation (Pereira et al., 2009) which is of uncertain frequency, 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 drought requires the development of a risk management plan to support the timely implementation of mitigation measures.

Nevertheless, policy making to plan for drought is hindered by the lack of clearly agreed definitions of drought, which makes it difficult to implement preparedness measures, 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 in the analysis of the phenomena. The prevailing technical dimension of drought management imposes indicators for drought analysis which are mainly based on the amount of precipitation and water availability.

Empirical investigations in scientific literature have highlighted the differences between the stakeholders' perceptions of drought phenomena and the results of scientific – technical evaluation (Noemdoe et al., 2006). Thus, characterizing drought simply as a departure from normal precipitation and as a reduction of the amount of 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 "objectivist" stance that sees problems as independent of individuals' views and beliefs. Soft system thinking, on the other hand, requires a "subjectivist" stance that recognises the importance of participants' perceptions (Rosenhead and Mingers, 2001). Facing a drought 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 an actor's perception of a problematic situation by influencing both his/her observation of the world and his/her conclusions based on that observation (Pahl-Wostl 2007). They can be considered as the windows through which people view the world (Timmerman and Langaas 2004). Mental models determine what information the actors perceive in the real world and what knowledge the 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 the related water use activities. 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 among the first to be detected. On the other hand, an urban citizen may not perceive the drought until water is not available at home, i.e., in the last stage of a drought because water supply drought, which is due to a surface storage deficit, is the last drought process to be detected (Pereira et al., 2009b).

Thus, different stakeholders can perceive a drought's severity differently, and, moreover, drought can be perceived at different times. These differences result in ambiguity in the definition of the problem. Ambiguity implies that a problematic 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 the actions taken by the others according to different criteria.

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

If the degree of acceptability is low, then the implementation of the mitigation actions could be hampered by strong opposition from stakeholders. 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 the worst cases, the low level of acceptability makes the implementation of mitigation actions impossible, resulting in an increase in the drought's impact and the cost of drought management. Therefore, sound methodologies to elicit, structure and analyze the stakeholders' perceptions of a drought are required to support effective drought management.

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

The remaining part of this article is structured as following. Section 2 summarizes a review of the literature on the potential of PSMs in supporting the resolution of complex and unstructured problems. Section 3 describes the approach adopted and the results obtained in the case study. Section 4 summarizes the lessons learned.

2 Problem Structuring Methods for Environmental Management

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 lack of consensus about values and norms to be considered in problem analysis and resolution, and in an uncertain knowledge base (Hommes et al., 2009). Therefore, the most demanding and troublesome task in environmental management often consists in 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 solution (Hommes et al, 2009). PSMs support the elicitation of the different perceptions of the problematic situation and facilitate the debate in which 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 the 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, iterative process design and adaptive decision making. Comparing these characteristics to those of environmental management approaches indicates that PSMs may provide a feasible platform for organizing public participation in environmental management (Hjorsto, 2004).

Among the 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 the causes and effects that are inside the mind of decision makers (Montibeller et al., 2001). On 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 reflect 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 have 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, balanced power, shared values, trust, and cooperation in order to enhance the management of relationships among organizational memers in airline services. Xirogiannis et al. (2007) developed a decision modelling tool based on FCM' intellingent computing characteristics able to support stratetic – level shareholders decisions. The FCM are increasingly applied in spatial and environmental planning are increasing. Ozesmi and Ozesmi (2004) used FCM to analyze the perceptions about an ecosystem held by people in different stakeholder groups. De Kok et al. (2000) adopted a FCM approach qualitative to integrate social science concepts in a quantitative modeling for water management scenarios development. 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 decision analysis point of view, during the divergent thinking stage, 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 during the debate among the decision makers. Thus, CMs as suggested by Eden and Ackermann (2001) can be useful during divergent thinking phase because Cognitive Mapping supports creative definition of the problem's 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, criteria are defined to measure the performances of alternatives on the objectives, data about these 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 the different management actions on the main elements of the 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 FCM to Support Drought Management

The methodology adopted in this work aims to elicit and analyze the different perceptions of drought, and to investigate the links between the ambiguity in drought perception and the emerging of conflict among actors in drought management. To this aim, a multi-step cognitive mapping approach was implemented.

The main steps are:

- elicitation of the stakeholders' drought perceptions;
- assessment of drought management acceptability.

The description of the results in the case study are used here to lead the narration of the adopted methodology.

3.1 Description of the Case Study

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

The Trasimeno Lake covers a surface area of 128 km^2. The lake has unusual hydromorphological conditions, characterized by the absence of substantial inlet and outlet rivers. The tributary catchment 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

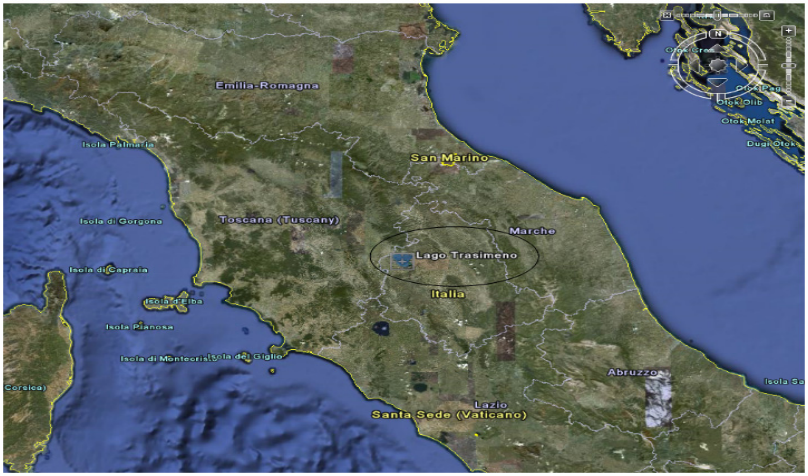

Fig. 1 Trasimeno Lake

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 the effects of already adverse climatic conditions. Drought is quite recursive in this area as shown in fig. 2.

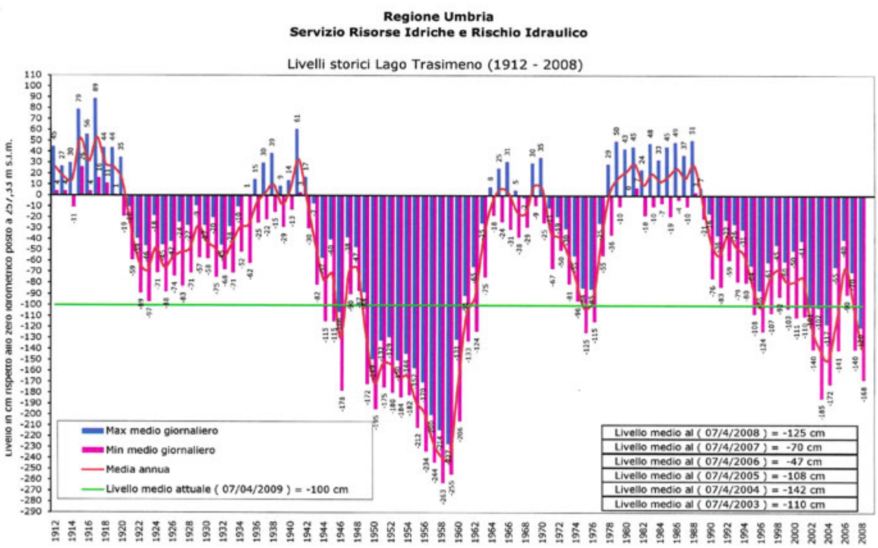

Fig. 2 Level of the lake Trasimeno from 1912 to 2008

The last strong drought phenomenon initiated in 2002 and finished in 2006. During this period, the drought had a strong negative impact on the local socio –

economic conditions. In fact, most of the economic activities were strongly influenced by the state of the lake. Farmers used to withdraw water for irrigation directly from the lake. Therefore, the reduction of the level significantly decreased the water available for irrigation. Moreover, the reduction in the level of the lake had a strong negative impact on the touristic industry in the area.

The drought management strategies adopted in the past were mainly based on the reduction in permits to withdraw water for irrigation directly from the lake. This led to conflicts between the different users. In many cases, farmers did not accept this strategy and continued to use the water from the lake for irrigation. This not only reduced the effectiveness of the drought management strategy, but also increased the perception of the negative role played by farmers in drought mitigation.

An analysis of the conflicts which have emerged in the past due to drought phenomena allowed the authors to identify the main stakeholders to be involved in this study. The list of participants is as follows:

- the Umbria Regional Authority;
- the Local Irrigation System Management (EIUT);
- the 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 are the decision makers, while the others can be considered as stakeholders who are influenced by decisions about drought management. The decision makers were 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:

- Emergency planning: this action concerns the limitation of permits to withdraw water for irrigation directly from the lake. This is the most common action taken by the Regional Authority in the first stages of drought phenomena.
- Reuse of wastewater: this action aims to increase the availability of water for irrigation by improving the use of treated water. This is a management strategy rather than an emergency decision.
- Technical support to farmers: this action aims to reduce the negative impact of drought on farmers' income by supporting them in the adoption of technical innovations.
- Changes in agricultural practice: this management strategy aims to decrease the quantity of water-demanding crops grown in the area, in order to reduce their impact on water resources.

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

3.2 Elicitation of Drought Perceptions

The first step of the adopted approach was aimed at eliciting and structuring the mental frames used by each stakeholder to perceive the drought. Any kind of drought assessment, and thus even the perceptual analysis made by the stakeholders, could concern the beginning 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, the 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), the stakeholder's perception of a drought is influenced by previous drought experiences. Therefore, the interviews were aimed at eliciting stakeholders' understandings about both direct and indirect drought impact on the perceptual environment. That is, the part of the whole environment which is closest to the stakeholder and in which she/he operates and makes decisions about how to respond and to behave (Slegers, 2008). Moreover, the 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:

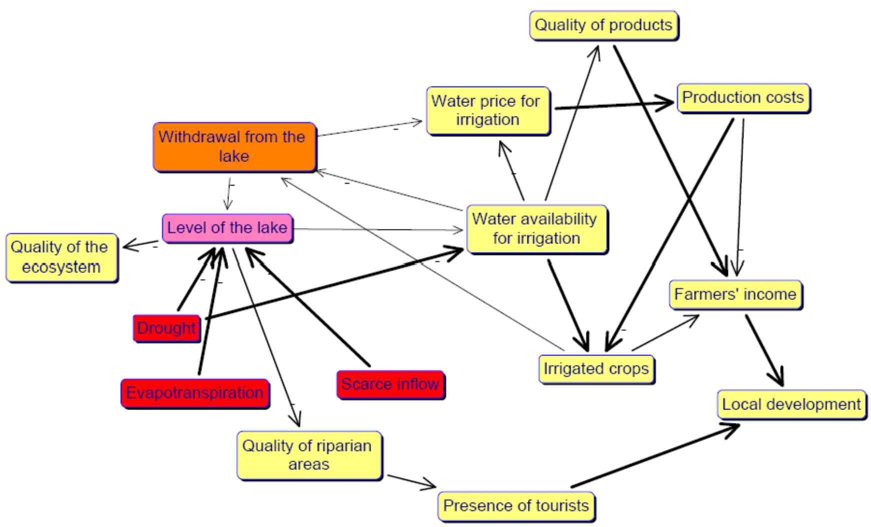

Fig. 3 Cognitive Map of Farmers' Association

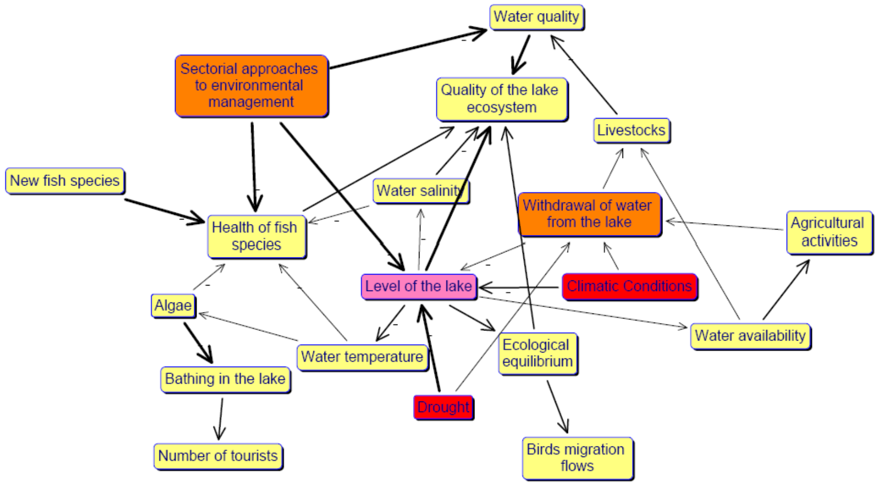

Fig. 4 Cognitive Map of the ARPA

The CMs developed were used to identify the most important elements in the stakeholders' perceptions of a drought, that is the "nub of the issue" (Eden, 2004). The basic assumption in assessing the degree of importance of the concepts contained in the CM is that the more central the concept in the CM, the 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 was 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, the authors used this method to identify the most important elements of the stakeholders' CM. Table 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. The stakeholders were quite satisfied with the 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 the stakeholders' CMs allowed the perceptual environment for each stakeholder to be structured. Next, the analysis of 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 basis for the development of the Fuzzy Cognitive Map (FCM) (Axelrod, 1976; Ozesmi and Ozesmi, 2004; Xirogiannis et al., 2004). A weight and a polarity were assigned to each link considering the results of the interviews with the stakeholders. A positive link between two variables A and B means that, according to the stakeholder's understanding, an increase in A results in 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 the relationship between them, that is to say, how strong is the influence of one concept over the other according to the stakeholder's 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 in the map to be inferred qualitatively.

The initial system state represents the value of the elements in the FCM at the beginning of the simulation process. The values in the square matrix represent the strength of the impact between the elements of the FCM. The adjacency matrix allows the propagation of the change in one variable in the FCM to be simulated, considering the system of causal relationships.

The impact of a drought on the main elements of the FCM was analyzed by comparing the state of the variables without drought (the drought value is 0 in the initial state vectors) and the system state 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 on the level of the lake are added to the already existing effects of the current climatic conditions in the study area.

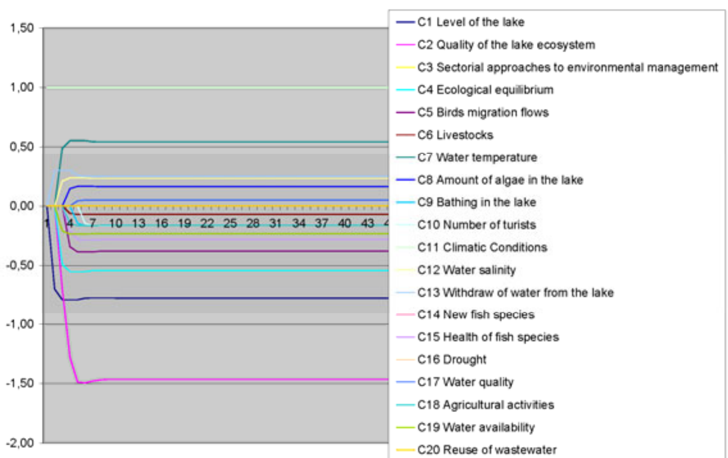

Fig. 5 State of system before beginning of drought according to the Arpa's FCM

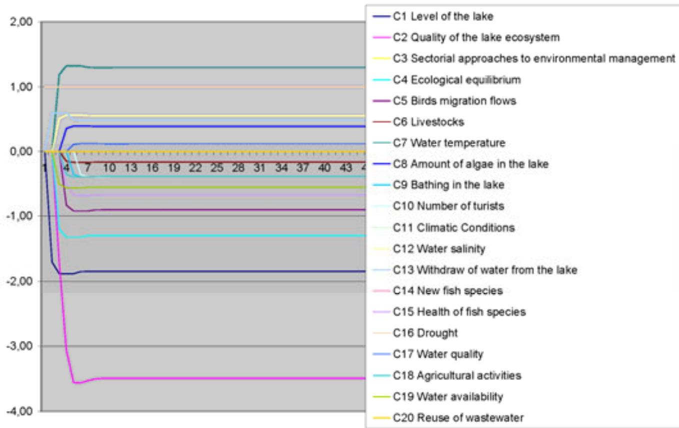

Fig. 6 State of system after beginning of drought according to the Arpa's FCM

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

The degree of change for each element in the FCM due to the beginning of the drought phenomenon was assessed using the fuzzy linguistic variable shown in fig. 7,

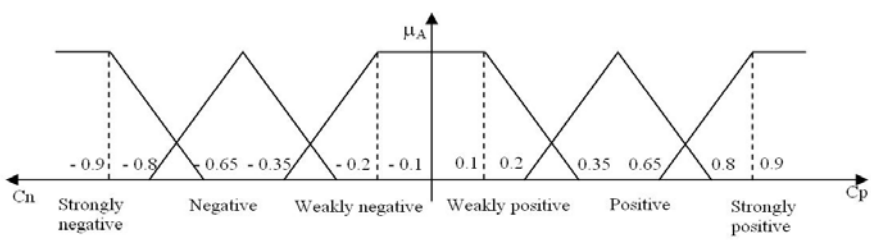

Fig. 7 Fuzzy function to describe the degree of change due to drought initiation

where C_n represents negative changes due to drought. A negative change can 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 (table 1).

Table 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 the degree of importance and the degree of impact allowed the elements with the highest impacts on stakeholder's perception of drought to be identified. The aggregation was carried out considering that the more important the element, and the more negative the drought impact, the stronger is the influence of the element on the stakeholder's perception of drought. Fuzzy *if...then* rules were defined. The degree of influence on drought perception was assessed applying the centroid defuzzification method.

Fig. 8 shows the defuzzification process for "quality of the lake ecosystem".

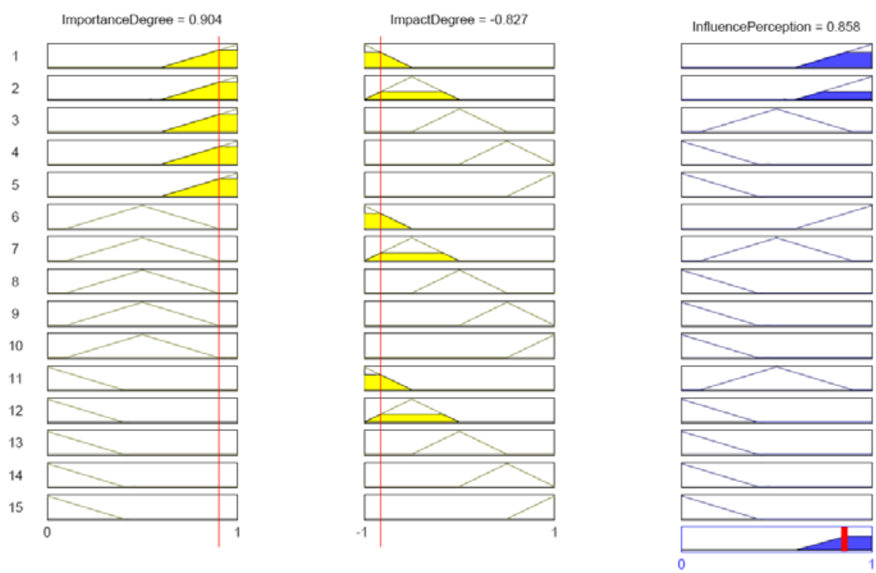

Fig. 8 Impact of "quality of ecosystem" on the stakeholder's perception of drought

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

Table 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 quality	0,14

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

Table 3 Results of FCM analysis for all the involved stakeholders

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
Trasimen 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 income	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

Table 3 (*continued*)

Stakeholder	Variable	Degree of importance	Degree of Impact	Perception of Influence
	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

Concerning the element "level of the lake", there is a high consensus among the participants about its importance to assess the impact of a drought phenomenon. In fact, as discussed with stakeholders during the FCM development phase, the level of the lake 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 with 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 degree of acceptability of potential drought mitigation actions, as described in the following section.

3.3 Assessment of Drought Management Acceptability

This step of the work was aimed at supporting the identification of the most consensual drought management strategies. The basic assumption was that if the consensus degree was high, then the proposed management action was considered acceptable by most of the stakeholders. This would facilitate the implementation of the drought management action.

The acceptability of actions was assessed considering their impact on the main elements of stakeholders' perception of drought. That is, the acceptability was based on the analysis of the impacts of each management action on the stakeholder's FCM.

To this aim, a third round of meetings with stakeholders was organized to define the expected impact of the set of potential drought management actions defined during the first round of interviews with the decision makers:

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

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

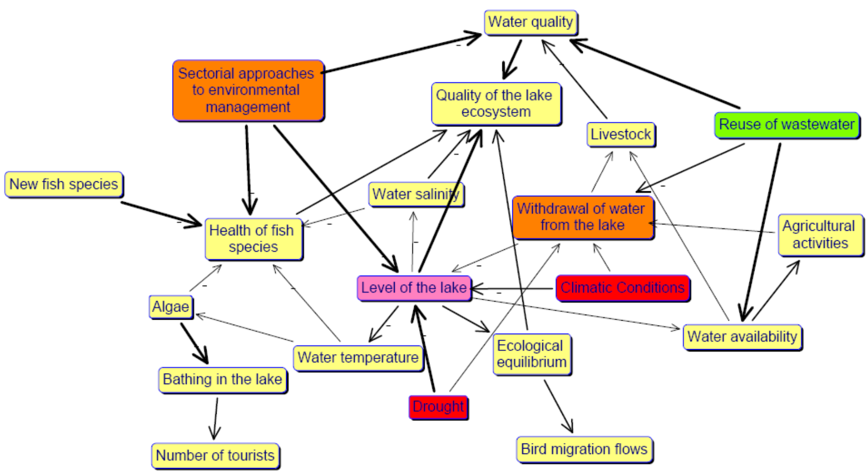

Fig. 9 In the Arpa's opinion, the reuse of wastewater will increase the water availability for irrigation, reduce withdrawals from the lake and will have a positive impact on the water quality

The adjacency matrix of this FCM allowed the impact of the proposed action on the main elements to be simulated (fig. 10).

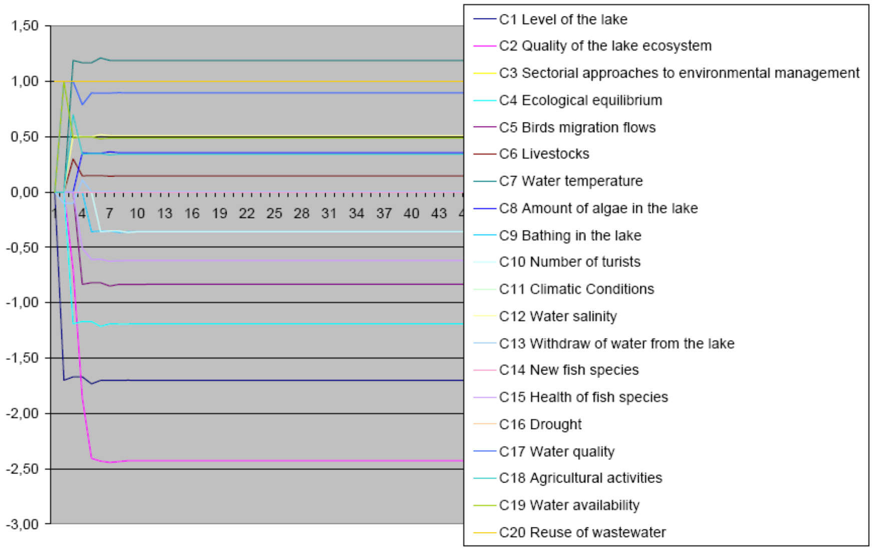

Fig. 10 Simulation of the impact of "reuse of wastewater" on the elements of the Arpa's FCM. Although the negative impact of drought cannot be avoided, this action would allow the impact on important elements such as "Quality of lake ecosystem" to be mitigated

Table 4 summarizes the impact of the proposed action on the main elements of the Arpa's perception of drought. The impact was calculated by comparing the results of the FCM simulation in case of drought and the results of the FCM with the action. That is, these two elements were activated (value = 1) in the system state vector. The influence on the stakeholder's perception is reported in brackets. The overall degree of acceptability was assessed combining the impact on each element and taking into account the influence on perception.

Table 4 Impact of "reuse of wastewater" on the main elements of the Arpa's 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 quality (0,14)**	**Degree of Acceptability**
Weakly positive	Positive	Positive	Weakly positive	Weakly positive	Acceptable

The proposed 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).

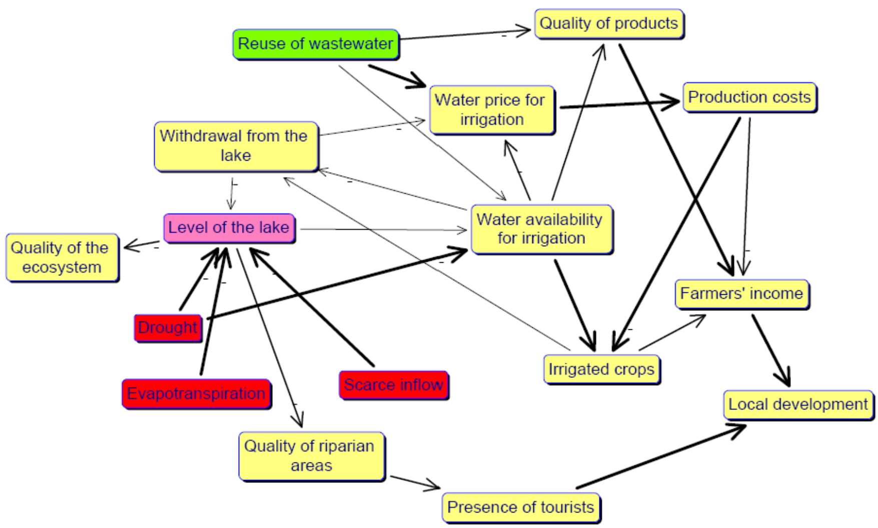

Fig. 11 Farmers' FCM with the introduction of the "reuse of wastewater"

In the farmers' opinion, although the proposed action could increase the water availability for irrigation, it would result in a great increase in production costs. The overall impact of "reuse of wastewater" on the farmers' FCM is shown in Fig. 12.

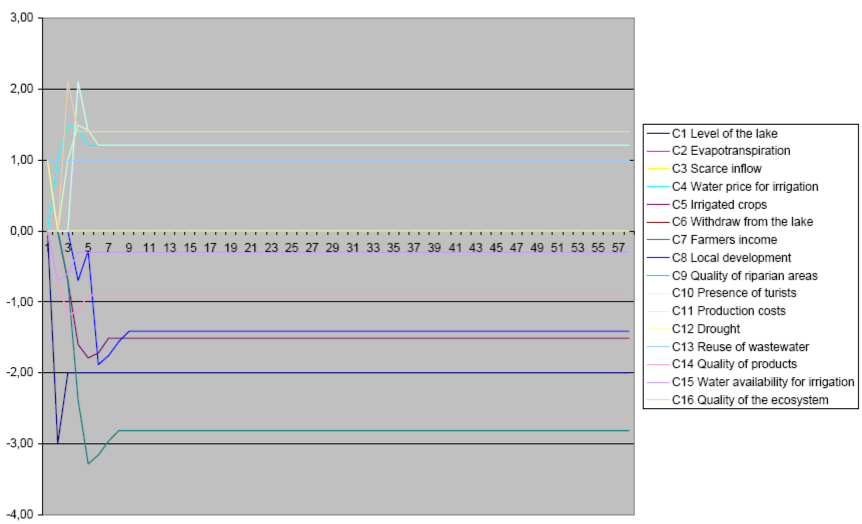

Fig. 12 Simulation of the impact of "reuse of wastewater" on the elements of the farmers' FCM

Table 5 Impact on the most important elements of the farmers' perception of drought

Level of the lake (0,90)	**Water availability for irrigation (0,90)**	**Farmers' income (0,93)**	**Irrigation water price (0,48)**	**Production costs (0,46)**	**Degree of Acceptability**
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.

Table 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 high similarity between the farmers' and tourist operators' opinions. In fact, neither did the latter accept the proposed 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, the stakeholders were 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 the stakeholders in the different clusters and the semantic distances between the clusters.

Using this methodology, the degree of consensus was calculated for each of the proposed drought mitigation actions. Table 7 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.

Table 7 Degree of consensus for the proposed drought management actions

The analysis of the FCM allowed the expected negative impact of the proposed actions on the stakeholders' perceptions of drought to be defined. Therefore, FCM can be used to identify the main reasons behind conflicts.

According to the obtained results, 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 highly controversial due to its negative impact on the local development in the FCMs of the farmers’ and the GAL. This could result in a strong opposition from these two stakeholders.

The “reuse of wasterwater” for irrigation has a medium level of conflict. This is because of the potential opposition of farmers (expected negative impact on farmers’ income and on the quality of products) and weak opposition from the tourism sector (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 was discussed with the involved stakeholders 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 of the suitability of the adopted approach concerned its ability to analyze different drought perceptions and to 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 the other participants about drought impact and drought management. In the opinion of the participants, as expressed at the end of the process, this information allowed them to reflect about divergences and similarities of problem perceptions. The methodology allowed participants to identify, confront the different perceptions and to start the debate about the integration of the 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 benefits, compared with other approaches adopted to analyze drought perceptions and to support drought management. As we learned during the feedbacks phase with stakeholders, FCM analysis – i.e. the assessment of the "perception of influence" – suggested important elements which were not immediately in participants minds but which were acknowledged as important during the discussion about the obtained results. Therefore, FCM supports participants to avoid anchoring to the first ideas, as it could happen applying methods based on the elicitation of participants memories and experiences in past drought situations (Slegers, 2008; Dagel, 1997).

From the decision makers' point of view, as they stated, the main benefits are related to the ability to make the 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 "side-measures" to be implemented together with the identify strategy in order to reduce the level of conflict. For example, the information about the farmers' concerns over the negative impact of treated wastewater on the quality of agricultural products suggested to decision makers that enhancing technical support for farmers could be an effective action.

For what concerns the consensus degree of the 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 measures. 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 the explicit opinions of the participants. The proposed methodology, based on the implementation of FCM, aims to support participante to formulate their opinions about drought mitigation actions by simulating their impacts, either positive or negative, on the main participants' concerns and interests.

One of the drawbacks highlighted during the analysis of the results concerns the qualitative nature of the results 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 the decision makers it was 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 the 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 the 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 the local actors. Scientific investigations are trying to enhance the knowledge base to address these issues. Particularly, many efforts are currently in progress to define an effective monitoring and early warning system able to make short term drought predictions more reliable.

Nevertheless, dealing with these 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 the 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 the stakeholders' perception of drought and to make this information accessible and easily understandable for both decision makers and stakeholders. Thus, it increased the awareness in each actor of the other members' interests and concerns over drought management. The sharing of this information allowed the 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 allowed them to define a negotiation strategy. Currently, the negotiation process has not yet started.

In future resarch 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 allow to select those having an interest in the topic to be discussed. 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 the actors' willingness to take part in collaborative decision making.

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