AG-WaMED | Advancing non conventional water management for innovative climate-resilient water governance in the Mediterranean Area

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National policy document for NCW upscaling - Tunisia

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Abstract	The present report is produced as deliverable for the task 4.2 of AG-WaMED,Integrated Watershed Management Plans and NCW out-scaling. The document contributes to the development of national policy frameworks for upscaling non-conventional water (NCW) uses in selected Mediterranean countries. It addresses the emerging concept of water transition, understood as a shift towards more sustainable governance and use of water resources. Through a systematic literature review, the study develops a conceptual framework that identifies the key barriers and drivers of water transitions. It applies this framework to a case study of a living lab (Tunisia) to analyze upscaling processes at the national level. The findings inform future policy recommendations and contribute to broader Mediterranean-scale strategies for NCW deployment.		
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Introduction

This document is intended for the development of Deliverable 4.2.2.5, "National policy documents for NCW upscaling (Italy, Spain, Egypt, Tunisia, Algeria, D34)." Subsequently, the results will also contribute to sub-task 4.3.1, “Policy document for upscaling and out-scaling NCW at the Mediterranean scale (M20-34).”

In the face of increasing global water scarcity driven by the combined effects of climate change and water appropriation regimes, transitioning to more sustainable water governance and usage has become a critical issue for our societies (Brudge 2005, 2007). The objective of this document is to collect data to compare the upscaling processes of NCW at the national level. In a narrower sense, the 'scaling out' process can be defined as the expansion of innovations to a larger group of actors, 'scaling up' as the implementation of political and legal changes, and 'scaling deep' as the enactment of profound cultural and institutional changes (Breaught et al. 2021).

These processes involve water transition, a new key concept in water governance. While several countries around the world claim to be engaging in water transitions, often framed by governments as a promise of success for moving towards water sustainability, the conditions necessary to achieve these objectives need to be better identified. Indeed, local administrations and organisations face obstacles or barriers of various kinds that can prevent, hinder, or slow the implementation of these transitions (Heiberg, Truffer, and Binz 2022; Sixt, Klerkx, and Griffin 2018)

In the field of research, the concept of water transition has been used by several scholars (Sullivan et al. 2017; Hartman et al. 2017; Travassos and Momm 2022). It has become an operational framework for analysing the transformation of water governance, as it implicitly incorporates the idea of a rupture towards more sustainable water uses (Eggimann et al. 2018; Novalia, Rogers, and Bos 2021). Much of this research falls within Sustainability Transition Studies. In the water domain, transition refers to the success of social or technological innovation that leads to the creation and implementation of institutional and technological changes to improve the sustainability of the water system (Hartman et al. 2017).

Although the notion of water transition is increasingly employed in scientific research and public policies, it has not been critically examined from the perspective of water governance research. We have not found any articles within this field that propose defining the contours of this concept. No research has yet undertaken a synthesis of the main empirical barriers and drivers of water transition implemented worldwide. We aimed to fill this gap by defining the boundaries of this concept through a systematic meta-analytical approach (Van Houtven 2007) in the literature on water transitions. By conducting a comprehensive analysis of this phenomenon, we identified the barriers that hinder water transitions globally, as well as the drivers that facilitate their deployment.

This paper is structured in three sections. First, we explain our methodology, which involves literature review. We then present the conceptual framework that we developed by identifying the barriers and drivers of water transitions. Finally, we present the results of

applying this framework to a case study of a living lab. This application helps to understand the upscaling processes of NCW at the national level.

Methods

Based on a literature review on “water transitions”, we have identified the main barriers and drivers to water transitions. We develop a conceptual framework of these barriers and drivers to then identify them in each living lab for understanding the up-scaling process of NCW.

Literature review

This research relied on a systematic meta-analytical approach (Van Houtven, 2007). This method uses empirical evidence to identify common points and causal mechanisms that contribute to the construction of notions or theories (Oberlack and Eisenack 2014, Wolfram and Kienesberger, 2023). Meta-analytical approaches are increasingly used to address global and regional patterns of socio-environmental change (Author et al. 2017). By capturing these processes, it bridges the gap between global assessments, which often lack detailed case studies.

Our research is based on systematic case selection and theory-grounded coding. First, the text corpus was constructed by consulting articles published between 2014 and 2024 from two databases: Social Sciences and Humanities Proceedings (ISI WOS) and Scopus “Social Sciences.” The search was conducted by combining several keywords (see Table 1).

Table 1. Keywords used for article research. Source: Authors, 2024.

WOS Social Science		
Search string	**Hits**	**Date**
“sustainab* system” AND Water	14	08-dic
(sustainab* AND socio*techn*) AND Water	46	08-dic
“sustainability transition*” AND Water	140	08-dic
(sustainab* AND transition*) AND Water	1006	08-dic

(sustainab* AND [niche* OR regime*]) AND Water	458	08-dic
(sustainab* AND pathway*) AND Water	535	08-dic
(“system transition*” OR “system transformation*”) AND Water	41	08-dic
(system* AND [transformation* OR transition*]) AND Water	1615	08-dic
(system* AND [niche* OR regime*]) AND Water	653	08-dic
(system* AND [niche* OR regime*] AND [transformation* OR transition*]) AND Water	145	08-dic
(system* AND pathway*) AND Water	770	08-dic
(system* AND pathway* AND [transformation* OR transition*]) AND Water	142	08-dic
([transformation* OR transition*] AND socio*techn*) AND Water	50	08-dic
([transition* OR transformation*] AND pathway*) AND Water	235	08-dic
(“transition stud*” OR “transition theor*” OR “transition approach*”) AND Water	31	08-dic
([niche* OR regime*] AND socio*techn*) AND Water	28	08-dic
(pathway* AND socio*techn*) AND Water	7	08-dic
SCOPUS Social science		
Search String	**Hits**	**Date**
“sustainab* system” AND Water	56	08-dic
(sustainab* AND socio*techn*) AND Water	31	08-dic
“sustainability transition*” AND Water	64	08-dic

(sustainab* AND transition*) AND Water	731	08-dic
(sustainab* AND [niche* OR regime*]) AND Water	522	08-dic
(sustainab* AND pathway*) AND Water	375	08-dic
(“system transition*” OR “system transformation*”) AND Water	30	08-dic
(system* AND [transformation* OR transition*]) AND Water	2066	08-dic
(system* AND [niche* OR regime*]) AND Water	1372	08-dic
(system* AND [niche* OR regime*] AND [transformation* OR transition*]) AND Water	147	08-dic
(system* AND pathway*) AND Water	642	08-dic
(system* AND pathway* AND [transformation* OR transition*]) AND Water	86	08-dic
([transformation* OR transition*] AND socio*techn*) AND Water	26	08-dic
([transition* OR transformation*] AND pathway*) AND Water	184	08-dic
(“transition stud*” OR “transition theor*” OR “transition approach*”) AND Water	34	08-dic
([niche* OR regime*] AND socio*techn*) AND Water	10	08-dic
(pathway* AND socio*techn*) AND Water	4	08-dic

After removing duplicates, we reviewed the titles of the results (n = 2184) to check whether they were concerned about water resources or drinking water. During this first screening, a large number of publications had to be excluded due to terminological overlaps but lacking relevant content (e.g. ocean, fish in rivers, and maritime transport). Second, the abstracts of the remaining articles (n = 350) were examined according to two criteria: first, whether the article mentioned governance issues, and second, whether the issue of change or transition reflected in the title was substantiated. Third, for the selected articles (n = 74), we reviewed the full text by reading the introduction, methodology, and results to verify that the article’s analysis focused on a case study of water transition, even if the author did not necessarily

use this term. This resulted in a corpus of 52 publications. We then coded the articles on Atlas-TI to describe these studies by identifying the theoretical framework, object of analysis (innovation, regime, or other), and use of hydrological data. Next, we sought to outline the contours of water transitions according to their application domains and geographical characteristics (country, space, and scale). Finally, we identified textual elements referring to barriers or drivers of transition.

Theorical framework proposal

In this section, we present the barriers and drivers identified from the literature review. For each of them, we provide a definition.

Barriers of water transitions

The analysis of the corpus identified eight types of barriers to water transition in 26 articles (Table 2).

Table 2. Presentation of eight barriers to water transition. Source: Authors, 2024.

	Barriers	**Definition**	**References**
1	Intersectoral barrier	Lack of relationships between actors at different levels, absence of individuals, collective, and technical synergies, and/or emergence of conflicts around an innovation.	(9) Ward and Butler 2016; Hess 2018; Liu and Jensen 2018; van Welie et al. 2018; Savini and Giezen 2020; Novalia, Rogers, and Bos 2021; Heiberg, Truffer, and Binz 2022 ; Nilsson and Blomkvist 2021; Travassos y Momm 2022
2	Political barrier	Lack of clear political support for local initiatives, absence of participation and consideration of local needs, and international orientation by funders towards policies and projects unsuitable for Southern regions.	(7) Acheampong, Swilling, and Urama 2016; Ward and Butler 2016; Silvestri et al. 2018; Sixt, Klerkx, y Griffin 2018; Yasmin, Farrelly, and Rogers 2018; Afghani, Hamhaber, and Frijns 2022; Travassos y Momm 2022
3	Institutional barrier	Institutional fragmentation and internal coordination problems, strong institutionalization of the existing sociotechnical regime	(6) Herslund et al. 2018; Kundu et al. 2018 ; Sixt, Klerkx, y Griffin 2018; Suleiman 2021 ; Helgegren et al. 2021 ; Pakizer et al. 2023

		entrenched in daily institutional practices and logics.	
4	Economical barrier	Lack of visualization of the benefits and economic viability of the innovation compared to established regimes, or costs too high relative to demand uncertainty.	(6) Domènech et al. 2015; Xu et al. 2016; Ward y Butler 2016; Kundu et al. 2018; Silvestri et al. 2018; Sixt, Klerkx, y Griffin 2018
5	Normative barrier	Regulatory obstacles produced by legal frameworks or poor definition of laws leading to interpretation issues.	(5) Baigorrotegui, Parker, y Estenssoro 2014; Domènech et al. 2015; Ward y Butler 2016; Liu y Jensen 2018; Afghani, Hamhaber, y Frijns 2022
6	Technical barrier	Inadequate infrastructure, difficulties in use or malfunction of the innovation.	(4) Domènech et al. 2015 ; Kundu et al. 2018 ; Eggimann et al. 2018 ; Nilsson y Blomkvist 2021
7	Cognitive barrier	Lack of knowledge to use or maintain new technologies.	(4) McConville et al. 2017; Liu y Jensen 2018; Suleiman 2021; Afghani, Hamhaber, y Frijns 2022
8	Behavioral barrier	Failure to consider contexts (practices, habits, beliefs) in developing innovation and the economic, social, and environmental benefits it can provide.	(3) Kundu et al. 2018; Silvestri et al. 2018; Afghani, Hamhaber, y Frijns 2022

The most recurrent type of barrier-to-water transition is the intersectoral barrier. This refers to situations where there are no relationships between actors (social, institutional, political, and economic) at different levels, or there is a lack of synergies and alignments to support innovation. It also refers to the presence of resistance or conflict regarding innovation. The second type is political barriers. In this case, the lack of political support for local initiatives, failure to consider the needs of local populations, and implementation of ill-suited projects by international donors and organisations hinder water transitions. The third type is institutional barriers, which are linked to institutional fragmentation and coordination problems among institutional actors or excessive institutionalisation of the existing sociotechnical regime, generating path dependence situations.

The fourth type is economic barriers. The lack of visibility of benefits and economic viability of innovation, compared to established regimes, as well as high costs relative to demand uncertainty and market existence, can hinder water transitions. The fifth barrier is normative barriers, referring to the obstacles produced by the current legal and regulatory frameworks. A lack of clarity in law definitions can also create difficulties in local interpretation and hinder water transition. The sixth is technical barriers related to difficulties in using innovation due to poor design or malfunction. Dependence on centralised infrastructure which is unsuitable for local practices, can also hinder transition. The seventh type is cognitive barriers: a lack of knowledge to use or maintain new technologies can slow water transitions. Finally, behavioural barriers to water transitions are linked to disregard for contexts (practices, habits, and beliefs) in which innovation can be adopted, as well as economic, social, and environmental benefits.

Drivers of water transitions

The analysis of the corpus identified eight types of water transition drivers in 28 articles (Table 3).

Table 3. Presentation of eight drivers of water transition. Source: Authors, 2024.

	Drivers	**Definition**	**References**
1	Shared vision driver	The existence of a common vision that shifts collective perception towards a new regime or widespread adoption of innovation.	(7) Fam et al. 2014; van der Voorn and Quist 2018; White et al. 2019; Lennartsson et al. 2019; Criqui, 2020; Miörner et al. 2022; Mguni et al. 2022
2	Cognitive driver	The creation and assimilation of knowledge to enhance policy orientation; the presence of professional knowledge to support innovation; individual and social learning to change practices.	(7) Hoolohan et al. 2019; Criqui, 2020; Herrfahrdt-Pähle et al. 2020; McConville et al. 2022; Mguni et al. 2022; Binz et al. 2016 ; Blomkvist et al. 2020
3	Institutional driver	The existence of formal and informal institutions to drive experimentation, a coherent and flexible framework, and multiple institutional mechanisms to facilitate regime change and support this transition.	(6) Werbeloff et al. 2017; Wutich et al. 2020; Herrfahrdt-Pähle et al. 2020 ; Ampe et al. 2021; Pollachi et al. 2023; Nastar 2014

4	Individual driver	The presence of a promoter who uses their influential power to support the transition, particularly from the beginning of the process and to steer towards regulatory framework change.	(6) Werbeloff et al. 2017; Wutich et al. 2020; Ampe et al. 2021; Pollachi et al. 2023; Travassos and Momm 2022; Nastar 2014
5	Networks drivers	The existence of networks with actors located at other scales to support innovations, their diffusion, or scaling up.	(5) Lieberherr and Truffer 2015; Mguni et al. 2022; da Conceição et al 2023; Dobre et al. 2018; Nastar 2014
6	Political driver	Political support from state actors and coherence of public policy instruments to support the transition.	(5) Sullivan et al. 2017; García Soler et al. 2018; Hoolohan et al. 2019; Karimi et al. 2021; Suleiman et al. 2020
7	Normative driver	Legal support through the presence of clear and strict regulatory measures, and assistance to stakeholders for their proper implementation.	(3) Werbeloff et al. 2017; Hartman et al. 2017; Suleiman et al. 2020
8	Economic driver	The existence of financial support from various stakeholders and demand or market to support the innovation.	(3) McConville et al. 2022; Binz et al. 2016 ; Suleiman et al. 2020

The most common driver of water transition is sharing a common vision among different actors. This refers to the existence of a collective vision built in collaboration among stakeholders that generates a change in perception, favouring a new sociotechnical regime. User support (both public and consumer) is also a key element in adopting innovation and supporting transitions. The second type is cognitive drivers. In this case, the creation and assimilation of knowledge improves policy orientation, and decision-making accelerates water transitions. Additionally, improving professional knowledge (2) and individual learning to integrate the use of innovation are key elements in their development.

The third type of driver, institutional, is linked to the existence of formal and informal institutions that can drive experimentation, a coherent and flexible framework, and several institutional mechanisms that can provide a solid foundation for water transitions. The fourth category refers to individual drivers. The presence of promoters, leaders with particular skills, and creative minds who use their influence to support the transition is key. This role is

particularly important if engaged early in the transition process towards changing regulatory frameworks.

The fifth driver is associated with the existence of networks. The presence of contact and relationships with actors at other scales supports innovation, diffusion, and scaling up. Political drivers refer to the importance of political support from state actors as well as the integration and coherence among different public policy instruments to support the water transition. The seventh type of driver is legal: legal support for innovations and regime changes through strict and clear regulatory measures and the training of officials and managers for their proper application strengthens the success of transitions. Finally, economic drivers are linked to the financial assistance required for innovation development, as well as the formation of demand by users, and thus, a market for further development.

Barriers and drivers in Tunisia

In this section, we aim to analyze the barriers and drivers identified for the case of Tunisia. These were derived from two main sources: the responses to the guidelines provided to the countries (a methodology specific to this deliverable) and the inputs from Deliverable 4.1.1, Integrated Governance and Policy Analysis Report.

Barriers

Intersectoral Barrier: Fragmented Coordination and Weak Stakeholder Engagement

In Tunisia, collaboration between actors in the water sector is inconsistent and fragmented, mainly due to water scarcity, institutional overload, and a lack of structured coordination mechanisms. Technical services and specialized agencies are often overburdened with corrective measures, leaving little space for proactive planning and stakeholder engagement. This results in weak interactions between different levels of actors, including beneficiaries, researchers, government institutions, and committees.

Among beneficiaries, conflicts arise over runoff water access, as individuals attempt to maximize their share at the expense of others. Additionally, in research and administrative circles, the absence of formal agreements, contracts, or collaborative frameworks limits the continuity of cooperation and knowledge-sharing. In the case of treated wastewater reuse, the CRDA (Commissariat Régional au Développement Agricole), GDA (Groupement de Développement Agricole), and ONAS (Office National de l'Assainissement) are the key stakeholders. However, their interactions remain limited to data sharing and occasional maintenance efforts, without a comprehensive governance approach .

While stakeholders recognize the value of mobilizing additional water resources, debates persist regarding wastewater quality and safety concerns, including the risk of aquifer contamination and pathogen exposure during irrigation. Other barriers include the high costs of rehabilitating irrigation systems, limited user acceptance, and weak collaboration between research institutions and public administrations, particularly regarding the valorization of

wastewater reuse results. In the Gafsa region, the lack of studies and projects on aquifer recharge further exacerbates the challenge.

Technical and collective collaboration exists but remains infrequent. Although some efforts are made within the framework of national soil and water conservation programs (CES) to enhance aquifer recharge, these interventions are sporadic and uncoordinated. A quarterly meeting at the governorate level serves as a formal coordination space for wastewater reuse in irrigation, but this is not sufficient to ensure long-term planning and implementation.

Tunisia's intersectoral barriers are primarily characterized by weak institutional coordination, lack of structured collaboration frameworks, and inconsistent technical cooperation. Without improved cross-sectoral engagement and stronger governance mechanisms, the implementation of NCW solutions will remain fragmented and ineffective.

Political Barrier: Centralized Decision-Making and Limited Stakeholder Participation

In Tunisia, water infrastructure development and allocation are centrally controlled by the Ministry of Agriculture, with limited involvement of regional and local actors in decision-making. Regional representatives merely implement national directives, while local water user associations (WUAs) are excluded from policy discussions. This top-down governance approach limits transparency, as the rules governing water allocation are not fully accessible to all stakeholders.

Water allocation plans are primarily shaped by national-level power dynamics, particularly those related to agriculture and regional development, rather than local needs or participatory governance structures. The current Water Code does not include provisions for the involvement of farmers or water users in decision-making processes, nor does it guarantee their access to relevant water management information. A new draft water code is under development, aiming to increase stakeholder participation in water allocation policies, but its implementation and effectiveness remain uncertain.

The political barriers in Tunisia are therefore characterized by centralized decision-making, lack of transparency in water allocation, and minimal stakeholder engagement at the regional and local levels. Without institutional reforms that strengthen participatory governance, NCW projects risk being poorly adapted to local realities, limiting their potential effectiveness.

Institutional Barrier: Budget Constraints, Regulatory Requirements, and Low Farmer Acceptance

In Tunisia, institutional obstacles to non-conventional water use (NCW) are not primarily related to governance structures but rather to financial and operational constraints. The lack of budgetary resources, weak integration of scientific research into policy, and discontinuity in multidisciplinary projects and collaboration programs hinder the large-scale implementation of NCW solutions (Living Lab responses).

Strict regulatory frameworks further complicate the process. Treated wastewater (EUT - eaux usées traitées) must meet stringent quality standards, ensuring it is free from bacterial, viral, or chemical contaminants that could pose risks to human health and ecosystems. The NT106.02 standard governs effluent discharge into natural environments, while NT106.03 regulates wastewater reuse for irrigation. Additionally, any project involving wastewater irrigation requires a socio-environmental impact assessment, and the types of crops that can be irrigated with EUT are strictly defined. A detailed regulatory framework (cahier des charges) is required before wastewater can be used in agriculture (Living Lab responses). While these regulations are necessary for safety and environmental protection, they prolong administrative processes and increase bureaucratic complexity, making the implementation of NCW solutions more difficult.

One of the major institutional challenges is low farmer acceptance of treated wastewater reuse. While some agricultural land is already irrigated using EUT, many farmers remain reluctant to adopt this practice, and consumers often avoid purchasing crops grown with treated wastewater. This lack of social acceptance highlights the need for greater outreach and education efforts to build trust and encourage adoption of NCW solutions (Living Lab responses).

Institutional barriers in Tunisia are thus primarily financial, regulatory, and behavioral. The insufficient integration of research findings into policy, complex administrative requirements, and farmer resistance to wastewater reuse all contribute to delays in the expansion of NCW solutions. Without targeted financial investments, streamlined regulatory processes, and strong awareness campaigns, Tunisia will struggle to scale up sustainable water management practices.

Economic Barrier: Lack of Valuation and High Implementation Costs

In Tunisia, aquifer recharge is recognized as a crucial and indispensable practice for water sustainability, yet it is not financially valued or integrated into economic planning. The volume of recharged water is not quantified, and its role in agricultural value chains is not clearly defined, making it difficult to prioritize in national water strategies. Without a clear economic framework, aquifer recharge remains undervalued and underfunded (Living Lab responses).

One of the main economic obstacles is the high cost of establishment and maintenance of NCW infrastructure. The long-term financial benefits of aquifer recharge and wastewater reuse are not always evident to farmers, who are often reluctant to invest in these technologies due to uncertainties about their efficiency and return on investment. Additionally, rural youth migration and the movement of mountain dwellers to the plains further contribute to the abandonment of traditional water conservation techniques, as fewer people remain engaged in these practices (Project Deliverables).

The economic barriers to NCW implementation in Tunisia stem from the lack of financial recognition of aquifer recharge, high implementation costs, and demographic shifts reducing engagement in water conservation practices. Without clear economic incentives, better integration into value chains, and targeted financial support, NCW solutions will continue to face significant adoption challenges.

Normative Barrier: Regulatory Clarity but Limited Scope for Wastewater Reuse

In Tunisia, there are no significant regulatory obstacles to implementing NCW solutions, except for treated wastewater reuse (EUT - eaux usées traitées). The existing Water Code does not create legal ambiguities, and the use of EUT is legally permitted (Living Lab responses). However, despite this regulatory clarity, practical constraints and limited enforcement mechanisms hinder the widespread adoption of NCW solutions.

While Tunisia's legal framework allows wastewater reuse, technical, economic, and social challenges slow its effective implementation. The lack of strong incentives, infrastructure limitations, and low public acceptance contribute to a gap between regulation and practice. Although the Water Code does not pose interpretation issues, the actual deployment of wastewater reuse remains restricted, requiring further institutional support and investment to enhance adoption (Living Lab responses).

Technical Barrier: Infrastructure Sufficiency but Limited Technological Advancements

In Tunisia, the existing infrastructure is considered adequate to support aquifer recharge solutions, including the intensification of recharge structures and injection wells. However, modern technologies for aquifer recharge have not yet been implemented, as current efforts still rely on traditional methods such as dams, lakes, and various soil and water conservation works (CES) (Living Lab responses).

A major technical challenge is the lack of innovation in recharge techniques, which remain dependent on conventional water sources, limiting their long-term sustainability. Furthermore, these techniques are often located in remote or difficult-to-access areas, where mechanization and infrastructure maintenance are challenging (Project Deliverables).

For treated wastewater reuse (EUT), several technical difficulties arise, including large volumes of treated water being discharged into the natural environment instead of being reused, pipeline clogging risks, and power outages or mechanical failures, which can lead to contaminated water being released into the environment (Living Lab responses).

Although Tunisia has sufficient infrastructure for NCW solutions, its technical capacity remains constrained by outdated methods, limited integration of advanced recharge technologies, and operational inefficiencies in wastewater reuse. Addressing these barriers requires investment in modern recharge techniques, improved wastewater management, and increased accessibility to NCW infrastructure in remote areas.

Cognitive Barrier: Basic Knowledge but Lack of Specialized Training and Support

In Tunisia, stakeholders involved in non-conventional water use (NCW) solutions generally have basic knowledge of water management practices. However, technical support and specialized training are essential to enhance their expertise and ensure the effective use and maintenance of NCW infrastructure (Living Lab responses).

Key training needs include aquifer and groundwater modeling and simulation, socio-ecological systems (SSE), and integrated water resource management (IWRM). Capacity-building programs through workshops, technical training, and field-based learning opportunities are necessary to improve the implementation and sustainability of NCW solutions (Living Lab responses).

A major gap is the absence of socio-professional structures in rural areas to support farmers in creating and maintaining NCW infrastructure. This lack of institutional support limits knowledge transfer and the long-term viability of NCW practices (Project Deliverables).

While basic awareness exists, Tunisia lacks structured educational programs and professional support systems tailored to NCW adoption. Without targeted training initiatives and enhanced access to technical expertise, the country risks underutilizing available NCW technologies and failing to maximize their potential benefits.

Behavioral Barrier: Resistance to Wastewater Reuse and the Need for Awareness Campaigns

In Tunisia, local practices and beliefs play a crucial role in the adoption of non-conventional water use (NCW) solutions. While rainwater harvesting is widely accepted, the use of treated wastewater (EUT - eaux usées traitées) faces strong resistance, requiring significant time and outreach efforts to build trust and ensure adoption (Living Lab responses).

Efforts to increase public acceptance of NCW, particularly wastewater reuse, have included field-based awareness campaigns and media outreach through television and radio programs. However, despite these initiatives, skepticism among farmers and consumers remains high, slowing the integration of EUT into agricultural practices (Living Lab responses).

The success of NCW solutions in Tunisia depends on changing perceptions through sustained awareness efforts, including educational programs, demonstration projects, and incentives for early adopters. Without continued public engagement and efforts to build confidence in wastewater reuse, NCW adoption will remain limited by cultural and behavioral resistance.

	Barriers	**Definition**	**Description**
1	Intersectoral barrier	Lack of relationships between actors at different levels, absence of individuals, collective, and technical synergies, and/or emergence of conflicts around an innovation.	Fragmented coordination and weak stakeholder engagement due to water scarcity, institutional overload, and lack of structured collaboration. Limited cooperation between key actors, particularly in treated wastewater reuse.

2	Political barrier	Lack of clear political support for local initiatives, absence of participation and consideration of local needs, and international orientation by funders towards policies and projects unsuitable for Southern regions.	Water allocation and infrastructure decisions are centralized, with minimal involvement of regional and local stakeholders. The current Water Code does not ensure farmer participation in decision-making, but a new draft code aims to strengthen stakeholder inclusion
3	Institutional barrier	Institutional fragmentation and internal coordination problems, strong institutionalization of the existing sociotechnical regime entrenched in daily institutional practices and logics.	Lack of funding, weak integration of research findings, and bureaucratic delays slow NCW adoption. Strict wastewater reuse regulations require impact assessments and limit the types of irrigable crops, while farmer resistance remains a key challenge
4	Economical barrier	Lack of visualization of the benefits and economic viability of the innovation compared to established regimes, or costs too high relative to demand uncertainty.	Aquifer recharge is not financially valued or integrated into national water strategies. High establishment and maintenance costs, combined with rural migration, contribute to the abandonment of traditional water conservation practices.
5	Normative barrier	Regulatory obstacles produced by legal frameworks or poor definition of laws leading to interpretation issues.	No major regulatory obstacles exist, except for treated wastewater reuse, which faces practical implementation challenges. While wastewater reuse is legally permitted, low adoption rates highlight the gap between regulation and practice.
6	Technical barrier	Inadequate infrastructure, difficulties in use or malfunction of the innovation.	Existing infrastructure supports aquifer recharge but lacks modern technological advancements. Wastewater reuse faces operational issues such as pipeline clogging, power outages, and large volumes of treated water being discharged instead of reused.
7	Cognitive barrier	Lack of knowledge to use or maintain new technologies.	Basic knowledge of NCW exists, but advanced training in aquifer modeling, socio-ecological systems, and integrated water resource management is needed. The absence of professional support structures in rural areas limits effective NCW adoption.

8	Behavioral barrier	Failure to consider contexts (practices, habits, beliefs) in developing innovation and the economic, social, and environmental benefits it can provide.	Rainwater harvesting is widely accepted, but wastewater reuse faces strong resistance from farmers and consumers. Awareness campaigns through media and field-based initiatives aim to increase trust, but skepticism remains high.

Drivers

Shared Vision Driver: Integration into National Strategies but Limited Local Engagement

In Tunisia, the vision for non-conventional water (NCW) solutions is incorporated into national strategies for water resource mobilization and soil conservation. These strategies include aquifer recharge as a recognized approach to addressing water scarcity. However, implementation is primarily led by the public sector, while farmers mainly contribute to indirect recharge.

There is no fully established shared vision among all stakeholders. Farmers and local actors are not systematically integrated into structured programs for NCW adoption. While the government initiates direct recharge projects, efforts remain fragmented, limiting broader adoption at the local level.

Workshops, seminars, and pilot projects have been identified as potential mechanisms to engage stakeholders and promote collaboration around NCW initiatives. These tools could help raise awareness and share successful experiences, yet they are not currently widespread. Efforts to establish a common approach remain in early stages, requiring further coordination between public authorities and local stakeholders.

Cognitive Driver: Research and Awareness Efforts with Limited Stakeholder Integration

In Tunisia, knowledge creation and assimilation regarding NCW are supported through in-depth studies that aim to demonstrate the technical, economic, and environmental effectiveness of aquifer recharge techniques. These studies provide valuable insights into cost-benefit analyses and long-term sustainability, serving as a foundation for decision-making in NCW financing and implementation.

Efforts to support professional learning and encourage behavioral change focus on awareness-raising and demonstration activities. These initiatives aim to highlight the advantages of recharge techniques, yet there is no mention of structured training programs or institutionalized learning mechanisms that actively drive capacity building.

In practice, individual and social learning processes are shaped by the division of roles between public institutions and farmers. Government agencies oversee direct recharge projects, which often involve high-cost infrastructure, whereas farmers contribute through indirect recharge methods. However, there is no structured mechanism to enhance knowledge exchange between these actors or to integrate local experiences into broader NCW strategies.

Institutional Driver: Presence of Key Institutions but Limited Coordination Mechanisms

In Tunisia, formal institutions play a central role in facilitating experimentation and innovation in water management. The Ministry of Agriculture is responsible for development and research, while the Ministry of Environment oversees environmental policies related to NCW implementation. These institutions provide a regulatory and technical framework for advancing artificial recharge initiatives.

A key institutional mechanism supporting NCW is the Hydrographic Basin Agency (ABH), which plays a crucial role in developing artificial recharge projects. The ABH provides technical and financial support for infrastructure development and promotes the integration of innovative water management practices. Additionally, it coordinates different stakeholders to enhance the effectiveness of NCW initiatives.

Despite these institutional efforts, there is no mention of structured coordination mechanisms between different agencies and local actors. The lack of clear integration between government institutions and local implementers may pose challenges for the widespread adoption and sustainability of NCW solutions.

Individual Driver: Absence of Leadership as a Barrier to NCW Adoption

In Tunisia, there is no key promoter or influential figure driving the transition toward the installation of NCW. The lack of strong leadership has slowed regulatory changes and hindered the structured support for artificial recharge models. Without a recognized champion, efforts to advance NCW remain fragmented and lack clear strategic direction.

The absence of individual leadership has also made it difficult to overcome initial barriers in the adoption process. Without key figures advocating for these solutions, there is no centralized guidance to mobilize stakeholders, facilitate funding opportunities, or streamline regulatory frameworks. The findings highlight the need for leadership figures who can guide initiatives, build political momentum, and create an enabling environment for artificial recharge projects.

Networks Driver: International Networks Supporting Knowledge Exchange but Limited Local Coordination

In Tunisia, there are some international networks that contribute to the diffusion and exchange of knowledge on managed aquifer recharge (MAR) and unconventional water use.

Examples include the IAH Commission on Managing Aquifer Recharge, CSIRO's MAR, Latin American MAR Community of Practice (LatinMAR), and IGRAC (UNESCO). These platforms provide resources, research, and best practices on aquifer recharge management.

The main contribution of these networks has been in knowledge sharing and dissemination. They serve as channels for scientific exchange, training, and research support. However, their impact on the direct implementation of NCW solutions in Tunisia remains limited.

At different scales, collaboration between local, regional, and national actors is essential for strengthening NCW adoption. The networks play a role in capacity-building, experience-sharing, and research support, but there is a lack of structured coordination at the national level to transform shared knowledge into concrete implementation efforts. Strengthening local and regional partnerships could enhance the effectiveness of NCW diffusion and scaling in Tunisia.

Political Driver: Government Support Through Investment and Traditional Water Conservation Policies

In Tunisia, state actors provide political support for NCW initiatives primarily through financial measures, including covering mobilization and treatment costs and granting subsidies. These mechanisms help facilitate the implementation of unconventional water solutions by reducing financial burdens on stakeholders.

Public policy instruments are aligned to support the shift toward NCW, with several large-scale infrastructure projects serving as examples of state commitment. Key policy actions include the construction of three major dams, artificial recharge structures, flood spreading systems, and the use of treated wastewater for irrigation in Gafsa.

Additionally, traditional water conservation policies play a crucial role in promoting sustainable practices. The Conservation des eaux et des sols (CES) policy encourages the use of indigenous hydraulic techniques such as "meskat," "tabia," and "jessour". These traditional methods help manage water resources effectively in arid environments, combining modern NCW approaches with historical water-harvesting systems that are locally constructed and adapted to soil and water conservation needs.

Despite this political and policy support, challenges remain in ensuring the long-term sustainability and adaptation of NCW initiatives to local conditions. Further integration of traditional and modern water management approaches could strengthen Tunisia's NCW strategies and enhance their resilience to climate change and water scarcity.

Normative Driver: Regulatory Framework Supporting NCW Implementation

Tunisia has a clear legal framework to facilitate the installation of NCW, primarily governed by the Water Code (Code des eaux) and specific norms for the use of treated wastewater (EUT). These regulations establish guidelines and quality standards that ensure the safe and efficient implementation of NCW technologies.

The existence of a well-defined regulatory framework encourages stakeholders to adopt and implement NCW solutions. By providing legal clarity, these measures help reduce uncertainty and create an enabling environment for water resource innovation.

Additionally, the regulatory framework assists stakeholders in correctly applying NCW innovations by offering structured guidelines. A transparent legal structure ensures that practices align with national policies and environmental standards, promoting sustainable water management.

While Tunisia's legal framework supports NCW implementation, continued regulatory adaptation and enforcement mechanisms are essential to ensure long-term effectiveness and stakeholder engagement in water conservation initiatives.

Economic driver: Public support mechanisms, market dynamics, and adoption incentives

In Tunisia, the economic backing for non-conventional water (NCW) initiatives comes mainly from public authorities, which cover project costs and provide direct subsidies to individual users. Demand is not always consistent: in the case of treated wastewater (EUT), supply can at times exceed farmers' uptake. The chief economic incentive currently driving adoption is the availability of subsidies specifically aimed at encouraging the use of EUT in agriculture.

Table 4. Main Drivers to water transition in Tunisia

	Drivers	**Definition**	**Description**
1	Shared vision driver	The existence of a common vision that shifts collective perception towards a new regime or widespread adoption of innovation.	NCW is integrated into national strategies for water resource mobilization and soil conservation. Implementation is primarily led by public institutions, with farmers contributing indirectly.
2	Cognitive driver	The creation and assimilation of knowledge to enhance policy orientation; the presence of professional knowledge to support innovation; individual and social learning to change practices.	Knowledge creation is supported through detailed studies on the technical, economic, and environmental efficiency of recharge techniques. Awareness campaigns and demonstrations are conducted, but broader learning support is limited.

3	Institutional driver	The existence of formal and informal institutions to drive experimentation, a coherent and flexible framework, and multiple institutional mechanisms to facilitate regime change and support this transition.	The Ministry of Agriculture and the Ministry of Environment facilitate innovation and development in water management. The Hydrographic Basin Agency (ABH) plays a key role in technical and financial support.
4	Individual driver	The presence of a promoter who uses their influential power to support the transition, particularly from the beginning of the process and to steer towards regulatory framework change.	There is no identified key promoter or influential figure driving the shift toward NCW, which slows the adoption of recharge models.
5	Networks drivers	The existence of networks with actors located at other scales to support innovations, their diffusion, or scaling up.	Some international networks support knowledge exchange and research collaboration on NCW, but there is limited structured national networking.
6	Political driver	Political support from state actors and coherence of public policy instruments to support the transition.	The state supports NCW through cost-sharing, subsidies, and public investment in large-scale water infrastructure, including major dams and aquifer recharge projects.
7	Normative driver	Legal support through the presence of clear and strict regulatory measures, and assistance to stakeholders for their proper implementation.	Tunisia has a well-defined legal framework, including the Water Code and norms for treated wastewater use, which support NCW implementation by providing clear regulations.
8	Economic driver	The existence of financial support from various stakeholders and demand or market to support the innovation.	Public subsidies play a central role in supporting NCW adoption in Tunisia, particularly for treated wastewater. However, in some cases, supply exceeds demand, highlighting challenges in matching availability with effective use.

Conclusions: Barriers and Enabling Conditions for Scaling Up Non-Conventional Water in Tunisia

Barriers: Fragmented Governance, Financial Constraints, and Sociocultural Resistance

The expansion of non-conventional water (NCW) strategies in Tunisia, particularly managed aquifer recharge and the reuse of treated wastewater, is shaped by a constellation of structural, institutional, and sociocultural barriers. At the core lies a persistent fragmentation in governance, with limited coordination between national, regional, and local actors. Centralized decision-making continues to dominate the water sector, reducing the agency of regional stakeholders and water user associations in shaping policy and influencing infrastructure planning. This top-down model inhibits the development of participatory governance mechanisms, undermining both transparency and local ownership of NCW initiatives.

Institutional and financial constraints further complicate implementation. Key public agencies often operate under significant budgetary limitations, and there is a marked discontinuity in multidisciplinary programs and cooperation between research and policy institutions. While Tunisia has a well-developed legal framework for water management, the regulatory process for wastewater reuse remains highly complex, requiring multiple layers of approval and impact assessments. These requirements, although grounded in legitimate safety and environmental concerns, result in protracted administrative delays and contribute to the low adoption of treated wastewater for agricultural irrigation.

Economic barriers remain particularly pronounced. The long-term benefits of NCW solutions such as aquifer recharge are not well integrated into national planning or agricultural value chains. Costs associated with establishing and maintaining recharge infrastructure are high, while financial incentives for local stakeholders remain scarce. The demographic shift driven by rural migration has also contributed to the abandonment of traditional water conservation practices, weakening the cultural and labor foundations necessary for sustaining NCW systems in rural areas.

Technical and cognitive barriers add further complexity. While basic infrastructure exists, current recharge systems often rely on outdated methods and are located in remote areas, complicating their operation and maintenance. The lack of integration of advanced technologies hampers effectiveness and scalability. In parallel, although general knowledge of NCW exists among stakeholders, specialized training in areas such as groundwater modeling and integrated water resources management is largely absent. This gap is compounded by the lack of support structures for farmers, limiting their capacity to implement and sustain NCW systems.

Finally, behavioral and cultural resistance—especially toward the use of treated wastewater—continues to pose a major challenge. Despite awareness campaigns and field-based initiatives, farmers and consumers remain skeptical, with safety and quality concerns reinforcing entrenched practices. Without stronger engagement strategies, these perceptions will continue to undermine public acceptance and stall the scaling up of wastewater reuse in Tunisia.

Drivers: Policy Commitment, Institutional Foundations, and Technical Knowledge

Despite these structural challenges, Tunisia demonstrates several promising drivers that can support the development and expansion of NCW solutions. At the political level, the state has shown a clear commitment to water sustainability through public investment in infrastructure and subsidies that reduce the financial burden of water treatment and distribution. The integration of NCW into national strategies—particularly within policies focused on soil and water conservation—reflects a high-level recognition of its importance in addressing water scarcity. These strategies not only provide formal support for NCW initiatives but also promote the preservation of traditional water management systems, bridging modern and indigenous approaches.

Institutionally, Tunisia benefits from established agencies such as the Ministry of Agriculture and the Hydrographic Basin Agency (ABH), which have played a key role in promoting aquifer recharge and experimenting with alternative water management practices. These bodies offer regulatory and financial support and help align technical development with broader environmental objectives. While coordination among institutions and with local actors remains limited, the existing frameworks provide a foundation that can be strengthened through improved multilevel governance.

Cognitive drivers are also present, albeit underutilized. Research institutions have conducted detailed studies demonstrating the technical, economic, and environmental benefits of aquifer recharge, providing a solid evidence base for future expansion. These efforts, complemented by pilot projects and awareness campaigns, contribute to individual and social learning, even if structured training programs remain lacking. Tunisia's participation in international networks further facilitates knowledge exchange and capacity-building, offering access to global best practices in managed aquifer recharge and NCW technologies.

The country also benefits from a clear normative framework. Regulations such as the Water Code and specific norms for treated wastewater provide legal certainty and set quality standards that enable the implementation of NCW projects. Although challenges persist in enforcement and public acceptance, the legal infrastructure is a valuable asset for scaling up. Continued refinement of this framework—especially in relation to wastewater reuse—could further reduce administrative bottlenecks and promote safer, more efficient practices.

Finally, while no individual leader or key promoter of NCW has yet emerged, the presence of institutional champions and committed public officials has facilitated initial experimentation. Further progress will likely depend on the development of leadership capable of mobilizing

cross-sectoral coalitions, aligning fragmented initiatives, and sustaining momentum for reform.

In sum, Tunisia's experience with NCW reveals both the limits imposed by fragmented and under-resourced systems and the possibilities offered by coherent policy frameworks, institutional engagement, and ongoing technical innovation. Strengthening coordination, enhancing training, and addressing sociocultural resistance through inclusive governance and targeted communication will be essential to transforming current drivers into a scalable, resilient NCW transition.

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