How to use ambiguity in problem framing for enabling divergent thinking: integrating Problem Structuring Methods and Concept-Knowledge theory

Raffaele Giordano, *Water Research Institute, National Research Council (Italy)*

Irene Pluchinotta, *King's Business School, King's College London (United Kingdom)*

Dimitrios Zikos, IRI THESys, *Humboldt - Universität zu Berlin (Germany)*

Tobias Krueger, IRI THESys, *Humboldt - Universität zu Berlin (Germany)*

Alexis Tsoukiàs, *LAMSADE-CNRS, PSL Research University, Université Paris Dauphine (France)*

Abstract

Collective behaviours and participatory models could be hampered by the presence of ambiguity, that reflects the multiplicity of interpretations that different actors bring to a modelling exercise. Despite commonly overlooked in modelling, how ambiguity in subjective problem frames is embraced determines the quality of the participatory modelling process.

This work describes an innovative approach based on the integration of Problem Structuring Methods, specifically Fuzzy Cognitive Mapping (FCM), and Concept-Knowledge (C-K) design theory, as mean to transform ambiguity from a barrier to an enabling factor of divergent thinking in participatory modelling. The integration of methods allows to identify and analysis ambiguity in problem framing, avoiding viewpoints' polarization that hamper the development of collective behaviours. However, individualistic problem frames can still yield organized collective actions when these frames are sufficiently aligned. Often environmental policies fail because decision-makers are not aware of the misalignment and their decisions are based on wrong assumptions about the others' problem frames.

This work discusses the results of two case studies aimed to design environmental policies for groundwater protection in Kokkinochoria area (Republic of Cyprus) and Apulia Region (South-East Italy), demonstrating the potential of FCM and C-K theory integration in supporting divergent thinking in participatory modelling.

Biography

Raffaele Giordano is a research scientist at the Water Research Institute (CNR) since 2005. His main research field concerns the integration of scientific and stakeholder's knowledge to develop decision support tools for drought risk assessment and water management. Current research activities are dealing with participatory modelling for conflict analysis in drought management.

Irene Pluchinotta is a Research Associate at King's College London, currently working on the innovative design of public policies. She is an environmental engineer using operational research methodologies to support decision-making processes for environmental policies and resilient cities. Based on a double PhD, her work provides formal approaches to assist decision-makers and to structure stakeholder participatory activities.

Dimitrios Zikos is a postdoctoral researcher at IRI THESys of Humboldt-Universität zu Berlin. He completed an MBA on Environmental Management at the University of Liverpool, and a PhD at the Panteion University of Social and Political Sciences. His research focuses on the implicit study of conflict and cooperation on natural resources from an institutionalist perspective.

Tobias Krueger is Junior Professor at the Integrative Research Institute on Transformations of Human-Environment Systems (IRI THESys) of Humboldt-Universität zu Berlin. His research interests include transdisciplinary water research, statistical modelling and uncertainty analysis. Tobias holds a PhD in Environmental Science from Lancaster University and spent five years as postdoc at the University of East Anglia.

Alexis Tsoukiàs is a CNRS research director at LAMSADE, PSL University, Université Paris Dauphine. He was Director of the LAMSADE until 2018 and is national coordinator of the Policy Analytics Research Network (www.gdr3720.fr). His research interests are MCDA, non-conventional preference modelling, policy analytics, non-classical logics, mathematical programming, AI and decision theory.

1. Introduction

Understanding the relationship between actors' knowledge, behaviour and action is a key challenge for modelling approaches (White, 2017). Participatory activities are expanding modelling beyond prediction in order to include processes co-designed with stakeholders and inclusive of multiple knowledge forms (Brugnach and Ingram, 2012). As White (2016) discussed, originally OR focused on the objectivity of the scientific method, and the adopted models assumed a singular version of rationality (Jackson 2006, Keys 1997, Mingers 2000) independent from different perceptions (Ackoff 1962 and 1978, Lesoume1990, Mingers et al. 2004, Raitt 1979). However, soft modelling approaches investigated the possibility of using qualitative methods, including subjective values to support decision-making (Checkland et al. 2004, Davis et al. 2010, Eden et al. 2006, Mingers, 2011; White et al. 2007, Yearworth et al. 2013). Capturing differences in problems frames, through models of viewpoints, enhance an understanding of a problematic situation and to help support its resolution (Eden 1992, Giordano et al. 2017a, White 2017).

In doing so the presence of ambiguity in the perception of the problem to be addressed, between model developers and model users, and among different users, is challenging the effectiveness of participatory modelling approaches (e.g. Brugnach et al. 2007, Janssen et al. 2009, Wood et al. 2012). Ambiguity is a type of uncertainty that indicates the confusion that exists among actors in a group regarding what the concerning issues, problems or solutions are (Weick 1995). It reflects the multiplicity of interpretations and meanings different actors bring to a modelling exercise. Ambiguity can be both a source of creativity and a source of conflict (Giordano et al. 2017a). While it is commonly overlooked during modelling, how ambiguity is resolved and embraced is determinant for the quality of the participatory process supported by the modelling exercise, influencing what is being modelled and the outcomes generated (e.g. Brugnach and Ingram 2012, Leskens et al. 2014). This is particularly true in participatory modelling activities for the design of environmental policies, where a plethora of different decision-actors, with different, and potentially conflicting, goals and values need to be involved. Furthermore, considering behaviour in participatory modelling activities should strengthen the relationship between "representing" and "intervening" focusing on the mediating role of the model and its social practice (White, 2017).

Within this context, what is the most suitable approach for representing different values, goals and knowledge when engaging stakeholders in a participatory modelling process? Providing answer to this research question is the main scope of this work.

On the one hand, representing the different contributions could produce several benefits in the modelling exercise. Firstly, integrating different pieces of knowledge allows to develop a model capable to support policy- and decision- makers in accounting for the different issues related to the problem at stage. Secondly, it could have a positive effect on the stakeholders' long-term engagement in the participatory activity. Evidences show that if the participants are capable to recognize their contributions in the developed model, then they will develop a sense of ownership toward the model itself, that could guarantee the long term engagement (Giordano and Liersch, 2012).

On the other hand, integrating different perspectives in the modelling process raises several issues. Firstly, dealing with conflicting problem understandings requires efforts from the modelers to achieve a consensus among the participants. Secondly, power issues need to be accounted for. That is, are the collected pieces of knowledge equally important or different weights have to be assigned according to the expertise of the stakeholders (Krueger et al., 2012; Giordano and Liersch, 2012)?

Addressing the above-mentioned issues is of utmost importance in order to facilitate the participatory modelling process and to make the obtained model suitable for supporting the decision-making process.

This work describes an innovative approach based on the integration between Problem Structuring Methods (e.g. Checkland 2000, Rosenhead 2006), and specifically Fuzzy Cognitive Mapping (FCM) (Kosko 1986), and Concept-Knowledge (C-K) theory (Hatchuel et al. 2003, Agogué et al 2014b, Le Masson et al. 2017) as a mean to transform ambiguity from barrier to enabling factor of divergent thinking in participatory modelling. The activities described in this work demonstrate the suitability of the integrated approach to avoid the polarization of viewpoints, conditions that can greatly interfere with the development of participatory models for collective actions. To this aim, as suggested by some authors (e.g. Brugnach et al. 2011, Giordano et al., 2017a; Pluchinotta et al. 2019a), we assumed that divergent frames can still yield organized collective actions when different problem frames are sufficiently aligned and a "shared concern" among the stakeholders is built, avoiding the formation of wrong assumptions about the others' problem frames.

The proposed approach was experimentally implemented in two case studies aiming to design environmental policies for water management and groundwater protection, namely Kokkinochoria area (Republic of Cyprus) and Apulia Region (South-East of Italy). The obtained results demonstrate the potentialities of FCM and C-K theory integration in supporting divergent thinking.

This chapter is structured as follow, after the present introduction, section 2 describes the integrated approach and discusses the case studies, while concluding remarks and the lesson learned are reported in section 3.

2. Integrating Problem Structuring Methods and Concept-Knowledge theory

In order to provide answer to the research questions, an innovative approach based on the integration between PSM and C-K theory, was designed and implemented in two case studies described further in the text.

This developed multi-methodology is meant to facilitate the alignment of different problem frames and available knowledge and to enable the creative process for innovative policy design and consensual participatory modelling exercises.

On the one side, C-K theory supports the innovation management within a design generative process. It is based on the distinction between two expandable spaces: a space of Concepts (C-space), and a space of Knowledge (K-space). The co-evolution of the C- and K- spaces represents the generative process (Hatchuel et al. 2003). In this work, the K-space expansion phase is supported by making the decision-makers aware of the main reasons of ambiguity, while the C-space expansion is realized accounting for the policy alternatives that could be implemented to overcome the main differences in problem framing.

On the other side, in this work FCM allows to elicit and structure individual problem frames, contributing to identify and analyse the mains elements of ambiguity and those that can alter the modelling outcomes. Thereafter, the results of the ambiguity analysis are used as elements of the K-space, supporting the creativity process within a C-K theory framework.

The following phases were identified in the proposed methodology:

1) PSM, and specifically Fuzzy Cognitive Mapping activities are used to elicit and structure stakeholders' individual problem understanding, and to detect the most important elements in their mental models;
2) Ambiguity analysis is implemented to detect and analyse similarities and differences in problem frames. To this aim, two elements were accounted for, i.e. the most central elements in the FCM and the expected dynamic evolution according to the FCM simulation.

Starting from the results of the previous phases, a C-K theory based tool, namely P-KCP, designed and implemented in the domain of policy design, was applied in order to facilitate the alignment of the problem frames and the creation of the shared concern as starting point for the generation of policy alternatives (Pluchinotta et al., 2019a for details). Therefore:

3) Phase K aims to gather missing information and building a comprehensive summary of current knowledge about the issue under consideration. It combines the outputs of the ambiguity analysis with scientific literature studies, available data, emerging technologies, best practices, etc. This phase supports the building of the overall K-space combining and aligning the individual stakeholders' K-spaces, in order to reach a shared concern and a common knowledge between each viewpoint.
4) Phase C for the development and expansion of the C-space supported by the creation of a shared base of knowledge. Phase C consists of one-day generative workshop in which stakeholders collectively evaluate and discuss the elements representing the dominant design

(i.e. traditional policy alternatives) and suggest expansions of the C-tree. The tree-like structure of the C-space allows to illustrate various policy alternatives as concepts connected to the initial design task under consideration.

5) An integrated model is developed referring to the aligned problem frame defined during the phase K. The model is capable to simulate policy scenarios designed during phase C, and to support the further expansions of the K-space by introducing the elements concerning the potential impacts of the selected policy alternatives.

The proposed multi-methodology was implemented in two case studies aiming to design environmental policies for groundwater protection in Kokkinochoria area (Republic of Cyprus) and Apulia Region (South-East of Italy). For sake of brevity, the case studies activities are used in this work for describing the different steps of the adopted approach.

2.1. Case studies description

The purpose of this section is to briefly presents the insights from the applications of the integrated methodology combining FCM and CK framework for supporting the co-design of environmental policies for groundwater (GW) protection in two case studies, namely Kokkinochoria area (Republic of Cyprus) and Apulia Region (South-East of Italy).

Generally, Mediterranean regions are heavily dependent on GW for socio-economic development (e.g. Zikos et al., 2015). Both areas under analysis are characterized by seawater intrusion caused by intensive agricultural activities in coastal areas, which rely on both surface water and GW (e.g. Pluchinotta et al. 2018, Zikos and Roggero, 2012). This situation is resulting in an increasing imbalance between withdrawn water and the GW recharge, causing an impoverishment in GW quantity and quality (Pereira et al. 2009). Furthermore, both challenging contexts are characterized by the presence of several decision-makers with conflictual objectives and different problem formulations (e.g. Ferretti et al., 2018).

Indeed, most of the policies implemented in the Mediterranean basin aim to improve the efficiency of GW use through innovative irrigation techniques or to restrict the GW use through tight control of farmers activities (Giordano et al. 2015). Nevertheless, evidence suggests that many times those policies largely failed to achieve a sustainable use of GW, due to an over simplification of the ambiguity in problem frames associated (Giordano et al. 2017a). The following table 1 summarizes the key elements of the case studies.

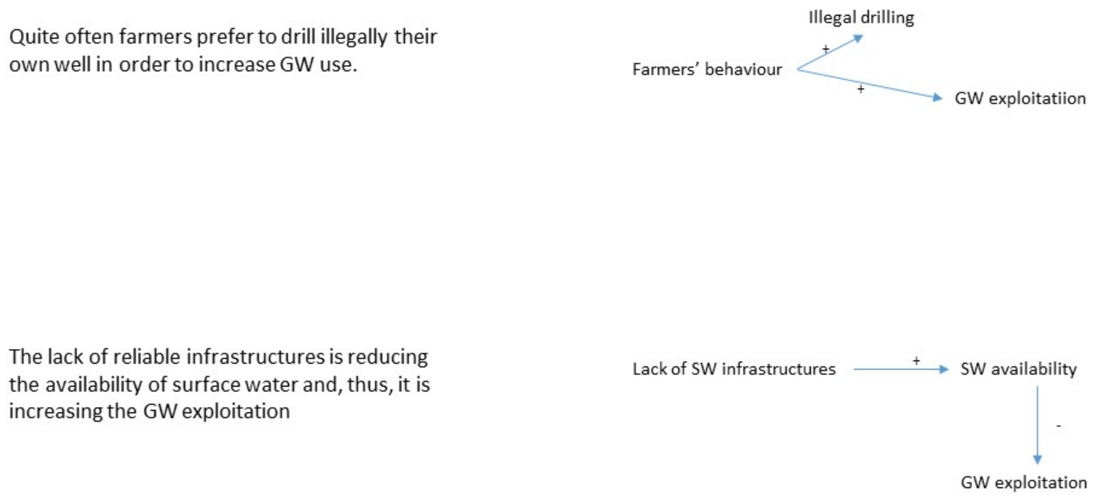
	Kokkinochoria area (Republic of Cyprus)	**Apulia Region (South-East of Italy)**
	(Zikos and Roggero, 2012, Zikos et al., 2015)	(Giordano et al. 2017a, Pluchinotta et al. 2018, Ferretti et. al, 2019)
Policy Goals	1. Provide sufficient water in both quantitative and qualitative terms for domestic and agricultural use 2. Protect the GW quantity and quality in Kokkinochoria aquifer	1. Provide sufficient water for agricultural use 2. Protect GW quality and quantity keeping high level productivity of the agricultural sector
Policy Means	1. Water transfer via the South Conveyor 2. Halt excessive water abstraction by: i) registering boreholes, ii) installing water metres iii) stop issuing new licences	1. Pricing strategy for water volume reduction 2. Direct control of water volume used by farmers
Time Framing	Several years	Several years
Stakeholders	Water Development Department (National and Regional), Regional Agricultural Department, Ministry of Agriculture, Farmers, Farmers associations	Apulia Region Authority, Surface Water Management Authority (Irrigation Consortium), Farmers, Farmers associations

Table 1 - Key policy elements of the case studies

2.2. Fuzzy Cognitive Maps

FCM was meant to elicit and structure the different stakeholders' problem frames. The basic assumption is that, to make ambiguity a source of creativity in policies co-development, decision-makers need to be aware of the existence of different, and equally valid, problem understandings. The first issue to be addressed concerned the selection of the experts to be involved in this. In order to minimise the selection bias and the stakeholders marginalization (Reed et al., 2009) a top-down stakeholder identification practice, namely “snowballing” or “referral sampling”, was implemented (Harrison and Qureshi 2000, Prell et al., 2008). The preliminary interviews carried out allowed to widen the set of stakeholders to be involved (Giordano et al. 2017b).

The individual FCM were developed through semi-structured interviews, collecting the stakeholders’ perceptions about the cause-effects chains affecting the GW management and protection in the two study areas. Then, the interviewees described causes, direct and indirect impacts of GW mismanagement. The interviews were analysed to detect the keywords in the stakeholders’ argumentation (the variables in the FCM) and the causal connections among them (the links in the FCM). Figure 1 shows how the stakeholders’ narratives, collected during the interviews, were translated into FCM variables and relationships. Figure 2 and 3 shows two examples of the stakeholders’ FCMs developed in the case studies, respectively Apulia region and Kokkinochoria area.


Quite often farmers prefer to drill illegally their own well in order to increase GW use.

The lack of reliable infrastructures is reducing the availability of surface water and, thus, it is increasing the GW exploitation

Figure 1 - Translating quotes from stakeholders’ interviews into FCM variables and relationships

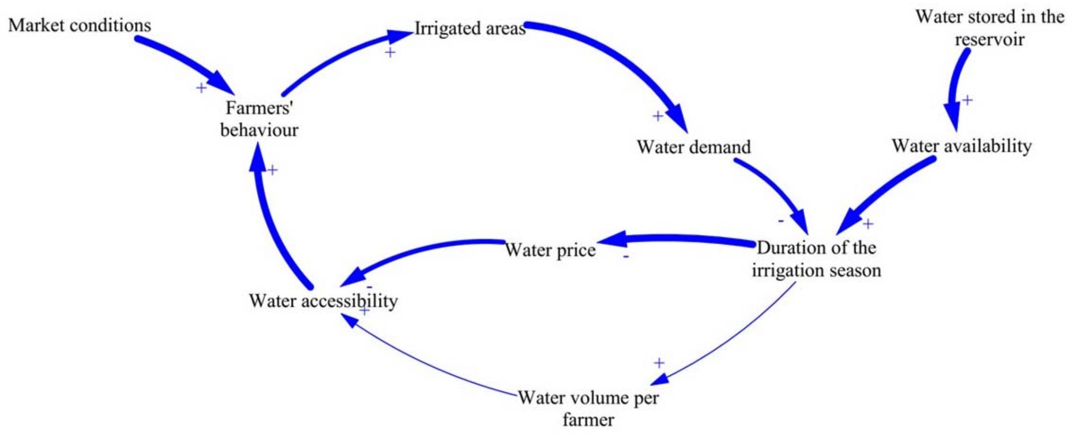


Figure 2 - Example of stakeholder's FCM developed for the Apulia case study (adapted from Giordano et al, 2017a)

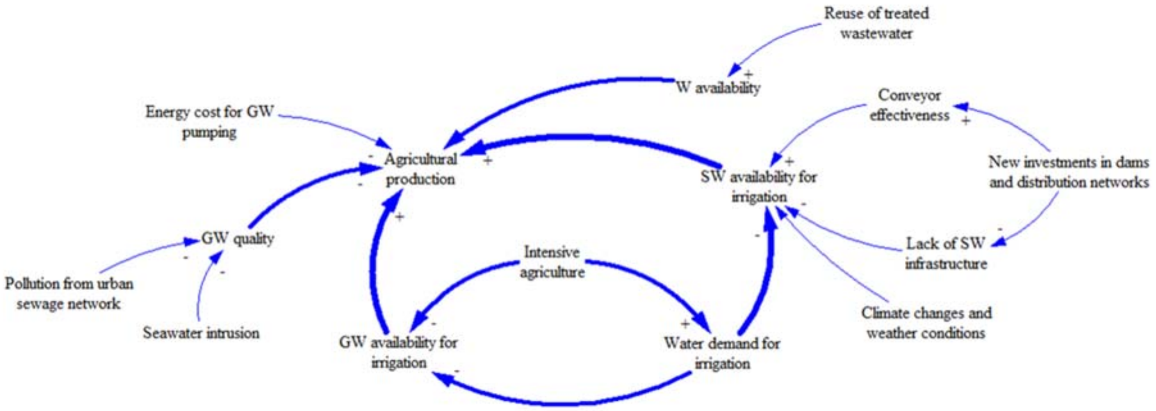


Figure 3 - Example of stakeholder's FCM developed for the Kokkinochoria area case study

The link/relationship of a FCM can be either positive or negative. The existence of a positive relationship between "A" and "B" means that if A increases then B increases. If the link is negative, then an increase in A implies a decrease in B. Once all the concepts and links were identified, the analysts were required to define the strength of the links accounting for the stakeholders' problem frames. The strength of a link between two concepts (in the interval [-1; 1]) indicates the intensity of the relationship between them, thus how strong is the influence of one concept over the other. The relationships between variables can be represented through an adjacency matrix (e.g.

Pluchinotta et al 2019b). In the FCM, this matrix allows the overall effects of an action on the elements in the map to be inferred qualitatively, as described below.

2.3. Ambiguity analysis

This phase aimed to detect and analyse the main differences and similarities among the different stakeholders' problem understandings, through two sequential analysis. Firstly, the FCM were examined to detect the most central elements in the stakeholders' problem understanding, the so called "nub of the issue" (Eden, 2004). Secondly, the FCM capability to simulate qualitative scenarios (e.g. Borri et al 2015) were used to describe the expected evolution of the variables' states according to the stakeholders' problem understandings.

Concerning the first analysis, FCM centrality degree was assessed: higher is a variable centrality degree, more central is the variable, and more important is the concept in the stakeholder's perception. Santoro et al. (2019) describes the methodology for assessing the centrality degree. The second analysis aimed at comparing the way the involved stakeholders perceived the evolution of the system through the change of state of the FCM variables. To this aim, the FCM capability to simulate qualitative scenario was adopted (Kok, 2009). Two different scenarios were simulated and compared, i.e. the Business-As-Usual (BAU) scenario and the GW overexploitation scenario. The comparison allowed us to identify the variables that, according to the stakeholders' mental model, will be affected in case of reduction of GW quality due to overuse for irrigation purposes. Figure 4 shows the comparison between the two scenarios for the Water Development District (WDD) in Cyprus.

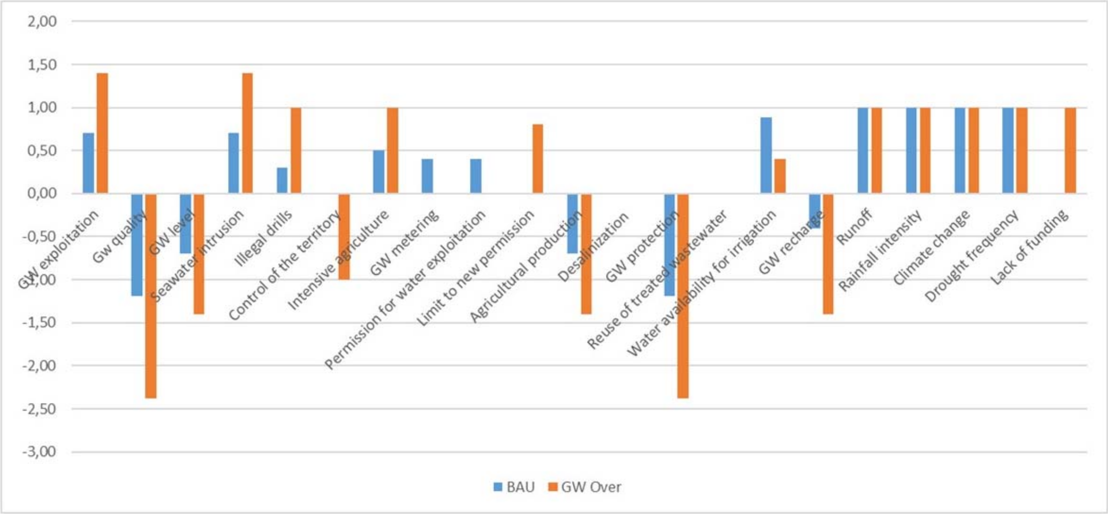


Figure 4 - Comparison between BAU and GW overexploitation scenario according to the Cyprus WDD's mental model

The graph shows that, according to the WDD's mental model, the overuse of GW for irrigation purposes will lead to a decrease of the water quality, an increase of the seawater intrusion with a consequent reduction of the agricultural production, due to the decrease of the GW quality. These are the most affected variables in the WDD's mental model. Thus, the higher the impacts of GW overuse on the variables in the stakeholder's mental model, the more central these issues are in the stakeholders' problem understanding.

The most important elements were, hence, detected by aggregating the FCM centrality degree and the impact degree, as shown in table 2. These elements represent the most important goals to be achieved through the implementation of a GW protection policy, according to the stakeholders' problem frames.

Decision actor	Variable	Centrality degree (index)	Impacts degree	Importance degree
Water Development Department	Infrastrastructure effectiveness	High	Weakly negative	Medium
	Reuse of treated wastewater	Medium	Negative	High

	Farmers' behaviour	Medium	Negative	High
	GW quality	High	Highly negative	High
	Territory control	Medium	Weakly negative	Medium
Farmers association	Agricultural productivity	Hight	Negative	High
	GW quality	High	Negative	High
	Energy costs for GW use	Medium	Negative	High
	Farmers' behaviour	Medium	Weakly positive	Medium
	Infrastructure effectiveness	Low	Positive	Medium
Regional Agricultural Department	Regional Livelihood	High	Negative	High
	Agricultural productivity	High	Negative	High
	Salinization process	Medium	Negative	High
	Infrastructure effectiveness	Medium	Weakly negative	Medium
Ministry of Agriculture	Agricultural productivity	High	Negative	High
	Optimization of water distribution	Medium	Negative	High
	Social sustainability	Medium	Negative	High
	Innovation adoption in irrigation	Low	Negative	Medium
	Territory control	Medium	Weakly negative	Medium
Farmers	Farmers income	High	Positive	High
	Agricultural productivity	High	Weakly positive	Medium
	Energy costs for irrigation	Medium	Weakly negative	Medium
	Irrigation infrastructure eff.	Medium	Weakly positive	Medium
	Innovation adoption in irrigation	Medium	Weakly positive	Medium

Regional Branch of the WDD	Seawater intrusion	High	Negative	High
	Illegal drills	High	Negative	High
	Agricultural productivity	Medium	Weakly negative	Medium
	Territory control	Medium	Weakly negative	Medium

Table 2: Identification of the most important elements in the stakeholders' problem understanding for the Cyprus case study

Table 2 shows how different stakeholders perceive the same problem differently. Some of the stakeholders used different elements to characterize the GW management problem. In other cases, stakeholders considered as central the same elements, but they perceived different evolution of the variables state. E.g. the agricultural productivity was considered important by most of the stakeholders. Nevertheless, among them, only the farmers consider this element as improving due to the increase of GW use.

A similar analysis was carried out for the Capitanata case study. The ambiguity analysis allowed us to analyse why and where stakeholders' problem understandings differ each other's. The results of this analysis were used to support the creation of a shared concern and the gather of knowledge on the issue under consideration, i.e. phase K.

2.4. C-K theory and the shared concern

A C-K theory-based tool has been designed and tested in the domain of policy design (Pluchinotta et al., 2019a for details). This participatory policy design tool (P-KCP) has been applied in both case studies for a methodological support to the K- and C- spaces expansions.

Specifically, within the policy design process decision-makers operate under conditions of uncertainty, due to limited information about policy outcomes, which can undermine policy effectiveness and complicate policy development (e.g. De Marchi et al 2016, Nair and Howlett 2016, Tsoukias et al. 2013). It has been recognised that novelty in the alternatives' design phase of a decision aiding process, can come through the expansion of the solutions space (Colorni and Tsoukiàs 2018). The expansion of the solutions space can be obtained through the evolution of problem formulations, due to revision or update (Ferretti et al. 2018) and to the alignment of ambiguous problem frames (Giordano et al 2017a). Within this context, design theory describes design processes through a formal methodology, supporting the capacity to be innovative in generation of policy alternatives (Pluchinotta et al, 2019a).

Briefly, modern design theories focus on generate objects, that are partially unknown and will be progressively discovered during the design process itself (Hatchuel et al. 2007, Agogué et al. 2014a). Thus, C-K theory is based on the distinction between two expandable spaces (Hatchuel et al. 2002). The K-space represents all the knowledge available to a designer at a given time and its elements are propositions whose logical values are known (i.e. the Designer can define them as true or false). Whereas the C-space is a set of propositions whose logical status are unknown, (i.e. it cannot be determined with respect to a given K-space) (Hatchuel et al. 2002, Agogué et al. 2014b). The design process is thus defined as the co-evolution of C- and K- spaces: Concepts are elaborated by using Knowledge and new Knowledge is gained through the elaboration of Concepts (figure 5) (Le Masson et al. 2017).

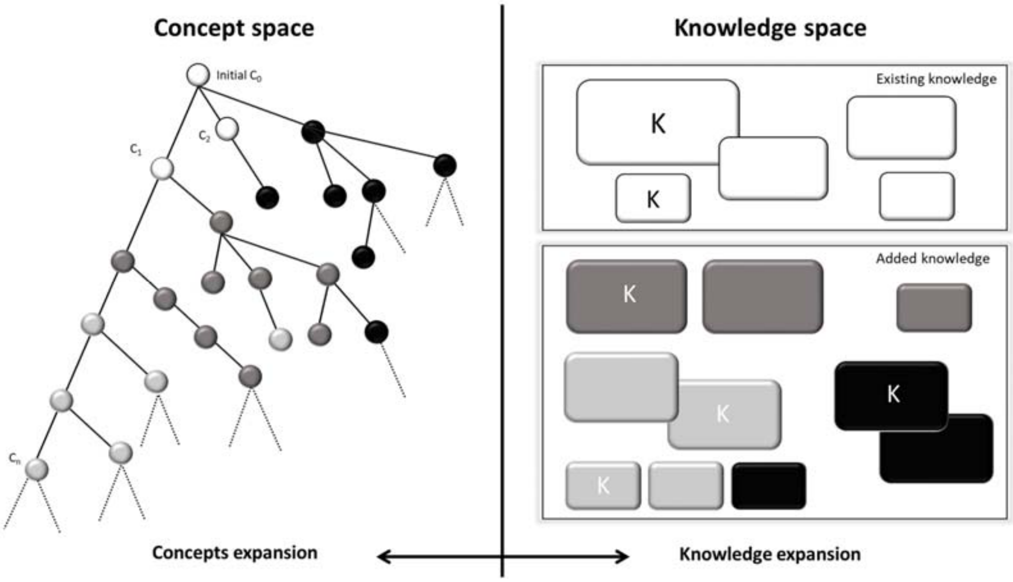


Figure 5 - The C-K approach

The phase K aims to build a shared base of knowledge supporting the subsequent generative C phase thanks to its expansions. The phase K uses the FCM and ambiguity analysis outcomes to support a participatory group activity where different stakeholders' problem frames are presented and discussed. It detects and analyses potential conflicts among stakeholders leading to the definition of common knowledge and a shared concern on the GW protection problem. The shared concern, namely a common problem formulation among the involved stakeholders, represents the starting point for the generation of policy alternatives.

Afterwards, a stakeholder generative workshop for the C-space building and expansion was carried out for the design of policy alternatives in both case studies.

During the one-day generative workshop, the process of designing policy alternatives was supported and managed accordingly to the C-K principles of innovation management. In the C phase, stakeholders evaluate the dominant design (traditional policies) and propose innovative policy alternatives through the expansion of the C-space. The C-space allows to illustrate various alternatives as concepts connected to the "initial design task" thanks to the tree-like structure (Agogue et al. 2014b). It represents the map of all possibilities, highlighting the dominant design and improving the search of new alternatives. Figure 6 shows the C-tree produced for the Apulia case study, where the initial design task was the design of GW protection policy for the agricultural sector. In both case studies, the discussions of the phase C lead to a portfolio of preferred policy alternatives shared with all the stakeholders and to the introduction of few innovative policy alternatives. For instance, for the Apulia case study, the alternative "shared management of GW aquifers" has been recognised a promising long-term strategy, enhancing the innovative management of GW through a collective decision-making process. A shared GW governance could empower the farmer community through reward regulations for virtuous GW use, overcoming the "command and control" traditional policy. The starting points for this C-space expansion were: i) a specific piece of knowledge in the shared K-space brought by one stakeholder on common pool resources management, according to Ostrom (1990)'s works, that introduced the awareness of the attributes defining the GW resource (i.e. the K-space expansion); ii) the outcomes of the ambiguity analysis that identified the pivotal role of the variable "illegal pumping" in different stakeholders' mental models (Pluchinotta et al. 2019a). Figure 6 uses a colour code: i) the branches describing known policy alternatives are coloured in black, ii) the ones in blue indicate attainable policy alternatives using existing knowledge or a combination of K-space subsets, and iii) the paths in green represent innovative policy alternatives, requiring the expansion of the K-space in order to enlarge the C-space.

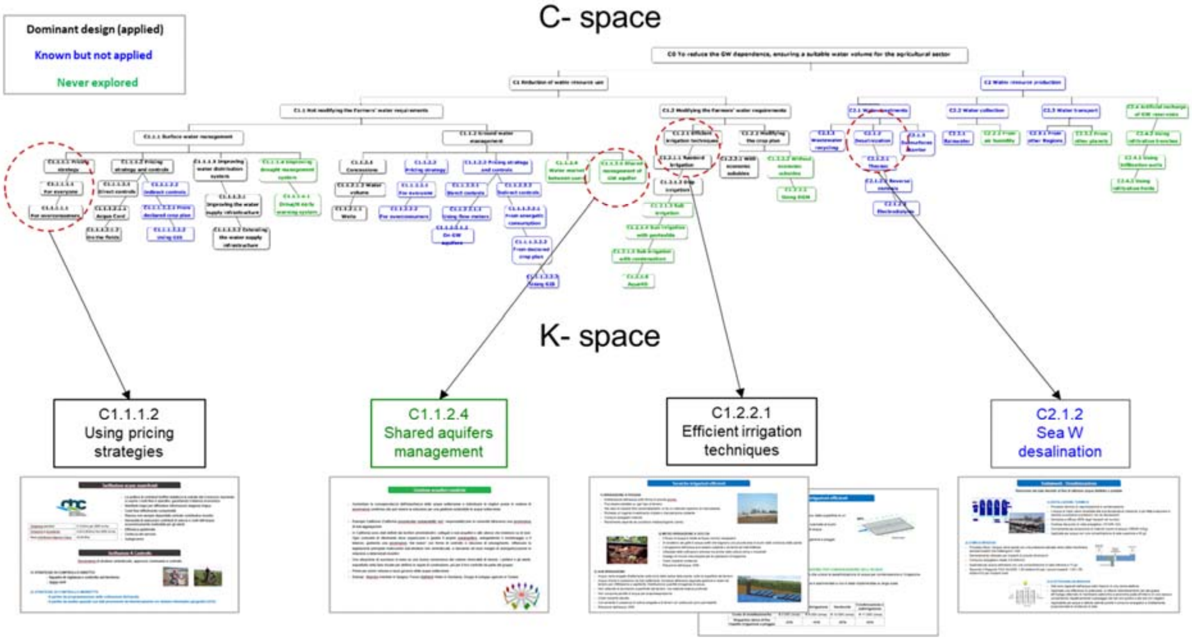


Figure 6 – The C-space showing all the policy alternatives generated (adapted from Pluchinotta et al. 2019a)

2.5. Integrated model development

As described previously, the results of the ambiguity analysis were used to support the discussion among stakeholders aiming to align individual problem frames and to support the development of the shared K-space. As result, an integrated model was developed based on the shared K-space in both case studies. Specifically, a Social FCM was defined in the Kokkinochoria case, whereas a

System Dynamic Model was developed for supporting the policy design in the Apulia case. Both models are based on the integration among the different stakeholders' mental models. In the Apulia case study, the availability of the ambiguity analysis results, contributed to enlarge the K-space, making stakeholders aware of the others' problem frames. At the end of this phase, the involved decision-actors partly adapted their frame. Particularly, the irrigation consortium became aware of the importance of providing information to farmers in time to actually influence their decision-making process. It also became aware of the illegal pumping activities, which requires a better understanding of the impact of the water price policy. Finally, the regional authority introduced the irrigation consortium's role in influencing the farmers' behaviour. These new elements were introduced in the adapted versions of the individual FCM. Then, by aggregating the individual FCM (Ozesmi and Ozesmi, 2004), the Social FCM was developed. The development of this model is described in Giordano et al. (2017a).

As further development, a System Dynamic Model was developed based on the Social FCM, as described in Pluchinotta et al. (2018) (figure 7). The model was used to simulate the impacts of the alternatives defined during the C-space creation phase and, in doing so, to contribute to further enlargement of the K space.

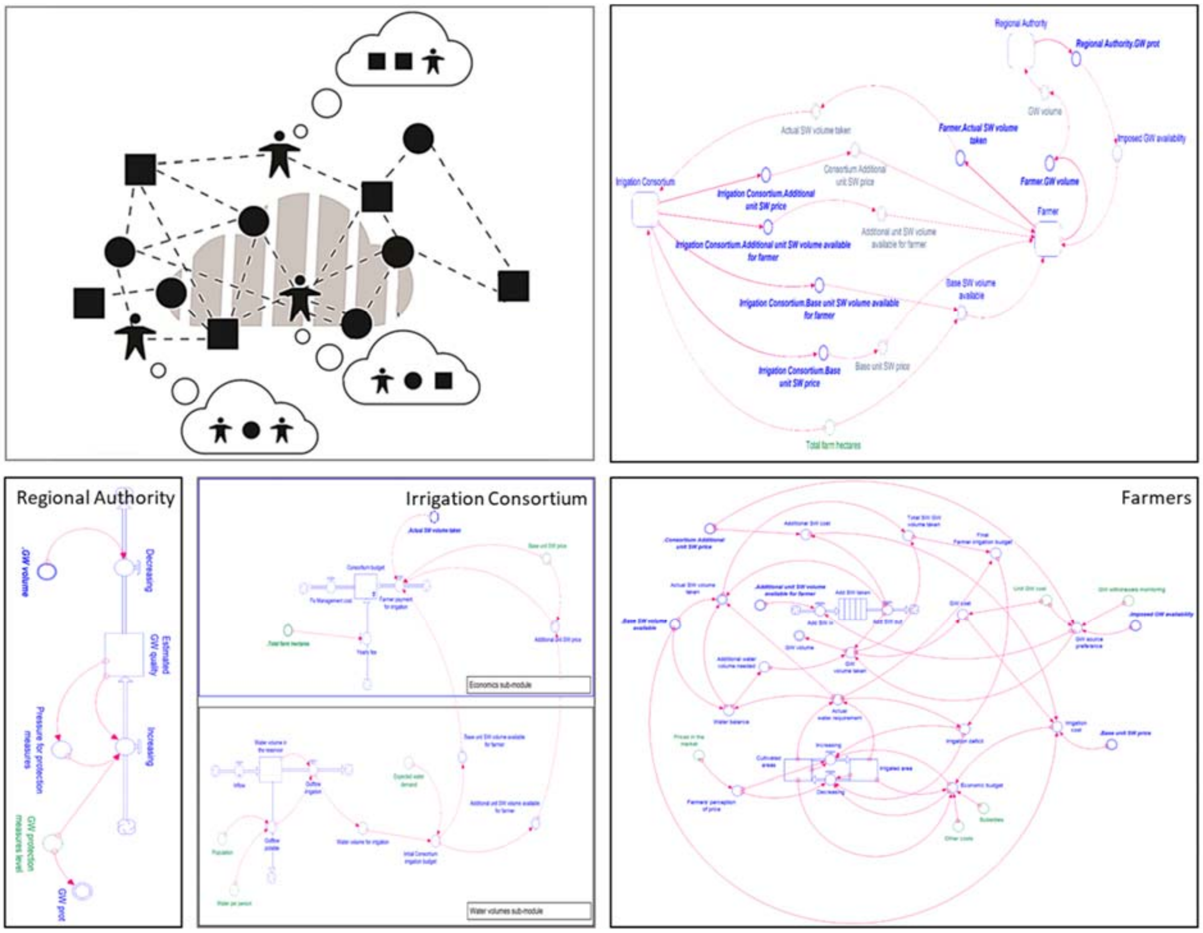


Figure 7 - SDM describing the farmers' behaviour in the Apulia case study (adapted from Pluchinotta et al. 2018)

Similarly, in the Kokkinochoria the results of the discussion during the K-space development were used to align the stakeholders' mental models and to enable the development of an integrated model. It is worth noting that in this case the misalignment that was hampering the development of the integrated modes was not provoked by the lack of common elements among the mental models. The misalignment was mainly due to differences in the perceived polarity of the causal connections and, thus, of the expected evolution of the state of the variables. In order to overcome the ambiguity as barrier, participants were required to discuss over the expected evolution of the system variables. A consensus was achieved for the interested variables. Figure 8 shows the aggregated FCM to be used for further discussing the effectiveness of the proposed alternatives with the stakeholders.

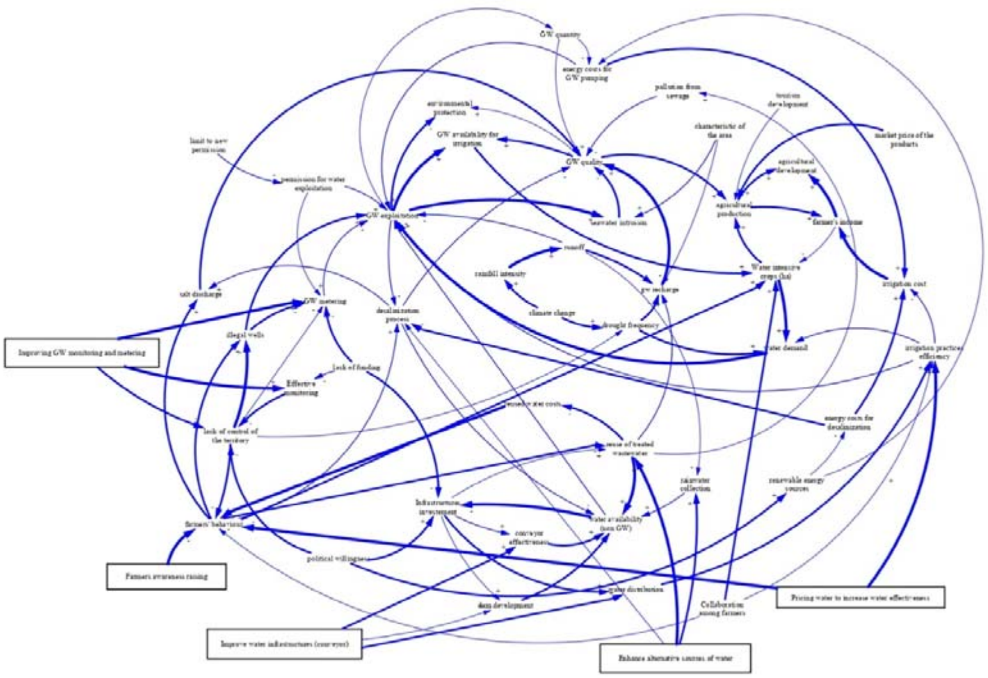


Figure 8 – Aggregated FCM developed during the stakeholders' WS in the Cyprus case study.

3. Discussion and conclusion

The results collected in the two above mentioned case studies allow us to draw some conclusion concerning the suitability of the PSM and C-K integrated approach to support analysts and modellers in dealing with ambiguity in problem framings during participatory modelling exercise for designing innovative policy alternatives. The PSM, and specifically the FCM, demonstrate their capability to structure the complex cause-effect chains affecting the stakeholder's problem understanding. The ambiguity analysis – based on the FCM modelling approach - allowed us to detect divergences and, in some cases, potential sources of conflicts in GW management. These elements were at the basis of the convergent thinking phase. Making the different stakeholders aware of the differences and similarities forced them to critically analyse their own problem framing, to identify the assumption they usually made concerning the behaviour of the other actors and to challenge those assumptions. In many cases, the discussion based on the results of the ambiguity analysis allowed to change the individual problem frames and to achieve a satisfactory alignment, allowing to co-define the share K-space capable to generate the policy alternatives for GW protection in the two case studies. Thus, the evidences collected during the experience in the case studies demonstrate that making the decision-actors aware of the existence of ambiguous problem framings is the key to enable creative and collaborative decision-making processes.

The analysis of the results obtained in the two case studies allowed to detect potential limits of the adopted approach. Firstly, it requires time and resources in the analysis phase – i.e. FCM development and ambiguity analysis. Nevertheless, the results showed that making the participants aware of the existing differences greatly facilitate the discussion. Therefore, it is possible to state that the time consuming first part of the process allowed a fast and effective convergent thinking phase.

Secondly, the adopted method claims for the long-term engagement of the stakeholders. Since the divergent thinking phase is based on the elicitation and analysis of the individual perceptions of the problem frame, having the same stakeholders participating in all the different phases is a key for the reach of the collective behaviour and the success of the whole process. Participants are sources of information and their opinions may also be compared against available data, contributing to further refinement of the model (Rouwette, 2017). To this aim, efforts were carried out since the early phases of the method implementation in order to meet the actual needs and concerns of the different stakeholders. The results of the individual FCM analysis concerning the main goals to be achieved were used to enhance the communication between the analysts and the participants and, thus, guarantee the stakeholders' involvement in the different phases of the process.

Lastly, the stakeholders expressed the need to have quantitative assessment of the effectiveness of the selected measures in protecting GW. To this aim, the models developed during the interaction with the stakeholders in the two case studies are used for providing further information to the involved stakeholders.

From a behavioural research perspective, as argued by several scholars (e.g. Hämäläinen et al. 2013) there is now a grow in need to incorporate different perceptions into modelling interventions

(White, 2016). In this sense the proposed study offered interesting insights for the understanding of the collective behaviour, proposing an integrated method to address behavioural concerns and to avoid the use of behavioural "objectivistic" assumptions in participatory models.

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