Public Participation in the Water Framework Directive: an application of Fuzzy Cognitive Mapping in the Pinios River Basin, Greece

Ioanna Mouratiadou[1], Dominic Moran[2]

[1] *University of Edinburgh and Scottish Agricultural College, UK;*
[2] *Scottish Agricultural College, UK*

Abstract

The EU Water Framework Directive requires the involvement and participation of stakeholders and the public for enhancing the sustainability of water resource management. The Directive is non prescriptive as to how public participation in water management should be operationalised in practice, and this creates a wider role for research that can inform this process. This study explores the issue of public participation, in the context of the Pinios River Basin in Greece, using Fuzzy Cognitive Mapping, a form of qualitative modeling directly related to stakeholders' perceptions. Fuzzy Cognitive Mapping has been used to elicit stakeholder and public perceptions on the current state and pressures on water resources, the acceptability of achieving full cost recovery for water services, and to explore the potential effects of different water management policy options on water resources of the area. The study offers a perspective on the potential contribution of Fuzzy Cognitive Mapping in involving stakeholders and the public in water resource management. The main advantages of the method include the ease in capturing both local and expert knowledge, the ability to elicit and compare the perceptions of different stakeholder groups, and the ability to unify the respondents' viewpoints and understanding of a system without demanding their direct interaction.

Key words: Water Framework Directive, public participation, Fuzzy Cognitive Mapping.

1. Introduction

The Water Framework Directive (WFD) is a key piece of legislation that aims to establish and enforce a framework for water management strategies that will deliver sustainable, efficient, and equitable management of European water resources. For the achievement of this broad goal the WFD introduces various policy innovations. One of these is the requirement for involvement and participation of stakeholders and the public into water resource management. This emphasis on public participation (PP) in the WFD should come as no surprise. Both the ambitious nature of the Directive and the shear number of stakeholders suggest that water quality objectives are unlikely to be met without considerable buy in from a diverse range of actors. But the process of actively involving the affected stakeholders is not straightforward (Van Ast & Boot, 2003), and the architects of the Directive are less informative on the ways in which PP should be implemented. In addition to that, in most Member States there is no tradition of participatory river basin planning. The complex nature of the process, the lack of experience in participatory river basin management (RBM), and the absence of clear guidance on how PP should be implemented, make PP a rather challenging task both for the institution that will initiate and manage the process, as well as for the stakeholders that will have to engage in it.

This emerging challenge creates a wider role for research that can inform this process. Indeed one pan EU project on participation processes in RBM is currently gathering best practice from several country case studies[1]. One of its reports suggests that PP can be significantly supported by the use of Information and Communication tools. Fuzzy Cognitive Mapping (FCM) is one of these tools and is thought to have some potential for informing participatory RBM (Maurel, 2003). This paper contributes to the evolving methodological toolbox by applying FCM to elicit stakeholder perceptions on the current state and pressures on water resources in the Pinios River Basin in the region of Thessaly in central Greece. The Pinios River Basin is the focus of the Greek pilot study for WFD implementation. As part of this WFD pilot implementation, there is a need to understand different stakeholder perceptions of water resources and to explore the potential effects of different water management policy options on water resources of the area.

FCM has been used to model their perceptions regarding the current state water resources, the drivers of water use and environmental change, their suggestions for diminishing the existing problems and their perceptions on the potential role of full water pricing. The latter is another requirement of the Directive which calls for the adoption of a pricing policy that will be approaching full cost recovery (FCR) for water services (Barraqué, 2003). This approach is influenced by both the 'Polluter Pays Principle' (PPP), and the fact that water uses typically have an opportunity cost that by default makes water an economic good. This opportunity cost becomes more important in water stressed environments and where the financial constraints on supply side measures are evident. The paper is structured as follows. In the next section we consider the role of PP in WFD implementation. In the second section the main methodological properties of FCM are briefly reviewed. The third section provides background information on the case study area of Thessaly. This is followed by a description of the FCM application and a discussion of the results. The final section outlines the conclusions of the study.

[1] See http://www.harmonicop.info/

2. Public participation

PP has been recognized as one of the key factors for successful integration and sustainable water use in the implementation of the WFD. The key PP provision of the Directive is Article 14 (PPWG, 2003), which encourages Member States to foster the active involvement of all interested parties in the implementation of this Directive, in particular in the production, review and updating of the RBM plans (European Parliament, 2000). Additionally, Preamble 46 emphasises the importance of PP for the formation of final decisions (European Parliament, 2000). PP can be defined in several ways. In relation to the WFD, the Public Participation Working Group (2003) characterises it as "allowing people to influence the outcome of plans and working processes" and distinguishes three levels of participation, building on each other: a) information supply, b) consultation, and c) active involvement. Information supply refers to providing access to the general public to background information. Consultation relates to the public having the right to react to plans and proposals developed by the authorities, while active involvement refers to stakeholders actively participating in the planning process by discussing issues and contributing to their solution (PPWG, 2003).

Many argue that public participation (PP) is one of the key factors for sustainable water use and that any river basin management (RBM) plan is unlikely to be successfully implemented if it does not meet public acceptance and does not gain the support of key stakeholders groups, such as local residents and water users (WWF Scotland, 2001). If stakeholders are not involved in the evaluation of water management policy measures, the decisions taken can be controversial and generate public opposition, thus making those decisions unfeasible (Giordano et al., 2005). Conversely, the engagement of the key water users in a single process can facilitate exchange of information and interaction between different groups and result in integration of knowledge and perceptions. This naturally leads to a better understanding of a specific situation, the problems faced by different stakeholders and their recommended solutions. This is of particular importance as the environmental pressures imposed on the water resources are the result of a wide range of land uses, policies and practices, which should be addressed in an integrated way, especially in the presence of external impacts from use. At the same time, the monitoring of social trends relevant to the water environment provides water managers with the ability to react to changes in human behaviour and to opportunities for the development of new policy attitudes (Van Ast & Boot, 2003). As a result, PP can arguably lead to more informed and higher quality decisions, which are more likely to meet public acceptance and support after the different groups are aware of the issues and have actively contributed to their solution.

Applying PP to the issue of water pricing is potentially problematic, although arguably vital if the full potential of water pricing is to be realized. Firstly, involving the public in studies related to water pricing prevents deepening distrust, as usually service providers are trusted more if people are approached as citizens rather than consumers (Barraqué, 2003). Additionally, a system that is perceived to be fair by the users may ultimately be more efficient than one that has been designed in the basis of strict efficiency but is seen as unfair (Levin and Coward Jr., 1989; cited in Ray et al., 2002). This is because the objective of pricing policies is very likely to fail if users do not see them as fair and reasonable, and therefore a carefully planned dialogue to increase public support before launching any pricing reforms would make the decisions more acceptable to the affected parties, eliminating compliance problems. In addition, when designing efficient water pricing schemes, economists often ignore information and knowledge needed for their implementation and underestimate distortions arising from mis-specification of institutional relationships between individuals and organisations (Dinar, 2000). But given that pricing policies have to perform within various institutional and cultural frameworks, a better understanding of these could effectively accrue through PP.

3. Fuzzy cognitive mapping

Involving all stakeholders into RBM within the framework of the WFD is a multi stage process, which consists of development and dissemination of practical information, actual implementation of participatory practices, and delivery and incorporation of the results into the planning process. The complex nature of the process requires the use of additional mechanisms to the traditional interactions between experts and decision-makers. It has been suggested that Information and Communication tools, including FCM, can provide these additional mechanisms and play a crucial role in supporting the social learning dimension of PP through bidirectional communication processes (Maurel, 2003).

FCM can be described as qualitative modeling that portrays how a given system operates (Özesmi & Özesmi, 2004). The qualitative model is derived by describing the system in terms of its component variables and the causalities among them (Park & Kim, 1995). A system can range from physical and environmental patterns to social, economic and political structures. Fuzzy Cognitive Maps (FCMs) can be obtained by asking people to define the variables of the system and to identify relationships among the variables using 'if-then' rules to justify the cause and effect relationship, and infer a linguistic weight for each connection (Stylios & Groumpos, 2000, 2004; cited in Papageorgiou & Groumpos, 2005). This information can be elicited by questionnaires or by interviews with people who draw the links directly (Özesmi & Özesmi, 2004).

FCM analysis proceeds in several stages. First, the variables of the system are identified and assigned values representing their current state. The variables can be either measurable quantities, such as water consumption per household or abstract qualitative concepts, such as fairness of governmental policies. From these values, a state vector, which specifies the current values of all concepts in a particular iteration, is encoded. Next, the causal relationships between variables are identified and the direction of the causality of the link indicated. Then a weight is assigned, indicating whether the relationship between the variables is positive or negative and which is the strength of the relationship. The weights assigned to the links are in the interval [-1, 1] (Papageorgiou & Groumpos, 2005). Values in [-1, 0) indicate a negative effect, values equal to 0 indicate no relationship between the variables, and values from (0, 1] indicate a positive effect. With the appropriate connection weights a FCM connection matrix is encoded from each FCM diagram (Banini & Bearman, 1998).

A Fuzzy Cognitive Map resembles a recurrent artificial neural network (Tsadiras & Margaritis, 1997). It can be initiated by stimulus, which then activates a continuous vector-matrix multiplication until equilibrium is reached (Chiu et al., 1994). By iteratively multiplying the previous state vector by the connection matrix using standard matrix multiplication, the new state vectors showing the effect of the activated concepts are computed (Peláez & Bowles, 1996). After every multiplication, the values of the state vector are normalized by a nonlinear function that allows the vector elements to take a value within a predetermined set of values. Commonly, the functions used allow the variables to take values in {0, 1}, in {-1, 0, 1}, or in [-1, 1] (Tsadiras & Margaritis, 1997). FCM inference goes on by nonlinear spreading activation, which implies that the inference or prediction is a temporal sequence of events or reverberating limit cycle (Kosko, 1988). Iteration terminates when it reaches a steady state and stops yielding new data, or when a prearranged iteration count has been reached (Taber, 1991). If the state vector has continuous values a Fuzzy Cognitive Map may as well exhibit chaos (Peláez & Bowles, 1996).

Kosko (1992) cited in Banini & Bearman (1998), suggested the respondents' maps can be combined so as to produce group or social maps. Initially, the connection matrices are augmented, and afterwards all the augmented connection matrices E_i are linearly added, producing the matrices of different stakeholder groups, or a single matrix that represents the social Fuzzy Cognitive Map. The combined FCM connection matrix E_c is finally obtained by normalizing each element by the number of experts according to the following equation (1) (Banini & Bearman, 1998):

$$E_c = \frac{1}{k} \sum_{i=1}^{k} E_i \qquad (1)$$

Where k is the number of experts.

Graph theory indices provide a way to analyse the structure of FCMs (Özesmi & Özesmi, 2003). The outdegree, indegree and centrality of a variable are indices that provide useful information on how the variables act in relation to the other variables. The outdegree shows the cumulative strength of connections exiting the variable, and thus provides an indication of how much this variable affects other variables. The indegree is the cumulative strength of connections entering the variable, and shows the extent to which the variable is impacted by other variables. The summation of the outdegree and indegree of a variable shows its centrality (Harary, Norman & Cartwright., 1965), which demonstrates the contribution of a variable in a Cognitive Map (Özesmi & Özesmi, 2004; Özesmi & Özesmi, 2003).

To date FCMs have gained considerable research interest (Papageorgiou & Groumpos, 2005; Papageorgiou et al., 2004) and have been used for modelling dynamic systems in various fields, such as political science, international relations, electrical engineering, medicine and history, (Stach et al., 2005). Their use in ecology and environmental management has been limited (Özesmi & Özesmi, 2004), and to our knowledge there are very few applications of the method in participatory water resources management and none that has attempted to reconcile the method with economic theory. Özesmi and Özesmi (2003) used it to develop a participatory ecosystem management for Uluabat Lake in Turkey, and Dataser and Özesmi to obtain the perceptions of different stakeholder groups in two wetland ecosystems in central Turkey (Özesmi & Özesmi, 2004). Giordano et al. (2005) used FCM to map a conflict that occurred some years ago in a river basin in the South of Italy. Here we use the method to develop an integrated participatory water management system for the Pinios River Basin.

4. The case study area

The Pinios River Basin is the biggest hydrological basin of Greece with an area of 10,550 km² (H.M.E.P.P.P.W., 2005), within which Pinios River, along with its tributaries, is the principal receiver (Bellos et al., 2004). It is located in the central section of mainland Greece, in Thessaly region. Thessaly is considered to be the principal agricultural region of Greece, as its plain is the most intensely cultivated and productive agricultural area in the country (Loukas & Vasiliades, 2004), with cultivated land covering 36% of the total area of the region (European Commission, 2002). The main crop produced is cotton, which is one of the major agricultural exports of Greece. Irrigation is the main water use in the area, accounting for 96% of the total water consumption (H.M.E.P.P.P.W., 2005).

The current water supply system is through self-service boreholes, and collective networks supplied by boreholes or by waters from the River Pinios under the jurisdiction of the local organisations of land reclamation (T.O.E.B.). It is estimated that 76,950ha are being irrigated through collective irrigation networks, supplied mainly by boreholes, and 112,450ha through private boreholes (YPAN et al., 2003). The main factors that have led to the expansion of water demand for irrigation and the construction of a great number of boreholes are: a) intensification of agriculture (European Commission, 2002), b) subsidies for water intensive crops such as cotton and corn, c) financing of boreholes construction, d) reduction in precipitation up to 30% in the period 1982-2001 (Euaggelopoulos, 2005), and e) mismanagement of water resources due to lack of a rational management scheme (European Commission, 2002) deriving from fragmented governmental water management policies. The Thessaly water basin is currently water deficient (YPAN et al., 2003), while a lack of adequate water storage infrastructure results in the loss of millions of cubic meters of water.

The most dominant pricing regime for collective networks is an area based payment, where the farmers pay depending on the size of land they irrigate and the type of the crop, regardless of the quantity of water they consume. The price covers part of the operation and maintenance costs, which are however relatively high. This is due to groundwater levels being very low and the main type of networks being open channels, which result in significant energy costs being imposed on farmers. The age of the irrigation networks leads to significant water losses, due to high levels of evaporation and absorption, and leakage.

Over-exploitation of groundwater is the key environmental problem at present (European Commission, 2002; Euaggelopoulos, 2005). This is gradually leading to soil destabilisation and potential irreversible depletion of the aquifers (Euaggelopoulos, 2005). Surface, coastal and ground waters are also under pressure from increasing diffuse and point pollution sources (Greek Contribution to the Governing Council Meeting of UNEP, 2004). In particular, overabstraction of groundwater in conjunction with nitrogen fertiliser application is resulting in groundwater quality deterioration (European Commission, 2002). The nutrient balance of Pinios River is mainly being affected by intensive agricultural activities, domestic sewage from the cities of Larissa and Tricala, and some industrial wastes (Bellos & Sawidis, 2005).

5. Fuzzy cognitive mapping: an application

In this context, FCM has been applied to model the perceptions of stakeholders regarding the current state of water resources, the drivers of use and environmental change, potential solutions to the current problems, and the possible implications of different water resources management policy options, including the acceptability of FCR. Data analysis and inferences have been conducted using the 'Fuzzy Cognitive Mapping Integrated Environment 1.16' software package, which has been developed in collaboration with the Information Technology Company 'Interplanetic'[2]. The FCMs have been obtained by 30 in-depth one on one interviews with people with differing perspectives and engagement with water use and management. These groups are broadly classified as farmers, local residents, water

[2] For further information on the software availability contact Dimitris Tsalkakis at dts@interplanetic.com.

experts, researchers-ecologists and government officials. The interviews were conducted in July 2005.

At the beginning of each interview, the respondents were informed on the purpose of the research, the research questions, and the procedure of assigning values to the variables and weights to the connections between them. First, the respondents were asked to describe the current state of water resources and the drivers of use and environmental change, in terms of the component system variables and the causalities among them. Some variables had been defined in advance by the authors, so as to facilitate conversation. The scale used for the variables was: 1: very small, 2: small, 3: moderate, 4: big, 5: very big, and the values assigned represented both quantitative and qualitative characteristics of the variable. The scale used for the connections was: 1: very weak, 2: weak, 3: moderate, 4: strong, 5: very strong. The respondents could use either the real numbers or their linguistic equivalents. The respondents were asked to assign values to the variables based on their beliefs on the current situation. The connections and their weights were obtained by asking questions on the ordered pairs of variables. During the phase of assigning weights, the respondents were encouraged to add more variables and connections to the system with questions such as "Do you think that variable x is affected by or affects any other variables?"

After the existing conditions were identified, the respondents were asked to express their opinion on the application of FCR and the PPP, more specifically on the inclusion of direct, environmental and resource costs of urban and irrigation water uses into water charges, and any reasons of disagreement. The discussion on direct costs focused on the capital and depreciation costs of investments for water supply, as operation and maintenance costs are already included in the prices of water. The environmental costs were specified as environmental costs caused by water abstraction and costs due to water discharge. The resource costs represented the welfare losses that households and farmers respectively are confronted with due to misallocation between high and low value users. Finally, they were required to suggest potential alternative solutions for improving the existing situation. Their suggestions were introduced into the system in the form of variables and connections, using the procedure that has been described above.

Once the variables and the causal relationships were defined, two types of maps have been created for each individual: a) the Current State Map which depicts perceptions of the present status of water resources and the factors impacting on them; and b) the Desirable State Map which shows what the stakeholders see as feasible and desirable for altering the existing conditions. The variables were encoded into vectors and the causal links into matrices. The initial vector elements have been set to specific values, as they have been defined by the respondents based on their beliefs on the current situation. The established fuzzy connections have been mapped to numerical values to the range [-1, 1]. Thereafter the individual FCMs were augmented and combined, so as to produce the Current and Desirable State stakeholder groups' FCMs, which were then combined for the formation of the Social Current State Map (Figure 1) and the Social Desirable State Map (Figure 2). In order to ensure that the appearing connections would be the most forceful ones, the threshold connection weight ≥ 1 was applied.

Finally, the FCMs were used to simulate different policy options and compare the effect of different alternatives on the system variables. Before running any policy options the steady-state conditions were determined, i.e. where the system would go based on how the stakeholders view the system, using the Social Current State Map. The three policy options that were simulated were a) increasing water supply,

b) applying FCR and the PPP, and c) bringing into effect the stakeholders' desirable policy option. The policy options of increasing water supply and applying FCR and the PPP were run using the Social Current State Map, after changing the variables and connections that represent the new policy. The induced initial changes were brought into effect by altering the appropriate values of the variables and/or the weights of the links that reflect the new policy. The stakeholders' desirable policy option was run using the Social Desirable State Map. After every multiplication, the values of the state vector were normalized by the typically used sigmoid threshold logistic function shown by equation (2) and allowing values in the interval [0, 1]:

$$f(x)=\frac{1}{1+e^{-\lambda x}} \qquad (2)$$

Where λ>0, is a parameter that determines its steepness and in this application it has been set to λ=1.

6. Results and discussion

6.1 Number of variables and connections and variables centrality

The mean (±SD) number of variables in the FCMs was 21.17 ± 12.58, the mean (±SD) number of connections 48.6 ± 42.4, and the mean (±SD) fraction of connections/variables 2.29 ± 1.21. The total number of variables obtained was 34 and the total number of connections 126. There are no statistically significant differences between the groups (Table 1). The group of government officials has the greatest number of variables and connections in their maps, followed by the group of researchers-ecologists and the group of water experts. In this FCM application, a greater number of connections may indicate greater acceptability of the WFD economic requirements, better understanding of the system's operation, increased ability of finding solutions to improve the existing conditions, or all the above. The groups of researchers-ecologists and government officials had the greatest percentage of relationships indicating agreement with the principles of FCR and the PPP, while farmers had the fewest. In contrast, farmers focused more on describing the system's operation and suggesting non-economic ways of improving the current situation compared to the other groups.

The variables with the highest centrality, indegree, and outdegree in the Social Current State Map and the Social Desirable State Map are depicted in Table 2. Water deficiency is the variable with the highest centrality, indegree and outdegree in the Social Current State Map, and with the highest centrality and indegree in the Social Desirable State Map. This reveals the respondents recognition of the water deficiency problem, the acknowledgement of water quantity as a factor of major importance to the whole environmental and socio-economic system, and their attempt to find solutions that would target this specific variable. The variable State-EU is the variable with the highest outdegree in the Social Desirable State Map, due to the respondents' keenness on assigning significant regulatory and financial responsibilities to the state and the EU for improving the existing situation.

6.2 Stakeholders' perceptions on water resources management

In the Social Current State Map, which depicts people's perceptions on the present status of water resources and agriculture, and the factors impacting on them, the strongest relationships in order of magnitude are represented by the following statements: 1) agriculture is heavily dependant on irrigation; 2) water consumption for irrigation increases water deficiency; 3) agricultural activities are a source of water pollution; 4) households are paying for sewerage services and waste water treatment; 5) water deficiency is increased by the water losses of the irrigation networks; 6) water deficiency increases the farmers' expenses for irrigation; 7) the increased expenses for irrigation have a negative impact on agriculture; 8) agriculture is contributing to the prosperity of the area and the country; 9) water consumption for irrigation depends on water availability; 10) long-term investments for water storage are insufficient; 11) insufficient water availability results in losses of income for farmers; 12) water pollution is reducing overall water availability.

The acknowledgment of water pricing as a potential measure and the acceptability of FCR for water services and the PPP was low, and varied across the different stakeholder groups. The group of researchers-ecologists and the group of government officials, followed by the group of water experts, were keener on the implementation of the water pricing requirements of the WFD. However, the only connections that on average had a higher than "moderate" acceptability, i.e. a higher than 3 connection weight, were the application of the PPP for urban water discharge, the inclusion of the direct costs of urban water supply networks, and the application of the PPP for diffuse pollution from agriculture. The participants' reluctance to assign an important role to full water pricing as a measure of water demand management derives mainly from the assertion that water is a social good, and from the tendency to advocate a form of protectionism for the agricultural sector due to its greatly acknowledged socio-economic significance to the local population and the country. This holds despite a perception of some inefficiency in agricultural water use. Additionally, the lack of supply side measures such as water storage infrastructure was largely advanced as a barrier to equitable implementation of the WFD requirements. This problem in particular is felt to be an important shortcoming in terms of the implementation of further pricing provisions as envisaged by the WFD. In effect the perceived failure of current institutions to implement adequate supply side provision handicaps the institutional legitimacy of WFD objectives, and the need for further financial contribution from users.

The stakeholders' views on what is desirable and attainable for improving the management of the water resources are shown in the Social Desirable State Map. The strongest relationships in order of magnitude are represented by the following policy suggestions: 1) increase in water availability through long-term investments, which will be financed by the state and the EU; 2) reduction of water losses from the networks and expansion of the networks so as to restrict the uncontrolled use of irrigation boreholes; 3) the state should keep the prices of water fair to the consumers; 4) FCR and the PPP will be enforced to a certain extent for agriculture; 5) the state increases educational and consultation services, which increase efficiency of water use for households and farmers and reduce pollution, and; 6) establishment of a transparent water council where all stakeholders, including farmers, will be able to participate.

6.3 Results of the policy options simulation

The state of the variables with the greatest differences between the policies is depicted in Figure 3. It should be noted here that the results of the simulations do not represent predictions for the future, but they are a means to understand systems behavior and how different policy options can impact on the system based on how this system is perceived and described by the stakeholders. Therefore, the state of the variables of each of the policy options simulations will be analysed having the steady state conditions as a reference and compared to their values obtained in the rest of the policy options simulations. In the steady state conditions the variables water deficiency, irrigation price, irrigation network, water losses, water pollution, resource costs for households and resource costs for agriculture are at very high values. Recreational activities are very low, while agricultural activities and irrigation consumption are almost zero.

The first policy option that was simulated involved increasing water supply though long-run water storage investments and improving and expanding the irrigation networks. Often in water deficient regions the approach taken to increase water availability entails investments for water supply augmentation. Additionally, this policy was considered as crucial for improving the current situation by the majority of the respondents. The supply increase policy option decreases water losses and irrigation expenses greatly, water deficiency moderately, resource costs for farmers and recreational activities slightly, and resource costs for households minimally. It leads to a great increase in irrigation consumption and agricultural activities and a considerable increase in water pollution, while it slightly improves the irrigation networks.

The second option modeled engages FCR and the PPP. This policy is consistent with the economic requirements of the WFD and derives from the approach of using water pricing as a means of water demand management. Two options of the FCR policy have been run: FCR (a) and FCR (b). The only difference between these two policy options is that FCR (b) assumes volumetric water pricing where the price of water affects irrigation consumption maximally. Both FCR policies decrease water pollution significantly and water deficiency considerably, and lead to a small decrease in the resource costs imposed on households and farmers. Additionally, they cause a very big increase in irrigation price and a significant increase in recreational activities. Their effect on irrigation consumption, agricultural activities, irrigation network and water losses compared to the steady state are minor. The results indicate slight differences between the impacts of the two options on the system's variables. Specifically, FCR (b) has a slightly larger effect compared to FCR (a) on the variables of water deficiency, water pollution, resource costs imposed on farmers, resource costs imposed on households, recreational activities and irrigation consumption.

The last policy option represents the stakeholders' view on what would be desirable and attainable for improving the current state as depicted in the Social Desirable State Map and analysed above. This policy consists of a combination of different measures, including increasing water supply, application of FCR and the PPP, maintaining a "fair" water price, and enhancing participation, education and consultation. The combination of policies proposed by the stakeholders causes a big decrease in water deficiency, water losses and pollution while simultaneously irrigation consumption and agricultural activities increase considerably. Irrigation price and irrigation networks increase slightly. Recreational activities rise notably, and resource costs imposed on households and resource costs imposed on agriculture are reduced.

By comparing the results of the simulation of the three policy options the following conclusions can be reached: 1) The supply side policy has considerable positive effects on decreasing the expenses of farmers for irrigation, securing large quantities of water for irrigation, and expanding agricultural production. On the other hand, it does not have any significant effects on increasing water availability, while at the same time it results in increased pollution levels; 2) The FCR policies are very effective in reducing water pollution, but have the least effect in increasing water availability. Nevertheless, water pricing influences water availability through water consumption for irrigation. However, irrigation consumption and water availability are at the same time being impacted by a number of other variables, and this restricts the effect water pricing can have on increasing water availability. For the same reason the policies FCR (a) and FCR (b) seem to have no significant disparity in relation to their repercussions on the system as a whole. While they lead to a very high water price, they increase the expenses born by agricultural producers, and therefore lead to the elimination of agricultural production; 3) The stakeholders' desirable policy option has the most positive effects on the system's variables on the whole. The levels of water pollution and water deficiency are decreased the most, while at the same time water allocated to agriculture, and agricultural production are maintained at a high level. Additionally, this policy option leads to the greatest reduction in water losses and resource costs, and the greatest increase in recreational activities. The desirable stakeholders' policy option seems to have the most favorable results overall, revealing the capacity of integration of knowledge and perceptions, and the potential of synergistic interaction between different policy options.

7. Conclusions

Fuzzy Cognitive Mapping has been demonstrated to be a useful tool for capturing the stakeholders' understanding of the system and their perceptions on the water pricing requirements of the WFD. The main advantages of the method derive from its ability to elicit and compare the perceptions of different stakeholder groups, and to unify their viewpoints and understanding of a complex system, in this case RBM. An important feature of the method is that it can be used to integrate perspectives of both lay and expert participants. That way the mobilization of scientific and non-scientific knowledge, values and preferences can improve the formulation of a generally complex and unstructured problem and the identification of alternative solutions.

A significant advantage of FCM compared to other participatory methods is that it does not require the direct interaction of the individuals or parties involved. The participants can be contacted and interviewed either individually or in groups and there is no restriction on the number of individuals that will be involved. Involving the participants individually can be particularly useful in the first stages of any participatory processes for the WFD implementation because it can assist in a) avoiding problems that might arise by disparities in the cognitive ability, the vocabulary and the ease of comprehension and reflection on the WFD requirements of the individuals or parties involved, and in b) overcoming practically difficult, time-consuming, inefficient and likely to create social tension procedures. Ideally at some point in time different stakeholder groups will have to interact. Therefore, having practiced such preliminary activities can assist in making the groups more qualified in participating and working towards reaching consensus.

This is because the use of FCM can enhance the participative abilities of the individuals involved and foster the social learning dimension of public participation. The construction of a Fuzzy Cognitive Map requires consideration and allows representation of all the variables and connections that coexist and interact in a certain socioeconomic and environmental system. Therefore, it encourages the participants to consider the operation of the system and the existing interrelations in a more holistic way, crossing the boundaries of their scientific discipline and overcoming potentially partial viewpoints. Additionally, it allows experts to simplify complex relationships, and improves non-experts capacity to develop and express their perceptions, thus creating a common reference point that lies between the two extremes of knowledge and reducing the gap between experts, policy makers and citizens. This could be seen as the first level of learning that the participants are required to think and reflect on their own ideas. Subsequently, the second level of social learning would be to use the obtained FCMs as an information tool to encourage the different interested parties to consider the viewpoints of other parties. This way FCM can assist in making the different groups consider the issues that have been raised by other groups and their recommended solutions.

Another important characteristic of FCM is that it provides a framework for integration of perceptions from different sources through elimination of opposing and strengthening of similar beliefs. Therefore, it provides an artificial consensus between the different interested parties and can reveal the degree of similarity of the viewpoints of different stakeholder groups. This is particularly useful for finding the point that lies between the different stakeholders' perceptions and gaining insights on which groups are likely to need more work in order to reach agreement. Other advantages of the method include that its methodological properties are very comprehensible and flexible, it is ideal for analysing systems behavior which involves uncertainty, it offers the opportunity to represent feedback loops, and it can be used for modeling systems behavior in data poor situations and when abstract relationships and variables that can not be easily measured are involved.

Finally, there is no restriction on the number of variables or connections a Fuzzy Cognitive Map consists of, nor on the type of systems that can be modeled. Therefore, the method can be used for integrated qualitative modeling taking simultaneously into account the physical, social, and economic characteristics and dynamics of a system. This makes it ideal for the qualitative and quantitative trade offs inherent in implementing some of the economic elements of the WFD. Because of the technical complexities inherent in WFD implementation and the role of water pricing, there is likely to be a limit to the extent to which public participation is a realistic and practicable goal across the EU. At best the process is likely to be piecemeal, and the question is whether there are some devices that are more attuned to eliciting and representing public preferences in a way that is comprehensible to stakeholders yet capable of generating meaningful information for policy. FCM appears to provide advantages in both cases.

But FCM has some limitations that should be noted and which could restrict its applicability to RBM planning. The limitations of FCM relate to the absence of any underlying theoretical structure for scoring preferences and conveying the heuristic motives and perspectives of stakeholders. Maps are inevitably a simplification of reality and their interpretation can be difficult or subjective. This subjectivity increases where the participants are unfamiliar with the method and the FCMs are not accompanied with additional information. Another drawback of FCM is that the simulations results can be disputable, as estimates are not based in real values and biases in the perceptions of the stakeholders can ultimately be encoded in the FCMs. This limitation arguably applies to many forms of participation.

References

Banini, G.A. and Bearman, R.A., 1998. Application of Fuzzy Cognitive Maps to Factors Affecting Slurry Rheology. Int. J. Miner. Process., 52:233-244.

Barraqué, B, 2003. Past and Future Sustainability of Water Policies in Europe. Nat. Resour. Forum, 27:200-211.

Bellos, D. and Sawidis, T., 2005. Chemical Pollution Monitoring of the River Pinios (Thessalia-Greece). J. Environ. Manage., 76:282-292.

Bellos, D., Sawidis, T. and Tsekos, I., 2004. Nutrient Chemistry of River Pinios (Thessalia, Greece). Environ. Int., 30:105-115.

Chiu, C., Norcio, A.F. and Hsu, C., 1994. Reasoning on Domain Knowledge Level in Human-Computer Interaction. Inform. Sci., 1:31-46.

Dinar, A., 2000. Political Economy of Water Pricing Reforms. In: A. Dinar (Editor), The Political Economy of Water Pricing Reforms. Oxford University Press, New York.

Euaggelopoulos, A.A., 2005. Management Report for the Groundwater Resources of the Areas under the Jurisdiction of the Local Organisations of Land Reclamation (T.O.E.B.) of the Prefecture of Larisa. D.E.B. Larissas, Larissa. *(in Greek).*

European Commission, 2002. Implementation of Council Directive 91/676/EEC Concerning the Protection of Waters against Pollution Caused by Nitrates from Agricultural Sources. Office for Official Publications of the European Communities, Luxembourg.

European Parliament, 2000. Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 Establishing a Framework for Community Action in the Field of Water Policy. Official Journal L327, 0001-0073.

Giordano, R., Passarella, G., Uricchio, V.F. and Vurro, M., 2005. Fuzzy Cognitive Maps for Issue Identification in a Water Resources Conflict Resolution System. Phys. Chem. Earth, 30:463-469.

Greek Contribution to the Governing Council Meeting of UNEP at Ministerial Level (2004) Integrated Water Resources Management: The Pinios Pilot River Basin Project, 8th Special Session of the Governing Council/Global Ministerial Environment Forum, Jeju, Republic of Korea, 29-31 March. http://www.unep.org/GC/GCSS-VIII/GreeceIWRM.doc

H.M.E.P.P.P.W., 2005. Water Framework Directive: Pinios Pilot River Basin-Greece. Hellenic Ministry for the Environment, Physical Planning and Public Works, Athens.

Kosko, B., 1988. Hidden Pattern in Combined and Adaptive Knowledge Networks. Internat. J. Approx. Reason., 2:377-393.

Loukas, A. and Vasiliades, L., 2004. Probabilistic Analysis of Drought Spatiotemporal Characteristics in Thessaly Region, Greece. Nat. Hazards Earth Syst. Sci., 4:719-731.

Maurel, P. (Editor), 2003. Public Participation and the European Water Framework Directive: Role of Information and Communication Tools, WP3 Report of the Harmonicop Project. http://www.harmonicop.info/_files/_down/ICTools.pdf

Özesmi, U. and Özesmi, S., 2004. Ecological Models Based on People's Knowledge: A Multi-Step Fuzzy Cognitive Mapping Approach. Ecol. Model., 176:43-64.

Özesmi, U. and Özesmi, S., 2003. A Participatory Approach to Ecosystem Conservation: Fuzzy Cognitive Maps and Stakeholder Group Analysis in Uluabat Lake, Turkey. Environ. Manag., 31:518-531.

Papageorgiou, E.I. and Groumpos, P.P., 2005. A New Hybrid Method Using Evolutionary Algorithms to Train Fuzzy Cognitive Maps. Appl. Soft Comput., 5:409-431.

Papageorgiou, E.I., Stylios, C.D. and Groumpos, P.P., 2004. Active Hebbian Learning Algorithm to Train Fuzzy Cognitive Maps. Internat. J. Approx. Reason., 37:219-249.

Park, K.S. and Kim, S.H., 1995. Fuzzy Cognitive Maps Considering Time Relationships. Int. J. Hum. Comput. Stud., 42:157-168.

Peláez, C.E. and Bowles, J.B., 1996. Using Fuzzy Cognitive Maps as a System Model for Failure Modes and Effects Analysis. Inform. Sci., 88:177-199.

Public Participation Working Group, 2003. Common Implementation Strategy for the Water Framework Directive (2000/60/EC): Public Participation in Relation to the Water Framework Directive Guidance Document n.° 8. Office for Official Publications of the European Communities, Luxembourg. http://forum.europa.eu.int/Public/irc/env/wfd/library

Ray, S.S., Dadhwal, V.K. and Navalgund, R.R., 2002. Performance Evaluation of an Irrigation Command Area Using Remote Sensing: a Case Study of Mahi Command, Gujarat, India. Agric. Water Manage., 56:81-91.

Stach, W., Kurgan, L., Pedrycz, W. and Reformat, M., 2005. Genetic Learning of Fuzzy Cognitive Maps. Fuzzy Set. Syst., 153:371-401.

Taber, R., 1991. Knowledge Processing with Fuzzy Cognitive Maps. Expert Syst. Appl., 2:83-87.

Tsadiras, A.K. and Margaritis, K.G., 1997. Cognitive Mapping and Certainty Neuron Fuzzy Cognitive Maps. Inform. Sci., 101:109-130.

Van Ast, J.A. and Boot S.P., 2003. Participation in European Water Policy. Phys. Chem. Earth, 28:555-562.

WWF Scotland, 2001. Securing Ownership and Participation in the Water Framework Directive. WWF Scotland. http://www.wwf.org.uk/filelibrary/pdf/wfdownership.pdf

YPAN., NTUA, IGME & KEPE, 2003. Management Plan of the Country's Water Resources. Ministry of Development, Athens. *(in Greek).*

Tables

Table 1 - Mean (±SD) number of variables, connections and connections / variables

Stakeholder Group	Farmers	Local Residents	Water Experts	Researchers-Ecologists	Gov. Officials
Maps	5	9	7	6	3
Number of variables	20.4 ± 4.6	20.2 ± 6.9	21.9 ± 7.4	21.3 ± 1.2	23.3 ± 2.2
Number of connections	45.8 ± 22.6	45.3 ± 21.1	49.3 ± 19.1	51.2 ± 6.84	56.3 ± 8.5
Connections / Variables	2.22 ± 0.67	2.24 ± 0.58	2.26 ± 0.61	2.39 ± 0.22	2.41 ± 0.3

Table 2 – Variables with the highest centrality, indegree, and outdegree

Social Current State Map		
Centrality	**Indegree**	**Outdegree**
water deficiency	water deficiency	water deficiency
agriculture	irrigation	irrigation network
irrigation	agriculture	irrigation
Social Desirable State Map		
Centrality	**Indegree**	**Outdegree**
water deficiency	water deficiency	State – EU
State – EU	Irrigation price	water deficiency
agriculture	water pollution	agriculture

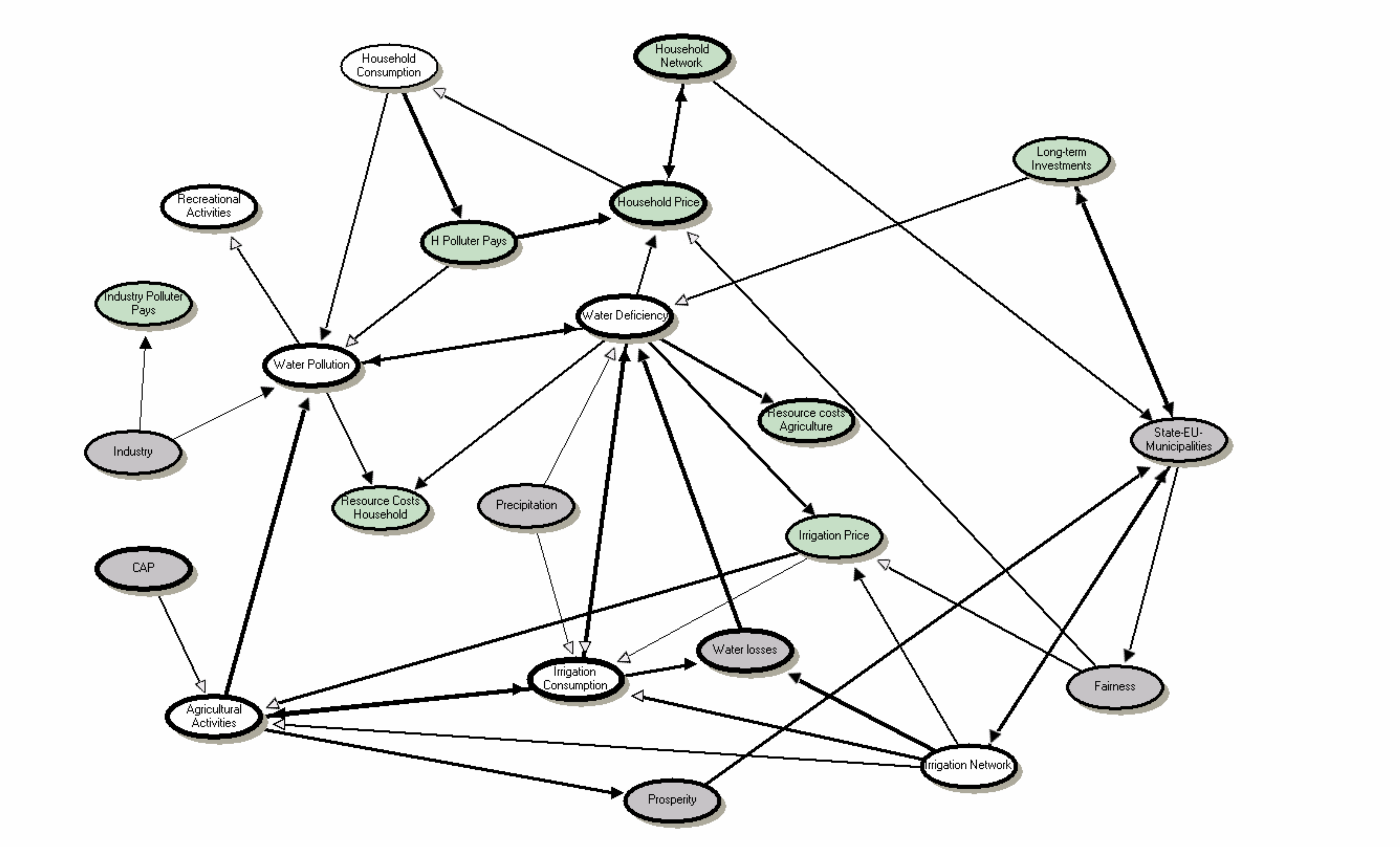

Figure 1 - Social Current State Map

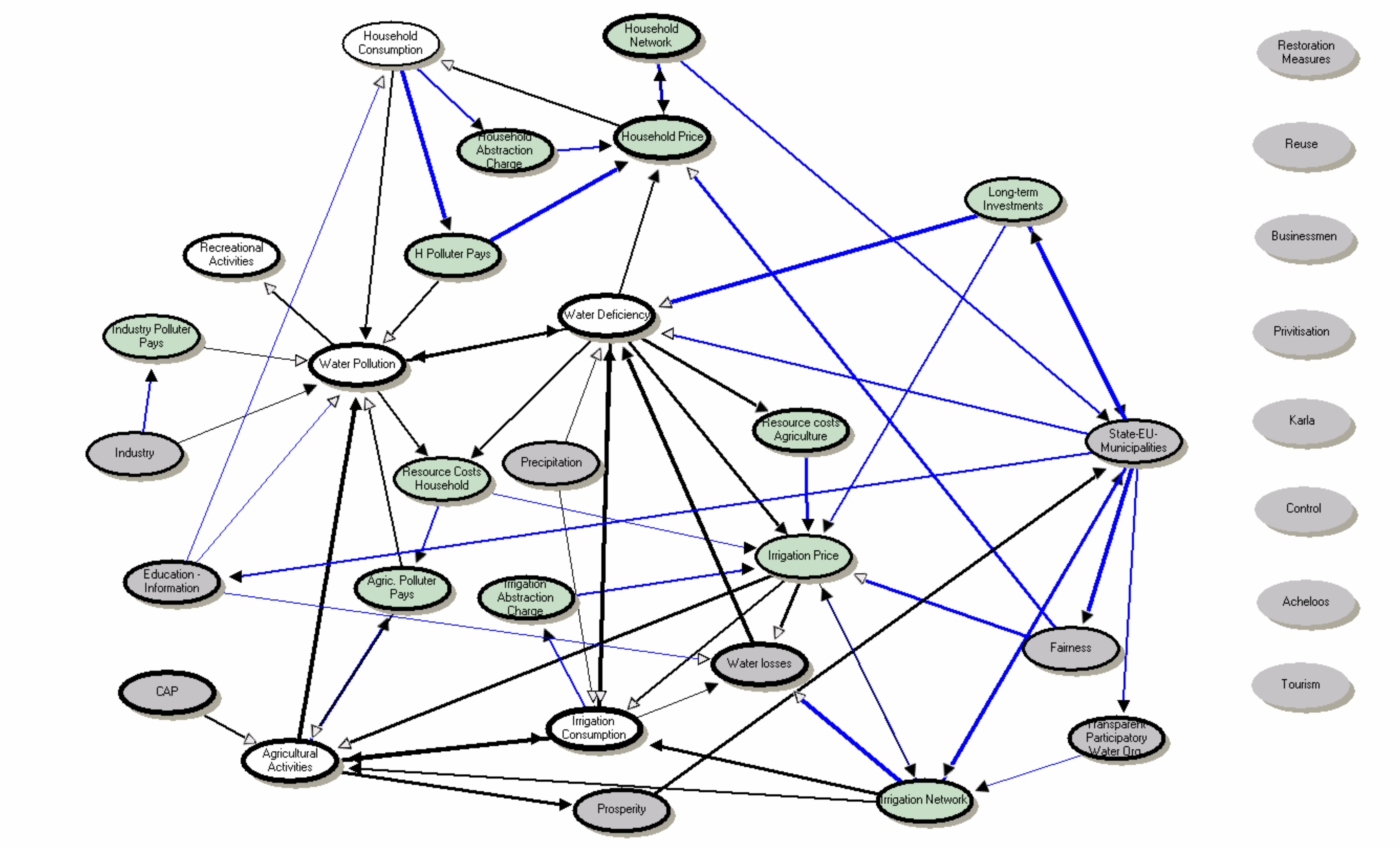

Figure 2 - Social Desirable State Map

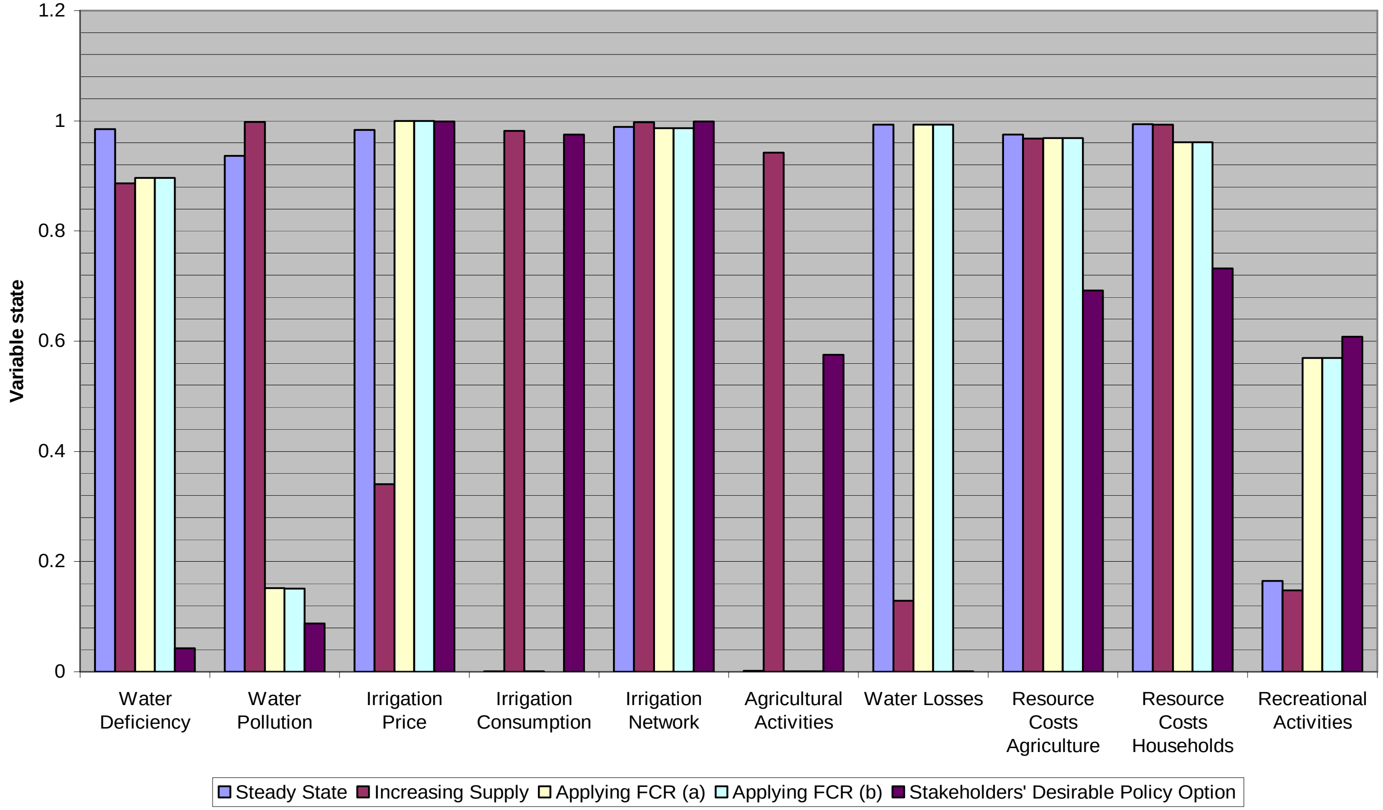

Figure 3 - State of variables with the greatest difference between policies