# Nuffield Report: Governing water for sustainable farming

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# Chapter 0
# Abstract and main takeaways

## 1. Abstract

Effective water management is increasingly critical in the face of global challenges such as climate change, population growth, and competing water demands. This comparative study examines various community-based water management systems worldwide, focusing on sustainable irrigation districts, water users' associations, and collaborative governance frameworks. Drawing insights from diverse case studies spanning regions like Arizona, Australia, California, Chile, France, Portugal, Singapore, Spain, and the Netherlands, this research explores how these systems address complex water challenges through adaptive management strategies, financial innovations and innovative structures for institutional support. Key findings highlight the pivotal role of collaborative governance in enhancing resilience and adaptive capacity among diverse stakeholders, including indigenous communities, agricultural sectors, and local governments. Capacity building and knowledge sharing emerge as essential tools for improving water management outcomes globally, facilitating the integration of local knowledge with scientific expertise. By applying these insights, communities can navigate water management complexities, ensuring environmental sustainability and enhancing food security for future generations. This study underscores the importance of policy support for locally managed water associations and adaptive legal frameworks that promote long-term sustainability in farming.

## 2. Main takeaways

- Effective water management hinges on robust collaborative governance frameworks that engage diverse stakeholders, enhancing resilience and adaptive capacity in the face of environmental uncertainties.

- Implementing adaptive management strategies is crucial to responding flexibly to evolving water challenges, particularly under unpredictable climatic conditions and varying water demand patterns.

- Financial innovations are a key to incentivize sustainable water management practices and promote integrated water management strategies among stakeholders.

- Capacity building and knowledge sharing initiatives are essential for fostering collaborative governance, improving water management outcomes, and integrating local knowledge with scientific expertise.

- The insights from this study can support long-term sustainable farming practices and ensure food security by enhancing water management practices globally, thereby benefiting farming communities and other sectors reliant on water resources.

# Chapter 1
# Introduction and research questions

"*Alone we can do so little, together we can do so much"*
Helen Keller

Globally, it is estimated that by 2050, 1.6 billion people, or more than a quarter of the population, will be exposed to flooding and 800 million people will be facing rising sea levels and storm surges (World Economic Forum, 2019). At the same time, the urban population facing water scarcity in 2016 (933 million people) is projected to increase to almost half of the total urban population by 2050 (between 1.7 and 2.4 billion) (He et al., 2021). It has been estimated that this water scarcity could cost some regions up to 6% of their gross domestic product, due to impacts related to agriculture, health and income, in turn resulting in an increase in water conflicts (United Nations, 2023; World Bank, 2016).

Predictions indicate that this situation will have disproportionately higher risks in Arctic ecosystems, dryland regions, small island developing states, and Least Developed Countries (Roy et al., 2018). Faced with this scenario, the need to improve water governance has been pinpointed as a critical measure for economic growth, social inclusiveness, food supply and environmental sustainability (OECD, 2018). While technology will undoubtedly play a significant role, effective water management and governance are essential steps in addressing these challenges. There are still gaps defining and understanding what a good governance at the watershed level, its critical role in sustainability and water adaptation, its applicability in diverse contexts, and its contribution to resilient societal development (Martínez-Valderrama et al., 2023).

Despite the recognized importance of integrated water management, challenges persist in its implementation. Most water administration systems worldwide involve public institutions, in charge of the planning, initial allocation of the resource, information provision and system surveillance, among other tasks (OECD, 2011, 2012). They also involve a local institution with various levels of public-private coordination (OECD, 2011, 2012). Here, self-governed systems where the community creates its own rules and norms, have been argued to achieve better results and adjust to the community's needs (Ostrom, 1990, 2015; Poteete et al., 2010).

This type of structure with various decision centers, each having limited and autonomous decisions, all operating under delimited set of rules is typical of common natural resources and has been called a social-ecological system (Martínez-Fernández et al., 2020). These systems are usually characterized by a multiplicity of institutions participating simultaneously, connecting the human and the natural world, in a rather complex and messy structure (Alessa et al., 2009; Berkes et al., 2002; Gain et al., 2021). For this reason, locally managed water associations confront multifaceted challenges in achieving their goals, including institutional, technological, transparency, and financial issues, often exacerbated by contentious environments.

Therefore, this project aims to look into how these challenges have been addressed internationally, seeking to draw lessons applicable to other community-based water management systems. Specifically, the study will analyze and compare sustainable irrigation district schemes and water users' associations known for their enduring effectiveness.

## 1. Research questions

Recognizing the critical role of technological advancements, there is a growing understanding that many water challenges can be effectively addressed through enhanced management practices and collective action. In the face of highly uncertain climatic conditions and increasing water demands across diverse user groups, to organize and improve water management in a sustainable and integrated manner has become imperative. This project seeks to investigate how these challenges have been tackled in various water systems, and whether their experiences can offer insights for enhancing community-based water management elsewhere.

The study will specifically analyze and compare sustainable irrigation district schemes, water users' associations and any sort of collective tool that have demonstrated effectiveness in managing water resources over time. The central question revolves around identifying the factors that contribute to the long-term sustainability of these water systems.

By developing and evaluating tools for more equitable distribution of water among farmers, urban areas, industrial sectors, and environmental needs, the aim is to ensure the sustainability of entire aquifers. Consequently, this research endeavors to enhance water security and mitigate conflicts at the basin level. This will provide tangible benefits to farmers by supporting their investment plans, while also bolstering other economic sectors dependent on reliable water resources.

## 2. Places visited with the scholarship

To address the research questions comprehensively, an extensive field study was conducted, involving technical visits and explorations of over ten key locations known for their advanced water management practices. These include the Mendoza Region in Argentina; the Hoover Dam in Arizona (USA); the Murray-Darling Basin and Tasmania in Australia; the Central Valley of California (USA); irrigation districts in Ontario and Southern Alberta in Canada; Taro plantations in Hawaii (USA); the wetlands in Lyon and farming in Montpellier, France; groundwater in Kansas (USA); the Alqueva project in Portugal; International Banks and the National University at Singapore; the Murcia region in Spain; sinking grounds in Netherlands; and Somerset in United Kingdom.

## 3. Case studies analyzed

From these visits, specific regions and systems were selected for in-depth analysis, each presenting unique approaches to addressing water challenges and illustrating the role of community or collective action in their management. Although the number of cases is limited, they offer a wide range of insights and comparative information. The following are the reviewed cases, along with a brief description of each:

- **Central Arizona Project, in Arizona, USA**: Investigated the collaborative efforts enabled by the Hoover Dam for large-scale water storage, hydroelectric power generation, and inter-

state water distribution. Emphasized the cooperative management between states and stakeholders to address water supply challenges in a semi-arid region.

- **Murray-Darling Basin, Australia**: Analyzed the intricate water-sharing agreements and collective management practices among states, and different groups, including indigenous communities and agricultural stakeholders. Explored how collaborative governance supports sustainable water use amidst competing demands.
- **Tasmania Irrigation Scheme, in Tasmania, Australia:** Explored the collaborative approaches between public and private sectors in managing water resources, focusing on shared responsibilities and adaptive management strategies.
- **Groundwater in California, USA:** Studied collective groundwater management practices in collaboration with diverse stakeholders, examining the cooperative efforts to sustain water availability during severe droughts and periods of high demand.
- **Copiapó groundwater associations, Chile**: Explored a self-emerged groundwater association and the tools they have developed for managing the scarce resource in an hyper arid productive area of the Country.
- **Wetlands and drylands in Lyon, France:** Examined the integration of farming, urban water management and natural wetland conservation, highlighting collaborative efforts between municipalities, conservation groups, and urban planners. Explored joint initiatives for flood control, biodiversity conservation, and recreational use.
- **Alqueva system in Portugal**: Investigated the huge Alqueva system, showcasing collaborative efforts to integrate multiple water systems into a cohesive infrastructure. Examined cooperative governance models and collective decision-making processes for sustainable water resource management.
- **Financial innovation in Singapore**: Studied innovative financial tools, that started with green bonds, and have expanded to include social, sustainability, and blue bonds. These bonds have the potential of advancing towards integrated water management strategies, promoting collaborative schemes and sustainable water management practices.
- **Collective action in Murcia, Spain**: Studied the role of local water associations in collaborative water management with farmers and communities. Explored grassroots-level initiatives and their contribution to sustainable agricultural practices and local governance frameworks.
- **Sinking grounds in South Holland, the Netherlands**: Provided insights into collective water management strategies involving innovative technologies and public-private partnerships. Explored collaborative approaches to address flood risks and land subsidence, emphasizing shared responsibilities and integrated planning.

Each case was selected based on its relevance to the study's objectives, offering unique lessons and practices that can inform better water governance and management strategies. By analyzing these diverse examples, the research aims to draw comprehensive conclusions and develop adaptable tools for improving water distribution, ensuring sustainability, and reducing conflicts at the basin scale. This comparative study is crucial given the urgency of addressing water management issues amid current and projected climate challenges.

**A little bit about the scholar**

Elisa Blanco is an Agronomist, focused almost exclusively on water issues. She has been working as a researcher in the Agricultural Economics Department at the Pontificia Universidad Católica de Chile for almost fifteen years now. With them, Elisa has recently completed and defended her PhD in Natural Resources Economics. She also has a master's in public policy from the University of Chicago.

Elisa's work as a researcher and consultant has been located in a diverse range of water basins and irrigation districts. These have concentrated in central Chile, thus, with a particular focus on fruits and vineyards.

# Chapter 2
# **Methodology**

To provide the research with a more coherent structure, a two-step methodological approach was employed. This approach allowed for a more systematic examination of the data and ensured a comprehensive analysis of the study's objectives.

## 1. Interviews

Semi-structured interviews were carried out with various actors, to gain a practical and concrete perspective of the international experiences. These interviews were carried out with the actors detailed in Table 1, selected in based on their knowledge and/or participation in a water organization or system.

To this end, an open guideline was constructed with the following main topics: i) institutional system: what agencies are involved, who is in charge of the planning, for example; ii) technological aspects: how the adoption of new technologies and innovation is promoted; iii) financial matters: who pays and what kind of tools, like subsidies, are in place; and iv) transparency issues. The application of the instrument was carried out during visits.

For this research, surveying local knowledge was essential, as it extends far beyond what texts and documents can convey. Engaging directly with local actors provides invaluable insights into the nuanced realities and practices that shape water management systems. These personal interactions reveal the contextual challenges and solutions that are often overlooked in written sources. This firsthand knowledge is crucial for developing a comprehensive understanding of the systems in place and for identifying effective strategies that are grounded in the lived experiences of those directly involved.

**Table 1: Interviews and meetings**

| Name | Entity | Country |
|---|---|---|
| Ana Kennedy | Yuma Center of Excellence for Desert Agriculture | Yuma, Arizona |
| Paul Brierley | Yuma Center of Excellence for Desert Agriculture | Yuma, Arizona |
| Meghan Scott | Noble Law | Yuma, Arizona |
| Richard Gardner | Annandale Farm | Tasmania, Australia |
| Richard Hallett | Llanberis Pastoral | Tasmania, Australia |
| Georgia Beattie | Bulla Park | Victoria, Australia |
| Wayne and Tash Shields | Peninsula Fresh Organics | Victoria, Australia |
| Jane Doolan | Murray-Darling Basin Authority and Southern Rural Water | Victoria, Australia |
| Dennis Donohue | Western Growers Center for Innovation & Technology | Salinas, California |
| Don Cameron | Terranova Ranch | Helm, California |
| Glenn Anderson | Anderson Almonds | Hilmar, California |
| Carolina Veroitza | Comunidad de Aguas Subterráneas de Malpaso-Copiapó | Atacama, Chile |
| Guillermo Donoso | Centro de Derecho y Gestión de Aguas UC | Santiago, Chile |
| Maxime Moinard | Nuffield Scholar | Marais Poitevin. France |
| Antoive Putavy | Etablissement Public du Marais Poitevin | Marais Poitevin. France |
| Simon Moinard | École nationale supérieure agronomique de Montpellier | Montpellier, France |
| Jean Daniel Rinaudo | Bureau de Recherches Géologiques et Minières | Montpellier, France |
| Pedro Branco | Futuralmond, SL. | Portugal |
| Alexandra | Departamento do Planeamento Estudos e Projetos, EDIA | Portugal |
| José Fialho | Gabinete do Relações Públicas e Comunicação, EDIA | Portugal |
| Stephanie Vallance | Head of Sustainable Finance, ANZ | Singapore |
| Chew Fook Tim | Faculty of Science National, University of Singapore | Singapore |
| Mariano Soto | Comunidad de Regantes Campo de Cartagena | Murcia, Spain |
| Christopher Abrams | Grupo G, Spain | Murcia, Spain |
| Frank Lessinck | Veenweiden Innovation Center | South Holland, Netherlands |

Source: Own elaboration, 2024.

## 2. Bibliographic review of secondary sources

Various secondary sources were reviewed and analyzed with the aim of complementing and deepening the international comparative study. The process included a bibliographic review of previous studies, government reports, academic documents and relevant publications related to water management in each of the selected countries. This review was carried out using academic databases, institutional repositories and virtual libraries. Subsequently, the information collected was organized and structured, to finally carry out the analysis of the findings, identifying similarities, differences, patterns and trends between the different national contexts.

## 3. Methodological considerations

In the scenario described and under the proposed method, it is undoubtedly necessary to inform the participants that they are being part of a study, making them part of the objectives of the research, and explaining the way in which the narrative they provide will be used. To encourage more honest responses, it could be emphasized that the study seeks to obtain perceptions from a totally partial point of view.

A second element to consider is the bias provided by the interviewees, regarding their visions, political stance and personal beliefs. Therefore, actors with different positions and organizations have been considered, as well as members of the public sector and not only from the private perspective. Again, although a degree of impartiality will continue to exist, this mechanism could reduce such barriers.

# Chapter 3
# International comparative study

With the goal of identifying and characterizing community-based water solutions in various countries, this chapter presents the international comparative study. As mentioned above, through the analysis of diverse case studies, the goal was to obtain a comprehensive and enriching perspective on the different strategies and approaches employed by countries worldwide to address the composition and functioning of these organizations. The aim was to identify practices and measures that have successfully resolved issues related to participation and governance, and to explore how these strategies can be adapted to other national contexts, particularly in countries vulnerable to water stress and management challenges.

In the following sections, each selected case study is reviewed in detail, along with the main results of the comparative analysis. To provide a brief descriptive framework of each Country analyzed, Table 2 summarizes key characterization indicators.

**Table 2: General characterization of Countries studied**

| | *Population (thousands of people)* | *Area (thousands of km2)* | *Average rain (mm/year)* | *GDP (millions of USD)* | *Adjusted income per capita (USD)* | *Agriculture, forestry and fishing (% of GDP)* | *Water productivity (GDP/ water extracted)* |
|---|---|---|---|---|---|---|---|
| Australia | 25,688 | 7,741 | 534 | 1,723,827 | 45,711 | 2.4 | 172 |
| Canada | 38,227 | 15,634 | 537 | 2,140,086 | 41,986 | 1.8 | 44 |
| Chile | 19,493 | 757 | 820 | 335,533 | 11,096 | 3.5 | 7 |
| France | 67,750 | 549 | 867 | 3,030,904 | 36,490 | 1.9 | 92 |
| Mexico | 126,705 | 1964 | 758 | 1,788,887 | 4,499 | 4.0 | 13 |
| Portugal | 10,277 | 92 | 854 | 287,080 | 19,318 | 2.0 | 33 |
| Singapore | 5,454 | 0.7 | 2,497 | 501,428 | 50,690 | 0.0 | 674 |
| Spain | 46,937 | 506 | 636 | 1,580,695 | 25,118 | 2.3 | 41 |
| Netherlands | 17,282 | 42 | 778 | 1,118,125 | 46,420 | 1.5 | 97 |
| USA | 333,288 | 9,832 | 748 | 27,360,935 | 59,006 | 0.9 | 44 |

Source: World Bank Databank (2024)

## 1. The Central Arizona Project and the Hoover Dam

Arizona, renowned for its stunning natural landscapes including iconic red rock formations, expansive deserts, and the majestic Grand Canyon, faces a significant challenge due to its arid climate: water scarcity. Despite this, Arizona supports a thriving agricultural sector, primarily due to innovative water management strategies. A critical component of these strategies is the Hoover Dam, which provides essential water storage and distribution, contributing significantly to the state's agricultural productivity. The Central Arizona Project, a 540-km-long system of aqueducts, tunnels, and pipelines, further exemplifies Arizona's commitment to efficient water use, delivering approximately 1.85 megaliters of the Colorado River water annually to central and southern Arizona (CAP, 2023). These measures have enabled Arizona to sustain its agriculture and urban development, even in the face of challenging climatic conditions.

Farming in the desert of Arizona is a testament to the ingenuity and resilience of its agricultural sector. Despite the state's arid climate, agriculture remains a vital part of Arizona's economy, with crops such as cotton, citrus fruits, and vegetables thriving primarily due to extensive irrigation systems (Arizona Farm Bureau, 2023). This heavy reliance on water underscores the critical importance of efficient water management strategies. Innovative irrigation techniques and the strategic use of water resources have enabled Arizona's farmers to maintain productivity even in a water-scarce environment (Arizona Farm Bureau, 2023).

**The Dam’s many hats**

A cornerstone of Arizona's water management efforts is the Hoover Dam, an engineering marvel that stands 221 meter tall and spans over 380 meters across the Colorado River (Rutledge et al., 2024). Completed in 1936, the Hoover Dam is not just a feat of construction but a multi-purpose giant that plays a pivotal role in water storage, flood control, and hydroelectric power generation (Rutledge et al., 2024). It impounds Lake Mead, the largest reservoir in the United States, which provides essential water storage for Arizona, California, and Nevada. The dam's ability to store and distribute water efficiently has been fundamental in supporting the agricultural and urban needs of the region, showcasing the crucial interplay between engineering innovation and resource management in overcoming natural challenges (Sabale et al., 2023). The Dam has many purposes (Rutledge et al., 2024):

- Water Storage: The dam creates Lake Mead, a massive reservoir that stores water for future use, providing a crucial buffer during dry spells.
- Hydroelectric Power: It harnesses the power of the Colorado River to generate clean, renewable electricity for millions of people.
- Flood Control: Regulates the flow of the Colorado River, preventing floods downstream.
- Interstate Water Distribution: Plays a key role in delivering water to Arizona, Nevada, California, and parts of Mexico through a complex system of canals and pipelines.
- Tourism and conflictive need: Balancing the needs of tourism, which relies on the scenic beauty of Lake Mead, with the need to conserve water for agriculture and hydroelectric power generation requires continuous negotiation.
- Environmental Concerns: Changes in water levels due to drought and upstream water usage can affect ecosystems downstream, requiring careful management to protect the balance.
- Interstate Cooperation: Allocating water equitably among several states with varying needs requires ongoing cooperation and sometimes even legal battles.

Thus, the Hoover Dam serves as a reminder of the delicate balance between water use, economic development, and environmental sustainability.

**Lessons learned from the Central Arizona Project**

The Hoover Dam and Central Arizona Project provide insights into sustainable water management. These case studies highlight key strategies and challenges in balancing water storage, multi-purpose infrastructure, environmental protection, and interstate cooperation. The following lessons learned can inform and improve water community experiences globally:

- Effective water storage is critical for managing periods of scarcity and ensuring a reliable water supply. Similar projects should prioritize the development of reservoirs to create buffers during dry spells, enhancing the resilience of water systems.
- Multi-purpose water infrastructure, such as the Hoover Dam, provides benefits beyond water storage, including hydroelectric power generation and flood control. Future projects should consider incorporating multiple functions to maximize the utility and sustainability of water infrastructure.
- Managing diverse and competing demands requires ongoing negotiation and a flexible management approach. Stakeholders should establish frameworks for continuous dialogue and adaptive management to balance various interests effectively.
- Large-scale water projects can have significant environmental impacts, requiring careful and ongoing management to protect ecosystems. Projects should include comprehensive environmental monitoring and mitigation strategies to maintain ecological balance and biodiversity.
- Successful water management often depends on cooperation among multiple states or regions, each with unique needs and legal frameworks. Establishing strong, cooperative governance structures and conflict resolution mechanisms is essential for equitable water distribution and management.
- Legal battles and the need for clear institutional frameworks highlight the importance of robust legal and policy environments for managing shared water resources. Developing clear legal and institutional frameworks can facilitate smoother water management and conflict resolution.

## 2. Managing a gigantic: The Murray-Darling basin in Australia

Australia, a wealthy nation of 25 million people, with a high urban coastal concentration, faces water management challenges despite a GDP of almost USD 1.6 trillion (World Bank, 2021a). Australia's arid landscape relies on the Murray-Darling Basin (BoM, 2023b), but climate change, population growth, and economic expansion threaten water security (Mallawaarachchi et al., 2020). Reduced rainfall and extreme weather events further exacerbate these challenges (BoM, 2022, 2023a).

Australia's water management has evolved significantly since the Federation drought of 1895–1902. Initially focused on infrastructure projects for irrigated agriculture, a complex system emerged involving multiple levels of government and public agencies (Mallawaarachchi et al., 2020; S. A. Wheeler, 2014). The National Water Initiative (NWI) of 2004 established a framework for water sustainability through tradable water rights, environmental considerations, and intergovernmental coordination (DCCEEW, 2023). The Water Act of 2007 further strengthened this framework by introducing a national approach and regulatory body (Connell et al., 2005). This act shifted water management from a state-based to a basin-level approach, aiming for long-term sustainability and optimized outcomes for water users and the environment.

With the Water Act 2007 and the Murray Darling Basin Plan (MDBP) 2012, the Murray Darling Basin Authority (MDBA) was created, focused on the planning and management of water resources in the basin. The MDBA plays a crucial role in the implementation of policies and programs for water management, including the conservation of water resources, flood control and the promotion of sustainable agricultural practices in the basin (K. G. Wheeler et al., 2018). The MDBA is responsible for managing water infrastructure and developing strategic plans to ensure long-term water supply. Also, it establishes and implements the MDBP, a plan that limits water extraction and protects the environment (MDBA, 2023b).

The MDBA is funded through government funds and water fees (MDBA, 2022b). It operates within the national water institutional framework, ensuring coordination and coherence in water management (MDBA, 2022b, 2023a). The MDBA interacts with diverse groups and stakeholders, including local communities, farmer groups, environmental sectors and NGOs (S. A. Wheeler, 2014).

**Murray-Darling Basin Participatory Body**

The institutional structure that supports the actions of the MDBA has an advisory body called the the Basin Community Committee. This recognizes the connection of indigenous communities with land and water, seeking their participation in decision-making (MDBA, 2022a). It was established to ensure that the voices of the basin's diverse communities are heard at the highest level, thereby recognizing that any plan, no matter how scientifically credible or politically popular, would fail unless it met the needs of the communities for which it served. Currently, the function of the Basin Community Committee is to advise the MDBA on the performance of its functions, including advising on:

- the preparation of each draft of the MDBP;
- community issues related to the water resources of the basin; and
- matters referred to the Committee by the MDBA.

This Basin Community Committee has become a key mechanism for the participation of diverse groups in the management and projects of the MDBA (MDBA, 2022a, 2022b). It is made up of a president and up to sixteen other members spread throughout the territory of the basin, all with

extensive experience in water matters, specialized in the problems that affect their area, and with high connections with local and indigenous communities (MDBA, 2022b). Representatives are selected based on their experience or interest in water use and management, First Nations and their connection to water, and local government issues.

**Lessons learned from the Murray-Darling Basin Authority**

The Murray-Darling Basin in Australia offers valuable insights into water management with community involvement:

- Basin Community Committee ensures diverse community perspectives are incorporated into water planning (e.g., environmental, cultural, social), including local knowledge for effective water management strategies. With strong community engagement, understanding and support for water management decisions is enhances.
- Government involvement at federal and state levels provides essential funding for implementing water management plans, supported on an established and official policy framework for water management and resource allocation.
- Collaboration between different government agencies, the Basin Authority, and community groups is crucial for success.
- Developing more inclusive and effective strategies to ensure all stakeholders have a voice.
- Transparency and Communication, together with maintaining clear communication and transparency throughout the planning and implementation process, are jey issues towards sustainable organizations. The latter, together with continuously monitoring and adapting water management strategies based on changing circumstances and community feedback, also ensure being able to adapt towards new scenarios.

## 3. Tasmania irrigation scheme

Tasmania, Australia's island state, is known for its lush landscapes and diverse agricultural activities. The state's farming sector is characterized by the production of a wide range of crops, including fruits, vegetables, and dairy products, contributing significantly to the local economy (CGTG, 2023). Rainfall varies dramatically across the State, and Hobart, with an annual average of 626mm, is Australia's second-driest capital city after Adelaide (Discover Tasmania, 2024). Thus, Tasmania faces challenges related to water management, particularly in ensuring a reliable and sustainable water supply for its agricultural activities. Variability in rainfall, coupled with increasing demand for water resources, has necessitated innovative approaches to water management.

**The Tasmania Irrigation Scheme**

To address these challenges and secure the future of farming in the state, the Tasmania Irrigation Scheme was established. The scheme is managed by Tasmanian Irrigation Pty Ltd, a State-owned company recognized as an economic enabler (TI, 2023). Founded in 2008, Tasmanian Irrigation is tasked with owning, operating, designing, and developing irrigation schemes that provide high-surety irrigation water to Tasmanian landowners.

Since its development, Tasmanian Irrigation has taken over the management of various inherited assets, including dams, irrigation schemes, and river works. Additionally, it has constructed 15 new irrigation projects and advanced planning on five more (TI, 2023). By 2025, Tasmanian Irrigation aims to manage an extensive portfolio of irrigation infrastructure valued at over $680 million, capable of delivering 168,998 megaliters of water via 1,451 km of pipeline, 55 pump stations, 24 dams, and three power stations (TI, 2023).

A key feature of the Tasmania Irrigation Scheme is its innovative financial structure, which facilitated the successful implementation of the project. The scheme was funded through a tripartite financial model, where the Australian federal government committed to providing one-third of the total required funding (Kumar et al., 2022). This investment underscored the national significance of the project and the federal government’s commitment to supporting sustainable agricultural practices. The Tasmanian state government also allocated one-third of the necessary funds and the remaining one-third of the funding was provided by local farmers, who invested in the scheme to secure their water supply. This model ensured that farmers had a vested interest in the success of the project, promoting responsible water use and management.

The Scheme was also designed with a strong emphasis on environmental sustainability and adaptability to future changes (Kumar et al., 2022). For example, it incorporated measures to ensure the sustainable use of water resources, balancing agricultural needs with environmental protection. It is also designed to be flexible and adaptable, allowing for adjustments in water management practices in response to changing climatic conditions, ensuring long-term resilience. Finally, the scheme included provisions for maintaining environmental flows in rivers and streams, supporting aquatic ecosystems and biodiversity.

The successful implementation of the Tasmania Irrigation Scheme has had a transformative impact on farming in the state. By providing a reliable and sustainable water supply, farmers now have access to consistent water resources, allowing them to plan and manage their crops more effectively, increasing their yields and improving crop quality. The scheme has also supported economic growth

in rural communities by boosting agricultural output and creating new opportunities for investment and development. Thus, the Tasmania Irrigation Scheme stands as a model of innovative water management, combining robust financial planning, environmental stewardship, and community involvement. It highlights the importance of collaborative approaches in addressing water challenges and securing the future of farming in regions facing similar issues globally.

**Lessons learned from Tasmania Irrigation System**

The Tasmania Irrigation Scheme provides valuable insights into how community enhancement and sustainable water systems can be achieved through innovative water management practices. The success of this scheme underscores the importance of collaborative approaches, robust financial structures, and environmental stewardship. Here are some key lessons learned:

- The tripartite financial model involving contributions from the federal government, state government, and local farmers ensures that all stakeholders have a vested interest in the project's success. This model promotes shared responsibility and encourages sustainable water use and management.
- Local farmers' investment in the scheme fosters a sense of ownership and accountability. By involving the community in the financial aspect of the project, the scheme ensures that the interests of local landowners are aligned with the project's goals, leading to more responsible and efficient water use.
- Designing the scheme with a strong emphasis on environmental sustainability ensures that agricultural practices do not compromise natural ecosystems. Measures such as maintaining environmental flows and adapting to climatic changes help balance agricultural needs with environmental protection, promoting long-term resilience.
- The flexibility to adjust water management practices in response to changing climatic conditions is crucial for the long-term success of water systems. This adaptability helps communities prepare for and respond to future challenges, ensuring the continued availability and quality of water resources.
- By providing a reliable and sustainable water supply, the scheme supports economic growth in rural communities. Increased agricultural output and new investment opportunities contribute to the overall development and resilience of the community, enhancing its capacity to thrive in the face of environmental and economic challenges.

## 4. California and innovation in groundwater

California's water management challenges are complex due to a unique combination of demographics, economics, and climate. The state's large and diverse population of nearly 40 million puts a strain on resources, with income inequality further complicating access to water (Thorman et al., 2023; United States Census Bureau, 2021). Despite a booming GDP of $2.9 trillion, agriculture, the largest water consumer, represents a small portion of the economy (IBIS World, 2023; Medellín-Azuara et al., 2016). The state's naturally variable climate, ranging from Mediterranean to semi-arid, creates uneven water distribution (Dettinger, 2013; Hanak et al., 2011). Climate change is exacerbating these problems with megadroughts, increased temperatures, and unpredictable wet and dry periods (Escriva-Bou et al., 2022; Swain et al., 2018). On average, California allocates 10% of water for households, 40% for agriculture, and the remaining 50% for the environment, but these proportions can fluctuate depending on precipitation levels (Mount et al., 2023). Rising temperatures further complicate matters by increasing water demand through evaporation (Escriva-Bou et al., 2022; Mount et al., 2018).

California's water management system involves a complex interplay between state and local entities. Local agencies like cities, counties, and irrigation districts have significant autonomy (Hanak et al., 2011). Public opinion plays a big role in policy decisions, with state agencies like the Department of Water Resources (DWR) and the State Water Resources Control Board (SWRCB) overseeing and supporting local actions (SWRCB, 2022). The DWR focuses on water storage and transportation, while the SWRCB protects the environment and allocates water rights. However, this decentralized system faces significant coordination challenges. The establishment of Groundwater Sustainability Agencies (GSAs) in 2015 introduced additional complexity, requiring innovative solutions to streamline and improve the system efficiency and overall, sustainability.

**Groundwater Sustainability Agencies and their corresponding plans**

California's water management has historically been divided between organized surface water users, like farmers with irrigation districts, and uncoordinated groundwater users (Méndez-Barrientos et al., 2020). This fragmented approach limited effective management, especially as reliance on groundwater increased use, due to climate change (Mount et al., 2018). The introduction of Groundwater Sustainability Agencies (GSA) with the Sustainable Groundwater Management Act (SGMA) aimed to address these issues. GSA are locally formed entities tasked with developing Groundwater Sustainability Plans (GSP) to manage the groundwater resources of their basin (Méndez-Barrientos et al., 2020). These plans can be tailored to specific local needs and incorporate best practices like flexible operations that can adapt to changing climatic conditions, and they can integrate the different parties involved (Mount et al., 2018). These agencies are formed by local entities like cities, counties, and water districts, giving communities a significant role in shaping their water future (Méndez-Barrientos et al., 2020). This allows for a more innovative and sustainable approach to groundwater management compared to the previous system.

One of the key strengths of GSA lies in their flexibility. Local entities can choose to form a GSA independently or collaborate with others, allowing for customization based on the specific needs of their basin (Mendez-Barrientos et al., 2019). This local control extends to the development of the GSP, plans that require a thorough characterization of groundwater conditions and the establishment of clear sustainability objectives (Kiparsky et al., 2017; Méndez-Barrientos et al., 2020).

While GSA have significant autonomy in crafting their plans, a balance is struck between local control and state oversight. The SWRCB plays a crucial role by approving GSP and ensuring compliance with SGMA's objectives (Méndez-Barrientos et al., 2020). This ensures that local plans align with the broader goal of sustainable groundwater management across the state. At the same time, to support informed decision-making, the Department of Water Resources (DWR) provides data and hydrological projections (Mount et al., 2018).

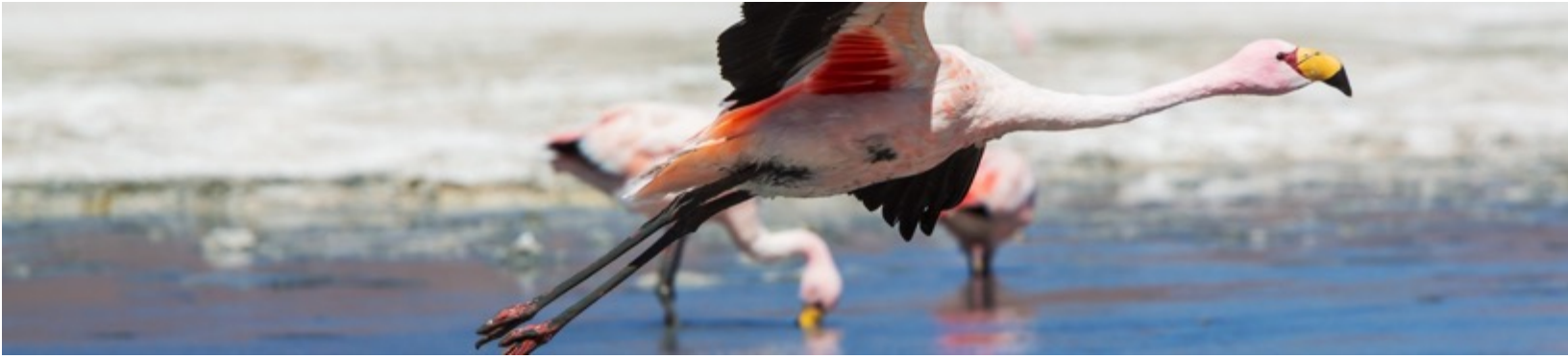
Another innovative aspect of the GSA system is the emphasis on coordination. In basins with multiple GSA, collaboration is essential for achieving shared sustainability goals. The legislation encourages the development of coordination agreements, ensuring a unified approach despite the involvement of multiple local agencies (Lubell et al., 2020).

Overall, the establishment of GSAs represents a significant shift towards a more innovative and adaptable approach to groundwater management in California. By empowering local communities to manage their own resources while maintaining state oversight (Méndez-Barrientos et al., 2020), California is fostering a system that is both responsive to local needs and accountable to broader sustainability goals. The variety of management strategies and operational rules observed across different GSAs reflects the flexibility and adaptability inherent in this system (Lubell et al., 2020).

**Lessons learned from the Groundwater Sustainability Agencies in California**

The California case study provides insights into the implementation of community-based sustainable groundwater management practices. The following lessons highlight the strengths and challenges encountered in empowering local communities, ensuring financial support, and fostering inclusive participation:

- The legislation truly empowers local communities by allowing them to form Groundwater Sustainability Agencies, tailored to their specific needs. A relevant aspect here, is that the law encourages participation from all stakeholders, including those outside traditional agency boundaries.
- For them to work on the long-term, basin plans require measurable objectives and consideration of potential negative outcomes, allowing for adaptation measures to promote a sustainable management.
- Financial support is a key element, and in this case, GSAs have the authority to collect fees and receive public funding to ensure plan implementation.
- However, complex agency structures can create barriers to participation for disadvantaged or isolated communities, where not all interests might be represented, potentially marginalizing certain groups.
- It is important to address the free-rider problem, where independent groundwater users may avoid contributing to the success of the management plan.



## 5. Groundwater management in the Copiapó water basin in Chile

Despite showing high levels of water runoff compared to the global average, Chile faces significant water challenges due to its extreme north-south length and hydroclimatic diversity (Santibáñez, 2016). Runoff varies dramatically, with arid northern regions struggling with overexploitation in less than 20 mm rain/year, while the south enjoys ample water. Furthermore, urban and industrial growth have led to a surge in groundwater extraction, with permits increasing 4,350% between 2001 and 2017 (Donoso et al., 2020). Compounding this pressure, climate change is projected to decrease rainfall and shrink glaciers, further reducing water availability (Donoso & Vicuña, 2019). The recent "mega-drought" exemplifies this vulnerability, highlighting the urgent need for adaptation (CR2, 2019; World Bank, 2021c).

Chile's economy relies heavily on water-dependent exports from mining, agriculture, and forestry (Banco Central de Chile, 2021). With 83% of national exports hinging on water availability, effective water management is critical for the nation's economic well-being. In response to these challenges, Chile has begun adapting its water system, empowering local water management organizations, considering groundwater management as well.

**Private Groundwater Associations supported with public tools**

The Copiapó basin in Chile's Atacama Region faced a critical situation. Water withdrawals exceeded natural recharge, leading to conflicts and a dwindling aquifer (Rinaudo & Donoso, 2019). However, the community rose to the challenge. In 2012, groundwater users took a bold step forming the first self-managed water association in Chile(PUC, 2014; Rinaudo & Donoso, 2019). This pioneering group paved the way for four more associations, ultimately leading to collective management of the entire basin's aquifer.

This organization did not come freely. Community members must actively participate, adapting their water usage and establishing rules for sustainable management. They also now have to pay fees, for their organization to work, something new to these groups (PUC, 2014). A remarkable achievement on this topic, involved creating a well-monitoring plan, that would made the organization have real control of all water intakes (Blanco & Donoso, 2021). This was developed with partial funding secured, through a collaboration with public agencies (PUC, 2014).

As a result, groundwater levels have stopped decreasing, and alliances have formed between upstream and downstream communities, even though legal hurdles still exist (Blanco & Donoso, 2021). Demonstrating how empowered they now are, a downstream community even purchased surface water rights. This strategic move granted them a role in managing the upstream Lautaro dam, a crucial factor for the aquifer (Abrigo, 2019). Despite their ongoing challenges, the Copiapó case stands as a testament to the power of community action with some public support. Through sacrifice, collaboration, and innovative solutions, the Copiapó communities secured a more sustainable water future for themselves and generations to come.

The groundwater communities in Copiapó have not only sustained farming in this truly arid region, where plantations were previously drying up, but they have also incorporated environmental considerations. For example, they have ensured that a flamingo population residing at the beginning of the basin now has a reliable water supply.

**Lessons learned from the Copiapó groundwater management case**

The Copiapó case offers valuable lessons for community-based water management:

- Clear and transparent accounting methods are crucial for monitoring water flow, individual extraction levels, and decision-making processes within meetings. This transparency should extend to formal conflict resolution mechanisms as well.
- The process of forming a community water organization, including the neutrality of the facilitating agent, should be transparent. Funding for operations and monitoring should also be demonstrably unbiased, even if public support is involved.
- While public agencies may offer support, they should limit their power to ensure local communities remain empowered in the decision-making process.

## 6. Multipurpose management in Vendée, France

With a nominal GDP of USD 2.96 trillion, France is among the top six global economies and the second largest in Europe after Germany (International Monetary Fund, 2023). Water use is decoupled from its economic structure, with the services sector contributing 70.3% to their GDP (World Bank, 2021b). While the industry contributes with 16.7% to their GDP, it is the largest water user, accounting for 69% of withdrawals, followed by the domestic sector at 20% and agriculture at 11% (World Bank, 2021b).

Regarding weather, France experiences an average annual rainfall of 867 mm, varying significantly across regions—from 600 mm in the south to over 2,000 mm in the northeast (Meteofrance, 2023). Despite having several water bodies, it is vulnerable to water scarcity due to overexploitation, climate variability, and rising water demands (EEA, 2018). These challenges and how they overcome them vary significantly according to the area. In Vendée, France, the agricultural landscape is uniquely characterized by two distinct yet complementary environments: the plains (Plaine) and the marshlands (Marais). This diverse territory requires strategic water resource management to address the specific needs and challenges of each area, ensuring sustainable agricultural practices across the region.

**Managing scarce and abundant water at the same time**

In Vendée, water resources vary significantly between the northern and southern parts of the department due to differing hydrographic and geological characteristics. In the plains region, with its limestone aquifer, almost all water is drained down to the marshlands. During the winter, when water is abundant, several hillside reservoirs or substitute reserves, store it. Here, there are around 340 irrigated farms, using around 24 million m³ of water, with 44% stored in collective reserves (Chambre D'Agriculture Vendée, 2022). In contrast, the marshlands, where all this water is drained to, have a dense hydrographic network composed of canals and ditches, which experience low to moderate flow rates. This area holds around 60 irrigated farms, using less water than the plains, less than 1 million m³ (Chambre D'Agriculture Vendée, 2022).

In 1991, over-exploitation in the Marais Poitevin caused saline water intrusion, highlighting the need for collective management, adopted in 1992. They started applying uniform rules and constraints across all farms using the same water resources (from April 1 to October 31), regardless of their agricultural focus (Rinaudo, 2020). From then on, flow meters were installed on all wells to monitor consumption, leading to the implementation of irrigation quotas per farm, based on historical cropping patterns or the number of wells (Maréchal & Rouillard, 2020; Rinaudo, 2020). These quotas now vary depending on the water available and are now allocated bi-weekly, to ensure equitable resource distribution among farms.

At the same time, the Water Development and Management Master Plans (the SDAGE), developed for each water basin, has introduced a substitution plan covering 45% of water needs. This ambitious project, initiated over a decade ago, had the goal of reaching 27 collective reserves spread across the southern plains (Chambre D'Agriculture Vendée, 2022). The aim is to enhance aquatic environments by ensuring longer water flows from overflow sources to the Marais Poitevin, while maintaining agricultural dynamism and the quality of produce that supports local agri-food industries. Local stakeholders are unified in these efforts, co-led by the different syndicate groups of Marais Poitevin and the Chambre d'Agriculture. While the syndicates act as project managers and owners

of the substitution infrastructure; the Chambre d'Agriculture supports farmers in adapting their practices, such as crop diversification, improving irrigation efficiency, and implementing sustainable farming systems, and collaborate on the development of five-year territorial contracts for Quantitative Management ensuring sustainable water management in the region (Chambre D'Agriculture Vendée, 2022). Thus, not only they are developing a long-term sustainable project for farming, but it is also including environmental and social concerns.

**Lessons learned from the Marais Poitevin case**

Based on the case study, some key lessons that can be applied towards sustainable collective water management systems are:

- The relevance of identifying a common threat, in this case, overexploitation, and fostering stakeholder unity through transparent and clear communication. This creates a strong incentive for collaboration. Omitting or not having all the information could hinder this process, potentially leading to distrust and resistance from stakeholders.

- The case highlights the importance of acknowledging geographical and resource disparities, developing a flexible system to deal with them. Effective management plans consider these differences and tailor solutions accordingly.

- Implementing monitoring systems, such as the use of flow meters and bi-weekly allocations demonstrates the value of measuring water usage. This allows for data-driven decision making and ensures fair distribution.

- It also shows how collective management can strike a balance between competing interests, such as environmental sustainability (protecting aquatic environments) and economic needs (supporting agriculture).

## 7. Alqueva project in south Portugal: an interconnected water system

In southern Portugal's Alentejo region, we encounter the *Empreendimento de Fins Múltiplos de Alqueva* (EFMA), namely, the Alqueva project. EFMA comprises a multipurpose system situated along the Guadiana River, anchored by the Alqueva Dam and encompassing a network of 69 dams and reservoirs. Centered on the Alqueva reservoir, Europe's largest strategic water reserve, with a total capacity of 4,150 million $m^3$, Alqueva project has a size, scope and modernity of infrastructure that allows it to irrigate an area of 120,000 hectares, produce reversible hydroelectric power enabling full complementarity with other renewable energies such as photovoltaic and wind energy, public and industrial supply, preservation of the environment and heritage or territory planning (EDIA, 2023a).

Southern Portugal experiences a Mediterranean weather, with hot and dry summers, and not so cold winters. During the summer months maximum temperatures are usually around 30-35°C, while winter maximum temperatures tend to be between 15-20°C, with minimum temperatures around 5-10°C. The average annual precipitation in the southern region of Portugal, including the Alentejo region, varies between 400-600 mm, concentrating most of the rain during the winter and early spring months. The Alentejo region presents a historical pattern of frequent drought events (Do & Roxo, 2008). These events have determined their particular water systems.

### Institutional system and organization

In the heart of Alentejo, Portugal's largest region, lies the transformative Alqueva project, centered around the Alqueva dam, at the Guadiana River. Managed by the Empresa de Desenvolvimento e Infraestruturas do Alqueva (EDIA), this initiative stands as a beacon of modern water resource management, since they oversees a comprehensive scope of responsibilities, encompassing the strategic allocation of water resources for irrigation, urban supply, and hydroelectric power generation across the region (EDIA, 2023a).

At its core, the Alqueva project serves as a multifaceted solution to the region's water needs, effectively mitigating seasonal water scarcity through a network of reservoirs and distribution channels. The project fosters collaboration with local water user associations and diverse stakeholders to ensure equitable and sustainable water use practices (EDIA, 2023b). These associations play a crucial role in the decentralized management and distribution of water resources, adapting strategies to meet the varying needs of agriculture, urban areas, and environmental conservation efforts (EDIA, 2023b).

EDIA's stewardship extends beyond mere water distribution; it encompasses a commitment to environmental stewardship and community resilience. The project integrates innovative technologies and adaptive management practices to optimize water efficiency, mitigate drought impacts, and safeguard fragile ecosystems. By empowering local entities and fostering a culture of adaptive governance, EDIA and the Alqueva project have designed a model of integrated water management, balancing economic development with environmental sustainability in Portugal's arid Alentejo region. Even though water availability could be challenging, because of this innovative infrastructure system, agriculture has flourished, and around 41% of the area's landscapes are now covered by agroforestry, dominated by cork oak trees, olive trees, vineyards, cereals, fruits and vegetables (Pais Dias et al. 2023).

**Lessons learned from the Alqueva project**

Overall, the lessons learned from the Alqueva project emphasize the value of holistic, inclusive, and adaptive approaches to water resource management, serving as a model for regions globally facing similar water challenges. In detail, these are:

- The project demonstrates the effectiveness of integrated water management approaches, where water resources are allocated strategically across multiple sectors including agriculture, urban supply, and hydroelectricity. This integration helps optimize water use efficiency and resilience against droughts.
- Involving local water user associations and stakeholders in decision-making processes ensures that water management strategies are responsive to diverse needs and challenges. This collaborative approach fosters local ownership, enhances transparency, and promotes sustainable water use practices.
- The project's ability to adapt to changing environmental conditions, such as climate variability and droughts, highlights the importance of adaptive governance. Flexibility in water management practices allows for timely adjustments in response to evolving challenges, ensuring long-term sustainability.
- By incorporating measures to protect aquatic ecosystems and promote biodiversity, such as maintaining environmental flows and mitigating impacts on local flora and fauna, the project underscores the importance of balancing development with environmental conservation.
- The Alqueva project serves as an economic catalyst by supporting agricultural productivity, creating jobs, and stimulating rural development in the Alentejo region. It showcases how investments in water infrastructure can drive economic growth while enhancing water security and resilience.

## 8. Singapore and advancing in the financial world

Singapore's story starts with its robust financial market. A global center for trade finance and asset management, Singapore plays a crucial role in channeling investments across Southeast Asia (USDS, 2023). This financial strength positions it perfectly to be a leader in innovative financial instruments like more social and environmental bonds.

**From Green to Social, Sustainability and Blue Bonds**

The financial sector is playing an increasingly important role in promoting sustainability. This is evident in the rise of various impact-oriented bonds, each building upon the previous one. The first and pioneer on the field were green bonds, which raise capital for projects with clear environmental benefits. They are associated to renewable energy, sustainable forestry, or energy efficiency initiatives. Their success paved the way for further innovation.

Recognizing the social dimension of sustainability, financial markets have introduced **social bonds**, which are designed to fund projects addressing critical social issues (ANZ, 2020). These bonds have been instrumental in supporting initiatives such as affordable housing, improved access to education, and healthcare services, thereby fostering inclusive and equitable growth. The scope of social bonds underscores the importance of addressing the needs of vulnerable and underserved populations as a fundamental component of sustainable development.

Building on the concept of social bonds and aiming for a more comprehensive approach, **sustainability bonds** have emerged. These bonds integrate both environmental and social objectives, financing projects that simultaneously tackle environmental challenges and contribute to positive social outcomes (ANZ, 2020). The holistic nature of sustainability bonds ensures that investments not only promote ecological resilience but also enhance social well-being, creating a balanced approach to sustainable development.

ANZ, an international banking giant, has been a key player in the issuance of sustainability bonds. By channeling funds into projects that address a wide array of issues, from climate change mitigation to social equity, ANZ exemplifies the financial sector’s growing commitment to sustainable development (ANZ, 2023). The bank's involvement in this area highlights the critical role that financial institutions play in mobilizing capital for projects that yield long-term benefits for both the environment and society.

Building on the success of the above, the latest innovative approach has been the introduction of **blue bonds**. These bonds are specifically designed to raise capital for sustainable ocean and coastal development projects (Thompson, 2022). The primary aim of blue bonds is to support a range of initiatives, including marine conservation, the promotion of responsible fisheries, and the implementation of pollution reduction strategies (Thompson, 2022; Tirumala & Tiwari, 2022). By channeling investment into these critical areas, Singapore is taking significant steps toward ensuring the long-term health and sustainability of its marine and coastal ecosystems.

Just like green bonds, sustainable and blue bonds offer investors financial returns alongside environmental benefits. However, these bonds have the potential to achieve even greater impacts by incorporating community aspects into their frameworks. One innovative approach is the introduction of community certifications, which prioritize projects that ensure community involvement and adhere

to fair practices. This could include initiatives that empower local water associations, support irrigation districts, or integrate traditional knowledge into conservation strategies. By fostering local participation and ownership, these certifications can enhance the effectiveness and sustainability of environmental projects.

Moreover, by focusing on socio-ecological benefits, these bonds can create a holistic approach that simultaneously promotes community well-being and environmental protection. Healthy ecosystems and empowered communities can reinforce each other, leading to a more resilient socio-ecological system. Sustainable and blue bonds that incorporate these elements not only address environmental challenges but also contribute to the social and economic vitality of communities, thus driving comprehensive and lasting positive change. Embracing such innovative financial instruments is a crucial step towards achieving a sustainable and inclusive future.

In essence, Singapore's new bond market, with its potential to integrate community considerations, offers a model for aligning financial investments with sustainable practices that benefit both the environment and local populations.

**Lessons learned from Singapore's innovative bond market**

By studying Singapore's green, sustainable and blue bond market, other countries can learn how to leverage financial innovation to achieve a future where environmental and social well-being go hand-in-hand. In detail, from this case study, some lessons can be drawn, such as:

- Strong financial markets can act as catalysts for environmental initiatives by creating new funding avenues.
- Social, Sustainable and Blue bonds demonstrate the potential to extend successful green finance models to address specific environmental challenges like sustainable farming.
- Integrating community considerations into these bond projects can create a more sustainable and equitable impact.

## 9. The Segura River Basin, Spain

The Segura River in Spain is characterized by a significant water deficit, making it a critical area for innovative water management practices. The basin is notable for its use of water transfers, non-conventional resources such as reuse and desalination, and the implementation of advanced technologies in water resource management (Palerm-Viqueira, 2010). Despite these efforts, the region faces substantial challenges, including the reduction of the Tajo-Segura transfer, overexploitation of aquifers, and environmental issues in the Mar Menor, their delta (CHS, 2023).

**Institutional Framework and planning for the Segura River**

The water management system in Spain is structured hierarchically, involving multiple levels of governance. At the national level, water management is regulated by comprehensive national legislation, which provides the overarching framework for water resource management across Spain (Lopez-Gunn, 2003). Within this framework, the Segura River Basin is managed by the "Confederación Hidrográfica del Segura" (CHS), a river basin organization responsible for planning and implementing water policies within the basin. Here, the Water Basin Plan serves as a strategic document that outlines the specific policies, objectives, and measures for sustainable water management in the Segura River Basin (CHS, 2023; Rica et al., 2014). This plan is crucial for coordinating the efforts of various stakeholders and ensuring that water resources are managed effectively and sustainably. Finally, at the local level, water communities, such as the "Comunidad de Regantes Campo de Cartagena," play a vital role in managing water resources. These communities are responsible for the day-to-day management of water distribution and use among farmers and other local stakeholders (CRCC, 2024). They operate within the framework set by the national legislation and the Water Basin Plan, ensuring that local water management practices align with broader regional and national objectives (CRCC, 2024).

The Segura River Basin Plan is a comprehensive strategy designed to address the basin's water challenges through a combination of conventional and non-conventional water resources. Key components of the plan include (CHS, 2023):

- Water Transfers: The Tajo-Segura transfer is a crucial element of the basin's water supply. The transfer system allows for the redistribution of water from areas with surplus to those with deficits, ensuring a more balanced and equitable water supply across regions. However, the reduction of the Tajo-Segura transfer due to increased ecological flow requirements in the Tajo River poses a significant challenge. Experts predict a reduction of 110 hectometers cubed ($hm^3$) from the current 160 $hm^3$ allocated for irrigation, which could lead to the closure of farms and loss of employment.
- Non-Conventional Resources: The basin relies heavily on non-conventional resources such as water reuse and desalination. These technologies provide alternative sources of water, reducing pressure on natural water bodies and aquifers. The implementation of advanced treatment technologies ensures that reused and desalinated water meets high-quality standards for various uses.
- Technological Innovation: The application of the latest technologies in water resource management is a cornerstone of the Segura River Basin Plan. This includes the use of advanced monitoring and control systems to optimize water distribution, reduce losses, and enhance the efficiency of water use. Innovative irrigation techniques and precision agriculture practices are also promoted to improve water use efficiency in agriculture.

- Environmental Sustainability: Addressing the environmental problems of the Mar Menor is a key priority. The plan includes measures to restore and protect this critical ecosystem, such as reducing nutrient loads from agricultural runoff, enhancing water quality monitoring, and promoting sustainable land use practices in the surrounding areas.
- Financial Structure and Community Involvement: A significant aspect of the Segura River Basin's water management success is its financial structure, which involves contributions from various levels of government and local stakeholders. The national and regional governments provide substantial funding for infrastructure projects and technological upgrades, while local water communities contribute to the operation and maintenance of these systems. The active involvement of local water communities ensures that water management practices are tailored to the specific needs and conditions of the region. These communities play a critical role in implementing the Water Basin Plan at the local level, fostering a sense of ownership and accountability among water users.

**Lessons Learned Towards Community Enhancement and Sustainable Water Systems**

The Segura River Basin offers relevant lessons in community enhancement and sustainable water systems. Here are some key takeaways:

- A hierarchical structure involving national regulation, basin-wide planning, and local water communities ensures that water management practices are coordinated and effective at all levels. This integrated approach promotes consistency and alignment with broader policy objectives.
- Reliance on water reuse and desalination technologies provides a resilient and sustainable water supply, reducing dependence on natural water bodies and mitigating the impacts of water deficits.
- The application of advanced technologies in water management enhances efficiency and sustainability. Monitoring systems, precision agriculture, and innovative irrigation techniques are crucial for optimizing water use and improving resource management.
- Balancing agricultural needs with environmental sustainability is essential for long-term resilience. Measures to protect and restore ecosystems, such as the Mar Menor, are integral to sustainable water management practices.
- Active involvement of local water communities and a robust financial structure ensure that stakeholders are invested in the success of water management initiatives. This collaborative approach fosters a sense of ownership and responsibility, promoting sustainable practices and long-term resilience.

## 10. The Netherlands and supporting local innovation

The Netherlands, particularly the province of South Holland, faces significant hydro-climatic challenges due to its low-lying topography, extensive water networks, and the prevalence of peat meadow areas. These regions are susceptible to soil subsidence and greenhouse gas emissions as a result of draining peatlands for agricultural use (Duri et al., 2014; Ollie et al., 2010). The groundwater levels play a crucial role in maintaining soil stability and reducing emissions (Pijlman et al., 2018). Over time, the Netherlands has implemented various measures to manage water levels and improve agricultural sustainability in these sensitive areas.

**"Farming at High Water" Program Case Study**

The "Farming at High Water" program is a pioneering initiative aimed at assisting farmers in the peat meadow areas of South Holland in transitioning to more sustainable agricultural practices. The program focuses on raising groundwater levels as a means to combat soil subsidence and reduce greenhouse gas emissions from peat soils(Veenweiden Innovatiecentrum, 2020). This approach necessitates changes in traditional farming practices to adapt to the new water conditions.

The program is part of the broader *Groene Hart Land Subsidence Regional Deal*, which seeks to address the environmental and economic impacts of land subsidence in the region (Veenweiden Innovatiecentrum, 2020). Supported by the province of South Holland, the program involves extensive research conducted by the Veenweiden Innovation Center (VIC).

Although the research period is still ongoing, initial results are promising. The carrying capacity of plots with higher groundwater levels and grazing remained comparable to those with lower groundwater levels. Also, grass production remained reasonably stable despite the changes in water levels(Duri et al., 2014; Pijlman et al., 2018). These findings suggest that experimenting with higher groundwater levels can yield valuable insights into sustainable farming practices in peat meadow areas.

This initiative, supported by the Groene Hart Land Subsidence Regional Deal and backed by the province of South Holland, underscores a community-driven approach to sustainable agriculture. One of its innovative aspects involves compensating farmers for economic losses incurred during the transition period, where plots must remain fallow for two years to allow for natural grass growth under higher groundwater conditions. This financial support from the community mitigates the individual economic burden, fostering cooperation among farmers and ensuring the program's viability.

**Lessons Learned from the program**

The "Farming at High Water" program offers a promising approach to addressing soil subsidence and greenhouse gas emissions in the peat meadow areas of South Holland. By experimenting with higher groundwater levels, the program provides valuable insights into sustainable collective farming practices. Continued research and collaboration are essential for refining these practices and ensuring the long-term viability of agriculture in hydro-climatically challenged regions of the Netherlands. Some lessons learned from the case studied are:

- The importance of collaboration between provincial authorities, research institutions, and farmers. Joint efforts are key to developing and implementing sustainable agricultural practices that address hydro-climatic challenges grounded in robust scientific knowledge.
- Farmers need to be flexible and willing to adapt to new practices. The transition to higher groundwater levels requires adjustments in traditional farming methods, which can be challenging but ultimately beneficial for long-term sustainability.
- Provincial support, as demonstrated by the commitment of South Holland, is vital for the success of such initiatives. Policy frameworks and financial backing enable the research and implementation of innovative practices.
- While early results are encouraging, longer-term planning, including follow-up and evaluations, are necessary to fully understand the implications and sustainability of high groundwater levels on farming practices.

# Chapter 4
# Comparative analysis and lessons learned

Based on the cases examined, the major results and lessons learned from the comparative study on community-based water management systems are presented ahead.

## 1. Comparative analysis of international experience

Across all cases reviewed, effective water management hinges on collaborative governance frameworks that involve diverse stakeholders. Examples include the cooperative efforts facilitated by the Hoover Dam in Arizona and the Murray-Darling Basin in Australia, where agreements between states, indigenous groups, and agricultural sectors enable sustainable water use amidst competing demands. These collaborations underscore the **critical role of a robust institutional system** and inter-institutional collaboration, ensuring that all stakeholders feel adequately represented and fostering trust among diverse actors.

Linked to the above, the study shows the pivotal role of **integrating public and private sectors in effective water management**. Tasmania's irrigation scheme serves as a prime example of how collaborative approaches between these sectors can foster shared responsibilities and adaptive management strategies. The case reviewed from Marais-Poitevin, in Lyon, France and the Copiapó case in Chile, also emphasize the relevance of public support in private water management schemes. By leveraging the strengths of both public and private entities, such collaborations not only enhance water security and resilience but also facilitate access to diverse funding sources and technological innovations. This integrated approach ensures sustainable water resource management by optimizing resource allocation and promoting long-term farming, aligned with environmental stewardship.

Financial innovations, such as Singapore's green, social, sustainability, and blue bonds, demonstrate how **funding mechanisms** can crucially address the perennial challenge of funding sustainable water management projects. These bonds not only finance vital environmental and social initiatives but also have the potential of fostering collaborative schemes and integrated water management strategies. By providing stable funding streams and incentivizing long-term investments, these

financial instruments not only address immediate funding gaps but also pave the way for innovative solutions and sustainable, future-oriented approaches to water resource management.

A common theme across the cases is the critical need for **adaptive management and resilience-building strategies**. California's groundwater management practices emerged after years of droughts illustrate how collaborative efforts among diverse stakeholders can sustain water availability and mitigate environmental impacts over time. This approach is crucial because it allows communities to adapt to current challenges while preparing for uncertain future conditions, including climate variability and population growth. By fostering collaboration, some flexibility into their operations and adaptive strategies, these initiatives not only address immediate water management needs but also build resilience to future water challenges that may be unpredictable.

Local water associations in Murcia, Spain, exemplify the role of grassroots-level initiatives in fostering sustainable agricultural practices and local governance frameworks. These initiatives play a crucial part in enhancing community resilience and adaptive capacity in water management. By operating within **nested systems of governance**, where local initiatives complement broader regional and national strategies, they effectively address local water challenges while contributing to the overall sustainability of water resources.

Regarding technological integration and innovation, the Copiapó Aquifer in Chile and the South Holland case in The Netherlands, both underscore the critical role of a **supportive public system in fostering innovative practices**. While public sectors often default to standardized rules, this collaborative approach addresses the specific challenges of the region—such as overexploited aquifers, flood risks, land subsidence, and urban water management—while promoting sustainable practices. This collaborative effort not only shares risks with the public sector but also pioneers a new model of public-private collaboration.

The study concludes that while each region faces unique challenges, the principles of collaborative governance, integration of sectors, financial innovation, adaptive management, and grassroots initiatives are universally applicable. These lessons can inform global efforts to improve water distribution, ensure sustainability, and reduce conflicts at the basin scale in the face of climate challenges.

## 2. Discussion and lessons learned

The findings of this comparative analysis shed light on the complexities and nuances of community-based water management systems across diverse geographical contexts. The results show the critical role of integrated water management frameworks in addressing global water challenges, as advocated in the literature (Blomquist & Schlager, 2005; Grafton et al., 2011; Hileman et al., 2015). Despite the prevalence of public-led water administration systems globally, this study reveals that locally managed water associations, empowered to create their own rules and norms, demonstrate notable advantages in adapting to local needs and achieving sustainable outcomes.

This aligns with previous findings on the matter. The literature, as synthesized from works by Elinor Ostrom and her successors, emphasizes the effectiveness of self-governed systems in natural resource management, highlighting their ability to incorporate local knowledge and foster community participation (Cole et al., 2019; McGinnis, 2011a, 2011b; McGinnis & Ostrom, 2014; Ostrom, 2015; Poteete et al., 2010; Poteete & Ostrom, 2008). Our findings align with these insights, showing that community-driven approaches, such as those observed in Murcia, Spain, and other case studies, promote resilience and adaptive capacity in water management (Alessa et al., 2009; Berkes et al., 2002; Gain et al., 2021)

As general lessons learned, the following can be stated:

- Effective water management hinges on robust collaborative governance frameworks that actively engage diverse stakeholders, including indigenous groups, agricultural sectors, and

local communities. This collaborative approach ensures broader acceptance of water management strategies and fosters resilience in the face of environmental uncertainties.

- Institutional support and robust frameworks play a critical role in facilitating effective water management. Strong institutional backing provides stability and coherence to collaborative efforts, ensuring that policies and practices align with long-term sustainability goals.
- The need for adaptive management strategies underscores the importance of flexibility in responding to evolving water challenges. This adaptability is crucial given the unpredictability of future climatic conditions and water demand patterns.
- The role of financial innovations, such as bonds and innovative financial structures, demonstrates how innovative mechanisms can incentivize sustainable water management practices. These tools not only address funding gaps but also promote integrated water management strategies and collaborative schemes among stakeholders.

# Chapter 5
# Conclusions and final remarks

This comparative study has underscored several critical lessons for enhancing water resource management through collaborative governance and innovative approaches. Effective water management hinges on robust collaborative frameworks that engage diverse stakeholders, promoting resilience and adaptive capacity in the face of environmental uncertainties. The need for adaptive management strategies is paramount, allowing flexibility to respond to evolving challenges in water availability and demand patterns.

Financial innovations, such as sustainable bonds, highlight how innovative funding mechanisms can incentivize sustainable water practices and promote integrated management strategies. These insights are not only crucial for addressing immediate water management challenges but also have broader applications in supporting long-term sustainability, including in agriculture and food security. By fostering inclusive decision-making processes and enhancing community resilience, these approaches can support farming communities in ensuring reliable water resources for sustainable agriculture.

Looking forward, policymakers and practitioners should prioritize supporting locally managed water associations by enhancing their capacity to operate autonomously within broader governance frameworks. These associations play a pivotal role in fostering community-driven solutions to water management challenges. By providing institutional support and ensuring adequate resources, policymakers can empower these associations to effectively manage water resources in accordance with local needs and environmental conditions. Moreover, integrating these associations into formal legal frameworks ensures their sustainability and legitimacy, thereby promoting long-term resilience in water governance. This approach not only enhances local decision-making but also fosters trust and cooperation among stakeholders, laying a foundation for sustainable water management practices that benefit both present and future generations.

Capacity building and knowledge sharing among stakeholders are indispensable for enhancing collaborative governance and improving water management outcomes on a global scale. Effective water management requires a shared understanding of challenges, solutions, and responsibilities

among diverse stakeholders, including government agencies, community groups, businesses, and academia. By investing in educational programs, workshops, and collaborative platforms, policymakers can facilitate the exchange of expertise and best practices. This fosters innovation and adaptive capacity, enabling stakeholders to respond effectively to evolving water challenges, such as climate change impacts and population growth. Moreover, promoting continuous learning and skill development ensures that stakeholders are equipped with the tools and knowledge needed to implement sustainable water management strategies. Ultimately, these efforts contribute to building resilient communities capable of addressing complex water issues and achieving environmental sustainability goals.

By applying the insights gained from this study, communities can navigate the complexities of water management more effectively, thereby ensuring both environmental sustainability and food security for future generations. Sustainable water management is essential for supporting agriculture, which is critical for food production and livelihoods worldwide. Implementing integrated water management strategies that balance agricultural needs with environmental conservation requires strategic planning, stakeholder engagement, and adaptive governance frameworks. Communities that leverage collaborative approaches and innovative financing mechanisms, such as sustainable bonds, can optimize water use efficiency while safeguarding natural ecosystems. This not only enhances food security by ensuring reliable water supplies but also mitigates risks associated with water scarcity and climate variability. By prioritizing sustainable water practices, communities can secure water resources for future agricultural generations, contributing to global food security and resilience in the face of environmental change.

While this study provides valuable insights, it is not without limitations. The comparative analysis focused on a select number of case studies, limiting the generalizability of findings across different geographical and socio-economic contexts. Future research should expand the scope to include more diverse case studies and explore emerging challenges and innovations in community-based water management.

Thus, this study underscores the importance of collaborative, community-driven approaches in achieving sustainable water management outcomes. By integrating lessons learned from diverse case studies and theoretical insights from the literature, this research contributes to advancing knowledge and informing effective water governance strategies globally.

# Chapter 6
# Policy recommendations

The insights gathered from this study have broad implications for policy and practice in water resource management. In summary:

- Policymakers should prioritize supporting the development of locally managed water associations and enhancing their autonomy within their institutional frameworks. This approach can foster adaptive capacity and community resilience, crucial for sustainable water resource management. Also, considering their autonomy formally in legal frameworks can provide clarity and commitment for overcoming their own challenges.
- To foster adaptive capacity and community resilience, should support initiatives that build community resilience, ensuring local groups can respond effectively to water-related challenges. This is done hand-by-hand with encouraging community-driven approaches to water.
- Initiatives aimed at capacity building and knowledge sharing among stakeholders are essential for fostering collaborative governance and improving water management outcomes. By promoting inclusive decision-making processes and ensuring equitable access to resources, policymakers can address the complex challenges posed by water scarcity and environmental change effectively.
- Policymakers should prioritize supporting the development of locally managed water associations and enhancing their autonomy within their institutional frameworks. This approach can foster adaptive capacity and community resilience, crucial for sustainable water resource management. Also, considering their autonomy formally in legal frameworks can provide clarity and commitment for overcoming their own challenges.
- Involving farmers in water management associations is critical, as they bring extensive knowledge and perspectives to water issues, having dealt with these challenges for longer than any other sector. Policymakers should encourage farmers to share their experiences and best practices, ensuring their voices are heard in decision-making processes.
- Providing targeted training and support for farmers can enhance their participation in water management associations. This can include workshops, seminars, and technical assistance to help farmers understand regulatory frameworks, water management techniques, and other sustainable water practices.

# Chapter 7
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