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Integrating Problem Structuring Methods And Concept-Knowledge Theory For An Advanced Policy Design: Lessons From A Case Study In Cyprus

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Abstract. Evidence suggests that policies frequently fail due, on the one side, to a simplification of the uncertainty and complexity associated with stakeholders' problem understanding and, on the other side, due to the lack of methodologies for innovative generation of policy alternatives. This work describes a methodology based on the integration of Problem Structuring Methods and Concept-Knowledge Theory, as a mean to transform ambiguity in problem framing from a barrier to an enabling factor in collaborative settings. This methodology supports the generative design process for innovative and consensual policies. The methodology was implemented for a case of designing water management policy in the Republic of Cyprus.

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1. Introduction

Policy design is an intricate challenge for policy makers as future policy outcomes are inherently uncertain (Nair & Howlett 2016). From a decision aiding perspective (see Tsoukias 2007), policy design can be considered the result of a collective decision-making process involving multiple stakeholders for the generation of a set of policy alternatives (Pluchinotta et al. 2019a). Alternatives tend to be few and similar when the policy design process is constrained (Alexander 1982). In contrast, a decision aiding process can bring novelty through the expansion of the solutions space (Colomi and Tsoukiàs 2018).

Especially the presence of ambiguity in problem framing among different decision-makers, as one type of uncertainty, indicates confusion regarding the problems for which the policy is expected to be designed (Weick 1995). Ambiguity reflects the multiplicity of interpretations that different actors bring to a collective process (Giordano et al. 2017). Ambiguity, which can be considered as a form of uncertainty and indeterminacy (Brugnach et al. 2012; Van den Hoek et al. 2012) is ineradicable in complex decision-making processes (Jasanoff, 2007).

The set of alternatives can be expanded also through the evolution (or integration) of problem formulations, such that stakeholders may enrich their perspectives, and establish reciprocity (Ferretti et al. 2019), recognizing the presence of ambiguity. It has been suggested that divergent frames can still yield organized collective action when the interaction frames are sufficiently aligned (Brugnach et al. 2011; Dewulf and Bouwen 2012). Through interaction mechanisms, different decision-actors tend to align their problem frames, overcoming the barriers that stem from the presence of ambiguity.

The problem of an advanced policy design process is shared by several research fields (i.e. policy studies, design theory, decision theory and operational research), although their intersection has not been properly investigated (see Ferretti et al., 2019). Some preliminary attempts have been proposed. For instance, Pluchinotta et al. (2019a) experimentally used a Design Theory methodology to support a formal process for the design of policy alternatives. The pilot case study

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3 created new insights and evidence regarding the issues at stake, bringing together stakeholders,
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5 experts, institutional and non-institutional actors.
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8 The present paper proposes an upgraded methodology, integrating Design Theory, specifically
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10 Concept-Knowledge (C-K) theory, and Problem structuring Methods (PSMs) for an advanced
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12 design of policy alternatives. PSMs (Rosenhead and Mingers 2001) build individual models of
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14 situations (Franco, 2013), where a model is an integrated representation of a situation that supports
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16 negotiation or develops new understanding (Smith et al. 2019). PSMs contribute to shape shared
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18 understanding and commitment across stakeholders (Ackermann, 2012) through facilitation
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20 (Franco & Montibeller, 2010), participation (Rosenhead, 1996) and stimulating dialogue (Mingers
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22 & White, 2010).
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26 C-K theory, in turn, defines the design process as the co-evolution of two expandable spaces, a
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28 space of Concepts (C-space) and a space of Knowledge (K-space) (see Hatchuel et al. 2003,
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30 Agogué et al. 2014b, Le Masson et al. 2017). Within a given design process, every C-space has a
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32 strong dependency on the related K-space, i.e. every element in the C-space relies on the structure
33
34 and content of the knowledge base (Hatchuel et al. 2007). In multi-stakeholder settings, developing
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36 the K-space starting from different, often conflictual problem framings, is challenging. Therefore,
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38 PSMs can support the analysis of ambiguities in problem framing, detecting similarities and
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40 differences, and therefore enhance the effectiveness of C-K theory in policy design. When
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42 integrating PSMs and C-K theory, PSMs need to be adapted to the design of policy alternatives, a
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44 field of application they have not originally been developed for, and C-K theory driven tools need
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46 improved knowledge elicitation and structuring methods to account for the complexity of the K-
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48 space in policy making situations (e.g. De Marchi et al. 2016) and the ambiguity in problem
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50 framing arising in multi-stakeholders settings (Giordano et al. 2017).
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55 Such an integrated and participatory policy design tool was implemented for the design of
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57 environmental policies for groundwater protection in the Kokkinochoria area (Republic of
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59 Cyprus). PSMs, specifically Fuzzy Cognitive Maps (FCM), were implemented to elicit and
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2
3 structure individual problem understandings in the area, detecting and analysing differences in
4 stakeholder concerns and interests. The C-K theory driven tool was then used to align the different
5 problem understandings and available knowledge and enable creative development of innovative
6 and consensual environmental policies. Building on a previous application of the C-K theory
7 framework by Pluchinotta et al. (2019a), in the present work, the K-space expansion phase was
8 enhanced by making decision-makers aware of the main reasons of ambiguity, while the C-space
9 expansion was realized by accounting for the alternatives that could be implemented in order to
10 overcome the main differences in problem framing (Giordano et al. 2020a).

11
12 The remainder of this paper is structured as follows. Section 2 reviews the concept of policy design.
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14 Section 3 describes the case study, while Section 4 describes and discusses the methodology and
15 its application. Lastly, section 5 discusses lessons learned.

30 2. Policy design

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32 Policy design is a specific form of policy formulation based on the gathering and application of
33 knowledge about policy tools for the development and implementation of strategies aimed at the
34 attainment of policy ambitions (Howlett 2011). At a time when policymakers are tasked with
35 developing innovative solutions to increasingly complex policy problems, the need for intelligent
36 design of policies and a better understanding of the policy formulation processes they involve has
37 never been greater.

38
39 The concept of policy design is controversial. Some academics suggest that policies cannot be
40 “designed” as one would design a physical object (Dryzek et al. 1988, DeLeon 1988). Other
41 scholars state that policies are designed and can be systematically studied and improved, similar
42 to the way one would improve urban planning or product creation (e.g. Shon 1992, Howlett 2011).
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44 Research on policy design often responded to 1970s implementation studies that held institutional
45 systems responsible for policy failures (Sidney 2007). This involved answering a set of key
46 questions such as: determining what constitutes a design process, what makes one successful, and
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3 what makes one design better than another (Howlett 2014). However, a design-oriented policy
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5 formulation contributes to the awareness of the “boundaries” of rationality (Simon 1947) in the
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7 policymaking process, in order to expand the set of policy alternatives, hoping to improve the
8
9 outcome (Pluchinotta et al. 2019a).

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12 Fields such as political science, economics, decision analysis and operational research, have
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14 developed methods addressing policy design, e.g. best practice analysis, consensus building
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16 activities (Bailey et al. 2016), ex-ante and ex-post evaluation (Dollery et al. 1996), public sector
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18 operational research (e.g. Larson 1981, Pollock et al. 1994, Keeney 1996), problem structuring
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20 methods (e.g. Eden 2004, Rosenhead 2006), soft system methodologies (Checkland 2000), group
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22 facilitation and participatory modelling (e.g. Vennix 1996, Voinov et al. 2016, Pagano et al. 2019),
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24 system thinking (Sterman 2000) and Multi Criteria Decision Analysis for public sector (Belton et
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26 al. 2002, Marttunen et al 2013) (for further details see Ferretti et al. 2019). However, the existing
27
28 formal methodologies of policy design were not originally conceived for this task (Ferretti et al.
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30 2019, Pluchinotta et al. 2019a). Researchers and practitioners use adapted methodologies without
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32 considering the emerging problems connected to the design of policy alternatives.
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37 Firstly, policy design is context-based, and policy transfer does not always provide satisfying
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39 outcomes. Policy design takes place within a specific historical and institutional framework that
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41 largely determines its content (e.g. May 2003). The exact processes through which policies are
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43 articulated vary by domain and reflect the differences between forms of government as well as the
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45 particular configuration of issues, actors and problems (Ingraham 1987, Howlett 2009). For
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47 instance, Bobrow and Dryzek (1987) advocate for contextual designs that explicitly incorporate
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49 values, and Weimer (1992) points out that developing truly innovative policy alternatives involves
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51 crafting designs that reflect substantive, organizational, and political contexts.
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55 Secondly, policy design is not a linear practice. Some policies emerge from processes such as
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57 logrolling (i.e. the practice of exchanging favours), patronage or bargaining and cannot be thought
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59 of as having been formally "designed" (Howlett 2011). In some circumstances, policy design
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3 outcomes will seem highly contingent and "less rational", driven by situational logics and
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5 opportunism rather than careful deliberation and assessment (e.g. Cohen 1979, Dryzek 1983,
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7 Kingdon 1984).

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10 Lastly, Linder and Peters (1988) argued that the abstract concept of policy design can be separated
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12 from the practical process of decision-making, in the same way as abstract architectural concept
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14 can be separated from its final spatial embodiment. In this view, policy design involves a
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16 systematic development of a set of policy alternatives by using knowledge about policy means
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18 gained from experience, and reason. This is followed by the development and adoption of a
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20 possible set of actions that are likely to succeed in attaining the predetermined policy goals
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22 (Bobrow 2006). Such a distinction allowed orientating policy studies towards policy design, by
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24 arguing that policies can be conceptually separated from the process of policy design. Central to
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26 the policy design perspective is the notion that public policy contains a design framework of ideas
27
28 and instruments to be identified and analysed (Sidney 2007).

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31 Thus, the design orientation of policy studies allows to explore how policy design can improve
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33 policymaking practice and to support the analysts. Specifically, policy scholars seek to reduce
34
35 "randomness" of policy making by structuring the process. For example, Alexander (1982)
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37 recommended a "deliberate design stage" in which policy analysts search for policy alternatives in
38
39 order to improve policy outcomes. He argued that the systematic design of policy alternatives
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41 involves creativity, in addition to rational processes of search and discovery. Linder and Peters
42
43 (1988) proposed a framework that policy analysts can use to generate, compare and match policy
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45 alternatives, resulting in a less random process of policy design. Bobrow and Dryzek (1987)
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47 proposed to search for alternatives from a wide range of policy designs (e.g. welfare economics,
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49 public choice, political philosophy), while Fischer and Forester (1993) suggested that looking at
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51 policy dialogue could unlock policy innovation and creativity. As such, the inclusion of
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53 marginalized populations and local knowledge in the design process could potentially play an
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55 important role in policy improvement.

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3 In conclusion, the existing mainstream literature on policymaking seems to underestimate the
4 potential for solving policy problems through policy design (Ferretti et al 2019) and, instead,
5 focuses on design as part of the political process, something that happens in a black box (e.g.
6 Birkland 2011), experimenting and transferring approaches derived, for example, from best
7 practice analysis, participation and consensus building activities (Bailey et al 2016). Nevertheless,
8 Dryzek (1983) argues that public policy's capacity to respond effectively to complex social
9 problems could be significantly enriched by a shift in policy analysis from an assessment of pre-
10 ordained and well-defined policy alternatives towards formal policy design (Considine 2014).

11
12 This idea encourages reflection on the role of Design Theory as a new approach for the definition
13 of innovative policy alternatives (Pluchinotta et al. 2019). In recent years there has been a growing
14 interest in Design Theory by governments, seeking to innovate policy practices (Bailey et al 2016,
15 Kimbell 2016). Exemplary attempts made in public policy context within design-based
16 approaches, are detectable in "policy labs" appearing in the past years: the New York Public
17 Design Commission¹, the European Policy Lab², the UNESCO Inclusive Policy Lab³, the Dutch
18 Mind Lab⁴, the PoliMi DESIS Lab⁵ supporting design-driven innovation. Furthermore, the UK
19 Policy Lab⁶ is an example of collaborative space where innovative policymaking processes are
20 experimented with. It claims to bring new policy tools and techniques to the UK government
21 departments, helping design policies around people's experience, using data analytics and new
22 digital tools (i.e. Open Policy Making Toolkit⁷). Lastly, the European funding campaign Design
23 for Europe⁸ introduced design thinking concepts to explore policy solutions. Several projects have
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53 ¹ <http://www1.nyc.gov/site/designcommission/index.page>

54 ² <http://blogs.ec.europa.eu/eupolicylab/>

55 ³ <http://en.unesco.org/inclusivepolicylab/>

56 ⁴ <http://mind-lab.dk/en/>

57 ⁵ <http://www.desisnetwork.org/>

58 ⁶ <https://openpolicy.blog.gov.uk/category/policy-lab/>

59 ⁷ <https://www.gov.uk/guidance/open-policy-making-toolkit>

60 ⁸ <http://www.designforeurope.eu/>

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3 been developed such as the Design Policy Lab in partnership with Deep Initiative⁹, promoting
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5 European innovation policies.
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8 However, the identified processes of policy design lack a formal approach, which limits the
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10 process of generating sets of policy alternatives. In lack of a formal description, the complex
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12 processes of building policy alternatives remain obscure. Within this context, we are interested in
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14 exploring how Design Theory can be combined with a Decision Aiding approach, in order to assist
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16 the innovative design of public policies.
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24 **3. The case study**

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26 The participative multi-methodology was implemented for supporting the design of environmental
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28 policies for groundwater (GW) protection in the Kokkinochoria area (Republic of Cyprus).
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33 **3.1. The context**

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35 Similarly to all Mediterranean countries, GW resources play a major role in the water economy of
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37 Cyprus and constitute the main supply for all applications (MED-EUWI, 2007). Although in recent
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39 years the introduction of non-conventional resources has considerably reduced the GW pressure
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41 (ibid.), Cyprus remains the most water scarce country in Europe (EEA, 2007). Water is essential
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43 not only for sustaining the agricultural sector (accounting for ca. 70% of total water demand) but
44
45 also for the booming tourism sector (according to some estimations 10% of total water
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47 consumption).
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51 The study region Kokkinochoria is situated at the South-eastern tip of the island and mostly
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53 coincides with the Kokkinochoria aquifer. The aquifer crosses all four self-administrative entities
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60 ⁹ <http://www.designpolicy.eu/> and <http://www.deepinitiative.eu/>

of Cyprus (the Republic, the occupied North Cyprus, the British Sovereign Territory and the UN Buffer Zone), which complicates the management of GW (Zikos and Roggero, 2012).

The aquifer is the most degraded of the island in terms of both quantity and quality of water due to over-abstraction and seawater intrusion (Figure 1). During the last decades and despite the rapidly diminishing water resources, there has been an increasing demand of water for tourism (the study area is the most popular tourist destination on the island) and for agriculture. The region mostly produces potatoes.

Alternative water sources, namely water transfer from the Western part of the Island, desalination and re-use of treated wastewater, have addressed the problem of overexploitation to some extent, but without resolving it completely. As a result, the remaining GW is so saline in most localities in Kokkinochoria that it cannot be used directly for irrigation. Instead it is mixed with the water provided by the South Water Conveyor or it is first treated by illegal small mobile desalination plants.

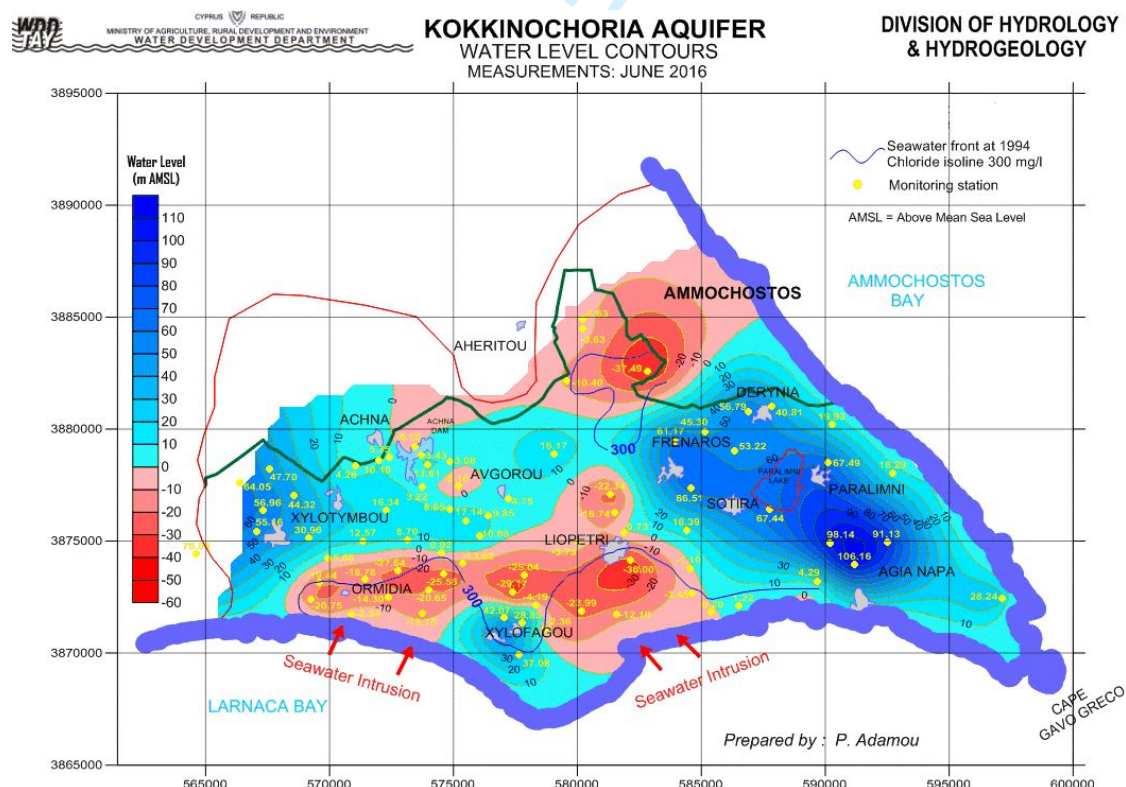


Figure 1- Kokkinochoria (CY_1) Aquifer (Source: Water Development Department). Notice that the area north of the UN's Green Line is not under the control of the Republic of Cyprus

A number of socio-technical measures have specifically aimed at halting the overuse of GW, but with limited success. Specifically, the South Water Conveyor, the largest ever water development project undertaken by the Government of Cyprus aims at collecting and storing surplus water from the most water privileged regions of the island and convey it to areas of demand for both domestic supply and irrigation.

Kokkinochoria receives the lion's share of the transferred water for irrigation. The project was expected to minimize GW use, a hope that gradually faded as the demand exceeded the supply. One of our interviewees explained the situation using a metaphor: "[...] the conveyor is like a bus. When it started, it was meant to have 50 seats, and the area of Kokkinochoria needed 30. What I mean to say is, the pipe network was more than sufficient. With the passage of time however, the demands increased but the supply remained the same. Right now, the bus passengers are sitting on the roof".

Additional measures were specifically targeted at another problem characteristic for Kokkinochoria: the high number of unlicensed (illegal) boreholes. An integrative step-wise approach was adopted by the Water Development Department (WDD) aiming at first registering existing boreholes, then installing water meters and in parallel stopping the issuing of new licences. Although island-wide this effort was largely a success, the situation only had minimal impact on Kokkinochoria. The number of unlicensed boreholes remained excessively high and therefore the installation of water metres and the "no-new-licences" policy largely failed. Table 1 summarizes the key policy elements of the case study.

Table 1 - Key policy elements of the case study

Policy Goals	<ol style="list-style-type: none"> 1. Provide sufficient water in both quantitative and qualitative terms for domestic and agricultural use 2. Protect GW quantity and quality in the Kokkinochoria aquifer
Policy Means	<ol style="list-style-type: none"> 1. Water transfer via the South Conveyor 2. Halt excessive water abstraction by: i) registering boreholes, ii) installing water metres, iii) stopping the issuing of new licences
Policy Failures	<ol style="list-style-type: none"> 1. Limited capacity (out-dated project, increase of demand) 2. Problematic water distribution between users (not significantly taking into account differences between users and uses of water)

	3. Failure to register the vast majority of boreholes (largely due to lack of trust in institutions), leading to minimum impact of water metering and the no-new licences policy
Time Framing	From several years to decades
Stakeholders	Ministry of Agriculture, Natural Resources and Environment via its National and Regional Departments (most notably the Water Development Department), Farmers, Agricultural Associations

3.2. The stakeholders

Several actors are involved in the decision-making processes regarding GW use in Kokkinochoria. However, both at National and Regional levels the exclusive responsibility for the management of water belongs to the Water Development Department (WDD), with several other governmental agencies holding a consulting role. The key National and Regional Governmental Agencies operating in the study area are:

- The Water Development Department (WDD) under the Ministry of Agriculture, Natural Resources and Environment (MANRE) has exclusive responsibility, according to the current legislation, for all water management on the island and according to the official mandate for “the protection and the rational and sustainable development and management of the country’s water resources within the framework of the Government of Cyprus’s water policy”. The regional office of the WDD deals with more technical aspects like recording the level of the water table, the network of deep drill wells and the falling level of groundwater. They are also responsible for measuring the quality and salinity of the water and for issuing permissions of water extraction, specifying who can pump water and how much.
- The Department of Agriculture, under MANRE, holds a consulting role and works closely with both farmers and the WDD at all levels. In a way, the Department also mediates between the WDD and farmers, by estimating the water needs of cultivations, or monitoring the water use for irrigation, and advising the WDD on these needs. The process and advisory role are facilitated with the operation of regional offices.

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3 – The Department of Environment, under MANRE, together with its regional offices, advises
4 the government on environmental policy and the coordination of environmental programs.
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6 The department also supervises the adoption and implementation of European policies and
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8 national legislation on the environment. Moreover, the department promotes the enforcement
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10 of laws relating to Water Pollution and Management of Waste and encourages environmental
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12 awareness and information. However, their practical role in GW management is rather
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14 minimal, if existent at all.
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19 The stakeholders representing the agricultural sector are the farmers and the agricultural
20 associations. Cyprus has a long history and a considerable number of very active farmers'
21 associations that exercise considerable influence on governmental decisions. Broadly speaking the
22 associations (each representing a different political party) have the shared goal of developing the
23 agricultural economy, improving the labour conditions and livelihoods of farmers, supporting
24 social and technological innovation in the agricultural sector and protecting the environment.
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26 Agricultural associations lobby the government for solutions in irrigation and water supply.
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35 The farmers in the region can be categorised into two types: large farmers, usually farming
36 enterprises, and small family farms. These two categories may be further distinguished in terms of
37 full time (either large or small farmers) and part-time farmers (usually small or very small
38 landowners). The latter can be further distinguished into two subcategories: part-time farmers that
39 are basically professional farmers but need to complement their income by a second profession
40 (often in the tourism sector), and non-professional farmers exercising farming for pleasure (often
41 without any profit from the activities).
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51 Large farmers are often exporting their products. There is a recent trend to utilise –illegal- mobile
52 desalination plants to treat the abstracted groundwater so it can be used for irrigation. These
53 farmers are facing increasing costs of energy (pumping of groundwater) and their demand is rarely,
54 if ever, satisfied by the available water from the South Conveyor. Smaller farmers, either full or
55 part-time, are struggling to meet the demand for water for their crops and they strongly prefer
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3 water coming from the South Conveyor, although this is complemented by abstracted GW. These
4 farmers increasingly quit agriculture or are forced to find a second or seasonal job. Family farms
5 contribute significantly to regional production and to the income of the family.
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9 Small farmers were criticised in most of the interviews, whether these be conducted with
10 governmental agencies, associations or other farmers, as the most unsustainable users of water.
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13 The share of water they receive from the South Conveyor is also regarded by many as a complete
14 waste of a precious resource. According to a governmental interviewee: “[this category] I call
15 gardens of Eden, especially in areas with access to the water network or a drill well. They plant,
16 for example, 50 citrus trees, for domestic consumption supposedly, although two trees would
17 provide more than enough for a household. They might also have olive trees, or a holiday house.
18 These cases I consider wasteful, because they end up serving non-productive needs, such as
19 entertainment or relaxation. [...] This also creates conflicts around conveyors and the network
20 about access and the quantity available”.
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35 **4. The methodology for advanced policy design and its application to the case**

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37 The present section briefly describes the integrated methodology used for the innovative design of
38 policy alternatives within a Design Theory framework (Pluchinotta et al. 2019a for details). A C-
39 K theory-based tool, namely Policy-KCP (P-KCP) was improved and applied in order to overcome
40 the barriers due to ambiguity in problem frames, and the creation of the shared concern as a starting
41 point for the generation of policy alternatives. For sake of brevity, the case study activity is used
42 for describing the different steps of the adopted methodology.
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54 **4.1. The K-space building phase**

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56 The aim of this phase is to build a shared base of knowledge (K-space) by combining and aligning
57 the individual stakeholders' knowledge - i.e. the K-spaces - in order to support the subsequent
58 generative phase (Policy C phase or P-C phase). The construction of this shared knowledge space
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3 needs to be consensual. Thus, the P-K phase intends to: i) elicit and structure the different
4 stakeholders' problem understandings; ii) support the identification of common knowledge on the
5 GW protection and water management problem; iii) detect and analyse potential conflicts among
6 decision-makers.
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12 The stakeholder involvement process for building the K-space is structured in three phases:
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- 14 - Elicitation and structuring of individual stakeholders' perceptions of the main issues and
15 concerns related to GW protection and management through individual semi-structured
16 interviews and individual Fuzzy Cognitive Maps (FCM).
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- 22 - Analysis of the main differences in problem understanding (Ambiguity Analysis) through
23 comparison of individual FCM. To this end, two elements were accounted for: the most
24 central elements in the FCM and the expected dynamic evolution according to the FCM
25 simulation.
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- 30 - Development of the overall K-space combining the individual stakeholders' K-spaces and
31 aligning the different perceptions. The final aim is to reach consensus over a shared concern
32 and a common knowledge between each viewpoint.
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38 Generally, the K-phase aims to gather missing information and build a comprehensive summary
39 of current knowledge about the issue under consideration. In this work, it combines the
40 stakeholders' knowledge - obtained through FCM analysis and scenario simulations - with
41 scientific literature studies, the available data, emerging technologies, best practices, etc. As
42 described further in the text, the overall K-space is developed by combining and aligning the
43 individual stakeholders' K-spaces.
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51 Firstly, individual semi-structured interviews were carried out aiming to understand how different
52 decision-makers (institutional and not) perceive the same problem. During this step, stakeholders'
53 roles, objectives and values were elicited. To this end, the interviews were based on 10 questions
54 for institutional actors and 14 questions for farmers grouped according to three main issues: i)
55 stakeholders' previous experience with water management issues; ii) stakeholders' knowledge on
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the main drivers influencing the problems pointed out and impacts, both direct and indirect; iii) stakeholders' knowledge regarding strategies used for dealing with these problems. The interviews were carried out involving institutional decision-makers and farmers (with slight differentiations in the guiding questions, see Supplementary Material for the original questionnaire). Concerning the latter, a sample of farmers was interviewed. In order to guarantee heterogeneity, the sample was created by considering the different characteristics of farms, i.e. size, crop patterns, part or full time. The farmers' FCM was developed by aggregating the individual sub-FCM. The process of individual sub-model aggregation ended when no new concepts and/or relationships emerged after a number of interviews (e.g. Özesmi & Özesmi 2004; Pluchinotta et al. 2018). For the selection of the stakeholders to be involved in the knowledge elicitation process, "snowballing" or "referral sampling" (Reed et al. 2009) was implemented. Specifically, the selection process started with the actors mentioned in the official documents and, during the interviews, each stakeholder suggested the involvement of other stakeholders considering their role and expertise.

In total 20 interviews were conducted on several occasions between April and June 2017 (see Table 2). The average duration of the interviews was 60 minutes, varying however from 15 minutes to 3 hours.

Table 2 - Interviews conducted with Cypriot stakeholders

Group	Sub-Group	Notes	No. Interviews
Administration	National	Water Development Department, Department of Agriculture (Ministry of Agriculture, Natural Resources and Environment)	2
	Regional	Regional Departments of Agriculture, of Water and of Environment	3
Associations	-	Agricultural Associations	2
Farmers	-	Large	3
		Small	4
		Non-Professional	3
Others	-	Other water users (not used in the model)	3

Secondly, the information derived from the semi-structured interviews was processed in order to build individual FCM, allowing investigating how people perceive a given system and comparing the perceptions of different groups of stakeholders (e.g. Eden 2004; Kosko, 1986). Each FCM variable represents an item related to water management according to the stakeholder's conceptual model, while the weighted and directional arcs symbolise causal relationships between items. The interconnection weights are in the interval $[-1, 1]$ and denote the strength of the connection between items of the map (Aguilar, 2005). The weights were assigned by the stakeholder during the semi-structured interviews. For instance, the individual FCM (Figure 2) shows that, following the WDD's conceptual 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 GW quality. Afterwards, the weights were used for developing adjacency matrices.

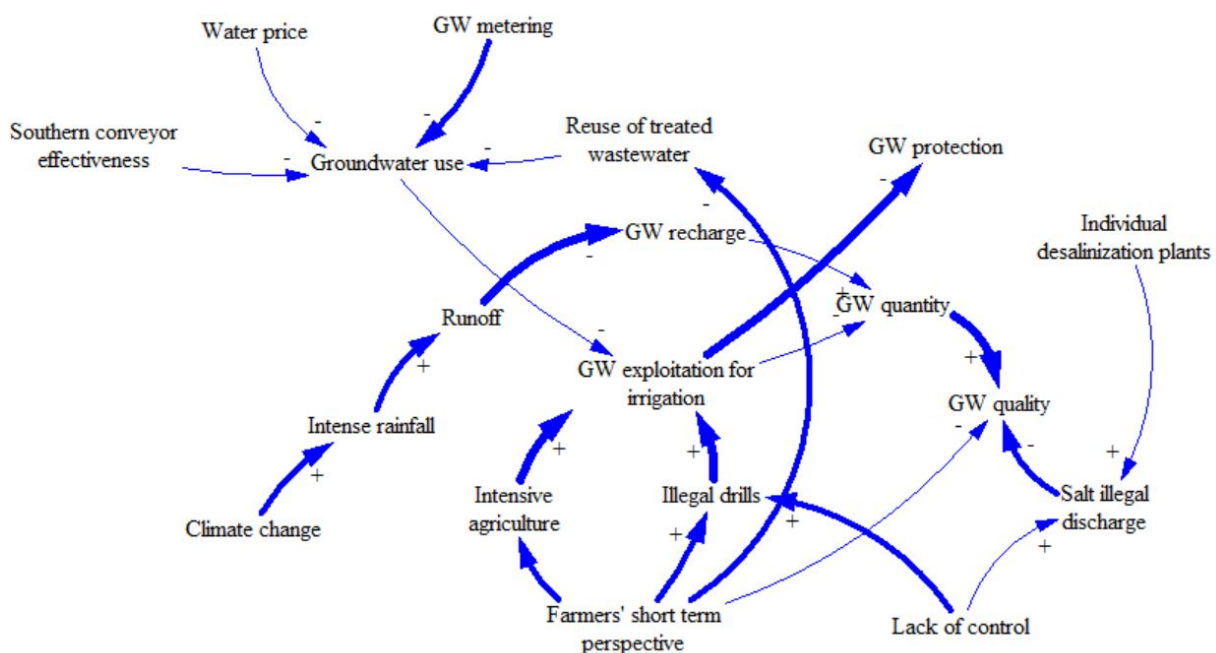


Figure 2 – Water Development Dpt.'s FCM

For each variable of the FCM, the Centrality Degree was measured, summing the incoming and outgoing cumulative strength of the connections entering/exiting the variable (Eden, 1992). The higher the Centrality Degree, the more important is the concept in the stakeholder's problem

understanding (see Giordano et al. 2020b and Santoro et al. 2019 for more details on the methodology). The Centrality Degree is a number within $[0, 1]$. In order to be used in the importance degree assessment, the values were translated into fuzzy linguistic assessment (Zimmermann, 1991). Figure 3 shows the fuzzy linguistic function for the Centrality Degree. The x-axis represents the numerical value of the Centrality Degree. Three different fuzzy sets were defined, i.e. “Low”, “Medium” and “High”. The y-axis represents the membership degree of the numerical value to the fuzzy linguistic set (e.g. Giordano et al. 2020b).

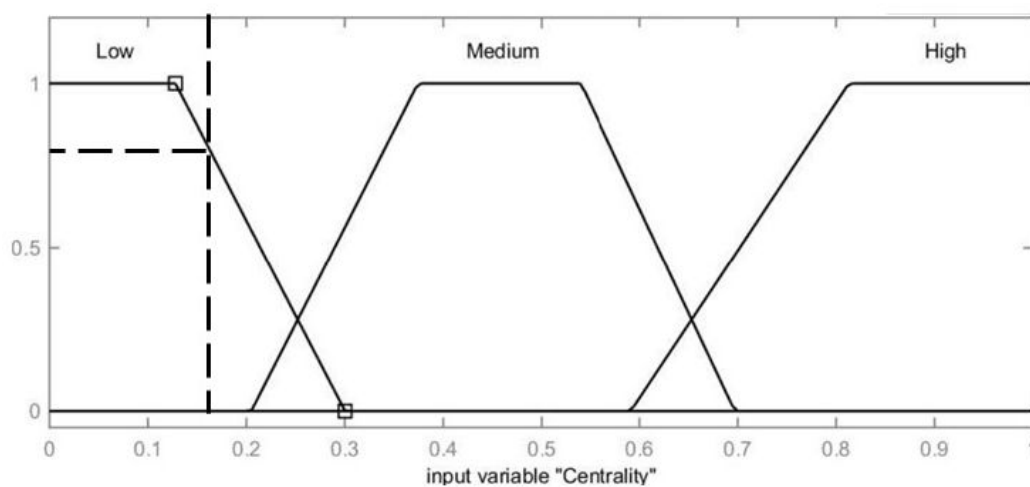


Figure 3 - Fuzzy linguistic function for the centrality degree (Giordano et al. 2020b)

Afterwards, related FCM qualitative scenarios (e.g. Borri et al 2015, Kok 2009, Pluchinotta et al. 2019b) were simulated to investigate the expected evolution of the variables' states according to the stakeholders' problem understandings. Two different scenarios were simulated in this work, i.e. the Business-As-Usual (BAU) scenario and the GW stress scenario. Following Kok (2009), the FCM scenarios were simulated by changing the values of the variables in the initial state vector. That is, the GW stress scenario was simulated by activating the climate variables in the FCM initial state vector. Figure 4 shows the stakeholder 'Agricultural Dept.'s conceptual map and Figure 5 displays the comparison between the two aforementioned scenarios.

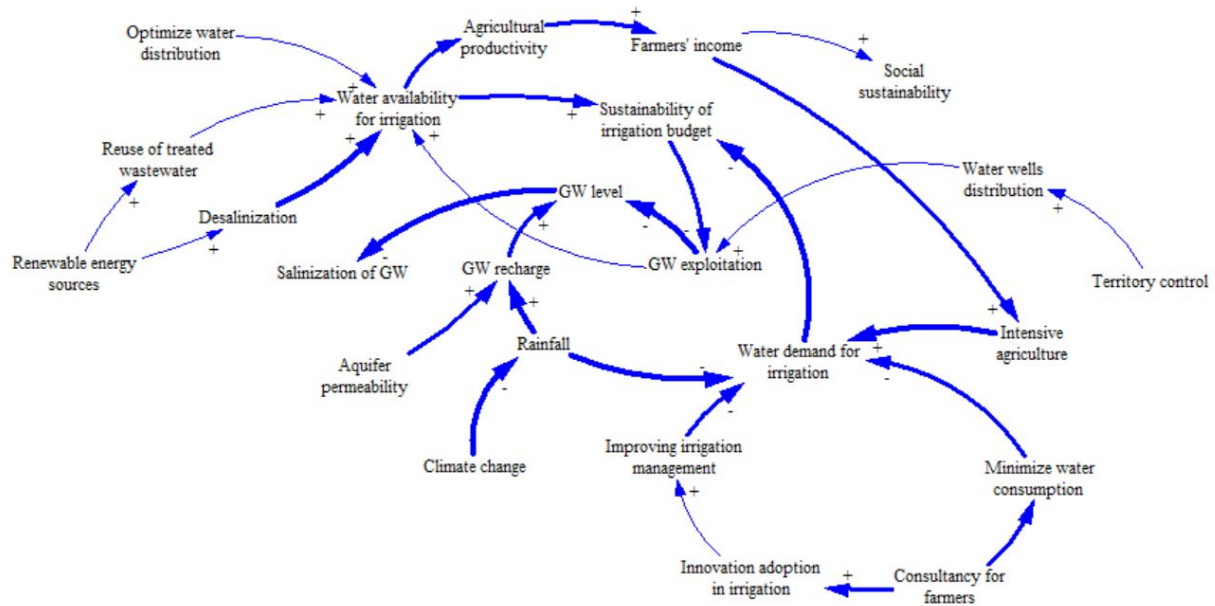


Figure 4 - Agricultural Dept.'s FCM

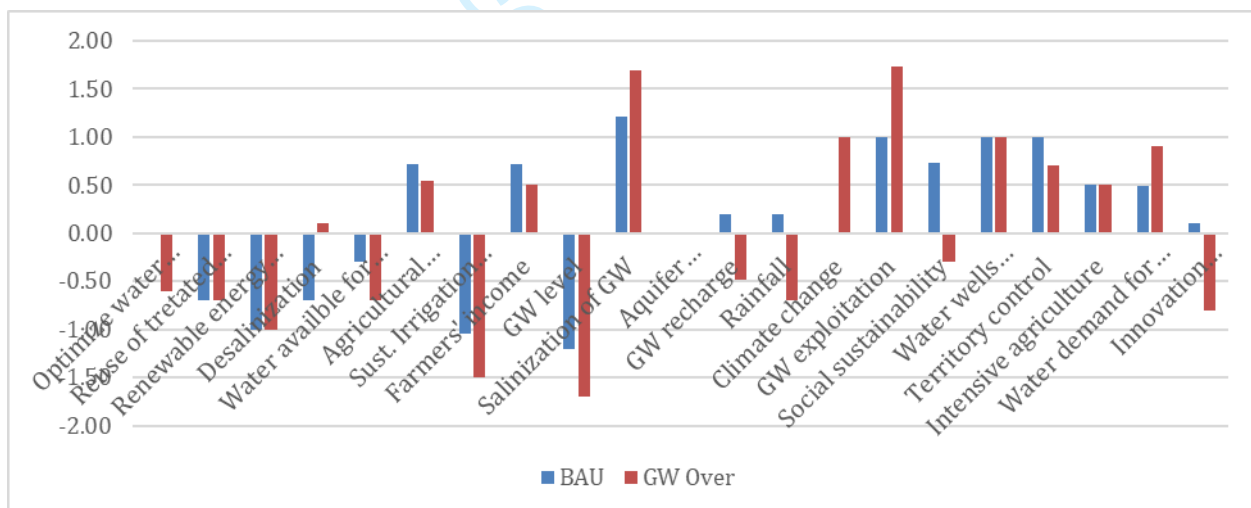


Figure 5 - Scenario comparison for the Agricultural Dept.

The FCM scenarios allowed to simulate the dynamic evolution of the system, as perceived by the stakeholders, and to identify the key elements affecting the GW exploitation and the main impacts. The Impact Degree was assessed accounting for the change of the state of the variables in the two scenarios. Specifically, the comparison between the two scenarios allowed to assess the Impact Degree, as shown in table 3. Table 3 shows the main variables for the different stakeholders.

The Impact Degree represents the different in the state of each variable in the considered scenarios, identifying a ranking of the different variables influencing the stakeholders' problem

understanding. Fuzzy *if...then* rules were implemented in order to aggregate the Centrality Degree and the Impact Degree to assess the Importance Degree for the FCM variables.

The rules are shown in the following:

IF *centrality degree* is **HIGH** AND *impact degree* is **HIGH** THEN *importance degree* is **HIGH**
 IF *centrality degree* is **HIGH** AND *impact degree* is **MEDIUM** THEN *importance degree* is **HIGH**
 IF *centrality degree* is **HIGH** AND *impact degree* is **LOW** THEN *importance degree* is **MEDIUM**
 IF *centrality degree* is **MEDIUM** AND *impact degree* is **HIGH** THEN *importance degree* is **HIGH**
 IF *centrality degree* is **MEDIUM** AND *impact degree* is **MEDIUM** THEN *importance degree* is **MEDIUM**
 IF *centrality degree* is **MEDIUM** AND *impact degree* is **LOW** THEN *importance degree* is **LOW**
 IF *centrality degree* is **LOW** AND *impact degree* is **HIGH** THEN *importance degree* is **MEDIUM**
 IF *centrality degree* is **LOW** AND *impact degree* is **MEDIUM** THEN *importance degree* is **LOW**
 IF *centrality degree* is **LOW** AND *impact degree* is **LOW** THEN *importance degree* is **LOW**

Table 3 - Identification of the most important elements in the stakeholders' problem understanding for the Cyprus case study

Stakeholder	Variable	Centrality degree	Impacts degree	Importance degree
Water Development Department	Infrastructure 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	High	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
The Department	Agricultural productivity	High	Negative	High

of Agriculture	Optimization of water distribution	Medium	Negative	High
	Social sustainability	Low	Highly 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

Finally, this analysis supported the K-space expansion and the identification of the shared concern, namely a shared representation and formulation of a “problem” which in reality serves as a representation or “recall” of the different concerns and stakes carried by the different stakeholders (see Ostanello and Tsoukias 1993, Pluchinotta et al. 2019), representing the starting point for group discussions leading to the generation of policy alternatives.

4.2. The C-space

Following the expansion of the K-space and identification of the shared concern, a one-day stakeholder workshop (Figure 5) was aimed at innovatively generating policy alternatives for the Kokkinochoria GW management using a C-K theory framework.

Within the P-C phase, stakeholders evaluate the dominant design (i.e. traditional policy alternatives) and propose innovative ones through the expansion of the C-space. The C-space allows illustrating various alternatives as concepts connected to the “initial design task” thanks to

1
2
3 the tree-like structure (Agogue et al. 2014a). It represents the map of all identified possibilities,
4 highlighting the dominant design and improving the search for new alternatives.
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7 Firstly, the individual K-spaces and the shared concern are discussed in order to build a common
8 knowledge ground, representing the starting points for the generative workshop. Secondly, the
9 traditional policy alternatives derived from the semi-structured interviews and the P-K phase (i.e.
10 dominant design) are described to all the participants. Stakeholders were asked to collectively
11 discuss and rank the traditional policy alternatives (i.e. the ranking represents the initial importance
12 that participants give to the proposed solutions as key action to resolve the problem under
13 consideration). The traditional solutions are (from most important to be considered to the least
14 important): Pricing strategy depending on water uses, Improvement of water distribution
15 infrastructure (conveyor), Raising of the farmers' and communities' environmental awareness,
16 Alternative sources of water (desalination and reuse), Improvement of GW monitoring and
17 metering, Agricultural subsidies (changing crops), Increased control of the territory, Improvement
18 of the irrigation techniques; Centralized systems for irrigation, Reduction of irrigated areas;
19 Central system for desalination; Use rainwater and surface water; Changing habits and mentality.
20 Thereafter, the participants were asked to suggest possible expansions of the C-tree, following the
21 C-K theory framework. The discussion led to the generation of different design paths within the
22 expansion of the C-space. The outcome was a portfolio of policy alternatives shared with all the
23 stakeholders which also included the introduction of a few innovative policy alternatives. Lastly,
24 a general discussion of the group activities concludes the generative workshop. The generative
25 workshop represented a learning process since the participants tend to learn beyond their actual
26 knowledge according to the principles of K- and C- spaces expansion (see Pluchinotta et al. 2019a
27 for details).
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Figure 6 - The P-KCP one-day generative workshop hosted by WDD

The C-tree showing the policy alternatives generated for the problem of GW protection and water management for the agricultural sector of the Kokkinochoria area is shown in Figure 6 and Supplementary Material. Using a colour code, the C-tree is divided as follows: i) the branches with known policy alternatives are coloured in black (dominant design), ii) the ones in blue indicate policy alternatives generated using existing knowledge or a combination of K-space subsets (i.e. policy alternatives used in best practices of comparable case studies), and iii) the paths in green represent new path for innovative policy alternatives. Both the alternatives in blue and green represent the C-space expansion, obtained thanks to the expansion of the K-space or of the C-space itself.

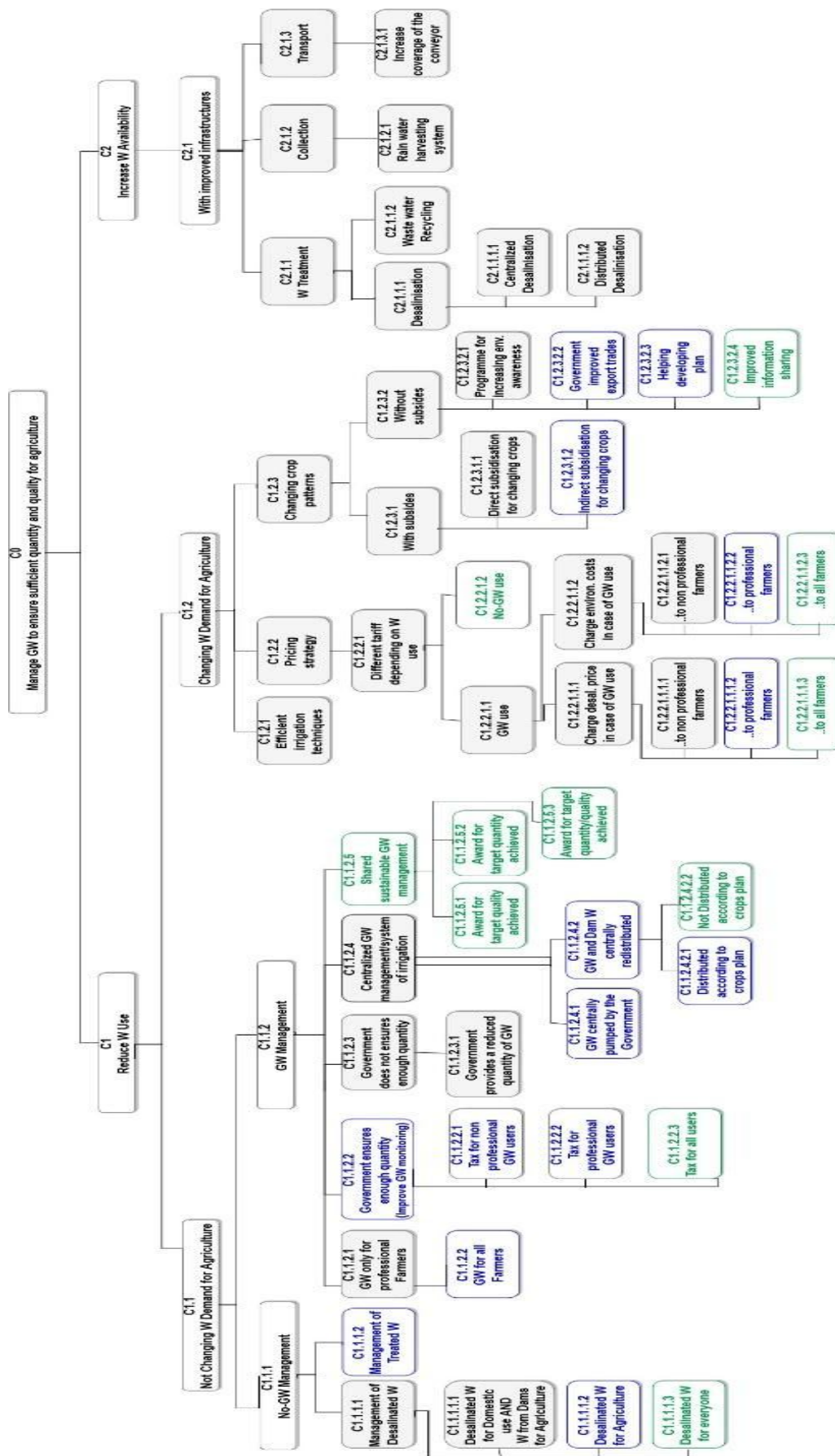


Figure 7 - The C-space showing all the policy alternatives generated - Dominant design (black), Known alternative (blue), Unknown alternative (green)

5. Discussion and conclusions

This paper develops and tests an upgraded methodology for policy design based on an integration of PSMs, for building and expanding the K-space, and a C-K theory-based tool, for supporting the generative C-phase. The results of the activities carried out in the Cyprus case study allow us to demonstrate that the P-KCP, an integrated and participatory tool generation of policy alternatives, could be considered as a suitable approach for supporting policy design, accounting for the main differences in problem framings among the different decision-makers and stakeholders. Generally, the P-KCP is a methodology formalizing the policy design process based on C-K theory. It supports the generation of innovative alternatives thanks to the co-evolution of the K- and C-spaces. It connects local and expert knowledge within the design process thanks to the construction of a collective problem understanding. The contribution of PSMs, for eliciting and structuring stakeholders' knowledge is a key element for ensuring an inclusive K-space.. The difference between the proposed method and other participatory and/or brainstorming procedures is that the collection of new ideas and suggestions is structured by the C-tree where the explicit presence of attributes (characterising any new design) are expected to be relevant for given stakeholders. The tree-like structure allows pinpointing how the problem and the possible solutions are seen by the stakeholders collectively. In other terms, a C-K theory-based tool for the design of policy alternative aims not only to collect ideas, but also to structure values that matter for designing and deciding. Specifically, PSMs are shown to be suitable to support the elicitation of the different viewpoints involved in the collective decision-making process. As demonstrated in the literature, differences in problem framings could enhance the effectiveness of the collective process by improving creativity. Nevertheless, the polarization of the participants' opinions, with consequent difficulties in finding a common base for discussion and for creating innovative policies, is a risk that needs to be dealt with in collective decision-making process. The

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3 experiences carried out in the Cyprus case study demonstrated that structured methods for
4 collecting different problem understandings, and to detect and analyse differences/similarities
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6 greatly facilitated the discussion for the development of the C-space. More specifically different
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8 views and conflicting interests converged under the recognition of similar threats related to water
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10 resources. During the discussion, the actors have reached compromising representations of reality
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12 and have largely understood the rationale of each other's views. It is interesting to note that a key
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14 decision-maker from the administration participating in the process, was initially astound
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16 especially by the farmers' position as a response to his presentation of the dire situation of the
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18 waters based on hard-evidence. He came to realise however that the important role and value of
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20 agriculture and especially of the Cypriot potato in terms of i) preservation of culture, ii) element
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22 of national identity and pride, iii) food security, iv) job security and v) an "absorber of shocks" or
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24 "insurance", is not just a national "myth" but rather an everyday reality for the local farmers. This
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26 special role legitimises "sacrifices to sustain the sector" (shared view to a different degree between
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28 actors). In this frame a lively discussion was sparked on potential solutions to overcome the
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30 obstacles. A surprising outcome of this discussion however was that the European directives and
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32 policies were viewed rather as a barrier for the implementation of locally devised solutions (e.g.
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34 subsidies for water, agricultural policies) with high potential in terms of legitimacy and
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36 acceptance. This has further implications for the role of EU policy making vis-à-vis the
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38 particularities of insular European territories.
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46 It is worth mentioning that the collection and integration of individual problem understanding
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48 allowed to build the policy design process attributing equal importance to the different pieces of
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50 knowledge gathered through the stakeholders' engagement. The risks associated with power
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52 relations were constrained by the structure of the C-K expansion process and the dichotomy
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54 between expert and local knowledge, characterizing the traditional policy design approaches.
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58 The construction of the C-Space is strictly dependent on the enhanced K-space, as explained by
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60 the C-K theory framework. The coevolution of the two spaces re-establishes communication

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3 between stakeholders by unfixing the group from the dominant design, i.e. traditional and known
4 policy alternatives. Fixation phenomena within the policy design process bring policy makers and
5 stakeholders in conflicting and unsustainable situations. Furthermore, the one-day generative
6 workshop for the C-space expansion led antagonistic stakeholders to discuss their collected
7 knowledge. The new knowledge injections represented the starting point for stimulating
8 discussions during the generative mechanism for the C-space exploration. For instance, initially,
9 the discussions were driven by conflicting situations due to knowledge limitations and fixation
10 phenomena, while after the injection of new knowledge and the alignment of problem frames,
11 participants were more willing to cooperate in constructive and operative debates. This had
12 positive effects on the workshop results, namely unfixed participants proposed non-traditional
13 solutions or integrated known alternatives in a different perspective.
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28 The experiences described in this work showed also some limitations of the implemented
29 approach. Firstly, capturing and processing stakeholders' knowledge starting from individual
30 inputs is time consuming and requires substantial efforts by skilled analysts for post-processing
31 the information collected during the individual interviews. Secondly, the selection of the
32 stakeholders is a key step in making the process successful. The knowledge elicited by interacting
33 with them is at the basis of the whole process. Therefore, their representativeness needs to be
34 accounted for during the selection of the stakeholders to be involved. Moreover, the process
35 described in this work is quite long and requires the stakeholders to go through different phases
36 of individual inputs and group discussions. Thus, the stakeholders' selection should also account
37 for their willingness to commit themselves to the whole process. Thirdly, the use of FCM for
38 simulated qualitative scenarios was questioned by some of the participants. The participants
39 seemed inclined to prefer quantitative evaluation, rather than qualitative results. Efforts for
40 combining the FCM with more quantitative modelling approach are already being performed.
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58 Concluding, although some improvements are still needed, the integrated approach described in
59 this work could be a valuable method for enhancing the policy design process.
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SUPPLEMENTARY MATERIAL

1. Guiding questions for the semi-structured interviews

Groundwater protection policy in Cyprus – Institutional actors

1. What the role of your organisation is with regards the protection or use of groundwater (GW)?
2. According to your experience what are the most important problems Cyprus faces regarding GW (e.g. quality, salinization, monitoring, etc.)
3. According to your opinion, how the situation will change within the next 10 years (e.g. level of groundwater tables dropping, increase of water reserves, reaching an equilibrium, etc.)
4. What are the main anthropogenic and environmental elements influencing the situation? (e.g. increase in demand, overabstraction, climate change, etc.)
5. Specifically in Kokkinochoria region, what are the local conditions influencing and causing the situation described before (e.g. intensification of agriculture, increase in tourism, lack of alternative water sources, etc.)
6. What are the direct impacts of the described situation in the region? (e.g. salinization, decrease of water availability, environmental problems, etc.)
7. What are the indirect impacts? (e.g. various socio economic effects like decrease of agricultural production, conflicts between sectors -tourism and agriculture- and between users –farmers getting water from the same groundwater reservoir, etc.)
8. Could you mention some strategies, plans or policies aiming at mitigating the mentioned problems of the region?
9. What are the expected results of such strategies, plans and policies? (e.g. reduce overabstraction, increase reserves, etc.)
10. Which plans, policies or strategies have been already implemented and with what results?

Groundwater protection policy in Cyprus – Farmers

1. What is the size of the arable land you are currently using?
2. What do you produce?
3. How do you irrigate your farm?
4. What is the yearly volume of water that you use for agricultural purposes (approximately)?
5. From where does that water come from (boreholes, conveyor etc)?
6. What percentage of this water comes from groundwater (GW) (approximately)?
7. If the used water comes from different sources (e.g. ground and surface waters) how do you manage it? For example, do you mix a percentage of GW with other water? Could you please describe the reasons influencing your decisions? (e.g. price or quality of different water resources, etc.)

8. How would you consider the GW quality of the last five years? (e.g. improved or not, water salinity problems or not, etc.)
9. Could you describe the reasons that change the quality of the groundwater? (e.g overabstraction leading to salinity problems, less intense agriculture leading to improvements, decreased rainfall increases irrigation needs etc)
10. What changes to agricultural production the pressures on groundwaters cause? Why? (e.g reduction of arable land, change of products, decrease n agriculture as a whole, increased costs of productions ...)
11. How do you respond to such changes?
12. Could you describe in detail what influences your decision on what and how you will produce? (less available water decrease of used land, increase price of products increases or intensifies agricultural activities or irrigated land).
13. Could you describe ways to mitigate the problem? What would be the effects of that actions and how could they be implemented?
14. Do you have another profession? If yes to what percentage it complements your income from agriculture?

2. List of policy alternatives generated during the stakeholder workshop (C-space expansion)

ID	Alternatives	Status
C0	To manage GW to ensure enough quantity and quality for agriculture	-
C1	Reduce Use	-
C1.1	Not Changing W Demand for Agriculture	-
C1.1.1	No-GW Management	-
C1.1.1.1	Management of Desalinated W	Dominant design
C1.1.1.1.1	Desalinated W for Domestic use AND W from Dams for Agriculture	Dominant design
C1.1.1.1.2	Desalinated W for Agriculture	Known
C1.1.1.1.3	Desalinated W for everyone	Unknown
C1.1.1.2	Management of Treated W	Known
C1.1.2	GW Management	-
C1.1.2.1	GW only for professional Farmers	Dominant design
C1.1.2.2	GW for all Farmers	Known
C1.1.2.2	Government ensures enough quantity (Improve GW monitoring)	Known
C1.1.2.2.1	Tax for non-professional GW users	Known
C1.1.2.2.2	Tax for professional GW users	Known
C1.1.2.2.3	Tax for all GW users	Unknown
C1.1.2.3	Government does not ensure enough quantity	Dominant design
C1.1.2.3.1	Government provides a reduced quantity of GW	Dominant design
C1.1.2.4	Centralized GW management	Dominant design

	system of irrigation	
C1.1.2.4.1	GW centrally pumped by the Government	Known
C1.1.2.4.2	GW and Dam, W centrally collected and redistributed	Known
C1.1.2.4.2.1	Distributed according to crops plan	Known
C1.1.2.4.2.2	Not Distributed according to crops plan	Unknown
C1.1.2.5	Shared sustainable GW management	Unknown
C1.1.2.5.1	Award for target quality achieved	Unknown
C1.1.2.5.2	Award for target quantity achieved	Unknown
C1.1.2.5.3	Award for target quantity/quality achieved	Unknown
C1.2	Changing W Demand for Agriculture	-
C1.2.1	Efficient irrigation techniques	Dominant design
C1.2.2	Pricing strategy	Dominant design
C1.2.2.1	Different tariff depending on W use	Dominant design
C1.2.2.1.1	GW use	Dominant design
C1.2.2.1.1.1	Charge desalination costs in case of GW use..	Dominant design
C1.2.2.1.1.1.1	..to non-professional farmers	Dominant design
C1.2.2.1.1.1.2	..to professional farmers	Known
C1.2.2.1.1.1.3	..to all farmers	Unknown
C1.2.2.1.1.2	Charge environmental costs in case of GW use..	Dominant design
C1.2.2.1.1.2.1	..to non-professional farmers	Dominant design
C1.2.2.1.1.2.2	..to professional farmers	Known
C1.2.2.1.1.2.3	..to all farmers	Unknown
C1.2.2.1.2	No-GW use	Unknown
C1.2.3	Changing crop patterns	Dominant design
C1.2.3.1	With subsidies	Dominant design
C1.2.3.1.1	Direct subsidisation of changing crops cost	Dominant design
C1.2.3.1.2	Indirect subsidisation of changing crops cost	Known
C1.2.3.2	Without subsidies	Dominant design
C1.2.3.2.1	Programme for increasing env. awareness	Dominant design
C1.2.3.2.2	Government improved export trades	Known
C1.2.3.2.3	Helping developing plan	Known
C1.2.3.2.4	Improved information sharing	Unknown
C2	Increase W Availability	-
C2.1	With improved infrastructures	-
C2.1.1	W Treatment	Dominant design
C2.1.1.1	Desalination	Dominant design
C2.1.1.1.1	Centralized Desalination	Dominant design
C2.1.1.1.2	Distributed Desalination	Dominant design
C2.1.1.2	Wastewater Recycling	Dominant design
C2.1.2	Collection	Dominant design
C2.1.3	Transport	Dominant design
C2.1.3.1	Increase coverage of the conveyer	Dominant design

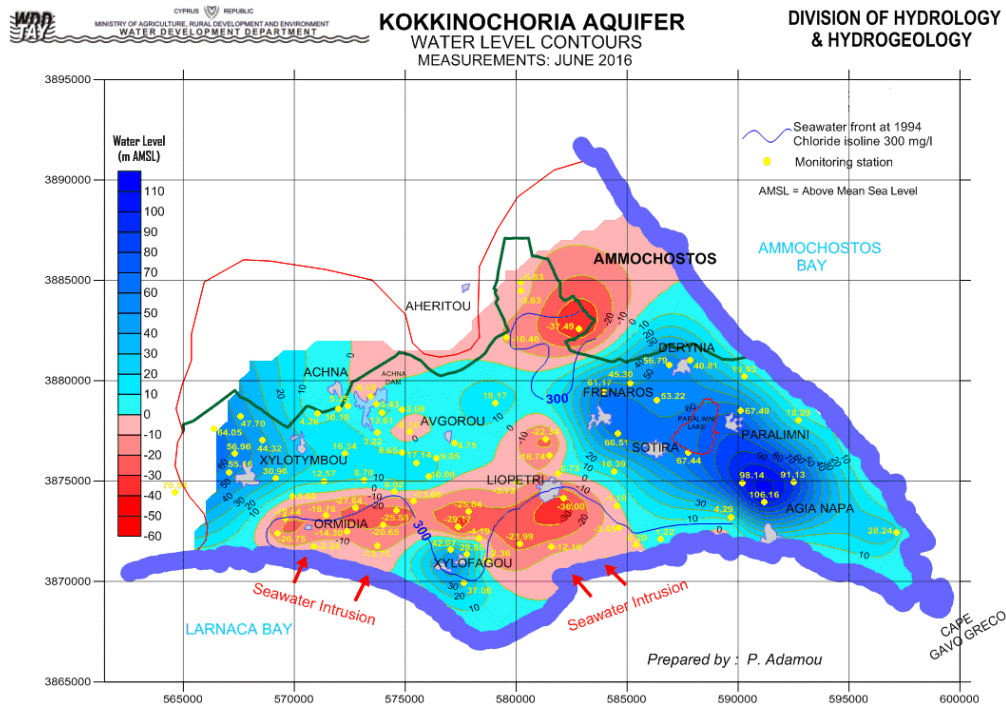


Figure 1- Kokkinochoria (CY_1) Aquifer (Source: Water Development Department). Notice that the area north of the UN's Green Line is not under the control of the Republic of Cyprus

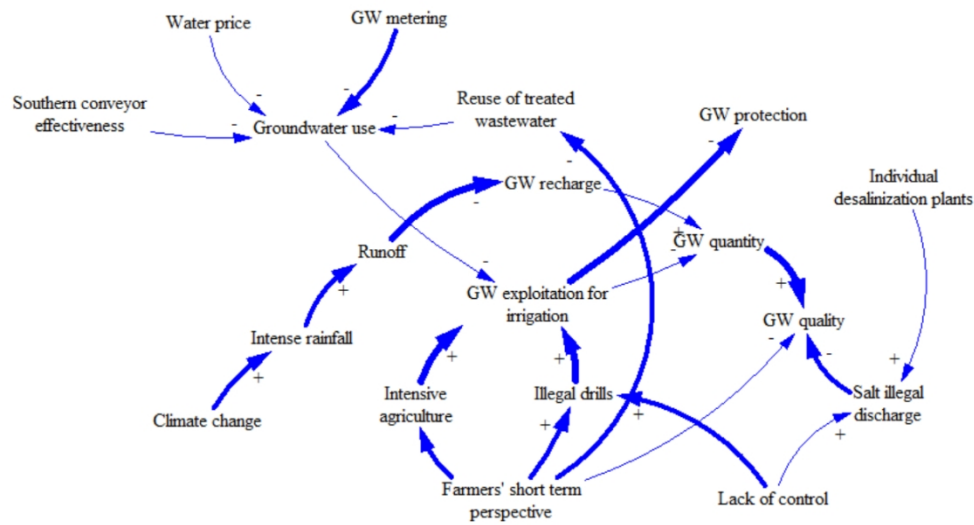


Figure 2 – Water Development Dpt.'s FCM

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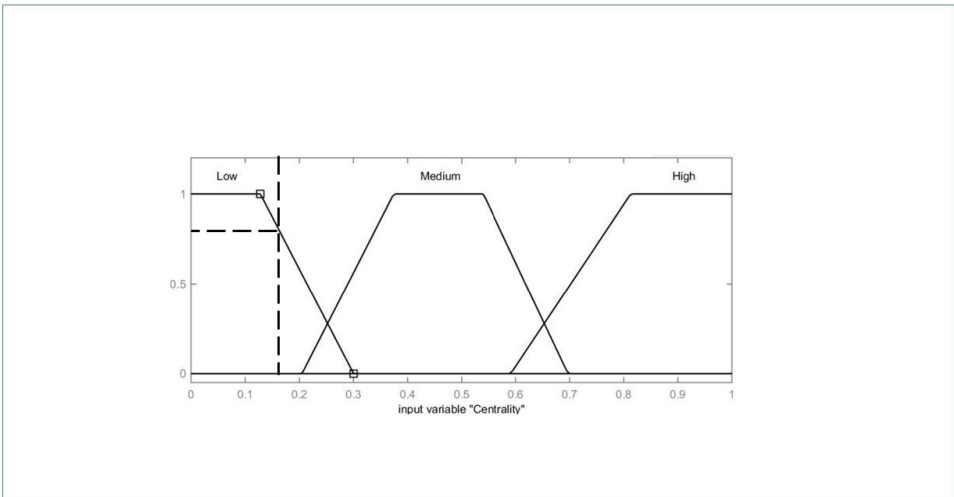


Figure 3 - Fuzzy linguistic function for the centrality degree (Giordano et al. 2020b)

338x190mm (96 x 96 DPI)

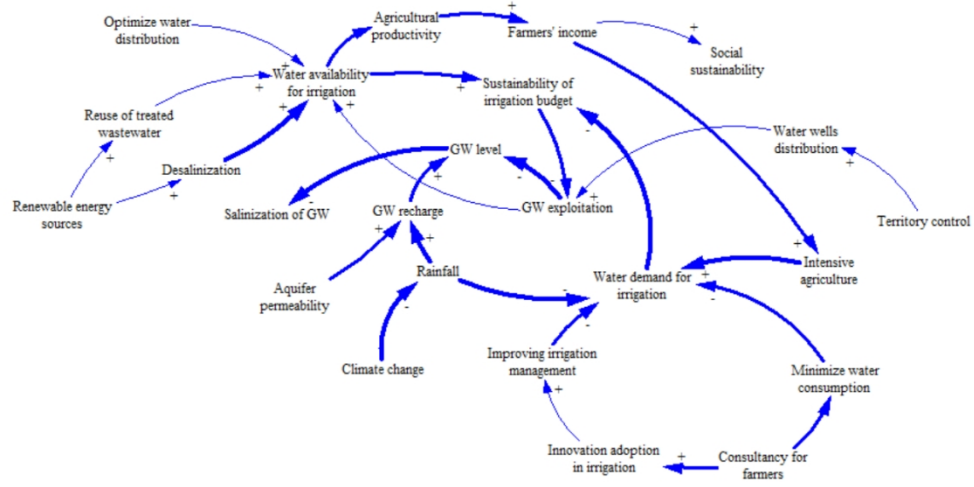


Figure 4 - Agricultural Dept.'s FCM

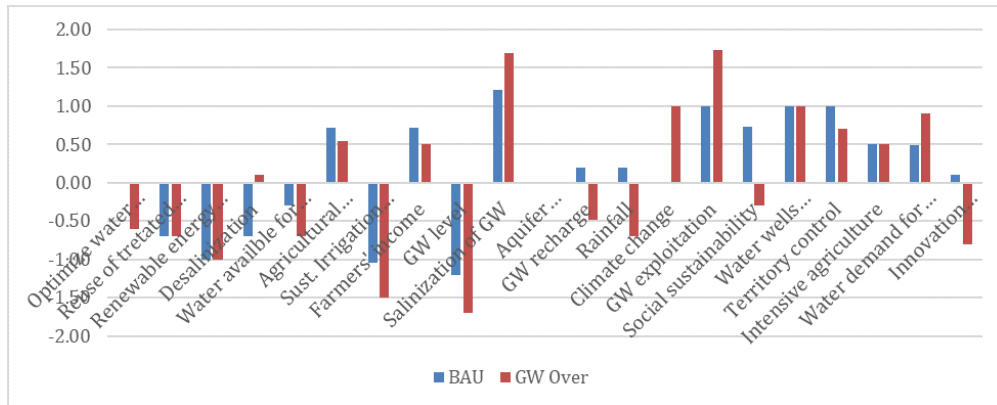


Figure 5 - Scenario comparison for the Agricultural Dept.



Figure 6 - The P-KCP one-day generative workshop hosted by WDD

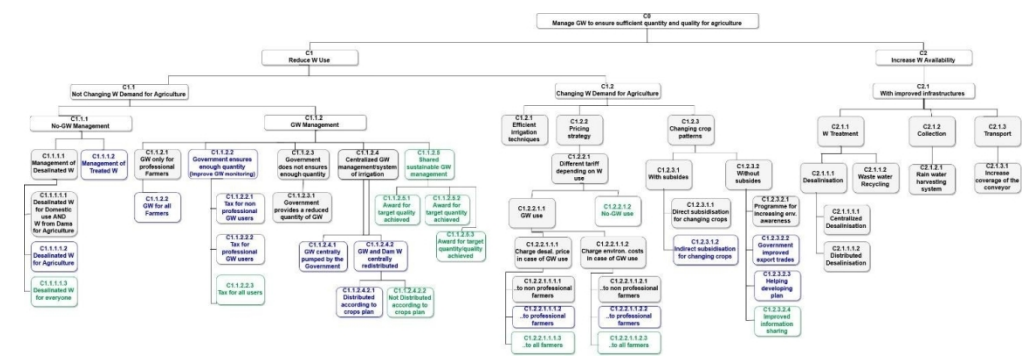


Figure 7 - The C-space showing all the policy alternatives generated - Dominant design (black), Known alternative (blue), Unknown alternative (green)

389x133mm (96 x 96 DPI)