Integrating problem structuring methods with formal design theory: collective water management policy design in Tunisia

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Abstract

Groundwater management, especially in Mediterranean regions such as Tunisia, is challenging due to diverse stakeholder interests and the arid climate, which makes the sustainability of water resources extremely difficult. This paper proposes an innovative approach to the design of decision and policy alternatives by combining Problem Structuring Methods (PSMs) and the participatory tool based on the Concept-Knowledge (C-K) theory, named Policy-Knowledge, Concepts, Proposals (P-KCP). In a multi-methodological perspective, using Cognitive Maps and Value Trees in combination with P-KCP, the study aims to innovatively generate alternatives to address the sustainability issue of the case study, namely collective groundwater management. The paper provides a practical and adaptable guide to fostering innovation for policy design and generation of alternatives. By bridging decision theory and design theory, the study addresses the methodological gap in alternatives generation and highlights the role of C-K theory for supporting innovative design processes. Integrating PSMs and C-K theory, the multi-methodology advocates participatory approaches to address complex sustainability challenges, provides an adaptable, replicable tool, and encourages the creation of unconventional solutions. Ultimately, this paper offers new collective practices for groundwater management, expanding the set of alternatives through the integration of PSMs and C-K theory and reflecting on the applied multi-methodology.[1]

Keywords: Problem Structuring, Alternatives, Conflict Transformation and Management, Design Theory, Policy Analytics, Sustainability, Stakeholders, Cognitive Maps, Value Trees

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1. Introduction

The clash between individual gain and collective well-being, and its impact on sustainability, is vividly captured in the concept of "Tragedy of the Commons". This theory illustrates how individual self-interest in the use of shared resources leads to overexploitation and depletion, suggesting that only external intervention or a change in moral values can prevent such outcomes (Hardin, 1968). In contrast, Ostrom (1990, 1999) shows that communities can effectively manage common-pool resources through self-organized governance structures, challenging Hardin's assumption of inevitable tragedy. This highlights the importance of sustainable practices and community-driven solutions in preserving shared resources for future generations. However, it has been acknowledged that while this groundbreaking approach has made significant strides, it has only partially addressed how to practically manage the inevitable conflicts that arise in such settings (Wolf, 2007; Meinard et al., 2021). Nevertheless, effective conflict management is crucial for sustainability, particularly in water management, where equitable distribution, long-term resource availability, and the resolution of disputes over water rights and usage are essential for maintaining both environmental and social stability (Dietz et al., 2017).

The critical role of groundwater for agriculture in Mediterranean countries, coupled with their arid climate and the challenges of overexploitation, has been of interest to the scientific community and literature (see Tringali et al., 2017; Mekki et al., 2013, 2017; Saidi et al., 2013; Dhaoui et al., 2022; Soula et al., 2023; Giordano et al., 2017). Groundwater serves as a vital resource for irrigation, especially in regions where surface water is scarce or unreliable (Pluchinotta et al., 2018). These challenges, further intensified by weak policy implementation capacity and resistance mechanisms caused by differing priorities of local farmers, policymakers, and environmental advocates, highlight the urgent need for a participatory approach and collective efforts to ensure the sustainable use and management of groundwater in the area (Hassenforder et al., 2025; Chrii, 2022).

Within this context, we present a multi-methodology for the innovative design of policy alternatives, applied to a case study focusing on participatory groundwater management in Tunisia. Groundwater in Tunisia is a critical resource, providing more than 40 % of the country's irrigation water, and it has suffered significant depletion due to overexploitation over the last three decades (Frija et al., 2014).

Our goal is to develop sustainable and equitable management solutions tailored to the region's unique context, effectively addressing the pressing groundwater issues. This paper describes the combination of Problem Structuring Methods (PSMs) with formal design theory. Our proposal consists in transforming Cognitive Maps (CM) (Eden, 1988; Eden and Ackermann, 2004) into Value Trees (VT) (Von Winterfeldt, 1987; Keeney, 1994; Pöyhönen and Hämäläinen, 1998) and integrating them with the Concept-Knowledge (C-K) theory (Hatchuel and Weil, 2003, 2009), and specifically the participatory tool for the innovative generation of alternatives P-KCP (i.e. Policy-Knowledge, Concepts, Proposals) (Pluchinotta et al., 2019), for addressing complex, multi-stakeholder decision-making environments.

The contribution of this paper is twofold. On the one hand, the multi-methodology provides the OR community with a tool for the innovative design of alternatives by combining descriptive stakeholder's perspectives with a structured, design-oriented methodology. On the other side, we aim to strengthen the P-KCP methodology by using CM and VT as foundational tools. Specifically, since setting up the design oriented phase of the P-KCP methodology can beresourcesan d time-consuming, we propose using CM and VT as a starting point for the generative process (as further discussed in Section 2).

This paper presents multi-methodology approach that addresses three crucial aspects of policy design and the generation of alternatives in sustainability settings: adaptation to different contexts, facilitation of replicability, and an innovative approach to the participatory design process. Firstly, the P-KCP tool has been carefully adapted to different contexts, taking into account the unique challenges and characteristics of each setting. This adaptability ensures that the methodology remains relevant and effective as well as driving the need for the multi-methodology approach presented in this paper. Secondly, to promote replicability, the study provides a detailed description of each stage of the multi-methodology. From problem formulation and stakeholder engagement to the co-evolution of concept and knowledge spaces, each step is outlined in a clear and systematic manner, allowing other researchers and practitioners to easily replicate and adapt the approach to their own contexts. Finally, the paper emphasises the importance of innovative policy design by integrating PSMs and the P-KCP methodology. In doing so, it encourages the generation of new and unconventional alternatives that go beyond the assessment of known options. This participatory approach encourages collaboration and empowers stakeholders to explore previously unknown policy solutions.

The paper is organized as follow. After the present introduction, the following section discusses the background and the key notions driving this research activity. Section 3 presents the case study, while Section 4 describes the multi-methodology integrating the P-KCP participatory tool with CM and VT to generate alternatives. Section 5 outlines the case study activities. Section 6 reflects on the multi-methodology and closes the paper.

2. Background

2.1. PSMs: Cognitive maps and Value trees

Problem Structuring Methods (PSMs) are invaluable tools for addressing the multifaceted nature of decision-making in complex scenarios. This perspective was originally discussed by scholars such as Ackoff (1979a), Ackoff (1979b), Rosenhead (1996), and Rosenhead and Mingers (2001). PSMs embrace the ambiguity and subjective elements inherent in real-world situations involving multiple stakeholders with diverse interests (see Mingers and Rosenhead, 2004; Pluchinotta et al., 2022; Giordano et al., 2017; Mingers, 2011).

In certain situations, they can also serve as descriptive tools, detailing who faces which problems and why, thereby helping stakeholders develop comprehensive assessments and establish common ground (Ackermann, 2012). Although PSMs are not primarily descriptive tools, it is important to distinguish, for instance, between Cognitive Map (CM) as a visual tool and Strategic Options Development and Analysis (SODA) as a more holistic PSM. CM is recognized as a problem-oriented approach to decision support, where structures on the map are often descriptive (Eden, 1988; Eden and Ackermann, 2004). Literature tend to emphasize the map functional nature as a visual tool; Eden (1988) drawing on Kelly (1955)'s "theory of human beings as problem solvers", positions CM as a descriptive tool to capture problem owners' perspectives of a problem situation. In contrast, methods like SODA integrate CM but extend beyond the descriptive to facilitate decision-making. In line with this, we acknowledge problem structuring as a critical step in decision support (Tsoukiàs, 2007, 2008), particularly when stakeholder involvement is central (Belton and Stewart, 2010) . By prioritizing the problem owner's perception, CM are especially suited for capturing and organizing subjective problem framings, thus serving as an essential component of the problem structuring process in our approach.

Nevertheless, PSMs would benefit from incorporating a design-oriented approach; they do not necessarily propose practical solutions or pathways to resolve the identified problems, particularly those requiring "out-of-the-box" thinking or addressing "wicked situations". Exceptions such as "Strategic Choice Approach" (Friend and Hickling, 1987) and "Value Focused Thinking" (Keeney, 1992) exist, but they also struggle to understand the structural dynamics of problems and the complexity of decision aiding (Tsoukiàs, 2008).

Recent research (see Colorni and Tsoukiàs, 2020; Ferretti et al., 2019; Pluchinotta et al., 2019) calls for a more "design-oriented" approach in decision support and problem structuring, emphasizing the need for methods that not only describe complex problems but also guide the design of alternatives.

Moreover, further reflections on PSMs encompass considerations on they should be integrated with other decision analysis approaches (Mingers, 2011). Marttunen et al. (2017) provide a comprehensive review of the integration of PSMs with Multi-Criteria Decision Analysis, demonstrating how different PSMs can enhance decision support by structuring problem spaces before formal evaluation. Bana e Costa et al. (1999) and Franco and Montibeller (2010) also used CMs to identify means-end relationships in the VT, however, as Bana e Costa et al. (1999) describe, the process depends on the effort of the facilitator, not a formalized procedure. Settanni et al. (2023) highlight the importance of integrating structural modeling techniques to bridging the gap between problem structuring and decision analysis. Our approach contributes to this effort by integrating a systematic approach that formalizes the transition from problem structuring to alternative design.

Within this context, our multi-methodology integrates CMs and VTs. CMs visualize stakeholders' perceptions to structure complex problems, while VTs support the hierarchical exploration of potential solutions.

Specifcially, CMs emphasize the subjective nature of problem handling, focusing on the problem owner's personal understanding, beliefs and objectives (Eden, 1994). In group decision settings is a powerful tool for enhancing the group's understanding of the problem (Cunha and Morais, 2016). However, using different and conflictual CMs in a participatory setting might create tensions (Shaw et al., 2003) and the approach does not inherently provide direct strategies for managing group conflicts, requiring advanced facilitation skills and additional steps in the problem-solving process.

VTs provide a structured approach, rooted in Keeney's value-focused thinking (Keeney, 1994), to prioritize values over available alternatives and fosters innovative solutions. They represent values hierarchically but may not capture the full complexity of the problem. The lack of a standardized methodology to build VTs can lead to information loss and attribute asymmetry (Jacobi and Hobbs, 2007; Pöyhönen and Hämäläinen, 1998) necessitating a critical application of the methodology in decision-making.

A recent paper (Tosunlu et al., 2023) proposes an approach that, together with the related algorithm, allows to transform a CM into a VT, the latter being considered as the driver of decision behavior. Combining CMs and VTs enhances problem structuring and solution generation in participatory settings and conflict management; however, it does not handle the matter of how to innovatively design solutions. For this purpose we need the support of formal design theory.

The integration of CMs and VTs, both are considered integral components of major Soft OR methodologies such as SODA and Value-Focused Thinking. This integration has also been supported by the literature, notably by (Marttunen et al., 2017), who proposed using CMs to structure decision elements into VTs within Multi-Criteria supported problem structuring.

2.2. Design Theory: C-K Theory and P-KCP

Design theory places design at the core of professional practice through its focus on creating preferred situations from existing ones (Simon, 1969). Design problems are inherently "wicked", due to their complexity and the interconnectivity of solutions and problems (Simon, 1988). The interdisciplinary nature of design theory, highlighted by Chakrabarti and Blessing (2016), is illustrated by the evolution of design theory over the last fifty years. This evolution shows a shift from systematic and rational processes towards embracing disruptive innovation and creative reasoning, recognizing the need for interdisciplinary approaches and stakeholder engagement to solve complex real-world problems (Bayazit, 2004).

Modern design theory, particularly through the lens of the Concept-Knowledge (C-K) Theory introduced by Hatchuel and Weil (2003), represents a significant advance by providing a methodology for innovative design processes. This theory encourages the generative process by leveraging existing knowledge to explore the unknown, addressing the need for breakthrough innovation and the development of new expertise.

In the context of a specific knowledge domain (named Knowledge space, K-space), a "concept" refers to a proposition or group of propositions that typically describe attributes qualifying entities (Hatchuel and Weil, 2003; Elmquist and Segrestin, 2009, see). The "Concept space" (C-space) encompasses all concepts relative to a specific K-space and it is designed to be expandable in order to adapt to the dynamic nature of design and innovation. The co-evolution of the K-space and C-space supports the creative design process; any improvement in one space will lead to improvements in the other. According to the C-K theory, the C-space, has a tree structure (hence it is also called Concept-tree or C-tree), as it operates through partitions and inclusions, enabling the exploration and generation of new concepts or design objects.

The KCP (Knowledge, Concepts, Proposals) methodology has been proposed for collaborative design (Hatchuel and Weil, 2009; Agogué et al., 2014). Pluchinotta et al. (2019, 2020) further this understanding by introducing the P-KCP methodology (Policy-Knowledge, Concepts, Proposals) as a participatory tool operationally integrating design theory and decision science to foster innovation.

The P-KCP tool highlights the significance of participatory processes and stakeholder engagement. It is designed to improve decision-making by focusing on a specific phase of the decision aiding process, namely the generation of alternatives. However, the P-KCP requires support in formulating the problem under consideration, especially when multiple stakeholders with conflicting objectives are involved. For this reason, we need the support of PSMs and formalized approaches from decision science. The P-KCP tool provides a way to analyze and map innovation processes, enabling structured exploration of the unknown, guiding exploration rather than giving step-by-step prescriptions. It shares some goals with Soft OR, namely supporting stakeholder-centered innovation, especially in collaborative settings where multiple perspectives are needed to expand the design space.

2.3. Our proposal: a multi-methodology for the innovative design of alternatives

This paper presents a novel expansion of the P-KCP participatory tool described in Pluchinotta et al. (2019), by integrating PSMs and using CMs and VTs. We revised and improved the P-KCP developing a multi-methodology to overcome the limitations of the methods applied.

The concept of multi-methodology, as described by Mingers and Brocklesby (1997) discusses the incorporation of various methodologies to address the intrinsic complexity of real-world challenges. They discuss several forms of multi-methodology: methodological isolationism (relying solely on one methodology), methodology enhancement (incorporating techniques like cognitive mapping into existing methodologies), methodology combination (applying entire methodologies complementarily), and multi-methodology in its fullest sense, where methodologies are partitioned and selectively recombined to form hybrid approaches. Our work fits within what Mingers and Brocklesby (1997) describe as both "methodology enhancement" (where one method is supported by techniques from another) and “partitioning and recombination” (where parts of different methods are selectively combined to serve distinct functions). Similar to how Eden (1994) employs CM to enhance System Dynamics modeling, we utilize CM to define problems and capture stakeholder values, thereby reinforcing the structured processes of the P-KCP. CM, as a versatile tool for eliciting and structuring stakeholders’ perspectives, has been integrated into various methodologies to enhance both the analytical and participatory dimensions of problem-solving. For example, Siau and Tan (2005) and Georgiou (2012) combined CM with Soft Systems Methodology, for proper stakeholder engagement and improved problem structuring. Horlick-Jones and Rosenhead (2007) combined CMs with ethnography in cross-disiplinary multi-methodological approach, Ferreira et al. (2011) combined Multi-Criteria Decision Analysis and CMs for benchmarking evaluation in a setting with conflicting interests and multiple stakeholders. Moreover, Lami and Todella (2023) shows how the integration of the Strategic Choice Approach with the Analytic Network Process enables a more structured decision-making process.

As Mingers (2011) notes, conflicts and compatibility issues are more likely to arise in multi-paradigm situations where tools originate from fundamentally different philosophical traditions. All the approaches used in this work are compatible as they operate under a broadly constructivist paradigm.

Using a design-oriented perspective, this integration aims to enhance the effectiveness of the P-KCP tool in facilitating stakeholder engagement in the designing alternatives and improving decision-making processes. This ’design-oriented’ perspective requires methods that not only capture problem situations, but also guide the formulation of actionable and innovative solutions. In this context, Ferretti et al. (2019) explore the intersection of decision science and design theory highlighting the potential of their integration to enhance policy design. Building on this, Pluchinotta et al. (2019b; 2020) developed the P-KCP participatory tool for the generation of alternatives, which bridge theoretical constructs with practical policy design. Our research builds on and extends these methodologies in important ways. While Pluchinotta et al. (2020) used Fuzzy Cognitive Maps (FCMs) for water management in Cyprus, we address the limitations of FCMs, particularly their restriction of node relationships to causality. Instead, we use CMs with a more flexible tool focusing on influence relationships. CMs align more closely with our goal of understanding and structuring the subjective, qualitative dimensions of stakeholder engagement in conflict transformation. By focusing on perceptions rather than numerical modeling, CM enables a more participatory and accessible problem-structuring process, which is central to the objectives of our study. This approach allows for the creation of distinct CMs for individual stakeholder groups, which are then aggregated to preserve both the uniqueness of each map and their common elements. By aggregating the individual CMs, we facilitate enriched discussions between stakeholders and avoid escalating conflicts. This aggregated map serves as the basis for the construction of VTs, which represent the stakeholder’s interests.

The case study is presented in Section 3, while the participatory structure of the

P-KCP tool, including interviews and workshops and their results are presented in Sections 4 and 5.

3. Case Study

3.1. The Area

To illustrate our multi-methodology, we present a real-world case study, concerning water management in Tunisia and sustainability. For a detailed description of the problem situation, the reader can see Hassenforder et al. (2025); Chrii (2022) and Tosunlu (2024). Geographically, the Limaoua area is strategically located within the Gabès governorate in southern Tunisia, bordered by the city of Gabès, Zeuss stream, the sea, and the Gabès Matmata airport. It is part of the Jeffara aquifer system, which incorporate the Gabès North, Gabès South, and El Hamma Henchou aquifers (Vernoux and Horriche, 2019). The area significantly depends on the Gabès South aquifer's lower senonian carbonate aquifer, found at depths of 60 to 250 meters. To address water overexploitation, in 2017 the administration introduced a "safeguard zone" policy to regulate the drilling depth with the overall aim to enhance sustainable water management practices (Hassenforder et al., 2025; Chrii, 2022).

The case study stakeholders are: 1) Government and administration representatives, including representatives from Territorial Extension Unit (CTV) and Regional Commission for Agricultural Development (CRDA), 2) Agricultural Development Group (GDA), 3) Tunisian Union of Agriculture and Fisheries (UTAP), 4) Local Researchers from the Center for International Cooperation in Agricultural Research for Development (CIRAD) and National Agronomic Institute of Tunisia, 5) Three groups of local farmers depending on the size of the agricultural areas, i.e. 50 hectares or more, between 10 and 49 hectares and less than 10 hectares.

Figure 1: Gabes area-CRDA, 2021

The problem arises from the overexploitation of the Gabès South aquifer, with annual withdrawals estimated at 47 million cubic meters versus a recharge of 36 million cubic meters per year (CRDA, 2016). This overuse, coupled with a low annual rainfall of 180mm and the increasingnumber of water collection points post-2011, led to a comprehensive 2021 inventory identifying 1597 water points, and highlighting a mix of public, private, simple, and illicit wells. The escalation in water withdrawal and new wells, especially following the 2011 Revolution and the establishment of the safeguard zone, is matched with extended drought periods, exacerbating concerns about water scarcity (Soula et al., 2021). The problem arises from the overexploitation of the Gabès South aquifer, with annual withdrawals estimated at 47 million cubic meters versus a recharge of 36 million cubic meters per year (CRDA, 2016). Agricultural intensification over the years has led to environmental degradation, including significant depletion of groundwater levels and the deterioration of water quality. This overuse, coupled with a low annual rainfall of 180mm and the increasing number of water collection points post-2011, led to a comprehensive 2021 inventory identifying 1597 water points, and highlighting a mix of public, private, simple, and illicit wells. The escalation in water withdrawal and new wells, especially following the 2011 Revolution and the establishment of the safeguard zone, is matched with extended drought periods, exacerbating concerns about water scarcity (Soula et al., 2021).

Water use in Limaoua is dominated by agricultural activities, particularly arboriculture, with approximately 630 farmers operating sizable plots and benefiting from fertile soil, energy access, and infrastructure. However, the influx of new residents and increase of well drilling have strained water resources, leading to aquifer depletion. The establishment of the safeguard zone in 2017, in the midst of drought, has heightened tensions due to increased illegal drilling and administrative enforcement challenges. This situation risks further complications from potential saltwater intrusion and stricter regulations if the area becomes a "prohibited area".

In the 2000s, efforts were made to establish an Agricultural Development Group (GDA) for collective groundwater management in Limaoua for regulating water use through shared, high-capacity wells. Generally, a GDA facilitate administration control over the water volumes used, to contrast the challenge of monitoring numerous private wells as described by Hassenforder et al. (2025); Chrii (2022) . A successful example of GDA water management is in Bsissi Oued El Akarit, suggesting potential benefits for Limaoua, despite the challenges of enforcement and the unique context of agricultural water management.

Despite being inspired by Bsissi's GDA success, the Regional Commission for Agricultural Development (CRDA) of Gabès sought to implement a similar model in Limaoua but faced challenges due to a lack of leadership, engagement and resources. As water demand has increased in recent years, reconsideration of this initiative is underway. However, the conflictual relationship between CRDA and local farmers has changed significantly in the current post-revolutionary context, making the direct application of previous strategies more difficult (see Frija et al., 2016b; Molle and Closas, 2020).

To tackle this challenging problem, the CRDA sought the support of Center for International Cooperation in Agricultural Research for Development (CIRAD) in Tunisia, which is specialized in supporting participatory natural resource management. Thereafter a research team was formed in collaboration with the University of Paris Dauphine (France), the Australian National University, University College London (UK), and the French National Centre for Scientific Research (France) to bring together a wider range of expertise in the innovative design of policies and water management, which resulted in the intervention discussed in the present paper.

To summarize, managing groundwater resources in Tunisia is a critical task due to the diverse interests of the stakeholders involved and the fact that water demand is higher than water availability. The arid conditions, coupled with the heavy reliance of groundwater for agriculture, underline the urgent need for effective groundwater management strategies. These strategies must balance the ecological health and agricultural productivity of the region, which is increasingly threatened by overexploitation and climatic uncertainties.The presence of illicit wells and administrative inertia, as well as tensions between farmers and the administration, play a significant part too; the varying needs and perspectives of local farmers, policy makers, and other stakeholders, highlighting the necessity of a sustainable approach to water use. Farmers need to water their crops and, therefore, want to use the water resources to satisfy the needs of their crops. However, water authorities need to preserve the water resource. In this kind of conflicting interest, there is a need for policy design focused on sustainability.

3.2. Our application: a multi-methodology for the innovative design of alternatives

The proposed multi-methodology was applied to address the multifaceted challenges of participatory resource management in Tunisia. Water management involves multiple stakeholders with conflicting interests, i.e., government agencies aiming for conservation, farmers seeking maximum usage, and inefficient bureaucratic processes exacerbating regulatory uncertainties and complex socio- environmental dynamics. According to Hanafizadeh and Bahadornia (2023), this aligns with complex problem situations characterized by high variety of diverse actors, interdependence of the underlining problems (policy-climate-agriculture), and low analyzability caused by nonlinear interactions.

Wicked problems like this resist technical optimization and require participatory, iterative approaches to achieve meaningful progress (Rittel and Webber, 1973; Mertens, 2015). The virtues of PSMs lie in its ability to structure such ill-defined problems by promoting stakeholder involvement, leveraging qualitative tools like CMs to capture diverse perspectives, and enabling consensus-building through iterative problem framing (Dyson et al., 2021). In the Tunisia case, PSMs are embodied through the integration of CMs and VTs, which facilitate a structured transition from understanding stakeholders' perceptions to designing actionable and innovative solutions, aligning with the broader strengths of PSMs in managing messy, multi-stakeholder challenges.

In addition, our study in Tunisia employs an aggregated CM as a descriptive tool and further develops the VT as prescriptive tool derived from these maps. By integrating these two tools, our approach aims to enhance both problem structuring and solution generation capabilities, particularly within challenging contexts. This integration bridges the descriptive and prescriptive dimensions of decision-making and provides a more comprehensive methodology. As highlighted in previous studies, such as Bana e Costa et al. (1999); Françozo et al. (2022) combining Value-Focused Thinking with Soft Systems Methodology, PSMs stand to benefit significantly from their integration and from the application of formal design theory principles. Similarly, our approach demonstrates how such integration can be effectively applied, leveraging the strengths of CMs and VTs to create actionable and innovative pathways for resolving complex policy challenges.

Lastly, in the present case study we introduced a modification of the procedure for the development of the VT presented in Tosunlu et al. (2023). Given the cooperative attitude among the stakeholders (although not conflict free), we decided to unify the different CMs to a single one resuming how the problem situation was perceived by the different stakeholders and using this as a basis for the further development of the procedure. The further step introduced for this case study, has gone beyond the construction of the VT (representing the decision making drivers of the group) and derives a "Concept-tree" where more attributes and their combinations can be tested in order to figure new potential actions or to identify otherwise unforeseeable consequences which could become potential hard constraints for policy design. In other terms, using design theory terminology, we used the VT as an important component of the "Knowledge space" (what we know about the actual decision making drivers of the stakeholders) from which create a "Concept space" (what could be decision making drivers for the stakeholders in case a policy design is tested).

Typically, creating a Concept-tree demands considerable time and relies heavily on the facilitator's skills. This aligns with literature (Hatchuel et al., 2004, 2009), which underscore the challenges of navigating and expanding the Concept space. Kazakçi et al. (2009) underlines that the elaboration of the Concept space in design involves a complex process of partitioning concepts and validating them through new knowledge, which assesses the feasibility of design propositions based on existing knowledge. The process applied to this case study (see Section 5) consisted in incorporating concepts little discussed during the workshops (unchecked consensus) together with "disruptions" concepts (Considine, 2012), including questioning the explicit absence of subsets of values.

4. Method

We used the P-KCP (K for knowledge, C for concepts and P for proposals) methodology, a participatory tool for the innovative design of policy alternatives as introduced by Pluchinotta et al. (2019). The P-KCP methodology, effective in generating innovative policy solutions and enhancing stakeholder collaboration, was particularly appropriate for our study's focus on groundwater management in Tunisia. To structure our activities, we categorized them into three main stages in line with the P-KCP methodology. These stages were designed to facilitate a generative and participatory process, allowing to design and explore a range of policy alternatives. The activities carried out in this case study, leverage the P-KCP's emphasis on creating novel policy alternatives to addresses the specific challenges encountered in the Tunisian public policy context.

The P-KCP methodology consists of four phases as described in Pluchinotta et al. (2019) and summarized below; for the purpose of the research, we will focus on the first three phases. The activities roadmap is shown in Table 1.

Policy–Definition Phase (P–D Phase) The P-D Phase has three main objectives: (i) to collect and analyze existing knowledge about the problem under consideration, namely water management in Limaoua, in order to build a baseline understanding; (ii) to understand characteristics of the involved stakeholders, focusing on their objectives and values; (iii), to gain an initial understanding of the

Policy Definition	Policy Knowledge	Policy-Concepts Generation
• Conduct preliminary semi-structured interviews with stakeholders to understand diverse perspectives. • Build individual cognitive maps for each stakeholder from the interview transcripts. • Organize Workshop-1 to share and gather knowledge about water resources in Limaoua.	• Finalize the aggregated cognitive map, integrating insights from all stakeholders. • Organize Workshop-2, focusing on validating the map and identifying the shared concern through a participatory approach.	• Develop a value tree from the cognitive map, using it as a benchmark for the initial concept-tree. • Organize Workshop-3 aimed at identifying and prioritizing solutions by creating a concept-tree that addresses the shared concern. • Enrich the concept-tree with findings from Workshop-3 and inputs from various stakeholders. • Organize an expert workshop to expand and finalize the concept-tree, incorporating comprehensive alternatives.

Table 1: The P-KCP Road Map

problem from different stakeholder perspectives (see Pluchinotta et al., 2019).

Policy–Knowledge Phase (P–K Phase): The P-K Phase, as defined by Pluchinotta et al. (2019), is aimed to establish a collective foundation for policy design. This phase is expected to produce several outputs: (i) a comprehensive summary of the state-of-the-art knowledge on the case study and policy issue, (ii) an expanded and detailed stakeholder analysis, (iii) a common problem formulation incorporating individual points of views, and (iv) the identification of the dominant design, namely the traditional policy alternatives, through an initial Concept-tree.

Policy–Concepts Generation Phase (P–C Phase): The P-C Phase, further strengthen the collaborative journey with the local stakeholders with the objective to innovatively design policy alternatives using the principles of the Concept-Knowledge (C-K) theory. Through the development of the Concept-tree, a tool guiding the collective exploration of policy alternatives, participants engage in rich discussions and propose expansions of the C-space. This collaborative effort aimed to reach consensus on innovative alternatives, culminating in a reflective discussion that solidified our findings and insights. Through this participatory and generative workshop, the C-space is also used to visualize and map out a range of policy alternatives, fostering an environment of creativity and collective problem-solving.

Phase	Activity	Participants	Total Number
P-D Phase	Semi-structured interviews	Farmers (8); CTV (1); CRDA(2); GDAs (4); UTAP (2); Local Facilitators (3); Researchers (3)	23
P-D Phase	Workshop-1	Farmers (9); CTV (1); CRDA (1); GDAs (6); Local Facilitators (3); Researchers (3)	23
P–K Phase	Workshop-2	Farmers (9); CTV (1); CRDA(3); GDAs (2); Local Facilitators (3); Researchers (3)	21
P–C Phase	Workshop-3	Farmers (18); CTV (2); CRDA(5); GDAs (3); Local Facilitators (3); Researchers (4)	35
P–C Phase	Expert workshop	Academic Experts (5); C-K Theory Facilitator (1)	6

Table 2: Summary of participants' involvement across different phases and workshops. The Researchers provided methodological guidelines, models, and interview and workshop scripts. They were not leading the facilitation activities.

5. Process and Application

To ensure replicability, this section outlines the multi-methodology employed, describing the various activities, and the case study application. Table 2 summarizes the different types of participants were involved in each phase.

5.1. Policy-Definition Phase (P-D Phase)

The initial phase entailed a series of preparatory activities to lay a groundwork.

We prioritized establishing direct dialogue with local stakeholders, integral to decision-making in groundwater management. Stakeholder selection aimed to include a variety of viewpoints and interests to provide a well-rounded perspective. Afterwards, semi-structured interview were carried out to drive substantive conversations and collect relevant date for building individual CMs for each stakeholder from the interview transcripts, using a methodology similar to the one described by (Kim and Andersen, 2012). We designed these maps to detail the specific concerns, objectives, and perspectives of the stakeholders involved. This approach allowed us to create a thorough representation of their varied viewpoints. The interview guide is provided in the Supplementary Materials.

This phase ended with Workshop-1 which aimed to share and gather knowledge about the topic under consideration, i.e., water resources in the area. For this workshop, farmers were divided in two groups based on the size of their land holdings, recognizing that land size often signifies differing interests within the agricultural community (Frija et al., 2016a). This approach allowed for more focused discussions, ensuring that the unique challenges and perspectives of both small and large farmers were adequately addressed.

Moreover, participants gained new knowledge on the topic when the water strategies and groundwater collective governance of the local area of Bsissi were shared. This provided valuable insights for consideration and application in the broader context of groundwater management in Tunisia.

5.2. Policy–Knowledge Phase (P–K Phase)

Transitioning into the P-K Phase, our study further engaged with the complexities of groundwater management in Tunisia. This phase was marked by two key activities: creating an aggregated CM and identifying the shared concern among the stakeholders during Workshop-2.

5.2.1. Aggregated cognitive map

The aggregated CM was created to achieve a unified problem formulation that integrates individual perspectives and summarizes current knowledge on the case study. While the individual maps offered insights into stakeholders' knowledge and perceptions about the groundwater management issue, the aggregated map, created merging these individual perspectives, facilitated the identification of both commonalities and variances among the groups.

Importantly, during the aggregation process, we ensured no loss of information from the individual maps as we recorded each concept and utilized it or aggregated with similar ones.

When aggregating CMs, it is essential to first identify the fundamental node, which represents the central goal or purpose of the map (Tosunlu et al., 2023). The presence of a shared fundamental node provides the basis for successful aggregation.

Since all of the stakeholders' fundamental nodes were related to agriculture, the common nodes influencing this node were selected and merged into a single map. The reason for merging the stakeholders' individual maps was that no conflicts had been declared yet, and we wanted to focus on the similarities rather than the differences.

The aggregated CM was instrumental in achieving the P-K phase's objectives by structuring stakeholder insights and fostering a common understanding of water management challenges.

This structured representation not only supported consensus-building among diverse stakeholder groups but also highlighted the interconnectedness of issues, demonstrating its value in enhancing collaborative problem solving efforts within the case study.

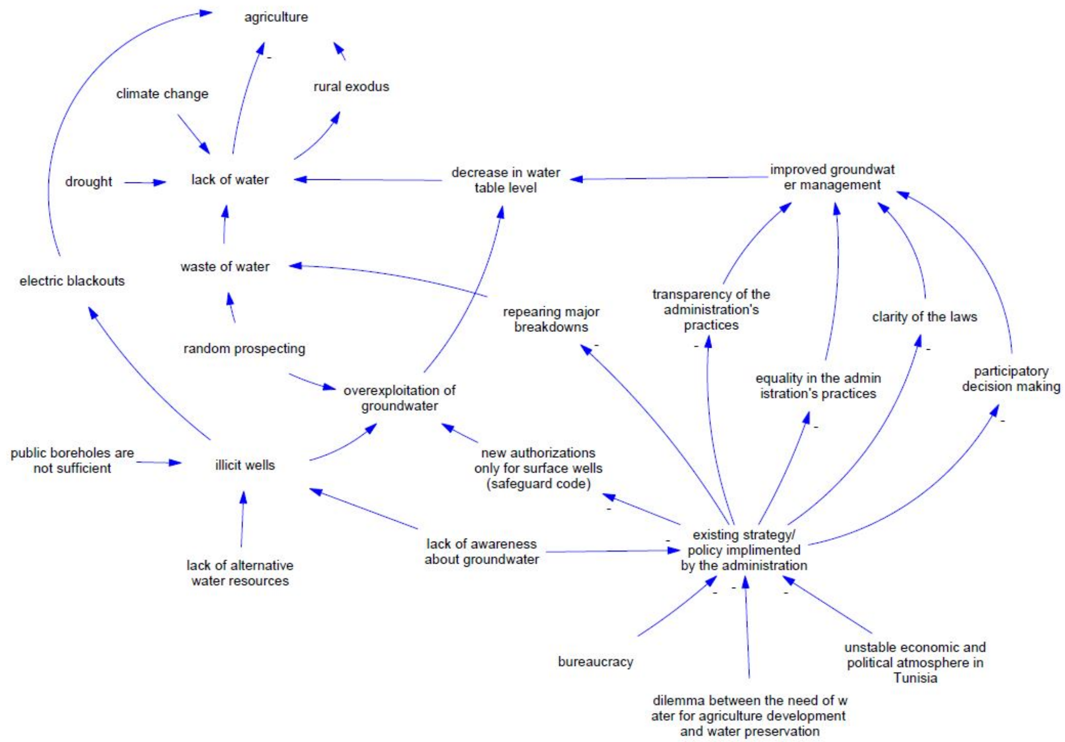

Figure 2: The aggregated cognitive map

5.2.2. *Definition of the shared concern*

Workshop-2 brought together a variety of stakeholders to collaboratively explore the challenges of groundwater management. These included representatives from CRDA, CTV, GDA, and both large farmers and small farmers. By presenting the aggregated CM and focusing on similarities rather than differences, facilitators steered the discussions towards unity and collaborative solutions, strengthening the group's collective approach to addressing the complexities of water resource management in Limaoua.

The aggregated CM was used to enhance the focus and productivity of the workshop. It provided a structured framework for exchanging perspectives and helped identify a shared concern among participants. First, the content of the CM, including its key insights, was presented to the stakeholders. This was followed by a validation exercise, during which participants were asked to comment on the key findings of the map, providing feedback and clarifying if anything was missing according to their opinion. Stakeholders' reactions to the aggregated CM were largely favorable. Small farmers, who sometimes held distinct views from other stakeholders, also found common ground, possibly due to the focus on similarities rather than disparities. Subsequently, the stakeholders were divided into two groups, each of which created a sentence summarising an objective on which they wanted to collaborate. The first group chose "solutions to organize farmers within a guaranteeing authority, ensuring sustainable agriculture, income improvement, water control and management, and access to subsidies". The second group emphasized the need for "good relationships between stakeholders, reasonable water management, and the use of irrigation techniques". Both sentences were presented to all participants, and the first sentence was chosen as it was considered to encompass all their goals.

5.3. *Policy-Concepts Generation Phase (P–C Phase)*

The P-C Phase consisted in: (i) constructing a VT out of the aggregated CM; (ii) building an initial C-space based on the VT and the discussions from Workshop-3. (iii) delivering Workshop-3 to identify a first set of alternatives with the stakeholders; (iv) further enlarge the C-Space through a workshop with experts.

5.3.1. *Value Tree*

To develop the VT from the aggregated CM, we employed the procedure introduced in Tosunlu et al. (2023) which consists in: (i) elicitation of the CMs involved in the problem through semi-structured interviews; (ii) transformation of the CMs into "value cognitive maps" where all concepts present in the CM become "values"; (iii) transformation of the value cognitive map into "ends-means graph"; (iv) transformation of the ends-means graph in VTs. This process has been designed for conflict transformation purposes with the aim of establishing common ground for discussion when manifest conflicts keep the stakeholders distant and not engaged in collaborative processes. The result is visible in Figure 3. This VT has not been explicitly presented to the stakeholders to manage complexity and reduce the level of information shared during the workshop, however, it has been a pivotal step. The VT has been used: (i) as a starting point for constructing the initial Concept-tree during the Workshop-3 preparation activities, ensuring that a broader spectrum of solutions was considered; (ii) to validate the alternatives emerged from Workshop-3, ensuring that these were compatible with the values established among the stakeholders

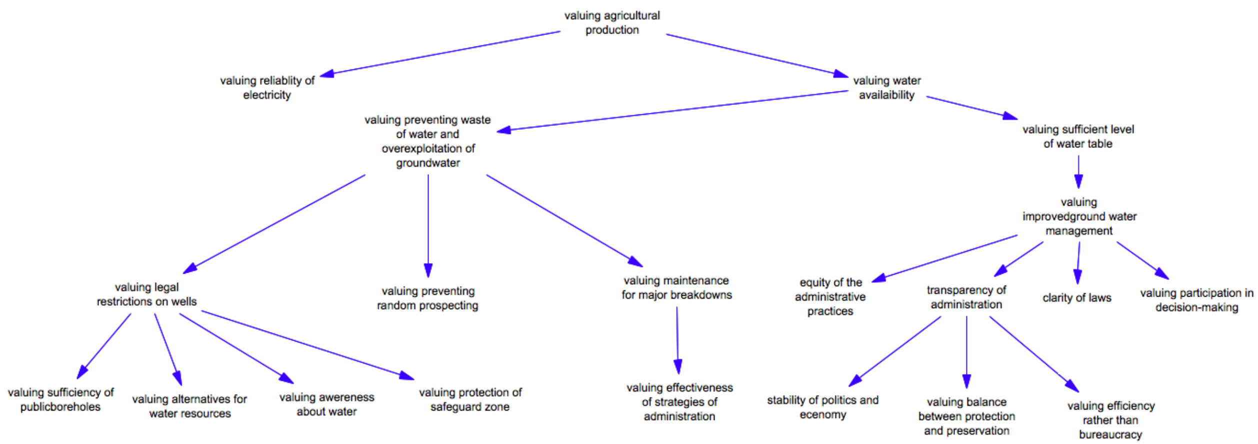

Figure 3: The value tree created from the aggregated cognitive map

5.3.2. Initial Concept-tree

We built the initial Concept-tree incorporating all relevant concepts and suggestions from the interviews and the insights from the VT.

Indeed, the initial Concept-tree is the rooted in the hierarchical structure of the VT. For example, it begins with the overarching shared concern aligned with the fundamental value of "valuing agricultural production", as identified in the VT. Afterwards, the tree introduces the concept of "sustainable agriculture" together with its negation (i.e., a solution to the shared concern that does not include "sustainable agriculture"), trying to provoke solutions that could boost farmers' income without relying solely on agriculture. Following this process, all concepts that were directly linked to VT were added to create an initial Concept-tree, which was used as a starting point for discussions during Workshop-3. Moreover, the initial Concept-tree also included findings from the interview guides that had not been included previously, due to the CM aggregation and simplification process.

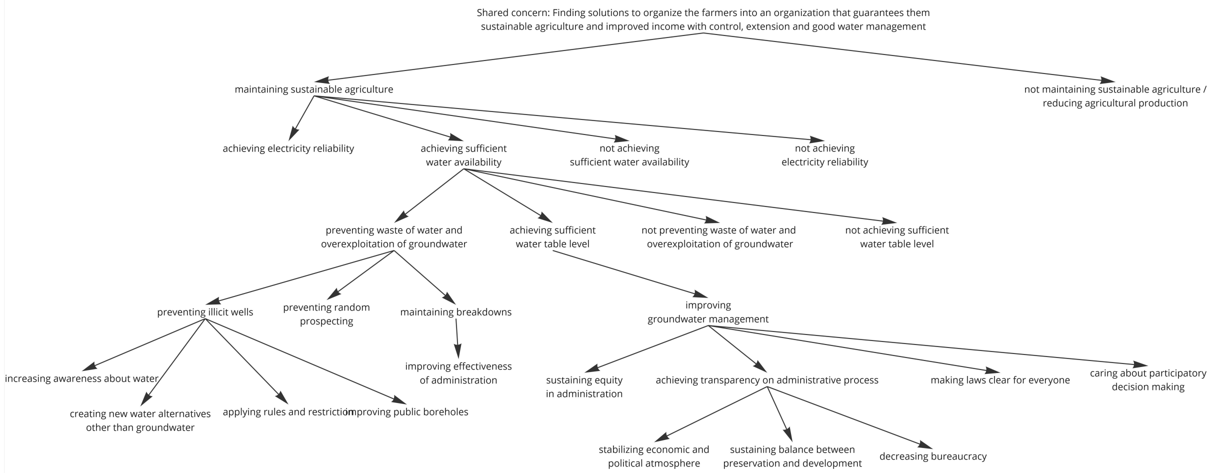

Figure 4: Initial Concept-tree derived from the Value Tree

5.3.3. Workshop-3

Using the C-K Theory principles, the workshop aimed at generating alternatives to collectively address the shared concern and prioritizing solutions by expanding the initial Concept-tree. The initial Concept-tree was used as the driving structure for the alternatives generative process.

Several alternatives have been identified during the workshop and the participants had the opportunity to prioritize them. Examples of the most voted alternatives, namely considered important by the stakeholders are:

1. Fight against corruption in the administration
2. Regulate illicit drilling
3. Renegotiate farmers' debts
4. Training for farming new sustainable crops
5. Create a financially viable GDA
6. Establish a collective authorization scheme for small farmers
7. Revise the existing laws regulating the GDAs.

The first five alternatives were inspired by existing water management strategies and knowledge, and focused on establishing a new, groudnwater dedicated GDA. The last two alternatives are unique to the region and were considered innovative by the stakeholders as they did not focus directly on known plans and dominant ideas. Specifically, some of these alternatives exist in other contexts but not in Limaoua; they were previously unrecognized within the limited set of alternatives prior to the expansion of the Knowledge space undertaken in this study. Consistent with C-K Theory, the items represented on the Concept-tree may correspond to the dominant design (based on established knowledge), known alternatives applied in other contexts, or truly innovative, groundbreaking alternatives (see Hatchuel and Weil, 2003; Pluchinotta et al., 2019). This process underscores the importance of both novel and known solutions for local challenges, promoting actionable and consensus-driven alternatives while supporting a knowledge co-production process.

These alternatives were checked against the VT:

1. Fight against corruption in the administration: The VT encompasses this through the values "equity in administrative process" and "transparency of administration," offering a nuanced approach to addressing corruption.
2. Regulate illicit drilling: This is considered in the following values "valuing preventing random prospecting" and "valuing legal restrictions on wells, "capturing the essence of regulation within the value tree".
3. Renegotiate farmers' debts: This alternative is considered as a means towards "valuing efficiency over bureaucracy" aligns financial support with broader efficiency values.
4. Training for farming new sustainable crops: This alternative is included in the VT through the value "valuing awareness about water," highlighting educational aspects as crucial for sustainable management.
5. Create a financially viable GDA: This alternative is covered under "clarity of

laws" in the VT, emphasizing the importance of clear, accessible financial frameworks.
6. Collective authorization scheme for small farmers: This concept, while new, can be derived from "valuing alternatives for water resources," which suggests broader principles of inclusiveness and equity in access to resources.
7. Revise the existing laws regulating the GDAs: This alternative is tied to "valuing participation in decision-making" and "transparency of administration," indicating a push for more inclusive and transparent governance.

Other alternatives widely discussed during Workshop-3 were: create new laws to limit the number of illegal boreholes, subsidize farmers with 40% of their expenses, involve qualified individuals in managing this GDA, process subsidy applications more quickly, use crops that require less water, desalination of seawater, use irrigation techniques to save water, ensure greater availability of plant protection products, use variable speed drives for boreholes.

5.3.4. Expanded Concept-tree

After Workshop-3 with the local stakeholders, an additional workshop with academic experts was organized to further extend the Concept-tree, to manage potential concepts loss due to the aggregation process and tree structures, and to address the need to further extend the knowledge space (Pluchinotta et al., 2019). This led to the expansion in both Concept and Knowledge spaces according to the C-K Theory principles (Hatchuel and Weil, 2003; Kazakçi et al., 2009)

Expanding the Concept-tree ensured also the inclusion of previously overlooked concepts from the semi-structured interviews that were not captured due to CMs aggregation process and the restrictive nature of the VT structure. This enrichment process significantly enhanced the depth and comprehensiveness of the Concept-tree, ensuring a broader spectrum of solutions was considered and the final concept tree was constructed.

This inclusive approach addresses the fact that the VT and the filtering process, might inadvertently omit certain stakeholder-specific concepts, ensuring the Concept-tree represents a fuller spectrum of stakeholder perspectives and insights. The result is visible in Figure 5.

For instance the expanded Concept-tree incorporates discussions on phytosanitary products, further technical details on seawater desalination, the introduction of novel crops, and a shift towards more water-efficient crop practices.

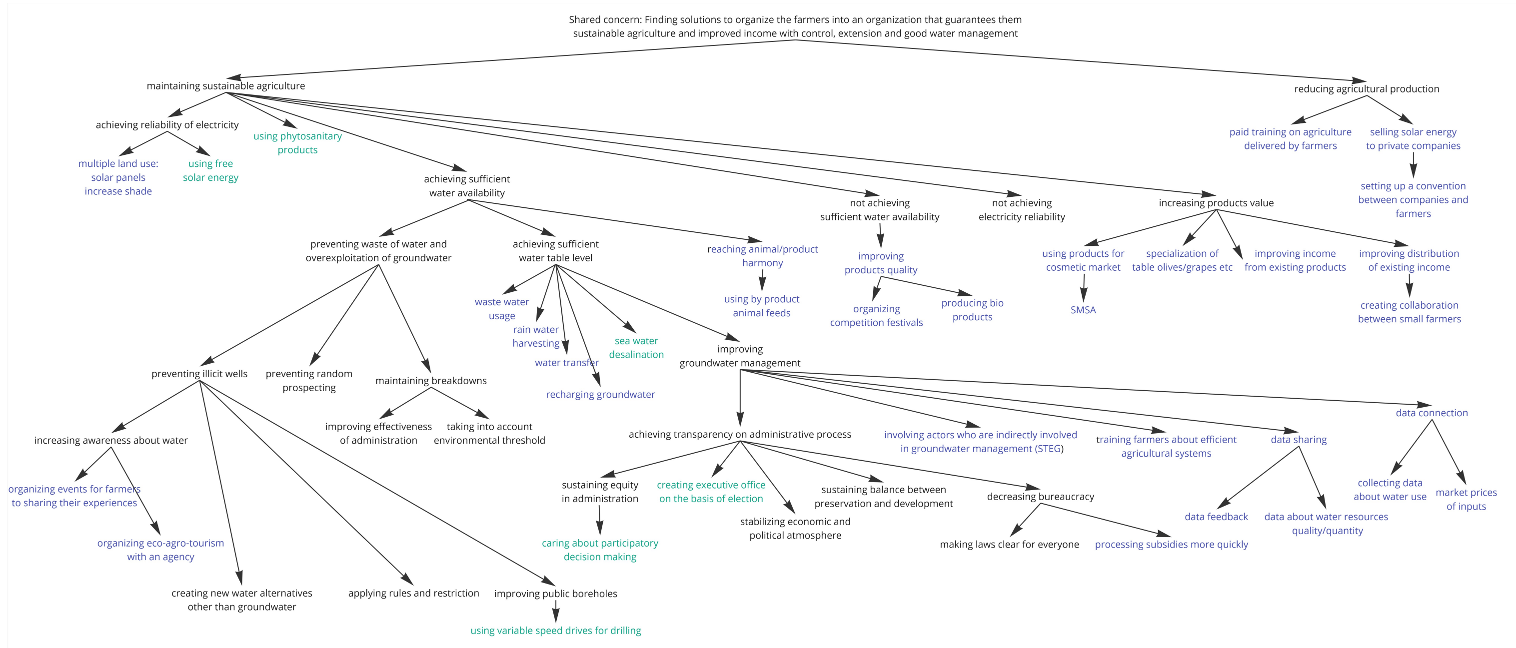

Figure 5: Expanded Concept-tree including the initial structure (black), the stakeholders' contributions (blue) and the experts' final expansion (gree)

In the expanded Concept-tree, the black concepts are part of the initial tree structure, the blue concepts were added during Workshop-3, and in green the concepts added during the experts workshop.

6. Discussion and conclusions

This study presents a multi-methodology designed to reconcile individual and collective interests and foster innovation in the development of policy alternatives. It makes two key contributions. First, the proposed multi-methodology provides the OR community with a tool for innovatively designing alternatives by integrating stakeholder perspectives within a structured, design-oriented approach. Second, it strengthens the P-KCP methodology by incorporating CM and VT as core elements. The combination of P-KCP with CMs and VTs not only offers a comprehensive understanding of stakeholder perspectives but also supports the creation of actionable, consensus-driven policy options through a knowledge co-production process.

Applied to the Tunisian case study, this approach addressed the pressing need for innovative water management strategies, ensuring the co-creation of equitable and sustainable solutions for groundwater use, demonstrating the added value of a multi-methodological perspective.

The multi-methodology developed in this study strengthens policy design in sustainability by addressing three key aspects: adaptability, replicability, and innovation. The P-KCP tool integrated with CMs and VT proved to be a flexible instrument. Clear documentation of each stage, from problem formulation to stakeholder engagement, supported replicability and provided a framework for future applications. Most importantly, by integrating PSMs with the P-KCP tool, the multi-methodology fosters creativity and collaboration in participatory setting, enabling the innovative generation of policy alternatives.

The following discusses the lessons learned from applying the proposed multi-methodology, and its general contribution to the OR community. We then focus on stakeholder participation and the impact of the application of this case study.

6.1. Lessons learned: Advancing through case-based insights

In our research, we used the P-KCP participatory tool in a real-world case study set in the Limaoua region. We adopted an approach similar to that in Pluchinotta et al. (2019), but diverging by integrating CMs and VTs to overcome the limitations of the methodology. This study not only contributes to the existing body of knowledge within the C-K Theory, it also introduces a multi-methodology for generating alternatives and designing policies, documenting a step-by-step process to ensure replicability.

Firstly, case studies are often associated with theory building (Gehman et al., 2018), yet, as argued by(Ketokivi and Choi, 2014), case research can serve as a scientific reasoning process, where theory and empirical inquiry iteratively inform each other to refine both conceptual and methodological frameworks; in this sense the focus of this paper is also methodological. We used the case primarily to explore how different PSMs can be combined in practice with a participatory design tool. While the case context offers a real-world setting, our analysis centers on the methodological implications of this integration.

In this work, CMs and VTs supported a flexible and participatory exploration of the problem space. This enabled stakeholders to articulate and connect diverse perspectives, ultimately reframing the problem. In contrast, design theory provided a structured, iterative process for generating alternatives. Working across these approaches created moments of tension, for instance, between open-ended exploration and structured progression, but these tensions became opportunities to test and reflect on how the methods could complement one another.

We interpreted this interplay through the lens of partial integration and enhancement in multi-methodology introduced by Mingers and Brocklesby (1997), where different methods are combined to address different aspects of a complex problem without imposing a single unifying theoretical frame. By doing so, our work contributes to ongoing discussions, demonstrating how participatory OR tools and design-based methods can be deliberately operationalised together, offering actionable insights for OR practitioners seeking to navigate methodological diversity in real-world problem situations.

Secondly, we advocate for the integration of the P-KCP with a VT (built from a CM) as the foundational element when embarking on the creation of a Concept-tree. Typically, constructing a Concept-tree has been a time-consuming and labour-intensive process, necessitating several sessions following a rigorous sequence of steps. Our multi-methodology aimed to simplify this process and increase its adaptability to real-world applications. Moreover, we aimed to gain a deeper insight into the commonalities and disparities between stakeholders by amalgamating individual CMs into one comprehensive representation, i.e. an aggregated CM. We then derived a VT from the aggregated CM with the following advantages: (i) the assurance that ideas and proposals arising from the participants would meet the consensual values of the group; (ii) the contribution to further expand the Knowledge Space from which start the generative process for creating innovative solutions. We contend that incorporating a VT not only simplifies the tasks for stakeholders and facilitators but also sparks creativity in the development of a Concept-tree. As such, we propose that the existing C-K Theory literature recognizes the VT as a fundamental component of the Concept-tree building process.

Thirdly, regarding facilitation, guiding the process required balancing methodological structure with responsiveness to group dynamics. The use of CM encouraged participants to explore different perspectives without feeling pressured to reach immediate consensus. In contrast, the VT provided a structured framework for developing the Concept-tree, ensuring coherence while maintaining the participatory nature of the process. This approach aligns with recent findings by Engin et al. (2024), who highlight the importance of facilitation in supporting critical sensemaking and promoting reflective epistemic engagement in decision-support settings. They also note the value of strategies such as devil's advocacy, which resonates with our method: in the Concept-tree, negated nodes served this role by provoking critical discussion and stimulating creative alternatives. At the same time, our facilitation approach differed in practice. While their study relied on Value-Focused Brainstorming, we generated value trees through a structural transformation of interview-based cognitive maps. This grounded the modelling in participants' expressed views while providing a structured foundation for collective analysis. In this way, facilitation was embedded directly within the modelling structures, combining convergence around shared representations with divergence enabled by deliberate provocations in the Concept-tree.

To conclude, the process allowed us to reflect not only on the case study application, but also on the challenges of combining methodologies with different levels of formalisation. Our experience confirms that combining PSMs with formal design methods is feasible even without full paradigm integration, as long as the interface between phases is carefully managed. This aligns with Mingers and Brocklesby (1997) distinction between technical, philosophical, and cultural compatibility, and shows that methodological innovation can emerge through local adaptation rather than strict unification.

6.2. The role of the Concept-tree and the P-KCP multi-methodology: reflections from the case study

The case study application of the multi-methodology confirmed the validity and interest of establishing CMs as the first step in constructing a descriptive model of what the problem is for each stakeholder and check how distant are these mental representations, which also allows a rough estimation of potential conflict escalations. It also confirmed the utility of deriving a more prescriptive representation of the decision making driving structure: the VT (see Section 2 for a reflection on descriptive and prescriptive PSMs). This provides assurance that the alternatives emerging from the participative process are legitimate with respect to the collective values of the group. The case study application confirmed the intuition consisting in using the VT as an important component of Knowledge Space from which start a design (creative) process formalized as the construction of a Concept space (coming in the form of a Concept-tree).

Focusing on Figure 5, we can observe how the Concept-tree allowed to incorporate all major issues valued during the design process. Our Concept-tree effectively encapsulates a multifaceted typology of water management strategies, showcasing innovative solutions for sustainable resource use in Tunisia (as also noted in Hassenforder (2023)). It integrates key elements such as "supply management", highlighted by initiatives like rainwater harvesting and desalination of seawater, and "demand management", where we address the prevention of water waste and overexploitation. Alternative energy resources are represented through the use of free solar energy. Further, the Concept-tree incorporates "aquifer recharge techniques" to ensure long-term water sustainability, while the water accounting principles are mirrored in our data sharing and data connection nodes, ensuring transparency and efficient resource allocation. The concepts of "drilling operations management" are evident in our efforts to prevent illicit wells, fostering responsible water extraction. Through these examples, our Concept-tree provides a comprehensive blueprint that aligns with the recognized typologies, directing us towards a holistic approach to water management in Tunisia.

For instance, the inclusion of 'rainwater harvesting' and 'desalination of sea water' aligns with mainstream supply measures applied in other contexts. Additionally, 'preventing waste of water' and 'improving public administration effectiveness' echo the demand and protection measures, emphasizing stakeholder involvement and policy dialogue.

We also received positive feedback as far as the different steps carried out for the construction of the Concept-tree are concerned: (i) Contrasting the nodes of the VT allowed to provoke the reaction of the stakeholders: understanding why "not supporting agriculture" is not a viable option makes clear which are the profound reasons for which it is necessary to pursue a viable groundwater management policy for agricultural development. (ii) Incorporating experts' concerns and precise suggestions allowed to add potential solutions otherwise concealed by the consensual process of the workshops activities. (iii) Incorporating single stakeholders experience and knowledge allowed to emerge critical aspects otherwise impossible to grasp. An interesting case concerns the consequences of using solar panels for producing electricity. The massive diffusion of this technology allowed producing cheap electricity encouraging more water pumping and more overexploitation of the aquifer. We now know that these energy sources need to be regulated as for the rest if a sustainable water management policy has to be established.

6.3. The impact on the case study: supporting stakeholder participation and knowledge co-production

From a practical point of view (the one of the stakeholders) the workshops and the whole participatory process allowed to construct a legitimated set of proposals as far as the groundwater management problem of the Limaoua area is concerned. The alternatives generated during Workshop-3 were considered reasonable, convincing for the whole set of participating stakeholders and actionable from the point of view of the administration. This was not at all obvious at the beginning of the process given the differences, both substantial and perceived, among the different stakeholders and the underlining conflicts. From the client's point of view the consensus reached about the establishment of a GDA was a success because gained the legitimacy from the farmers (who should implement it). At the time of the end of Workshop-3 there was a clear operational direction to follow.[2]

An important lesson learned from this case study has been recognising the importance of a "model driven participation" (Mazri et al., 2019). With this term we

[2]The unstable political situation in Tunisia prevented further knowledge of the practical implementation of the GDA from being obtained for a few months. However, the new GDA working as water user association for groundwater resources in Gabès South was established on 21 December 2023.

intend the use of a formal methodology on how participation should be conducted beyond brainstorming or just unstructured and unfocussed group discussions. If participation is supposed to produce any usable results then it has to be driven by some model. Within the case study we conducted 3 workshops. Workshop-1 primarily involved the sharing of individual concerns and varied knowledge, contributing to the Knowledge Space building. In Workshop-2, participants gained a deeper understanding of the issue through the presentation of the aggregated CM, promoting knowledge co-production and Knowledge Space expansion. Workshop-2 facilitated a deeper understanding of the interconnected nature of the problems, encouraging more detailed discussions and a focus on finding collective solutions. Finally Workshop-3 has essentially been driven by the VT derived from the aggregated CM, in order to simplify the initial stage of the generative workshop. Overall we had a much more effective and efficient participative process, despite the many problems participation implies.[3]

In conclusion, the proposed multi-methodology not only addresses the complexities of diverse contexts, but also provides a practical and adaptable guide to fostering innovation in policy-making.

6.4. Limitations

While the P-KCP participatory tool has delivered meaningful results, both by generating actionable solutions for sustainable groundwater management in the Limaoua area and by establishing a process from CMs to Concept-tree development, it also presents a number of shortcomings and limitations that merit further research.

From a practical point of view, Workshop-3 was less "innovative" than anticipated. A substantial part of the stakeholders were primarily focused on the establishment of the new GDA which constrained discussions to its form and successful implementation rather than exploring alternative paths. This highlighted the need for an additional workshop with sector experts to expand the Concept-tree further, and then share it with the stakeholders for further discussions. Nevertheless, the creation of the GDA itself represents an innovative step compared to existing practices and demonstrates a strong commitment to sustainability. Indeed, the application of the P-KCP tool enabled the alignment of stakeholder interests while promoting the co-creation of knowledge around a now shared vision.

Morever, besides the difficulties related to the conjuncture (pandemic, political instability, etc.) the fact that the participatory activities have been conducted with participants having extremely different cultural, scientific and linguistic backgrounds has been an important limitation to the innovation capability of the whole experiment. The local workshop facilitators were not at all familiar to design theory and decision support, but were native Arab speakers as the stakeholders, while

[3]The reader should note that the whole case study and the workshops have been conducted during the COVID19 pandemic imposing the well known restrictions.

the researchers, experts in their domain, did not speak at all Arab. These are aspects which need to be considered better and in time when such experiments are designed.

To conclude, our application demonstrates the potential of the multi-methodology that integrates the P-KCP participatory tool with CMs and VTs for generating alternatives. It offers both theoretical and practical contributions, particularly in contexts that demand innovative solutions, such as sustainability challenges. While this study provides a promising direction, further research is needed to further explore its adaptability across different contexts and to continue refining the P-KCP tool.

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