The Missing Piece of the Puzzle:

Stakeholders Engagement and Social Learning in

Adaptive and Integrated Water Resources Management

by

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ABSTRACT

Global freshwater management is facing unprecedented challenges due to climate change, population growth, and economic development. As water-related challenges have become increasingly complex, water management systems have evolved to incorporate social and environmental dimensions, resulting in the emergence of integrated water resources management (IWRM) and adaptive water governance paradigms. However, the challenges associated with IWRM include vagueness in operationalization, inadequate treatment of uncertainties, ineffective stakeholder engagement, and poor understanding of learning processes for adaptation to multiple changes. To address these challenges, this study proposes the use of the concept of adaptive governance to understand the role of social learning and stakeholders multi-level engagement in developing resilient water management systems. A bibliometric analysis is conducted to trace the intellectual development in the field, identify trends in water management regimes, highlight gaps in the IWRM approach, and explore the role of social learning in resource management systems. Integrating the different concepts and approaches from this analysis, a conceptual framework is developed to analyze the interlinkages among the social, ecological, and technological domains of water systems, focusing specifically on stakeholder engagement at different scales and the identification of the stages and types of social learning. The framework is then used to conduct a comparative assessment of water systems at the national level in two countries that have adopted IWRM: Australia and Uzbekistan. The comparison is based on the country reports that track global progress on the implementation of IWRM. The study's findings contribute to the current literature on adaptive water governance in the context of globalization and climate change and emphasize the importance of social learning in improving adaptive capacity and system resilience. The study provides an analytical framework for policymakers and water managers to analyze and improve the cooperation between various levels of water management authorities and among sectors involved in decision-making.

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1. INTRODUCTION

Freshwater resources are globally under increasing pressure as a result of rapid population growth, increasing economic development, and improved living standards, leading to increased conflicts over finite freshwater resources (Agarwal, 2000). Throughout the 20th century, the population increased threefold while water withdrawals rose by a factor of approximately seven, resulting in a considerable proportion of the global population experiencing increased water stress (Agarwal, 2000). In addition, climate change as a major global issue exacerbates threats and stress to the social, economic, and environmental aspects of our lives (Sawassi & Khadra, 2021).

The effects of climate change and the interconnections between different social, ecological, and technological components of water systems make it even harder to deal with the water management challenges caused by urbanization and population growth changes. Systems for managing water are inherently complex because they encompass ecological, social, and technological domains. This means that the problems and unknowns in such systems are multifaceted. With such complexity, technological or institutional panaceas—such as privatization or centralization—were frequently applied automatically to all different kinds of water problems worldwide without careful consideration of their applicability or the conditions necessary for their effective operation (Pahl-Wostl et al., 2010). However, a lot of water management issues are more related to governance shortcomings than to the resource base (Bakker et al., 2008) necessitating significant reforms in water governance that take the environment into account (Pahl-Wostl et al., 2010).

Governments are unable to resolve water issues without systems that facilitate stakeholder engagement and contributions toward developing water solutions (Rogers & Hall, 2003). A system that promotes societal involvement by enabling the participation of stakeholders

across multiple scales through institutional settings. Incorporating social learning into water management systems that connect stakeholders at various scales in flexible networks and build sufficient social capital and trust to cooperate in a wide range of formal and informal relationships are essential (Pahl-Wostl et al., 2007). Social learning extends beyond observing and imitating others in social contexts (Bandura, 1977); it also encompasses the development of shared meanings and practices that characterize social unity as a whole (Pahl-Wostl et al., 2007).

IWRM introduced the concept of stakeholder participation in water management. A participatory approach entails decision-making at the appropriate level with comprehensive public consultation and user engagement in the planning and implementation of water projects (Setegn & Donoso, 2015). IWRM is a process that "promotes the coordinated development and management of water, land, and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems" (Agarwal, 2000).

The United Nations endorses the IWRM concept through the Sustainable Development Goals (SDGs) framework, with SDG 6.5.1 focused on achieving integrated water resources management at all levels. SDG 6.5.1. evaluates the implementation of IWRM by assessing four key dimensions: the enabling environment, institutions and participation, management instruments, and financing (UNEP, 2021). The Progress on IWRM Report 2021 reveals that governments or stakeholders from 170 member countries regularly contribute to reporting their progress towards achieving SDG indicator 6.5.1.

Although the concept of IWRM has gained global popularity, it has been widely criticized by scholars and practitioners for the unrealistic nature of its principles (Biswas, 2004). Efforts to employ IWRM for managing micro- and mesoscale water policies, programs, and projects more effectively have proven unsuccessful (Biswas, 2004). It generated confusion and failed to achieve universal acceptance (Grigg, 2008). Implementing the IWRM is challenging for a number of reasons, including the ambiguity arising from its complexity and incorporation of numerous water

management aspects, as well as the institutional obstacles connected to political and geographic complications (Grigg, 2008). In certain countries, the national water institutions exert influence or control over other institutions for reasons of better integration, neglecting the fact that these institutions are associated with diverse stakeholder groups with differing interests (Biswas, 2004). This consolidation reduces institutional responsiveness to the needs of stakeholders (Biswas, 2004) contrary to IWRM's objectives of decentralization and stakeholder engagement.

Recent reports from the OECD and United Nations organizations indicate IWRM's failure concerning stakeholder participation and management. The United Nations SDG 6 and the OECD have established standardized approaches to assess government performance in water management. The OECD has developed twelve water governance principles aimed at enhancing water governance systems that address "too much," "too little," and "too polluted" water in a sustainable, integrated, and inclusive manner at an affordable cost and within a reasonable timeframe (OECD, 2021). One of the principles focuses on the importance of stakeholder engagement. In many countries, stakeholder participation in water management regimes is not achieved, according to a new OECD policy paper on water governance in the Asia-Pacific region. Among the 48 countries surveyed, only 1% of countries with an advanced economy have developed stakeholder mapping through which they identify stakeholders, their responsibilities, and the level of their engagement (OECD, 2021).

Despite the shortcomings of IWRM, it facilitated the shift toward adaptive water governance, which further builds upon the principles of adaptive management and IWRM (Pahl-Wostl et al., 2012). Adaptive water governance emerged as a response to water resource management's increasing complexity and uncertainties. Traditional water governance approaches, which were often centralized and technocratic, have been found to be insufficient in addressing the multifaceted challenges posed by the interdependencies between the social, economic, and ecological dimensions of water systems (Pahl-Wostl et al., 2010).

The concept of adaptive water governance has its roots in adaptive management, which originated in the fields of ecology and natural resource management in the 1970s (Holling & Walters, 1978). Adaptive management emphasizes the importance of learning from the outcomes of management actions and adjusting strategies based on that learning, given the uncertainties and complexities associated with ecosystems (Lee, 1993). Adaptive water governance recognizes the importance of collaboration and coordination among stakeholders at multiple scales and the need for flexible, learning-oriented approaches to decision-making in the face of uncertainties (Folke, 2006). Over the past few decades, the concept of adaptive water governance has gained increasing attention among scholars and practitioners, leading to its incorporation in water management policies and strategies worldwide (Pahl-Wostl et al., 2013).

In light of these findings, the thesis focuses on promoting the concept of adaptive water governance, embodying IWRM, to foster multi-layer stakeholder engagement, improve social learning, increase the adaptive capacity of organizations in the water sector, and strengthen the resilience of water management systems in the face of uncertainties such as climate change and socio-economic developments.

This study highlights the significance of collaboration, engagement, and social learning in achieving sustainable and effective water management outcomes. It emphasizes the need for a participatory and adaptive approach to water management that recognizes the importance of involved stakeholders' knowledge and engagement. It also emphasizes the learning process through participation and collaboration, increasing stakeholders and institutions' understanding of how to adapt to changes and transform the water management system. Policymakers and water managers can use these findings to prioritize the establishment of collaborative decision-making structures that promote knowledge sharing among stakeholders. The thesis provides a roadmap for improving water governance systems that are more responsive, inclusive, equitable, and sustainable, building a more resilient water management system that can meet future challenges and ensure the availability of this essential resource for generations to come. The research

questions proposed by this study provide a guide to understanding the shortcomings and gaps that are linked to stakeholders' engagement within a water system in IWRM and can be filled by the concepts of adaptive governance.

Research Questions

The research answers the following questions:

- What are the gaps and shortcomings in the IWRM approach to stakeholder engagement that could be improved by incorporating adaptive water governance?
    - Why did the collaboration under the regime of IWRM fail?
    - What aspects of adaptive governance can address the challenges in stakeholder engagement and increase collaboration?
- What potential mechanisms can be employed to facilitate social learning and improve collaboration among diverse stakeholders in water management?

Research Design

In order to address the research questions, Chapter 2 of this study carries out a systematic literature review to understand the trends in adaptive water governance and IWRM approaches. The review examines various documents sourced from the Scopus database for the years 2004–2023. The process involves four distinct searches within article titles, abstracts, keywords, and author names. A preliminary screening process is subsequently employed to ensure that the selected articles cover essential aspects, such as the differences between IWRM and adaptive water governance, social learning, collaboration, stakeholder engagement, and uncertainties, including those associated with climate change. Integrating the different concepts and approaches from this analysis helps in the development of a conceptual framework for analyzing water systems and their relevant components. By synthesizing the existing knowledge on adaptive water management and governance, and IWRM approaches, the review provides a

foundation for a comprehensive understanding of the various aspects and relationships within water systems.

In Chapter 3, an Adaptive and Integrated Management Framework (AIMF) is presented, drawing on our findings from the literature review, concepts from the Institutional Analysis and Development Framework (IAD), and the Management and Transition Framework. The AIMF offers a comprehensive approach to analyzing the interconnectedness of variables in water management systems, highlighting how dependencies can promote collaboration through stakeholder engagement and different types of social learning.

Chapter 4 focuses on the application of the Adaptive and Integrated Management Framework (AIMF) to examine water management practices in two case studies with distinct social and environmental contexts. Employing the AIMF as a shared language, the case studies analyze various components of water governance regimes. The chapter seeks to assess the usefulness and applicability of the framework by turning it into an operational tool for studying water systems and their underlying governance regimes, particularly in settings where individuals and institutions engage in collective management through learning and adaptation. Utilizing data from the IWRM Data Portal for Australia and Uzbekistan, the chapter draws conclusions about the framework's ability to assess the strengths and weaknesses of the water systems in both countries.

2. BIBLIOMETRIC ANALYSIS

This chapter focuses on a systematic review of the literature to comprehensively understand the trends in adaptive water governance and management and integrated water resource management approaches[1]. This study conducts a review of documents (articles, books, and book chapters) from the Scopus database for the years 2004–2023. Our analysis considers 2004 as the starting point, as it coincides with the launch of the United Nations Development Programs Water Governance Program. This program was launched with the objective of strengthening water governance and management in developing countries by promoting the application of IWRM principles. The bibliometric analysis will include four separate searches that are within (article title, abstract keywords, keyword plus, and authors) and will be followed by a preliminary screening process to ensure that articles address the differences between IWRM and AWM, social learning, collaboration, stakeholder engagement, and uncertainties, including climate change. Figure 1 is the visual representation of the steps for the bibliometric analysis.

[1] In our analysis, we will use the term adaptive water governance and adaptive water management interchangeably, as both are concepts related to the management of water resources under changing environmental conditions although they differ in their focus. Defining the difference between them is out of the scope of our study.

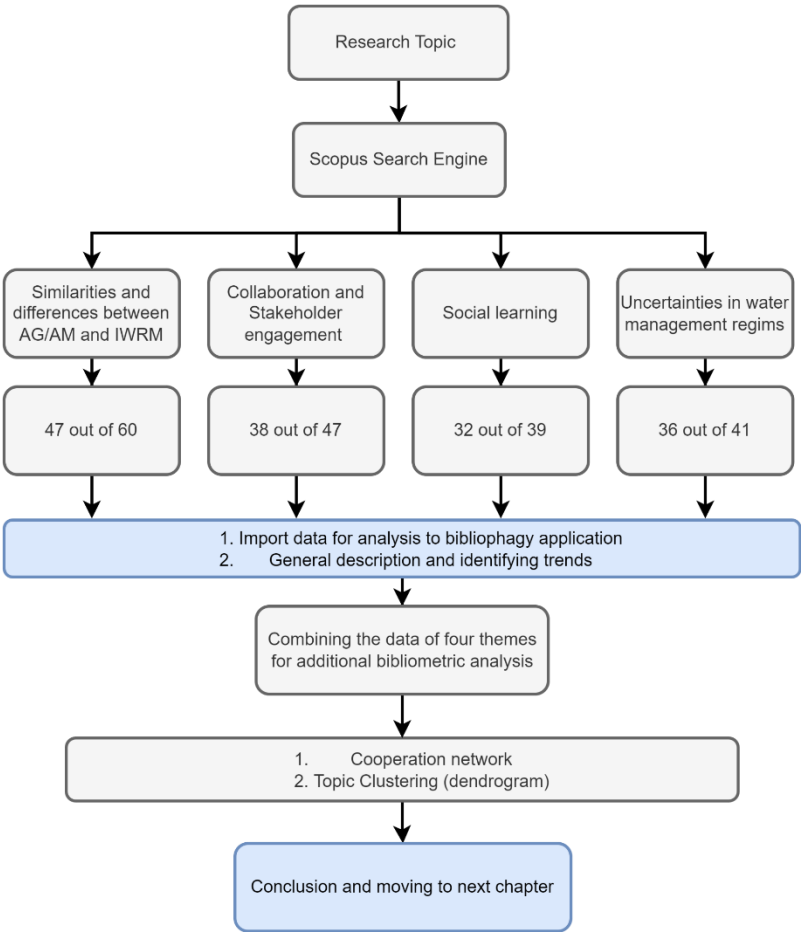

Figure 1: Visual Representation of the Process of Bibliometric Analysis

Introduction

With the increasing pressure on water resources due to climate change, socio-economic development, and competition over water use, how water is governed is critical to dealing with the complex nature of such challenges. Different water governance and management regimes are developed by countries or multi-national organizations to regulate the use and conservation of water resources while also ensuring the sustainability of those resources in the face of growing uncertainties. Scholars, water managers, and policy analysts are using various methods to compare those regimes and adapt them to ecological, social, and economic dimensions. They draw their conclusions based on the overall vision, processes, and outcome and merge the

concepts when needed to meet their needs. In this section of the thesis, attention is given to tracking the developments, appropriateness, and shortcomings of IWRM and adaptive water management (AWM). The study conducts a systematic review of these approaches, particularly to understand stakeholder engagement, collaboration, and social learning and their importance in increasing the adaptive capacity of the system in the face of uncertainties. It reviews how the concepts are defined and conceptualized and will also evaluate their operationalization. The bibliometric analysis aims to investigate the transition towards integrated, participatory, and collaborative decision-making to address the challenges posed by climate change, population growth, and stakeholder engagement. It covers four thematic areas: 1) Understanding the similarities and differences between adaptive water management and governance and IWRM, along with emerging topics 2) the existence of collaboration and stakeholder engagement in water governance. 3) the role of social learning; and 4) identifying the potential uncertainties of the system and its ability to identify and deal with them. The goal of four themes is to explore the gaps, shortcomings, and strengths of two water management regimes as well as the key components of the contemporary water management paradigm.

The concept of IWRM has been criticized for its vagueness and bureaucratic structures, leading to a focus on adaptive water resource management and governance. This approach aims to increase the adaptive capacity of the water system and engage a diverse group of stakeholders for more sustainable and resilient water management outcomes. The literature also emphasizes the importance of social learning and stakeholder involvement for knowledge democratization, collaboration, and trust building. The need for an adaptive approach is driven by increasing uncertainties in water management due to changing socioeconomic development and climate change. The literature also highlights the significance of addressing uncertainties in water management regimes for informed decision-making and effective management of the system.

Bibliometric Data

Different search strings using different Boolean operators have been used to search the articles in the Scopus database. The Scopus database is employed in this study due to its status as the largest abstract and citation database for academic literature, providing quality and reliable data for researchers. Biblioshiny, a web-based graphical user interface for the R package “bibliometrix" is used for data analysis and visualization.

Table 1: Bibliometric Data from the Scopus Database in Four Themes

Themes	Search terms	No. of articles	No. of selected articles
The similarities and differences between adaptive governance and IWRM (AG and IWRM)	(((adaptive OR "Adaptive Water") AND governance) AND management) AND (("Integrated Water Resources" OR "Integrated Water") AND management))	60	47
collaboration and stakeholder engagement	((adaptive OR "Adaptive water") AND governance OR management) AND (("Integrated Water" OR "Integrated Water Resources") AND management) AND (collaboration OR "Stakeholder Engagement" OR "Stakeholder" OR "Stakeholder Management"))	47	38
Adaptive governance to support social learning in water systems	((adaptive OR "Adaptive water") AND (governance OR management)) AND (("Integrated Water" OR "Integrated Water Resources") AND management) AND ("Social Learning" OR "Social-Learning" OR "Learning" OR "Feedback"))	39	32
Uncertainties in water management systems	((adaptive OR "Adaptive water") AND governance OR management) AND (("Integrated Water" OR "Integrated Water Resources") AND management) AND ("Uncertainties" OR "Uncertainty"))	41	36

Result and Analysis

The analyses are divided into four sections depending on themes and use topic clustering (dendrograms) and a collaboration network of authors for each theme, as well as the

corresponding authors' countries of origin, a country collaboration map, a research thematic map, and thematic evolution using a Sankey plot for the additional analysis.

The dendrogram is used to represent the hierarchical relationships between the keywords in search themes that could be clustered in a hierarchical way according to their similarity. The author’s keywords are used as a unit of our analysis. Author keywords are a collection of terms writers think will summarize the articles. The distant clusters in a dendrogram indicate that other articles do not share the keywords in the sample and that only a tiny percentage of articles use them together (Agusdinata et al., 2022). Each cluster represents a group of words that have often appeared together and are commonly used in a number of articles. The height of the dendrogram represents the separation between words or word clusters (Agusdinata et al., 2022).

The collaboration network in our analysis shows high-yield and high influence authors, which are recognized by examining the quantity of the published work and the number of citations. By examining the number of publications produced as well as their citation frequency, high-yield writers and high-influence authors are marked with a node of a larger size (Cheng et al., 2022), making it easier to see who the influential author is. Thicker lines signify closer relationships between writers, with lines linking the nodes representing collaboration. Multiple nodes can form a network, showing greater interaction and cooperation among the authors.

Theme 1: The Similarities and Differences Between IWRM and AWG

In this theme, the focus is on the emerging concepts of IWRM and adaptive water governance, and attention is given to the similarities and differences. Multiple authors have contributed to the development and understanding of the above concepts and have provided analysis for improving or figuring out the shortcomings. Figure 2, based on the 47 documents from the Scopus database, shows the network of high-yielding authors in the field. A node represents an author, and the node size shows the influence of the author's contribution.

Figure 2 shows two networks with more than four nodes, four networks with four nodes, and four networks with fewer than four nodes. It indicates that the authors are divided into subgroups in which the nature of their collaboration or their areas of expertise might differ, but they are all part of the larger collaboration on this theme. Pahl-Wostl et al.(2007a) belong to a category of authors with high-influence and a cooperative network in which water systems are studied in a complex world with increasing uncertainties. The study of articles in this sub-category provides an analysis of the characteristics of the adaptive water management regime to take into account the uncertainties and the role of social learning in managing the transformation to such water management regimes. Huntjens et al. (2010) provide an evidence-based and policy-relevant contribution to the characteristics of the water management regimes in the study of multiple river basins. Alike, Arthington et al., (2018) discuss the importance of environmental water allocation for humans and the ecosystem through the participation of stakeholders, collaboration, and adaptive governance in the face of climate change and population growth.

The collaboration network in this theme helps us in the interpretation of Figure 3, in which the authors' contribution to the field is discussed in detail.

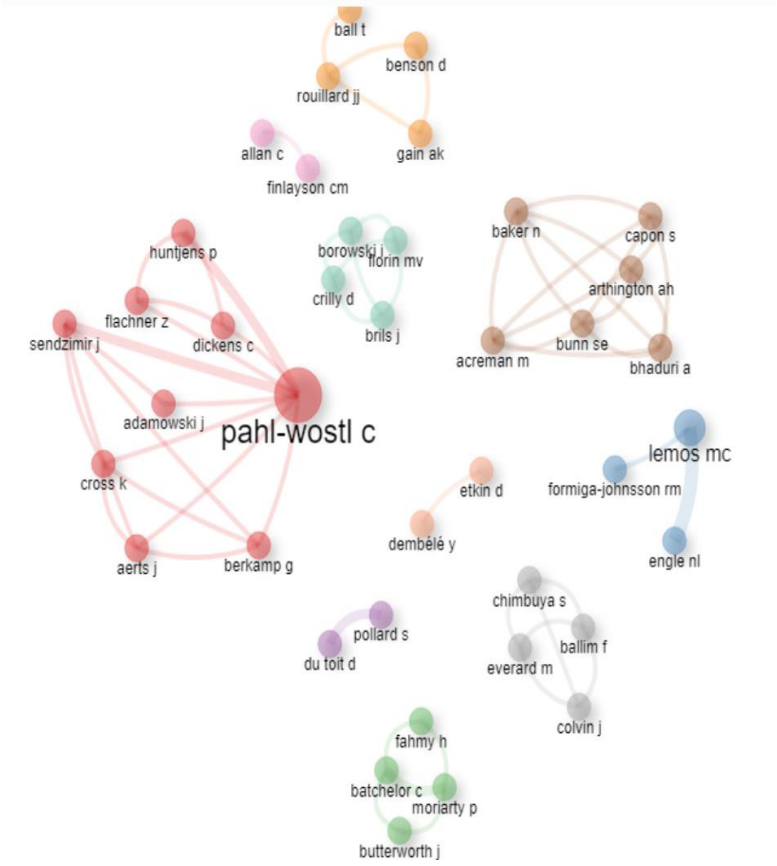

Figure 2: The Collaboration Network of Authors in Theme 1

The cluster of topics discussed by authors is visualized in Figure 3. The keywords that are commonly connected with the literature of both water management regimes are scattered across the clusters and show the closer ties between both regimes. Stakeholder engagement, climate change variability and adaptation, and sustainability are the commonly used keywords in our literature review. Overall, the literature, particularly the middle cluster, points out a paradigm shift in the management of water resources that is moving towards more integrated and participatory approaches and collaborative decision-making (Pahl-Wostl et al., 2007a; Pahl-Wostl, 2020; Ridder et al., 2013; Schoeman et al., 2014). Climate change, nexus strategies for integrated landscape management, and the function and growth of indigenous communities are some of the causes that lead to such transitions (Pahl-Wostl, 2020). The importance of stakeholders' engagement and the uncertainties that include lack of knowledge, system behavior,

and our understanding of the system are highlighted as crucial parts of contemporary water management regimes since such factors add to the complexity of management factors. According to Pollard & du Toit, (2009), it is becoming more and more clear to academics and practitioners that past management strategies have fallen short of meeting the difficulties of complex and fast-changing systems. The concept of IWRM was developed to reflect such challenges. It aims to find sustainable solutions for the growing challenges (Schoeman et al., 2014). The approach is developed to promote sustainable social and economic development by providing a governance platform for stakeholders to negotiate integrated land and water management at basin scales (Schoeman et al., 2014; Grigg, 2008; Saravanan, 2008).

Creative tools and procedures alone are not enough to implement IWRM; the idea must also be incorporated into existing management institutions and paradigms (Halbe et al., 2013). IWRM can also not be achieved if human dimensions are conceptualized as separate entities from ecosystems (Schoeman et al., 2014). It needs approaches that increase adaptive capacity in preparation for uncertainties emerging from the complex interconnections and feedback between societies, economies, and the environment (Schoeman et al., 2014; B. Walker et al., 2004). Furthermore, water governance science focuses on the analysis of regulatory processes that affect the behavior of actors in water management systems in order to address this human dimension (Halbe et al., 2013; Pahl-Wostl et al., 2007a; Schoeman et al., 2014). Adaptive water management is necessary as a paradigm shift to enable decision-making in the face of uncertainty (Serra-Llobet et al., 2016).

Several articles discuss the shortcomings of IWRM in terms of the vagueness of its conceptualization, regardless of its foundational principles, which allow managers to overlook fundamental changes while claiming the adaptation of global thinking (Schoeman et al., 2014; Serra-Llobet et al., 2016; Grigg, 2008; Biswas, 2004). IWRM has developed new management organizations with centralized control over water management at the scale of river basins or catchments (Rouillard et al., 2014; Serra-Llobet et al., 2016). This method, however, aids in

coordination across interconnected hydrologic and ecological systems. Still, river basin or catchment boundaries may not coincide with other significant ecological boundaries. New authorities may lack legitimacy if they do not adhere to jurisdictional boundaries, adding to coordination issues (Serra-Llobet et al., 2016; Huitema et al., 2009).

With such challenges in the implementation of the concept of IWRM, many articles, e.g. (Pahl-Wostl et al., 2007a; Schoeman et al., 2014; Halbe et al., 2013; Engle et al., 2011; Huitema et al., 2009; Pahl-Wostl et al., 2012) discuss adaptive water resource management and governance. By establishing both learning mechanisms and the conditions necessary for those processes to occur, adaptive water management strives to increase the adaptive capacity of the water system (Pahl-Wostl et al., 2007a). As we can see in Figure 3, the concept of adaptive water governance brings to the literature the terms of social learning, uncertainties, adaptive capacity, resilience, climate change, and public participation. These trends lead us to explore these concepts through a detailed bibliometric analysis of these terms in Themes 2, 3, and 4 of this chapter.

The shift toward adaptive management, despite its potential strengths, poses challenges and has shortcomings. The transition toward adaptive water management is slow due to limited empirical evidence, and moving from a top-down to a more participatory approach without changing the approach to information and risk management is not simple (Pahl-Wostl et al., 2007). The lack of empirical evidence and knowledge makes the prediction of outcomes challenging and leads to resistance by stakeholders that are accustomed to traditional management approaches. Instinctual barriers also arise as this approach necessitates significant changes to existing structures, policies, and regulations. The complicated social dynamics, institutional rigidities, and financial restrictions make it harder to adopt this approach (Pahl-Wostl et al., 2007).

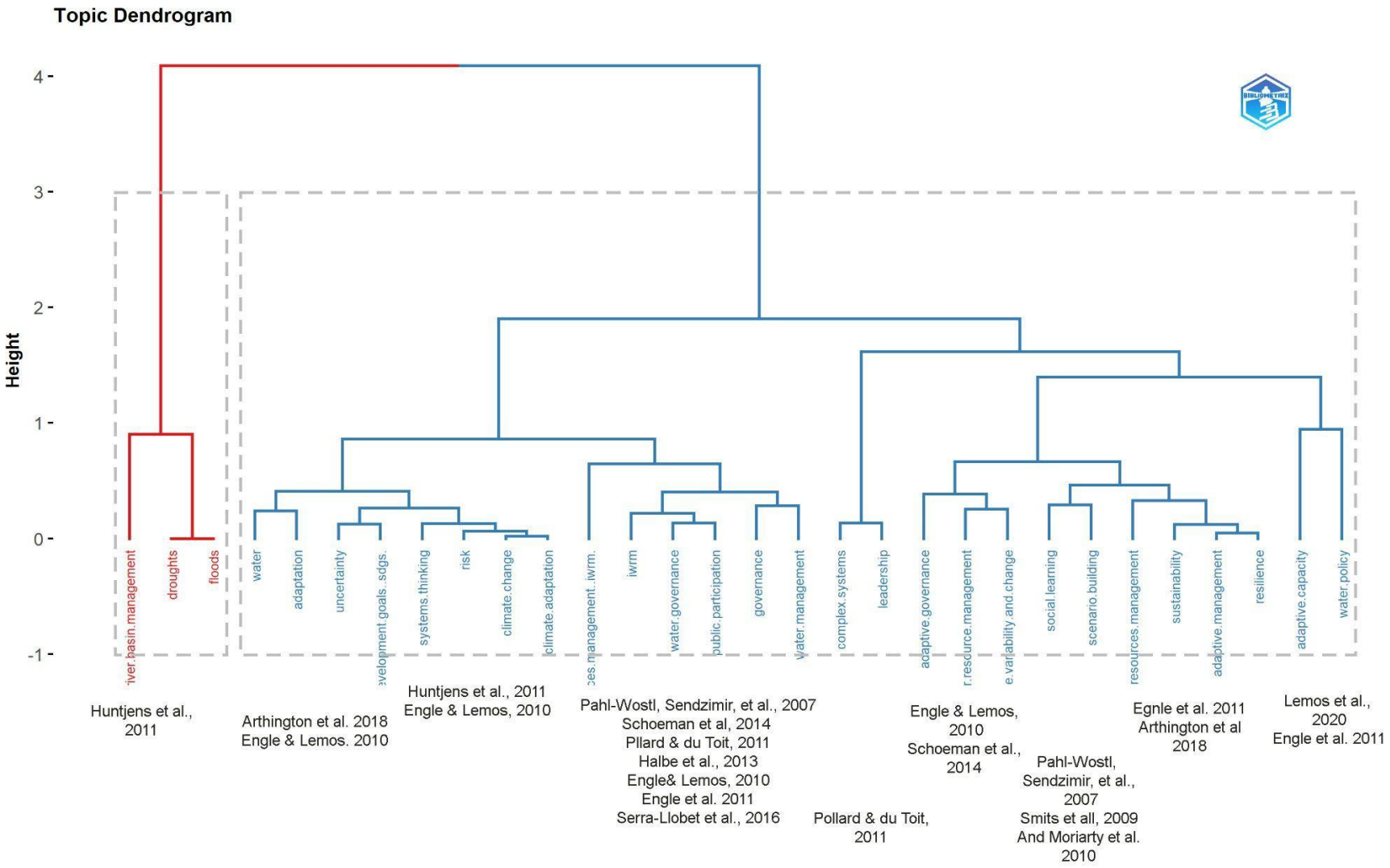

Figure 3: Topic Clustering for Theme 1

Although both IWRM and AWM focus on broader stakeholder engagement, there is a higher possibility of tension during integration and decision-making. The idea of "shared dialogue" implies equality and fairness among stakeholders, but power differentials can prevent this from being achieved (Schoeman et al., 2014; Saravanan et al., 2009). This means that some stakeholders may have more influence and decision-making power than others, making it difficult to achieve true integration and rational decision-making through dialogue. On the other hand, adaptive management requires an open and inclusive management process involving many stakeholders. This includes not only current stakeholders but also those who have been affected by management decisions in the past and those who will be affected in the future (Engle et al., 2011).

Engaging with a diverse group of stakeholders and incorporating their perspectives into adaptive management ensures that management decisions consider a wide range of interests and concerns. This participation highlights historical viewpoints and future concerns, as well as intergenerational equity issues, which can inform current decision-making and prevent the repetition of past mistakes. In addition, involving stakeholders in the management process can enhance the transparency and accountability of management decisions and actions, fostering support and buy-in for the management plan. However, challenges such as varying interests and priorities, communication barriers, and power imbalances can arise in the process.

From a conceptual perspective, merging the strengths of the adaptive management approach with the shortcomings of IWRM can enhance the overall effectiveness of water management. Adaptive management focuses on stakeholder engagement, adaptive capacity, and collaboration, while IWRM focuses on addressing the technical and scientific aspects of water management. By combining these two approaches, a more comprehensive and effective water management regime can be established (Engle et al., 2011; Halbe et al., 2013; Schoeman et al., 2014)

Including stakeholders on both horizontal and vertical scales contributes to a more inclusive and equitable management system that takes into account the wants and concerns of all stakeholders. This comprises not just local communities but also regional and national stakeholders, as well as many sectors and industries that are influenced by decisions made about water management.

Combining IWRM and adaptive management can be challenging as both follow different philosophies, with IWRM being more prescriptive and centralized and adaptive management being more flexible and decentralized. The other challenge is the inadequacies of top-down management organizations when it comes to decentralization and IWRM, as well as the difficulty of making decisions regarding water management in the face of uncertainty when utilizing adaptive management (Engle et al., 2011). Adaptive management has gained increased attention in recent times owing to the growing complexity and impacts of climate change. The transition towards a combined adaptive and integrated approach signifies the necessity of addressing the intertwined structural and procedural challenges that IWRM and adaptive management were initially designed to tackle, albeit independently (Engle et al., 2011).

Highlights:

- *The authors in the collaboration network are scattered into multiple subgroups based on collaboration nature and expertise.*
- *The largest group is focused on the work of* Pahl-Wostl et al., 2007a *on adaptive water management in complex, uncertain water systems. It addresses uncertainties and the role of social learning in transitioning to adaptive water management.*
- *Merging adaptive management strengths with IWRM shortcomings can enhance overall water management effectiveness by combining stakeholder engagement, adaptive capacity, collaboration, and technical/scientific aspects for a comprehensive regime.*

- *An inclusive and equitable management system is achieved by incorporating stakeholder input on both horizontal and vertical scales, ensuring representation from local, regional, and national levels, as well as diverse sectors and industries.*
- *Challenges in combining IWRM and adaptive management due to differing philosophies, top-down management inadequacies, and decision-making difficulties in uncertain situations; Transition highlights the necessity of addressing intertwined structural and procedural challenges.*
- *Adaptive water management also faces challenges such as limited empirical evidence, resistance from stakeholders, and complex social dynamics, making the shift from traditional approaches difficult.*
- *Institutional rigidities and financial constraints further hinder the adoption of this approach, despite its potential benefits in managing water resources.*
- *The authors allude to a shift toward an integrated, participatory approach to water resources management that places an emphasis on collaborative decision-making.*
- *The literature of IWRM and adaptive management shares keywords between regimes, including stakeholder engagement, climate change variability, mitigation, sustainability, and governance.*

Theme 2: Collaboration and Stakeholder Engagement

Theme 1 introduced us to the two prominent water management regimes and their similarities and differences, including the terms that are commonly used to define the characteristics and objectives of the systems. Adaptive management focuses on stakeholder engagement, adaptive capacity, and collaboration; it can be applied at different scales and emphasizes collaboration between stakeholders, including local communities, NGOs, and government agencies, to build adaptive capacity and foster knowledge sharing. In this theme, we will be looking to find parts of the answer to the question: What factors lead to the failure of collaborations under the IWRM framework? And in what ways can adaptive management tackle the issues of involving stakeholders and enhancing collaboration?

In the search for theme 2 in the Scopus database, 50 documents were extracted. After a careful review of the abstracts, 39 documents were selected for the final study that were more

related to this section of the study. Although 11 documents contained some shared keywords, their primary focus was not on water management. From our understanding of theme 1, stakeholder engagement is a major objective of both regimes, and the keywords related to it are widespread in the literature. Figure 4 and the scattered subgroups in the collaboration network confirm that multiple authors are part of the broader network, but the nature of their collaboration and expertise might differ.

In this theme, Henriksen & Barlebo (2008a) suggest that effective integrated water resource management requires a shift towards adaptive management, including learning and addressing complexity and uncertainty. It is important to understand not only the natural environment but also the complex and uncertain interactions among water managers, stakeholders, authorities, and researchers when using specific tools and processes for environmental management (Henriksen & Barlebo, 2008a; King & Thornton, 2016). Some papers, e.g., (Huntjens et al., 2010; Fritsch, 2017; Abdalla, 2008), discuss fostering collaboration between water managers and stakeholders, the connection between science and policy, the significance of participatory learning processes, handling uncertainty, and evaluating various options and potential future scenarios in the context of an integrated adaptive water resources management regime. In recent literature, the need for adaptive management has been attributed to the IWRM's inability to manage stakeholders and ensure collaboration.

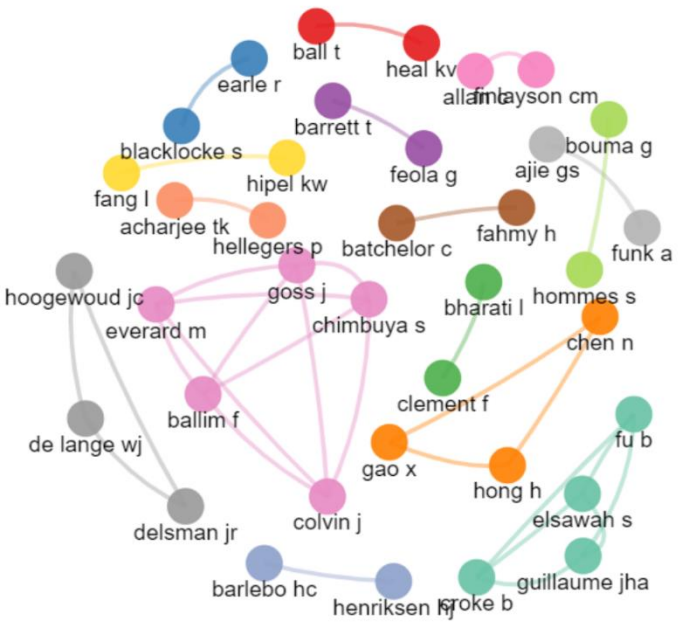

Figure 4: The Collaboration Network for Theme 2

The topic clustering in Figure 5 shows that stakeholder engagement, public participation, and stakeholder participation are seen in different clusters. Schoeman et al., (2014) discuss that the principles of IWRM promote centralization and large bureaucratic structures instead of decentralized, community-based planning and management at a local level (Biswas, 2004), and such top-down framing results in disappointment and a lack of ownership among stakeholders (Fritsch, 2017). The idea of involving stakeholders on a basin-wide level has also brought up questions about how to put inclusion and representation into practice, particularly in nations where locally elected government agencies are lacking or where civil society is weak or does not adequately represent all segments of society (Suhardiman et al., 2015). In addition, it is essential to clearly define roles and responsibilities for stakeholders in order to ensure that all parties are aligned and working towards the same objectives. This includes promoting the simplification and unification of responsibilities and encouraging better collaboration among local, regional, and national authorities in situations where multiple agencies are involved (Fritsch, 2017).

Furthermore, the integration and decision-making processes in IWRM can be challenging due to potential tensions. The concept of "shared dialogue" assumes equality and fairness among stakeholders; however, unequal distribution of power can hinder this (Schoeman et al., 2014; Saravanan et al., 2009). This implies that certain stakeholders may hold more sway and control in decision-making, which can obstruct the attainment of actual integration and sensible decision-making through discussion. Contrarily, adaptive management necessitates an open and comprehensive management process that involves a wide range of stakeholders. Engaging diverse stakeholders at all levels (local, regional, and national) in the decision-making process empowers even marginalized groups, enhances their skills and knowledge, and creates transparent and accountable governance. This encompasses not just current stakeholders but also those whose past management decisions have impacted them and those who will be impacted by future ones (Engle et al., 2011). It shows the inclusiveness that encourages participation for even those who have been marginalized by traditional water governance.

A legal framework is necessary in order to achieve successful cooperation and its key components, such as transparency and stakeholder participation (Abdalla, 2008). A legal framework is needed to support collaboration in implementing IWRM. It helps establish clear roles and responsibilities and provides a framework for transparency and stakeholder participation. But the fact that IWRM is only being implemented as a collection of initiatives supported by donations is an example of the institutional barriers that must be overcome for IWRM to be implemented (Suhardiman et al., 2015).

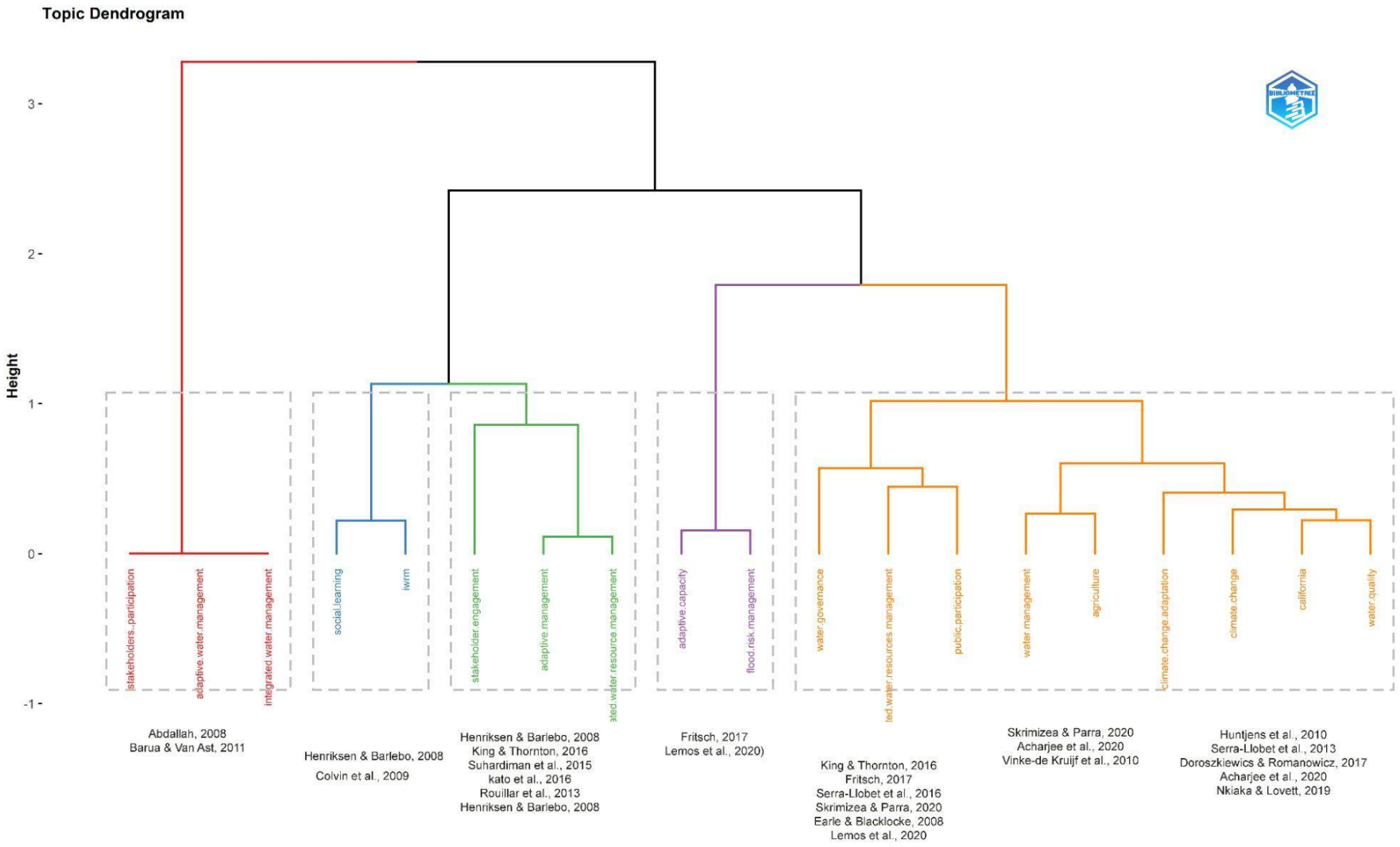

Figure 5: Topic Clustering for Theme 2

Adaptive water governance requires continuous stakeholder engagement and collaboration to manage human and water resources. Stakeholder engagement is a dynamic and evolving process of educating and empowering individuals or groups, fostering relationships, building trust among stakeholders, and promoting collaboration (King & Thornton, 2016). The underlying principle is that the success of any type of participatory effort relies on trust, which takes a significant amount of time, patience, and transparency to establish (Henriksen & Barlebo, 2008a). King & Thornton, (2016) introduce collaborative modeling as an effective technique that brings together diverse stakeholders perspectives, promotes discussion, provides room for problem identification, and develops consensus-based strategies and solutions to address current water resource issues. According to King & Thornton, (2016) , collaborative modeling process in the study of two cases showed an improvement in group dynamics, the building of relationships and trust, and exploring potential futures and opportunities for improving long-term resilience. During the process of building simulation models in both basins, stakeholders have become more willing to talk about controversial topics like climate change, growth, and scientific uncertainty. This creates a pre-conflict exploratory space for designing and discovering resilient governance.

Furthermore, the knowledge of stakeholders has the potential to democratize and enhance the efficiency of decision-making, as stakeholders who are better informed are better equipped to make informed choices (Lemos et al., 2020). When a particular set of stakeholders or groups of people control knowledge, they may be inclined to prioritize their own interests, restrict the scope of decision-making, and result in unequal power distribution (Lemos et al., 2020). Contrarily, broader stakeholder involvement across various scales, disciplines, and sectors in adaptive management strengthens adaptive capacity by engaging individuals with diverse skills and experience and fostering knowledge exchange through network formation (Schoeman et al., 2014). Through open and transparent communication, it promotes knowledge sharing and trust building. Communication and information sharing are essential to ensuring that all stakeholders are aware of the problems and opportunities related to water management and can provide input into decision-making.

Building the capacity of stakeholders, including governmental agencies, NGOs, and local councils, through workshops, community discussion groups, and consultation, to actively participate in decision making ensures that the decisions are informed and effective. This system of governance can enhance the ability of individuals and groups to experiment with new concepts, adjust approaches to fit specific situations, and create novel methods of collaborating together (Rouillard et al., 2013; Huitema et al., 2009; Folke et al., 2005). Capacity building also engages and enables stakeholders to participate in regular monitoring of the water systems, during which they identify successes and challenges and contribute to improvement.

Highlights

- *The theme is focused on stakeholder engagement, collaboration, and transparency.*
- *The subgroups in the collaboration network are spread out, which shows that different authors with different kinds of expertise have made different contributions.*
- *The lack of a well-defined core group of authors in the collaboration network suggests slow progress in information flow but also room for more research and improvement.*
- *Less attention is given to identifying factors of stakeholder engagement failure in IWRM.*
- *Topic clustering alludes to how water managers, stakeholders, managers, and researchers interact in complex and uncertain ways when they use certain tools and processes for environmental management.*
- *IWRM principles are criticized by authors for promoting centralization and a lack of stakeholder ownership, while adaptive management emphasizes active stakeholder participation and inclusiveness for marginalized groups.*
- *Trust-building among stakeholders is essential and can be promoted through collaborative modeling to develop consensus-based strategies.*
- *Broader stakeholder involvement and knowledge sharing through open and transparent communication leads to informed decision-making.*
- *Capacity-building among stakeholders, including governmental agencies, NGOs, and local councils, enhances the ability to experiment with new concepts and adjust approaches.*

Theme 3: Social Learning

In theme 2, we learned that there are multiple reasons why IWRM is not effective in improving stakeholders' engagement or strengthening collaboration among stakeholders, such as power imbalance, legal framework barriers, difficulty in knowledge sharing, different interests and priorities of stakeholders, and a lack of trust among them. We learned that the learning process and knowledge sharing of stakeholders are essential to effective decision-making and increasing the system's adaptive capacity. In this theme, we are looking for possible mechanisms that improve social learning and what role social learning plays in adaptive water governance. For this theme, after the search in Scopus, we found 35 documents, of which 32 were selected after a critical review of the abstracts. Three documents contained some shared keywords, but their primary focus was not on water management, and they were excluded from further analysis. Unlike theme 2, we can see in figure 6 that the cooperation network is not scattered, and multiple authors have added to the literature on social learning in water management systems. (Figure 6)

The cooperation network of this theme is summarized in figure 6, in which the biggest centrality is focused on the work of (Pahl-Wostl, Sendzimir, et al., 2007a) and is well-connected in the research community of this theme. The focus of the network is the paradigm shift in water management from a top-down to a participatory style; the concept of social learning also emerged in response to the challenges of top-down approaches to water governance (Pahl-Wostl et al., 2007a; Schoeman et al., 2014; Huntjens et al., 2011). As stated by Roux et al., (2011), social learning, also known as co-learning, has developed to promote shared comprehension and joint efforts among different yet interrelated groups. According to various articles, to effectively handle the intricacies and unpredictability of systems, it is necessary to continually learn from past management actions through the use of adaptive management (Allan, 2012; Dent, 2012; Pahl-Wostl et al., 2007a; Schoeman et al., 2014).

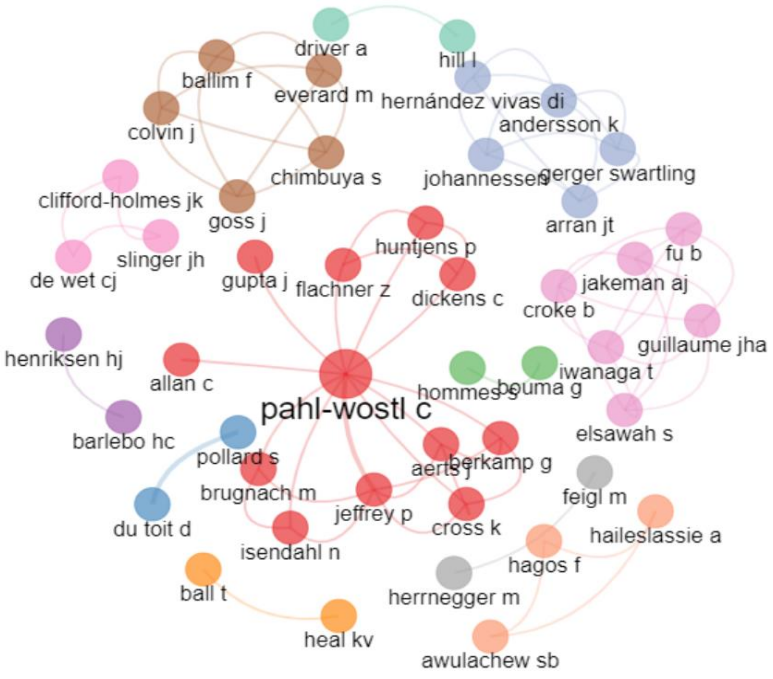

Figure 6: Collaboration Network for Theme 3

There is a strong urgency for elevated social learning to revamp water governance and make it more integrated and responsive (Johannessen et al., 2019). Social learning is essential in river basin management to maintain and develop the capacity of involved stakeholders, including authorities, experts, and the general public, to manage their resources in a sustainable manner as well as to balance different interests for the main goal of the sustainability of social-ecological systems (Johannessen et al., 2019; Pahl-Wostl et al., 2007b). With our understanding from themes 1 and 2 about the participatory approach in water management or stakeholder engagement, social learning plays an important role in sharing experience and knowledge among stakeholders, leading to a better understanding and collaboration towards water management's prominent challenges.

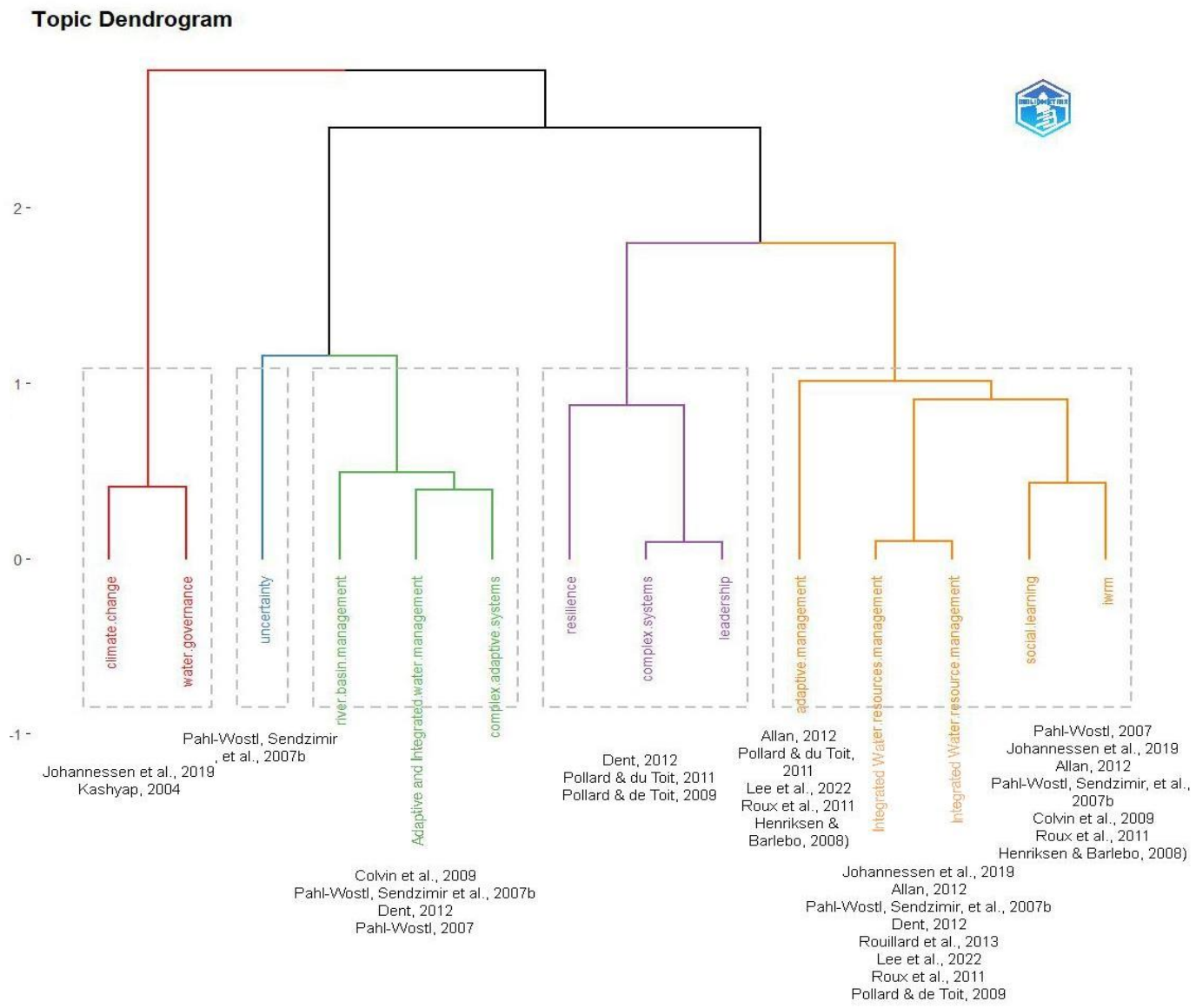

Figure 7: Topic Clustering for Theme 3

The topic cluster of theme 3 is summarized in figure 7, and it shows that the concept of social learning has also ties with IWRM. IWRM is defined as a response to the wicked problems and complexities of water management by allowing multi-party participation, whereas adaptive management provides a framework for the participatory process and social learning to contribute to changed policies and practices (Allan, 2012; Dent, 2012; Henriksen & Barlebo, 2008a; Pahl-Wostl et al., 2007a; Roux et al., 2011).

By providing a systematic approach for ongoing learning and improvement, adaptive management helps close such gaps in IWRM. By enabling flexible and responsive decision-making, it helps address the complexity and uncertainty of managing water resources. Some authors in this cluster argue that a transition from IWRM to adaptive water management is required due to the need for a structured learning process that deals with complexity and uncertainty (Henriksen & Barlebo, 2008a; Lee et al., 2022; Pahl-Wostl, 2007a; Pahl-Wostl et al., 2007a). The development of leadership plays a significant role at all levels in the process of such social learning, self-organization, and transition (Dent, 2012; Pollard & du Toit, 2011). Figure 7 shows the proximity between complex adaptive systems and adaptive water management and resilience. Adaptive governance is not limited to the governance of social-ecological systems, but much of the related research stems from studies on resilience and social-ecological systems (Chaffin et al., 2016; Johannessen et al., 2019; Pahl-Wostl et al., 2007a). Water systems are complex adaptive systems, and social learning is essential in promoting the integration of local knowledge and perspectives, increasing collaboration and cooperation among stakeholders. It also enhances the effectiveness and efficiency of water management decisions and activities. In the face of changing social and ecological situations, it can also aid in strengthening the resilience and adaptability of water management systems.

Highlights

- *The collaboration network in this theme has a few large subgroups, with the biggest centrality on the work of Pahl-Wostl, Sendzimir, et al., (2007a) are well connected in the research community of this theme.*
- *The theme emphasizes the importance of social learning in promoting shared understanding and joint efforts among different groups involved in water governance.*
- *Emergence of social learning as a response to the challenges of top-down approaches and the need for adaptive management to handle the complexities of systems.*
- *The urgency for elevated social learning is emphasized in order to restructure water governance and make it more integrated and responsive.*
- *Topic cluster shows social learning is not only tied to the concept of adaptive management but also found in the literature of IWRM.*
- *Adaptive management provides a framework for participatory processes and social learning that contribute to changed policies and practices.*
- *Water systems are complex adaptive systems, and social learning is essential in promoting collaboration among stakeholders, enhancing the effectiveness and efficiency of water management decisions and activities, and strengthening the resilience and adaptability of water management systems*.

Theme 4: Uncertainties in Water Management Systems

Based on the literature, adaptive governance takes into account the challenges of control and the need to move forward in the face of uncertainty (Dietz et al., 2003). Because this concept focuses on managing water resources in the face of uncertainty, it is necessary to understand the potential uncertainties confronting water resources. This theme focuses on recognizing and introducing the types of uncertainties and the aspects of adaptive governance that can identify them. In the search through Scopus, 36 out of 41 documents were selected for the study.

Figure 8 shows the cooperation network of the authors, in which Pahl-Wostl and Henrikson are the most influential authors. Based on this network node, adaptive water management is a transition toward considering the uncertainties and complexities of water systems in decision-making and management processes (Pahl-Wostl et al., 2007b). The need for such a transition is confirmed by the increasing challenges in water management arising from fast-changing socio-economic development and climate change, which the IWRM approach cannot effectively address (Henriksen & Barlebo, 2008b; Pahl-Wostl, 2007a; Engle et al., 2011).

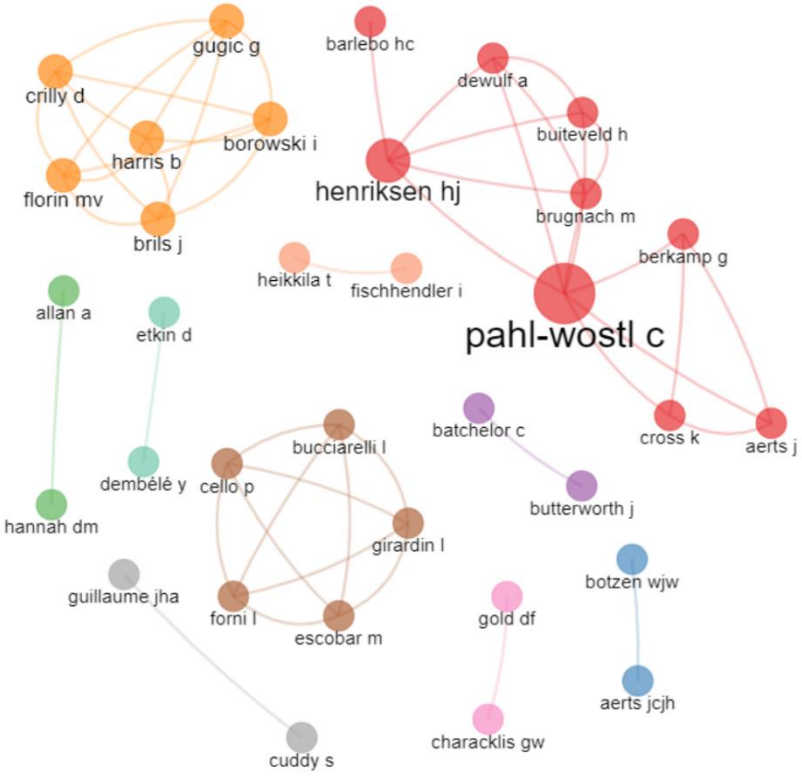

Figure 8: Collaboration Network for Theme 4

On the other network of nodes in Figure 8, the authors point out that water management is undergoing a sustainable development phase where various environmental challenges interact in a complex manner (Müller-Grabherr et al., 2014). On the one hand, achieving sustainable development is needed, while on the other hand, decision-making under conditions of uncertainty

and complexity is challenging (Müller-Grabherr et al., 2014). A new risk-informed water governance process is required that is well-informed, robust, and participatory, which is described as adaptive integrated water management (Müller-Grabherr et al., 2014). Forni et al., (2018) find out by using simulation modeling of integrated water resources and decision space visualization to find out the significant impacts of climate change, which are complemented by an increase in the generation of hydropower and irrigated agriculture. The influential authors in the cooperation network of Theme 4 discuss the rising uncertainties and complexities in the water management system and the need for an adaptive water management regime.

Figure 9 summarizes the topic cluster of theme 4, and the literature is focused on the significance of uncertainties in water management regimes and identifying the potential uncertainties to be addressed in adaptive water governance. The dendrogram shows close proximity among complexity, resilience, climate change, adaptive management, adaptive governance, uncertainties, adaptive capacity, and resilience. There is a need to address and improve the understanding of how to handle uncertainties in order to better manage water resources in a sustainable manner (Engle et al., 2011; Pahl-Wostl et al., 2007b; van Keur et al., 2008).

Various authors focus on the types of uncertainties in water management regimes. The well-known type of uncertainty is the lack of knowledge due to the unavailability and variability of the data (Pahl-Wostl et al., 2007b), and the uncertainty caused by the inherent variables of the system is called ontological uncertainty (van Keur et al., 2008; W. E. Walker et al., 2003). Such uncertainties are seen as an undesirable function of the quality of data, simplification in process description and schematization, and the limitation of our knowledge of the complexity of processes (Ludwig et al., 2014). A few approaches have been developed to recognize the uncertainties in the system. Waterpath is one of the few technical approaches that simulate modeling while accounting for uncertainties such as “hydrological or climate extremes, permitting time, demand growth, the effectiveness of water-use restrictions, construction costs, and

financing uncertainties." (Trindade et al., 2020). Some of these uncertainties are difficult to identify, or decision-makers lack knowledge or consensus on the probability distribution of critical system parameters or the definition of the system itself (Trindade et al., 2020). Although the accuracy and representativeness of data and modeling are frequently emphasized, underlying standards and values are not (Ludwig et al., 2014; W. E. Walker et al., 2003).

The second type of uncertainty is our limited comprehension of the system, including not just its past trends but also the components and interactions that create those trends, such as nonlinearities, feedback loops, and delays (Pahl-Wostl et al., 2007b), and is described as epistemic uncertainty (van Keur et al., 2008; W. E. Walker et al., 2003). This type of uncertainty is particularly relevant to socio-economic systems and includes human behavior in the event that multiple interpretations of a phenomenon in the system exist (Pahl-Wostl et al., 2007b). In water management regimes, a comprehensive understanding of the complexity of social, ecological, and technological systems and the interaction between them is needed (Pahl-Wostl et al., 2007b). Recognizing and addressing this type of uncertainty is essential for informed decision-making and effective management of the system.

Pahl-Wostl et al., (2007b) introduce the system behavior that arises from the inherent unpredictability of certain factors in the system. The degree of uncertainty in water management systems is determined by the physical condition, climate, political environment, and socioeconomics (Pahl-Wostl, Sendzimir, et al., 2007a; van Keur et al., 2008). Climate change and its impact on the natural environment and the likelihood of extreme events are examples of such uncertainty (Alexandra, 2021; Ludwig et al., 2014; Pahl-Wostl et al., 2007b; Piscopo et al., 2021; Stakhiv, 2011). This unpredictability might make it harder to predict the system's behavior and can add to the uncertainty in general when it comes to understanding and managing the system. In the case of climate change, scientists agree about its impact on the availability of water, but there are quantitative uncertainties about whether water availability will increase or decrease (Ludwig et al., 2014; van Meerkerk et al., 2013).

The diversity of rules and the mental models behind them can contribute to the uncertainty in water management systems (Pahl-Wostl et al., 2007b). It has the potential to influence the stakeholders' perceptions and actions, as well as their proposed solutions and outcomes (Ludwig et al., 2014; Pahl-Wostl et al., 2007b). Negotiation among stakeholders with varying priorities and different perspectives on water problems raises uncertainty, which is compounded by discordant policies and regulations, adding further complexity (Roncoli et al., 2009).

Uncertainties in water management regimes are a significant challenge that arises from a variety of sources, such as lack of knowledge, limited comprehension of the water systems, physical and climatic conditions, the unpredictability of certain factors, and the diversity of rules among stakeholders and human behavior. Addressing these uncertainties is essential for informed decision-making and the effective management of water resources. A comprehensive understanding of the complexity of social, ecological, and technological systems and their interactions is necessary to manage the uncertainty in water management regimes.

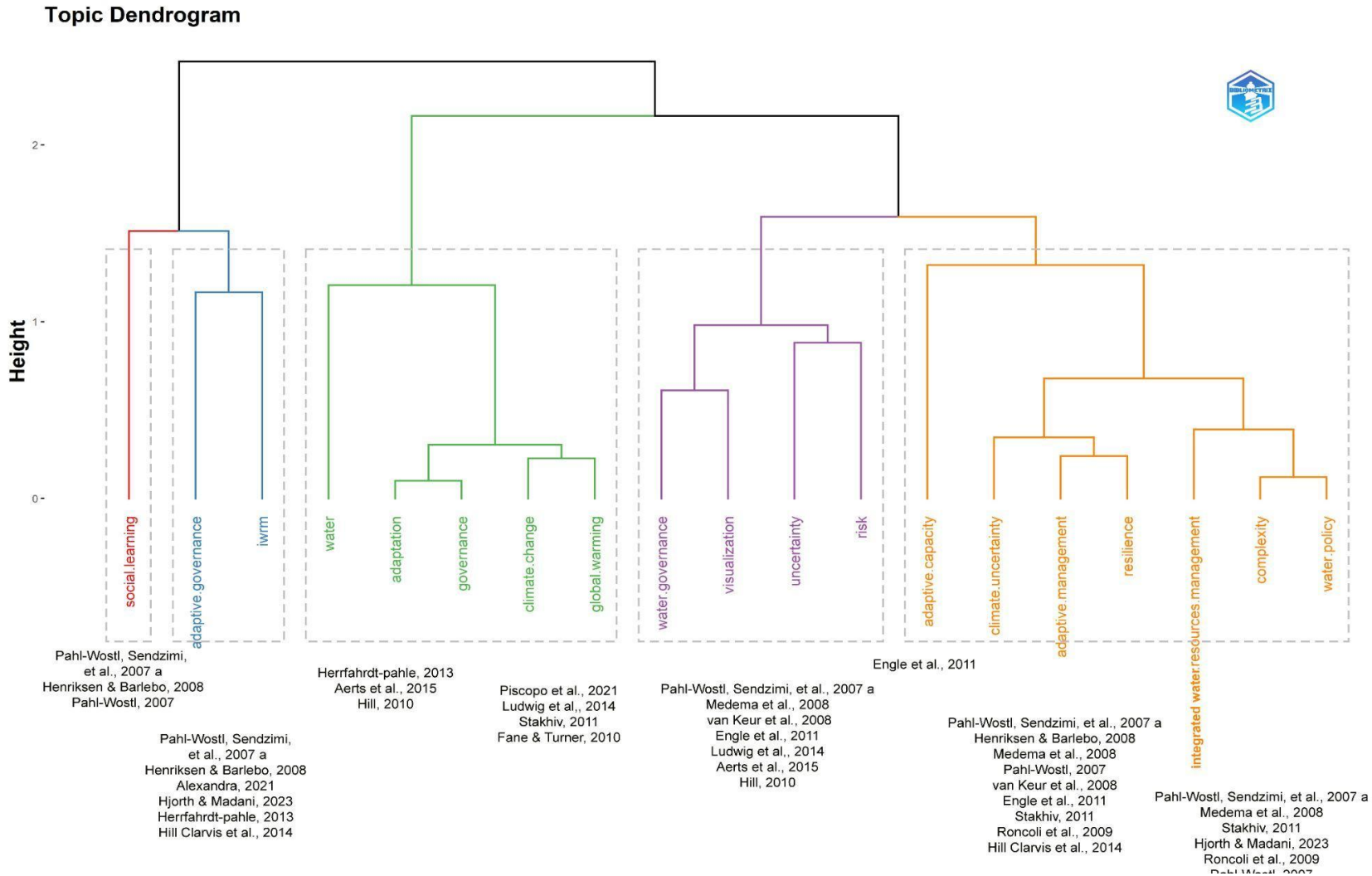

Figure 9: Topic Clustering for Theme 4

Highlights:

- *The theme focuses on recognizing and introducing types of uncertainty and aspects of adaptive governance that can identify them.*
- *The IWRM approach was found inadequate in addressing uncertainties arising from fast-changing socio-economic development and climate change.*
- *Multiple authors propose a new risk-informed water governance process called adaptive integrated water management that is well-informed, robust, and participatory.*
- *Adaptive integrated water management takes into account the uncertainties and complexities of water systems in decision-making and management processes.*
- *Topic clustering in this theme shows close proximity among complexity, resilience, climate change, adaptive management, adaptive governance, uncertainties, adaptive capacity, and resilience.*
- *Key words like "climate uncertainty," "complexity," "risk," "uncertainty," and "global warming" show how important uncertainty is to water management.*
- *Two types of uncertainties are discussed in the literature: lack of knowledge due to the unavailability and variability of data and limited comprehension of the system, including past trends, components, and interactions.*
- *Climate change and its impact on water management systems have been identified as a significant source of uncertainty, making it harder to predict system behavior and adding to uncertainty in general.*

Additional Analysis

For the purpose of additional analysis, we have merged the data from all four themes into a single file, thereby removing the duplication. This analysis took into account 102 documents in total.

This section of the study focuses on the author's collaboration network, which shows the relationship between the author and their country of origin. It helps in understanding the global

information flow that relates to adaptive water management. Figure 10 shows the country of origin of the corresponding author and evaluates the level of cross-country collaboration.

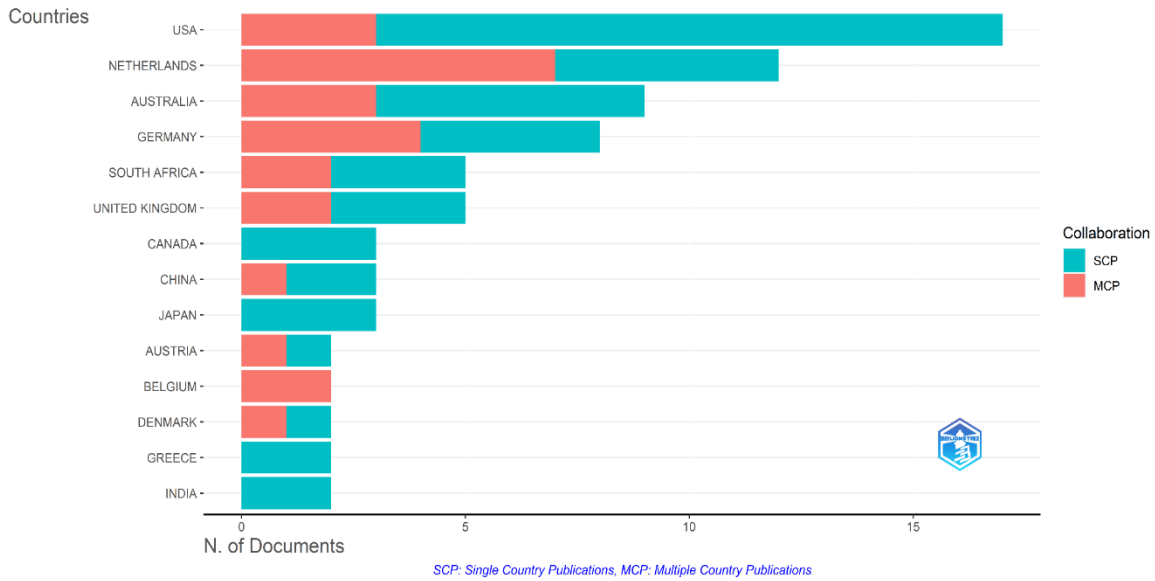

Figure 10: Corresponding Author's Country of Origin

The United States, the Netherlands, and Australia are the top three countries that have produced the most relevant publications. The United States has the largest contribution as a single country or is at the top of SCP countries, followed by Australia and the Netherlands. On the other hand, the Netherlands has a higher proportion of international contribution, or MCP, followed by Germany, the USA, and Australia.

Figure 11 visualizes the patterns of international collaboration and provides a geographical representation of the relationships between authors and their respective countries in terms of joint contributions related to our research. The world map provides insights into the international exchange of knowledge and information as well as the contribution to the academic literature on water management regimes. It also depicts trends in information flows between countries and regions.

The collaborative scientific network with an emphasis on integrated and adaptive water management is centrally located in the United States, Germany, South Africa, the Netherlands, and Australia. Other nations, such as Argentina, China, India, the UK, and Canada, have contributed to the field of literature; however, they have fewer publications in the MCP (multiple country publications).

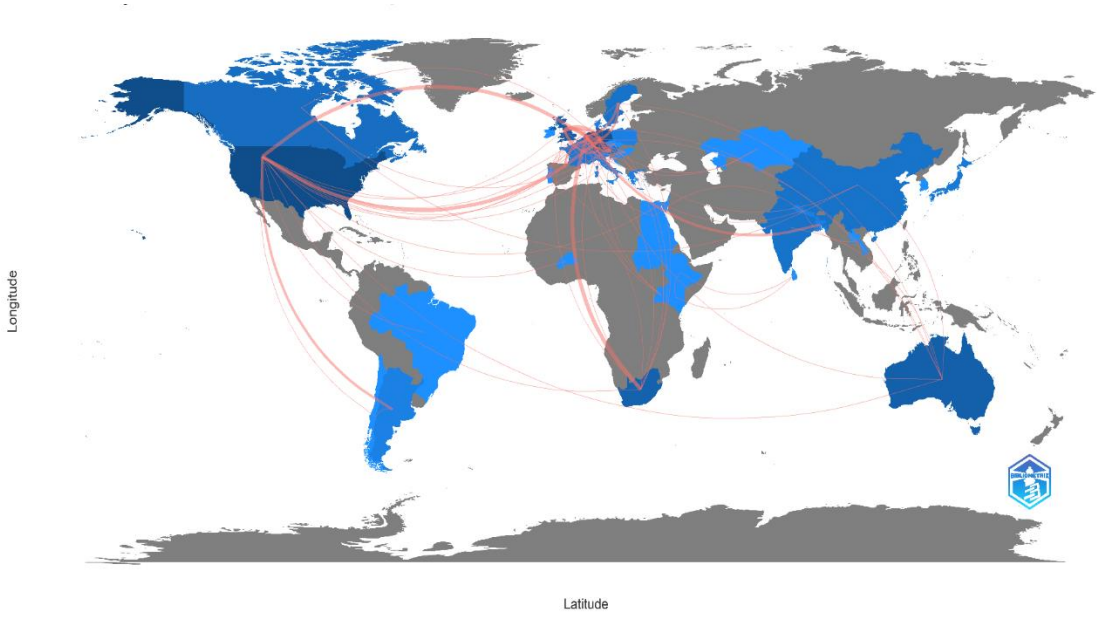

Figure 11: Country Collaboration Map Based on the Corresponding Author's Country and Collaboration Network. The Color Intensity Defines the Number of Publications.

This high level of collaboration among the United States, Germany, and the Netherlands can be attributed to their strong scientific communities and shared research interests, while lower levels of collaboration between smaller nations may be caused by their access to resources and smaller research groups. The map demonstrates the significance of international collaboration in scientific research and suggests that efforts should be made to boost cooperation between nations with weaker ties.

Evolution of research theme via thematic map

The thematic map helps us understand the concentration of research in diverse categories based on the level of centrality and density (Rejeb et al., 2022). The thematic map shows how important (based on the number of citations) and well-developed (based on the number of publications) each of them is in the literature (Agusdinata et al., 2022). In addition, creating a thematic map that establishes themes based on grouping keywords offers additional, unbiased information (Rejeb et al., 2022). The map is divided into four thematic groups by dotted lines based on the concepts of density and centrality (Agusdinata et al., 2022), and the size of the bubbles in each group represents the frequency of the keyword appearing in published works.

Figure 12 illustrates the transition from traditional command and control to integrated and adaptive water management. The “motor” theme displays both high centrality and density, demonstrating the progression towards a new water management paradigm that emphasizes both integration and adaptation. It shows emerging concepts such as adaptive capacity, river-based management (decentralized), and resilience in the face of external and internal variables and describes the water management systems as complex adaptive systems. The basic theme has high centrality but low density; it is less integrated but highly adaptive. This quadrant shows the emergence of topics in adaptive management related to such uncertainty, including climate change, social learning, stakeholder engagement, and the need for institutional transformation. An emerging or declining theme has low centrality and low density and shows the command-and-control regime of water management. Meanwhile, the "niche" possesses low centrality but high density. The group of keywords in the quadrant describes the integrated water resources management regime, which shows its close ties with sustainable development goals.

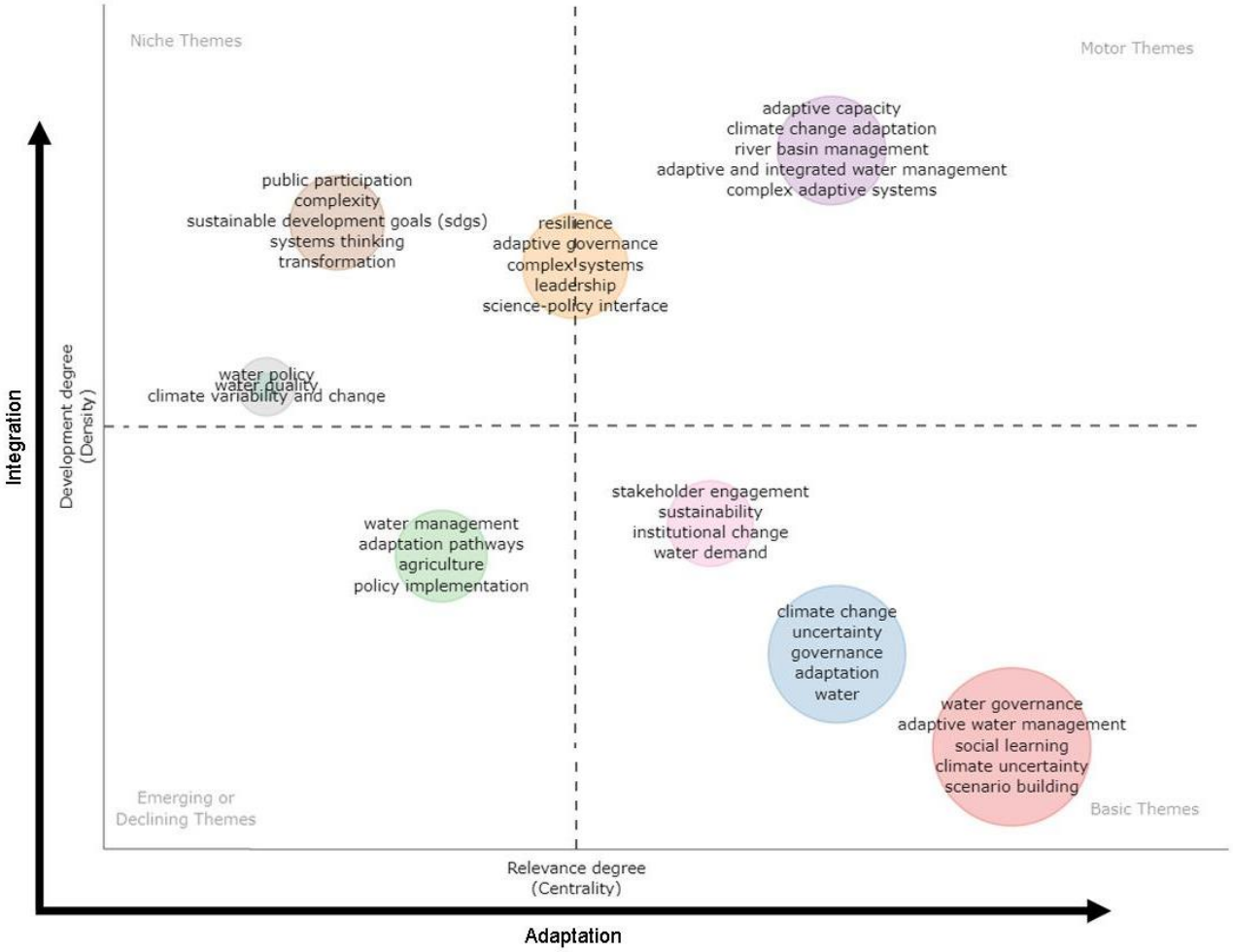

Figure 12: Research Theme Evolution from 2004-2023

The Connection Between Sources, Keywords, and Intellectual Roots

We also employ a Sankey diagram to examine the relationship between keywords, their source, and references. The width of the link or band represents the flow of information between nodes from left to right. The combination of source, keyword, and reference enables us to trace the sources of the articles that have a significant impact on our discussion and where the research is published (Agusdinata et al., 2022). We see that the terms "integrated water resources management" and "adaptive management" are the two most commonly used keywords

and are linked to most of the sources; however, the largest source of these keywords is ecology and society. Both concepts have their roots in the work of Holling and Walters (1978), who are primarily concerned with the management of uncertainty through formalized experimentation and process-based learning (Engle et al., 2011; Huitema et al., 2009). They are continuously used in almost all the references in our literature, and both have outgoing flow counts of 18 out of 20.

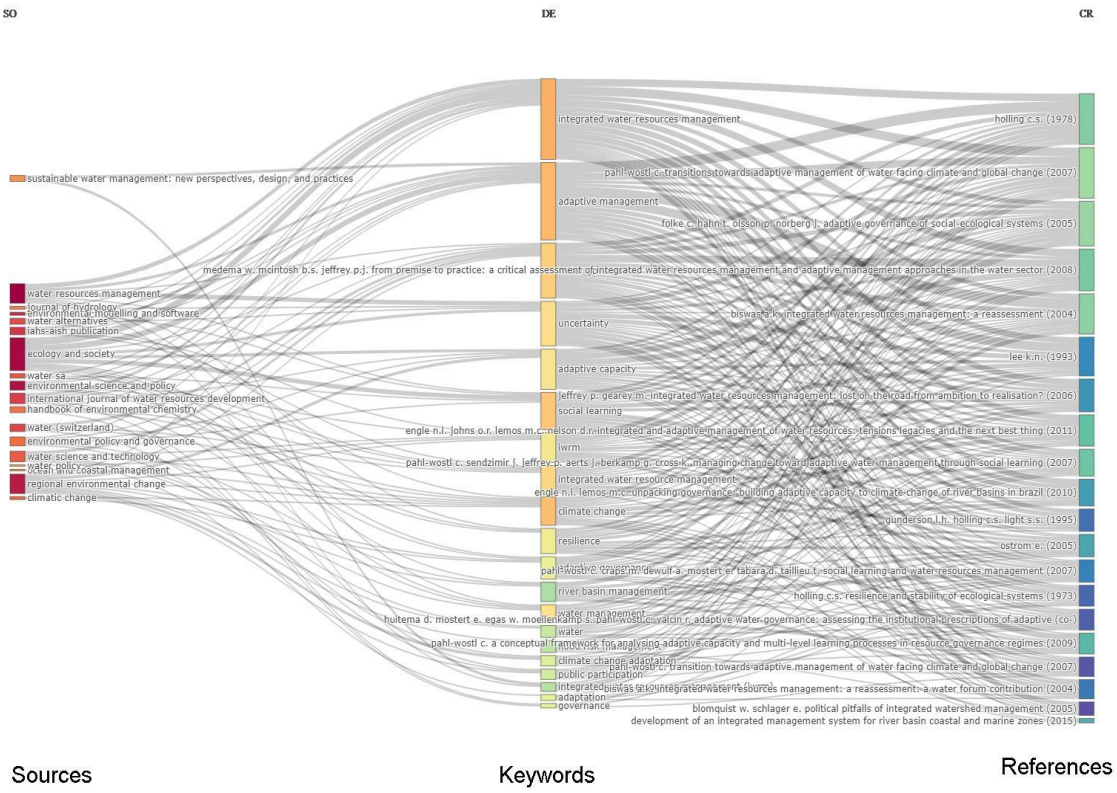

Figure 13: Sankey Diagram of Connection Between Source, Keywords and References

Authors have had a significant contribution to the literature of adaptive management and been published in *Ecology and Society* (Folke et al., 2005; Pahl-Wostl, 2007b; Pahl-Wostl et al., 2007b). Uncertainty is another common word used in the literature on water management regimes and has roots in the earlier work by Holling, (1973) and is seen in the work of various author e.g., (Pahl-Wostl, 2007b; Pahl-Wostl et al., 2007b; Gearey & Jeffrey, 2006; Folke et al.,

2005). The analysis illustrates the dominance of literature on adaptive management that includes the concepts of uncertainties, resilience, social learning, adaptive capacity, and stakeholder participation. Ecology and Society is the major source of the literature and multiple authors have contributed to the enrichment of the literature.

Conclusion

The bibliometric analysis is divided into four themes to gain insight into the structure of two well-known water management regimes and trace the evolution of new topics that contribute to developing solutions for anthropogenic challenges. The literature indicates a paradigm shift towards integrated, participatory, and collaborative decision-making that takes into account the uncertainties posed by climate change, population growth, and stakeholder engagement. The concept of IWRM has been criticized for being vague and for allowing managers to overlook important changes while claiming to adapt to global thinking. Despite the creation of new management organizations with centralized control, there are challenges in the implementation of IWRM due to issues with coordination and legitimacy. As a result, many studies focus on adaptive water resource management and governance, which aim to increase the adaptive capacity of the water system and engage a diverse group of stakeholders. Combining the strengths of adaptive management with the shortcomings of IWRM can lead to a more comprehensive and effective water management regime that addresses the complex interconnections between water-related issues and engages all stakeholders, leading to more sustainable and resilient water management outcomes.

The literature discusses how the principles of IWRM promote centralization and bureaucratic structures, leading to disappointment and a lack of ownership among stakeholders. The involvement of stakeholders requires a legal framework to support cooperation and establish clear roles and responsibilities, but there are barriers such as cultural, linguistic, and institutional differences. The decision-making process in IWRM can be challenging due to the unequal distribution of power among stakeholders, while adaptive management requires an inclusive and

comprehensive management process involving a wide range of stakeholders. Knowledge democratization and stakeholder involvement across various scales, disciplines, and sectors can enhance decision-making efficiency and strengthen adaptive capacity by promoting knowledge sharing and trust building.

Another important part of our literature review focuses on social learning. It has emerged as a response to the challenges of top-down approaches. It promotes shared understanding and joint efforts among different groups. The concept of social learning is closely related to IWRM, which allows multi-party participation in response to the complexities of water management. Adaptive management provides a framework for the participatory process and social learning to contribute to changed policies and practices. Adaptive governance, which is not limited to social-ecological systems, helps address the complexity and uncertainty of water management by enabling flexible and responsive decision-making. The literature insists on the importance of social learning in promoting the integration of local knowledge, increasing collaboration and cooperation among stakeholders, and enhancing the effectiveness and efficiency of water management decisions.

The need for an adaptive water management approach is driven by increasing challenges in water management due to changing socioeconomic development and climate change and the uncertainties resulting from them. Water management is moving towards a sustainable development phase where environmental challenges are complex, and decision-making is challenging. The literature focuses on the significance of uncertainties in water management regimes and the need to improve the understanding of how to handle uncertainties for sustainable water resource management. Two types of uncertainties in water management regimes are discussed: the lack of knowledge and the limited comprehension of the system. The former is due to the unavailability and variability of data, and the latter is related to the complexity of social, ecological, and technological systems. Addressing these uncertainties is essential for informed decision-making and effective management of the system.

3. ADAPTIVE AND INTEGRATED MANAGEMENT FRAMEWORK (AIMF)

Theoretical foundations

Freshwater resources are globally under increasing stress as a result of rapid population expansion, increased economic activity, and improved living standards, which are fueling increased competition for and conflicts over finite freshwater resources (Agarwal, 2000). During the 20th century, the population expanded by a factor of nearly three while water withdrawals climbed by a factor of around seven, leaving a large portion of the population under increasing water stress (Agarwal, 2000). In addition, uncertainties such as climate change, a major global issue of our era, increase the threats and stress to the social, economic, and environmental dimensions of our lives (Sawassi & Khadra, 2021). Not only is the increased use of water a problem, but so is the system's complexity and the way that different social, ecological, and technological parts are linked to each other.

Water management systems are among the complex systems interconnected by elements of ecological, social, and technological domains, so the challenges and uncertainties in such systems are immense. Despite such complexity, technological or institutional panaceas—such as privatization or centralization—were frequently applied automatically to all different kinds of water problems worldwide without careful consideration of their applicability or the conditions necessary for their effective operation (Pahl-Wostl et al., 2010). However, the majority of water management issues are more related to governance shortcomings than to the resource base (Bakker et al., 2008) necessitating significant reforms in water administration that take the environment into account (Pahl-Wostl et al., 2010).

According to Rogers & Hall (2003) governments cannot solve water issues unless their systems allow stakeholders to engage and contribute to providing solutions to water issues by sharing their learning and knowledge. It shows another factor in the failure of water management systems, which is the absence of a societal role in which stakeholder participation is required at multiple scales via institutional settings. It is important to build social learning into water

management systems that connect stakeholders at different levels through flexible networks and help them build up enough social capital and trust so they can work well together in both formal and informal relationships (Pahl-Wostl et al., 2007). Social learning is more than just seeing and imitating others to learn in a social setting (Bandura, 1977); the emergence of common meanings and practices is another factor that defines the social unit as a whole (Pahl-Wostl et al., 2007).

In our literature review, we learned about two common water management regimes and the trends in scientific knowledge that define the way forward to deal with contemporary challenges. We found a transition from command and control to a more adaptive and integrated water resources management regime. This study will contribute to the literature and development of this regime through the development of a conceptual framework that is focused on stakeholder engagement and social learning.

The Adaptive and Integrated Management Framework (AIMF) is built on our findings from the literature review, and draws upon a range of concepts from the Institutional Analysis and Development Framework (IAD) (Ostrom, 2005) and the Management and Transition Framework (Pahl-Wostl et al., 2010) to analyze the interconnectedness of various variables in water management systems and how dependencies can improve collective action through stakeholder engagement and social learning that enhance the adaptive capacity of the system in the face of uncertainties.

IAD is mainly based on the concept of action situations and was developed by Ostrom and colleagues (Ostrom, 2005). The IAD framework, which was created to investigate the function of institutions in processes of collective decision-making. In order to provide analysis for water management institutions and the collective choice process, we use IAD as a base for the development of AIMF. The IAD framework has mostly been used to examine typical common pool resource issues (Pahl-Wostl et al., 2010) including water resources.

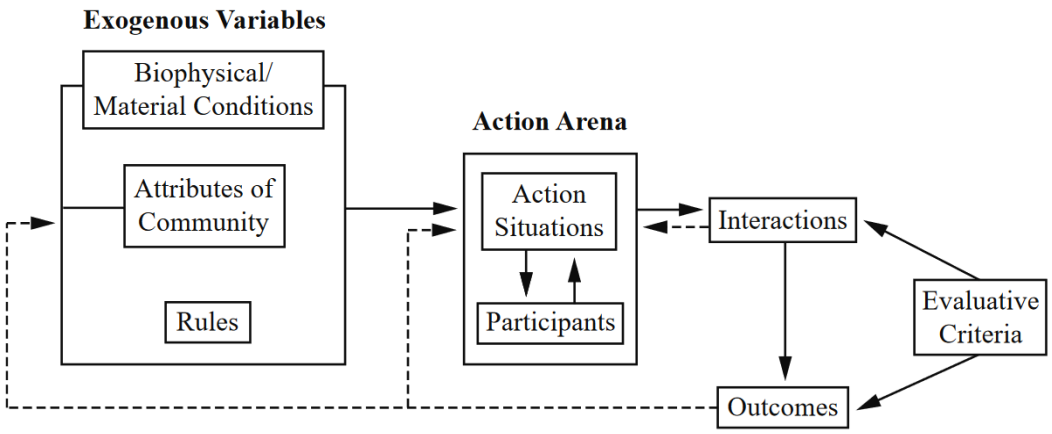

Figure 14: Action Situation as a Focal Level in the Institutional Analysis and Development Framework (Ostrom, 2005)

The framework comprises an action situation that refers to the social context in which actors (individuals or organizations) engage in activities such as interacting with others, exchanging goods and services, solving problems, exerting dominance, or engaging in conflicts (Ostrom, 2011). Action situations are an important component of our theoretical work, in which the stakeholders engage in collective action. Biophysical conditions, attributes of the community, and rules-in-use are the exogenous variables of the action situation (See Figure 14). These variables are unchangeable during the process of learning and negotiating within an action situation. However, it is possible for these variables to be altered as a result of the outcomes of this process (Pahl-Wostl et al., n.d.). The concept of action provides a powerful analytical tool to understand water management institutions.

In order to comprehend the impact of social learning and knowledge production and its impact on the final outcome, we utilize several concepts from the Management and Transition Framework (MTF) developed by (Pahl-Wostl et al., 2010). The MTF is designed to analyze water systems and management regimes with the goal of enhancing scientific understanding of the complexity of water management and governance regimes and providing practical guidance for implementing change processes that lead to more adaptive regimes (Pahl-Wostl et al., 2007; Sendzimir et al., 2010). The framework integrates a range of concepts to help in understanding

the complexity of water management regimes, with a particular focus on adaptive capacity and learning processes (Knieper et al., 2010; Sendzimir et al., 2010).

MTF underscores the value of situated knowledge, which illustrates the importance of contextually framing and reframing information while acknowledging the deep-rooted connection between knowledge and its social context (Pahl-Wostl et al., 2010) and the knowledge that encompasses significant information and experiences that are generated within the context of an action situation through a range of tools, such as group model building (Pahl-Wostl et al., 2010). However, the stages and levels at which learning takes place in the MTF are not well-defined. Additionally, the specific types of social learning and how they provide feedback to different components of the water system remain unclear.

In this review, we develop a framework focused on advancing adaptive governance concepts embedded in IWRM to enhance the adaptive capacity of organizations in the water sector, strengthen stakeholder engagement, and improve the resilience of water management systems in the face of uncertainties such as climate change and socio-economic developments. Drawing upon insights from the literature review, we base the Adaptive and Integrated Management Framework (AIMF) on the stages of an action situation that produces knowledge and fosters learning during a series of action situations within a water system. We also define and distinguish various types of social learning and explain how they provide feedback to different components of the framework.

Utilizing the AIMF as a common language, case studies examine diverse water governance regimes. The objective of this chapter is to elucidate how the components and attributes of the framework function together in a water system. We introduce the AIMF as a practical tool for examining water systems and their underlying governance structures, particularly in contexts where individuals and institutions engage in self-organization through learning and adaptation.

Adaptive and Integrated Management Framework

The Adaptive and Integrated Management Framework is a conceptual framework that focuses on stakeholder engagement, social learning, knowledge sharing, and the overall significance of adaptive governance. The AIMF depicts the interconnectedness of the components of a water system and shows multi-stakeholder engagement in decision-making and water management issues, as well as the feedback loop that is incorporated into the system in the form of learning at different levels to enhance the system's ability to identify uncertainties and contribute to increasing the adaptive capacity of the system in the face of uncertainties.

The framework situates the water system in the midst of technological infrastructures, social systems, and ecological systems, and the interaction is complex, with both socially positive and negative consequences for the water system. The social, ecological, and technical domains are interconnected components of a water system that play a crucial role in ensuring sustainable water management. Each domain has its own unique components, as described in Figure 15.

The natural environment and ecosystems where water resources are found are part of the ecological domain of a water system. It affects the social and economic aspects of water management. For example, changes in water quality or quantity can impact the health and well-being of human communities that rely on those resources. Changes in ecosystems and habitats can also influence the economy, for example, by affecting fishing or tourism.

The physical infrastructure and technologies used to manage water resources make up the technological part of a water system. The technical domain can influence both the social and ecological domains. For example, the design and operation of water treatment plants can have ecological impacts, such as through the discharge of treated wastewater into rivers and streams. Similarly, the cost of water treatment and distribution can have social and economic impacts, such as affecting the affordability of water for low-income communities.

The social domain includes human communities and institutions involved in water management. This domain is the primary focus of our research, and it interacts with and influences the ecological and technical domains via water-use policies, laws, and regulations. Water allocation policies, for example, can determine how much water is available for human use and how much is reserved for ecological purposes, such as fish population support. Similarly, social attitudes among stakeholders in the social domain toward water resources can influence the technologies used for water management.

Discussing the specific details of the domain's interaction as well as the internal variables of the system is beyond the scope of this study. However, it helps us understand the complexity of the water systems and the foundation of AIMF (see Figure 16). We focus on the action arena within the social domain of the framework. The framework consists of 20 interrelated and interdependent components.

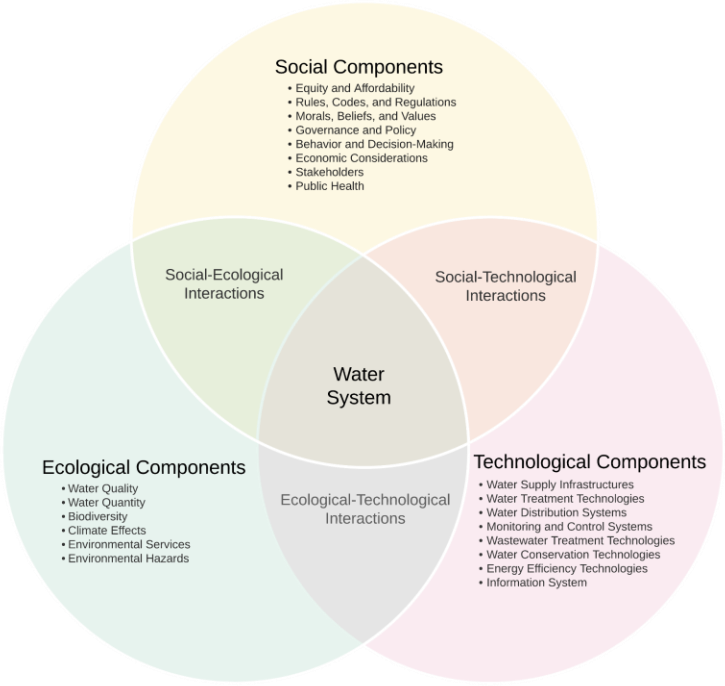

Figure 15: Water System as a Hub for Social, Ecological, and Technological Components as Well as the Interactions Between Them. Adapted From Markolf et al., 2018

Water System: The water system is at the center of the framework, with social, ecological, and technological systems as direct components. Through action situations, the processes of social learning and stakeholder engagement take place within a social component. A water system can be distinguished by its hydrological boundaries, source, water quality, and accessibility.

Technological Infrastructures: Technological infrastructures refer to the physical and technological components that support the collection, treatment, distribution, and management of water resources, e.g., dams, pump stations, storage facilities, water treatment plants, canals, etc. These infrastructures can be public or private, single- or multi-purpose, temporary or permanent, and built at different scales.

Ecological system: It is the main component that provides the water for the water system and includes the biotic and abiotic components of the water system (Pahl-Wostl et al., 2010). The ecological system supplies the system with the necessary water in terms of both quality and quantity, as well as the influence it has on or is influenced by water use by the water system and social system.

Environmental Aspects: The component of the framework that links the ecological domain with the social domain and has indirect impacts on water systems refers to the environmental aspects that have an impact on the natural environment, including biodiversity, water availability, climatic conditions, resource depletion, and land use changes.

Social Domain: The social domain encompasses a wide range of elements, encompassing not only individuals and their respective roles and actions but also cultural and institutional values, knowledge, public discourse, policies, economics, governance, public health, financing, citizens, regulators, managers, and the establishments in which these components exist (Markolf et al., 2018). Action arenas and action situations are situated in the social domain. The different scales of attributes in this domain support different scales of social learning, which

also depend on the education, communication, values, attitudes, lifestyles, and decision-making of the individual or groups of stakeholders in the system.

Action Arena: In the IAD framework, the action arena comprises actors and action situations, which interact with each other while being influenced by external factors (Ostrom, 2005). In our framework, the action arena is focused on water management issues and is characterized by the strategic goals, the rules and regulations, the type and redundancy of actions, and the inclusion of stakeholders on multiple scales. The functioning of the water systems is the result of the action arena. The action area differs according to the type of water management approach, e.g., river-based administrations, hydrological boundaries, or social administrations.

Action Situation: In the IAD framework, "action situation" refers to the activities - such as interacting with others, exchanging goods and services, solving problems, exerting dominance, or engaging in conflicts - that the actors engage in (Ostrom, 2011). In action situations, stakeholders hold positions and are assigned to actions using the knowledge and information they have to produce an outcome. Stakeholders possess the knowledge, and their knowledge is improved through networks and collaborations, which affect the quality of action and outcome. Each position has rules that interact within the action situation and are categorized as Boundary, Position, Choice, Information, Aggregation, Scope, and Information rules (Ostrom, 2005).

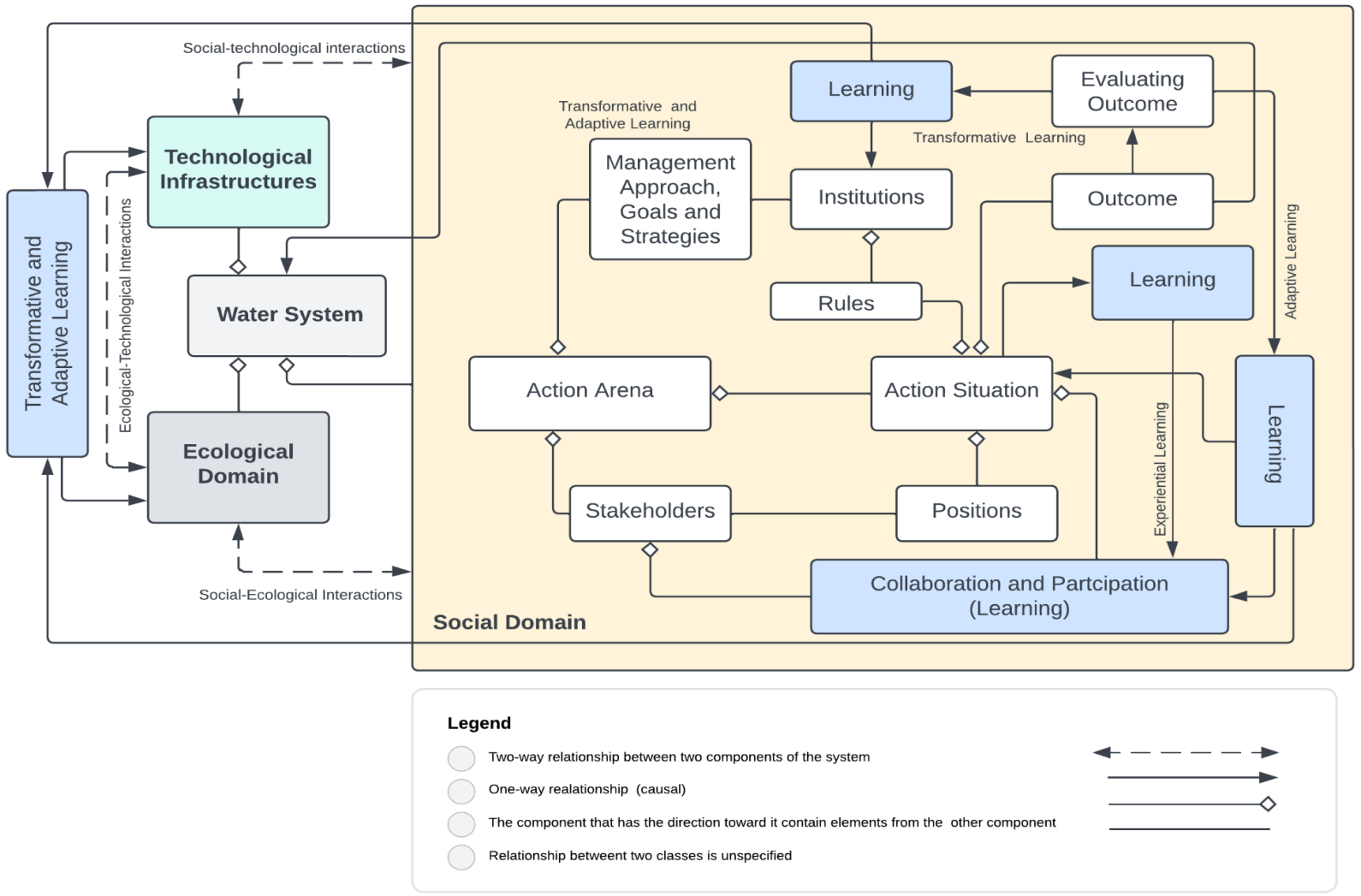

Figure 16: Adaptive and Integrated Management Framework (adapted from Management and Transition Framework (Pahl-Wostl et al., 2010)

Collaboration and Participation: In the water system, the stakeholders possess knowledge that is utilized while entering a specific action situation. An action situation is robust and effective when it reflects the multiple perspectives and knowledge of multiple stakeholders incorporated into it, e.g., after management experts from legal governmental departments possess knowledge of the overall hydrological situation of the system, while members of local councils possess knowledge of irrigation patterns and crops and can have valuable inputs in conflict resolution since they embody the cultural and traditional norms of their local community. An essential aspect of this component is experiential and adaptive learning from action situations. Experiential learning is the type of informal learning that is crucial to adaptive water management, and it happens during interaction within action situations. Adaptive learning could result from the evaluation and assessment of the outcomes in both formal and informal settings.

Stakeholders: Stakeholders are individuals, groups, or organizations that have a stake in the system and/or can influence it. They are individuals or any wide diversity of organizational entities that may or may not be part of an action situation or collective action in the arena. In water systems, stakeholders include government agencies, community groups, NGOs, water utilities, industry, agriculture, environmental groups, residents, and scientific or technical experts. Stakeholders are the actors in action situations who possess positions, and each position has rules through which they engage in collective action. Each individual has particular knowledge or understanding of the system that can be crucial to the action situation. Their behavior, values, and goals are important because of their influence and impact on the system.

Institutions: Institutions could be both formal and informal rules, regulations, and practices that guide the decision-making and behaviors in the system. The institutional setting in this framework provides a balance between providing stability and certainty and avoiding being too rigid and inflexible while allowing creativity and innovation, as well as encouraging stakeholders to include new ideas. The attributes support social learning that involves experimentation, exploration, and adaptation to new situations and contexts. However, the

institutions also maintain a sense of structure and predictability that allows stakeholders to feel secure and confident in their learning environment. Institutions comprise learning through evaluation and are the first step towards developing strategic goals, adapting water management and governance regimes, and creating legal frameworks that consider cultural norms.

Rules: The framework relies on the rules described by (Ostrom, 2005) and can describe the internal structure of the action situation. Each action situation can be affected by seven types of rules:

- Boundary rules define the number of stakeholders, their attributes, and resources and also define criteria for entering and leaving the action.
- Position rules define a set of positions and the number of stakeholders that can hold them.
- Choice rules regulate the actions that stakeholders may, may not, or must take.
- Scope rules affect the potential outcome, they determine the possible result and identify the actions that are connected to an outcome.
- Aggregation rules define the process of decision-making and affect the level of authority of a stakeholder that makes a decision in their defined position.
- Information rules define how the information affected by the knowledge of stakeholders is communicated.
- Payoff rules determine the cost and benefits that will be associated with specific combinations of actions and outcomes.

Positions: The positions and the number of positions vary in water systems according to the size and type of the system. Positions link stakeholders to actions, and each position is taken by stakeholders to participate in activities to achieve a particular outcome. The authority to decide or take any specific action is assigned to particular positions via formal or informal institutions, defining the standing of stakeholders in the action arena. Standing in the set of authorized and

limited actions that the person holding the position can take at particular points in the situation (Ostrom, 2011).

Goals and Strategies: Goals and strategies vary in water management systems depending on region, a broader management and governance approach, specific needs and challenges, or the geographical and hydrological area. It is a component of the action arena affected by institutional settings. The attributes are the degree of adaptability to changing environmental, social, and economic situations, level of integration across sectors; a collaboration that requires collaboration among different levels of stakeholders; and feasibility in the context of existing institutional, legal, and financial frameworks.

Outcome: The outcome of an action situation in a water system could be operational, knowledge creation, or institutional change at large. The outcome affects social interactions in action situations or the rules of other action situations, and it defines the necessity for physical interventions in technological systems. The framework mainly focuses on learning from the outcome along with the learning from action situations. We identify two major types of learning loops from the outcome: adaptive learning, which leads to awareness among involved stakeholders to incorporate it directly into the next actions, and transformative learning, which is achieved through pre-defined evaluation criteria. Such learning outcomes have effects on a larger scale on the settings of institutions, the adaptation or amendment of strategic management goals, and the operations of water systems.

Social Learning: The learning process that builds and maintains the capacity of various stakeholders, such as authorities, experts, interest groups, and the general public, to effectively manage their river basins is called social learning (Pahl-Wostl et al., 2007) in our system. The learning process takes place in four types of learning methods falling under the categories of single, double, and triple-loop learning. The learnings are described as collaborative and participative, experiential, adaptive, and transformative learning. The action situation that involved multiple stakeholders under specific enabling conditions led to information exchange and

experiences in the form of social learning. Such information sharing requires tools such as communication and access to information. The attributes of social learning are collaboration, ongoing dialogue, adaptation, and transformation.

The learning processes in the framework are also called feedback loops, in which the outcomes of the action situation are used to inform subsequent decision-making processes that affect the next action. The loops of social learning create a continuous cycle of learning, adaptation, and transformation where the system's context is considered when making decisions about future actions.

Evaluating Outcome: The outcome of the action situation is evaluated by those involved in the action and by those observing from the outside. Such a process not only evaluates the outcome but also the overall process used to achieve the outcome, including stakeholders' involvement. The evaluative criteria can vary widely depending on the context and the goals of the participants. However, we rely on a few broad categories of criteria discussed by (Ostrom, 2005) and related to water systems.

The first category is economic efficiency, which refers to the ability of an action or process to achieve the desired outcome while minimizing the use of resources. The second category refers to equity among stakeholders including distributive, procedural and recognitional equity. This category is essential to ensure a broader vision of integration in water management systems and mitigate power imbalances between different groups of people with different interests. Adaptability, resilience, and robustness are the main features of adaptive complex systems as described in the literature. It refers to the ability of a particular action or process in a water system to respond effectively to changing circumstances, unexpected events, or other disruptions.

Learning through Action Situation

The Adaptive and Integrated Management Framework facilitates the analysis of social learning processes that transpire during and after an action situation in water systems. It specifically pertains to water systems that are structured with an integrated and adaptive management approach, aimed at promoting stakeholder engagement and social learning. The framework seeks to enhance comprehension of the varying levels of learning and methods of learning as well as adaptability in response to change.

In defining the various levels of social learning, we refer to the concepts of collaborative single, double and triple-loop learning. Single loop learning focuses on identifying and correcting errors within a given framework or set of rules and seeking alternative strategies and actions (Armitage et al., 2008). It emphasize on incremental improvement of established actions and practices without questioning the underlying assumption, beliefs or values (Pahl-Wostl, 2009). Double loop learning occurs when underlying values or assumptions that derive actions and decisions are challenged (Armitage et al., 2008). Such reframing involves reassessing goals, problem prioritization, incorporating new aspects, modifying system analysis boundaries, and reevaluating assumptions about goal achievement (Pahl-Wostl, 2009). And triple loop learning focuses on the norms and protocols that underlie or regulate single- and double-loop learning processes (Armitage et al., 2008). At this level of learning, transformation or transition to a different management paradigm takes place. This transformation results in the evolution of actor networks, the introduction of new groups, the modification of boundaries and power dynamics, and the implementation of new regulatory frameworks (Pahl-Wostl, 2009).

While developing the framework, we identified various learning methods that can be categorized into single, double, and triple-loop learning. Participative and collaborative learning emphasize enhancing existing practices and procedures through collaboration and involvement without challenging the underlying assumptions, thus falling under single-loop learning. Adaptive and experiential learning concentrates on making adjustments during the learn-by-doing process

and adapting to changes that do not necessitate fundamental changes but do call for reevaluation or questioning of assumptions and beliefs. This places adaptive and experiential learning within the double-loop learning category. Both triple-loop and transformative learning involve reassessing assumptions, norms, and beliefs, leading to a paradigm shift and significant alterations in the system. We can further delineate these learning methods in the subsequent section based on these classifications.

Learning from Feedback Loops

Experiential Learning

Experiential learning happens through social interactions and multi-stakeholder experiences in an action situation. Water systems are complex and dynamic, largely affected by the behaviors and interests of stakeholders. An understanding of the operationalization of the water system is gained at this stage of learning prior to any formal evaluation of the outcome. For example, in an irrigation project that introduces a new technology such as drip irrigation to a group of farmers. The stakeholders in such projects include farmers, engineers, and water system managers, each possessing a particular type of knowledge. During irrigation as an action situation, the farmers are trained for the purpose of using and maintaining the network. At the same time, stakeholders with technical knowledge observe and learn about water use efficiency, technology effectiveness, and crop yield. Such learning is essential for future action situations and helps build trust and foster collaboration, although formal monitoring and evaluation processes might not be included.

Adaptive Learning

Adaptive learning is learning from practices in action situations by evaluating the outcome and adapting to changing conditions in the system. Such social learning in water systems refers to continuous amendments in management practices and policies based on new information from the system. The information is collected using mechanisms such as monitoring and evaluation

and technologies to collect real-time data. It is then used to rethink strategies, effect behavioral change, evaluate stakeholder positions, develop technological infrastructure, reevaluate ecological aspects, and improve water system performance. Adaptive learning is essential to ensuring sustainability, resilience, and efficiency through continuous improvement and adaptation after feedback from past actions and outcomes.

Transformative Learning

This type of learning focuses on a fundamental change after evaluating the outcomes of continuous action situations. The learning process suggests a collective change in which the involved stakeholders examine their assumptions, beliefs, and values about water management. They develop new ways of thinking and acting to provide appropriate solutions to emerging challenges. Such learning leads to institutional change, envisioning the water system differently, and amendments in strategic management goals and water management approaches. Transformative learning involves challenging deeply held assumptions and beliefs about water systems and developing new perspectives that enable stakeholders to act more effectively, sustainably, and equitably. Transformative learning may lead to a transition in technological infrastructure or re-evaluate the mutual impact between the outcome of the action situation and the ecological domain. This type of learning involves recognizing the interconnectedness of water and social systems and taking a systems-thinking approach to water management.

Learning from Collaboration and Participation

The adaptive and integrated water resource management approach focuses on the active participation and collaboration of stakeholders. An essential element of these approaches is learning through collaboration and participation. This approach fosters an inclusive, multi-disciplinary environment where stakeholders engage in mutual respect and open dialogue, ensuring that diverse perspectives are heard and considered in decision-making.

With the complex and continuously changing process of water management, the AIMF highlights the need for a component that emphasizes participatory and collaborative learning in water systems. Each stakeholder activates situated knowledge through collaboration and participation during and after the action situation. They work together to identify common issues and develop solutions that take into account the perspectives and expectations of all stakeholders. Such processes, in which stakeholders are involved in decision-making and their inputs are considered, promote collaborative and participatory learning and help in the development of trust, conflict resolution, and a sense of ownership over the water management system.

Conclusion

During this, we reviewed the multifaceted and complex nature of water systems, emphasizing the importance of evaluating both outcomes and processes, including stakeholder involvement. The IAD framework and the concept of action situations are critical components of the theoretical foundation for the AIMF, which provides a valuable analytical tool for understanding water management institutions. Furthermore, the MTF is also used to develop the framework. However, the MTF is focusing on situated knowledge and its connection to social context. It lacks clarity in terms of learning stages, the specific types of social learning, and their feedback mechanisms within water systems.

To address these limitations, we have developed the AIMF, which advances adaptive governance concepts in the water sector, strengthens stakeholder engagement, and improves resilience in the face of uncertainties. This framework builds upon insights from the literature review to provide a practical tool for examining water systems and their underlying governance structures, especially in contexts where learning and adaptation are crucial.

By employing the AIMF as a shared language, various water governance regimes can be analyzed, offering a deeper understanding of how the components and attributes of the framework interact within a water system. This review ultimately contributes to the growing body

of knowledge surrounding water systems and adaptive management, providing valuable insights for both researchers and practitioners.

AIMF situates water systems in the middle of social, technological, and ecological domains in which the system is affected and improved by the interaction of the components of these domains. The framework only highlights the action situations within the social domain that emphasize the inclusion of stakeholders, and highlight levels and methods of social learning and how the learning process affects the components and action situations.

4. SOCIAL LEARNING AND COLLABORATION IN CASE STUDY

Introduction

The goal of this chapter is to use the Adaptive and Integrated Management Framework to examine water management systems in two countries with different institutional and environmental settings. The AIMF is used as a shared language across case studies to analyze water governance regimes. We also want to find out how useful and applicable the framework is by making it an operational tool for analyzing water systems and the governance regimes behind them in a setting where individuals, groups, and institutions are interacting, learning, and adapting to the changes.

To do this, we develop a list of elements based on the components, sub-components, and attributes of the framework in our study (see Appendix A) that are needed for understanding the governance of a water system. We then use the framework, with the support of the list, to examine the progress of IWRM at the national level in Australia and Uzbekistan.

The United Nations supports the concept of IWRM through the SDG framework. SDG 6.5.1 is an indicator used to measure progress toward achieving the United Nations' SDG 6. The level of IWRM implementation is measured by Indicator 6.5.1, which looks at four key areas: the enabling environment, institutions and participation, management tools, and financing (UNEP, 2021). The Progress on Integrated Water Resources Management Report 2021 indicates that the governments or stakeholders of 170 member countries contribute to reporting their progress toward achieving SDG indicator 6.5.1 on a regular basis.

Since we use data published in the IWRM Data Portal in partnership with UN member countries that report their progress towards IWRM implementation, we take into account both the components of the framework for a water system and those that the data covers. The IWRM Data Portal provides access to country reports on water resources management for a range of

countries around the world (http://iwrmdataportal.unepdhi.org/country-reports). These reports are prepared by national governments, international organizations, and other stakeholders and provide valuable information on the current state of water resources management, challenges and opportunities, and strategies and actions being taken to address them.

Why AIMF?

According to the literature study, the water system is seen as a complex adaptive system that consists of several interrelated components that interact with one another and change in response to environmental and social factors. These components include water resources, infrastructure, institutions, communities, and ecosystems. The water system is characterized by feedback loops, non-linear relationships, and multiple scales of organization, making it difficult to predict the behavior of actors and outcomes. Understanding the uncertainties and dynamics of water systems necessitates a transdisciplinary approach to managing them in a sustainable manner.

The governance regime behind any water management system is a significant factor that considerably impacts its performance (Knieper et al., 2010). Many challenges in water management are due to ineffective governance, such as inadequate institutional capacity, inadequate representation of diverse stakeholders, the absence of mechanisms of social learning, insufficient transparency and accountability, or weak enforcement of regulations. When we discuss a governance regime in the context of a water system, we are referring to the institutional arrangements, policies, regulations, and learning mechanisms that determine how various stakeholders manage, distribute, conserve, and use water resources. These actors can be from both the state and non-state sectors and can interact in various ways, both horizontally across spatial boundaries and vertically across administrative scales, through formal and informal institutions.

AIMF can be used to analyze this complexity and helps understand the underlying factors of a water governance regime and how the components of the regime can help achieve the strategic management goal. It helps identify risks and challenges through participatory and collaborative decision-making and transitions and guidelines for plans to mitigate them. The framework helps us understand governance at different levels from local to global and the interaction between these levels. This multi-level approach helps to identify possible conflicts and synergies between various players and scales, which is important for efficient water management. The framework can support the analysis of the cases in this thesis as it describes water governance and management in multiple layers of government. The framework emphasizes the crucial role of social learning and innovation in nurturing water management practices. By encouraging the sharing of knowledge and fostering learning experiences among diverse participants, AIMF contributes to enhancing the capabilities of stakeholders and facilitating the collaborative development of inventive strategies for addressing water management challenges. It helps to analyze how stakeholders work together by making it easier for them to understand each other and by making them more aware of and knowledgeable about how the system works through experiential and adaptive learning. It highlights the importance of learning and transformation in a multi-level collaboration that helps the system's adaptability and resilience in responding to changing conditions. It offers a structure to make decisions that incorporate data, analysis, and input from stakeholders.

Structure of Analysis

The water system, as represented by AIMF, encompasses the integration of various components. The analysis of this part of our study focuses mainly on action situations with connected components in a water system. Action situations vary in water systems depending on the geographical location, hydrological situation, institutional arrangement, expected outcome, stakeholder goals, and changing environment. Generally, action situations take place at multiple organizational levels (e.g., local level, national level, or transboundary level). There are also

multiple stages of an action situation in a system (e.g., planning phase, formulation, or implementation).

In Chapter 3, we elaborated on each component of the framework and their respective attributes, offering detailed descriptions for better understanding. For a comprehensive understanding of each component, including elements and attributes, refer to Appendix A, which draws upon the Total System Database (Knieper et al., 2010) and IWRM principles and indicators. The list of attributes could be a key step in setting up a database to collect data on action situations in water systems in the future. We concentrate on those components and elements of the list that can examine the water system to implement IWRM.

In our study, the action situation is defined as the implementation of IWRM and encompasses the interaction of the action situation with institutions, management approaches, goals and policies, collaboration and participation, learning, outcome evaluation, and knowledge sharing across various levels. The action occurs at multiple organizational tiers, including international, regional, transboundary, national, sub-national, river-based, and local levels. Each of the above-listed components has a number of indicators that governments report and that can happen at one or more organizational levels.

In our analysis, we divide the organizational level into seven levels (local, river-based, sub-national, national, regions, transboundary, and international) and the progress of the action situation into six stages that comply with the reports from member countries of the United Nations in tracking SDG 6.5.1. To evaluate the level of progress of an action situation, scoring is included. A score is given between 0 and 100, with 10-point increments, unless the question is determined to be "not applicable" in the country report. The possible scores that can be assigned for each question include 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, or 100.

Country Selection

We have selected Australia and Uzbekistan for our comparative analysis for several reasons. Firstly, the country map in Chapter 2 highlights Australia's significant contribution to developing and implementing adaptive and integrated water resources management concepts. In contrast, Uzbekistan, located in Central Asia and neighboring Afghanistan, has made a lower contribution to the development of adaptive water management literature. The author's familiarity with the context stems from their experience working with the Regional Environmental Center for Central Asia, a non-profit international organization working to address environmental and sustainability challenges in Central Asia and Afghanistan.

Secondly, the reports from both countries are detailed and comprehensive, facilitating an understanding of the interactions between multiple sectors at various organizational levels in the implementation of IWRM. Thirdly, the countries exhibit different governmental structures as well as geographical and climatic disparities. Analyzing these differences can reveal how these factors influence the implementation and success of IWRM in each country. Lastly, the fourth reason is the significant variance in stakeholder engagement scores during policy development and decision-making in water management, which may provide valuable insights into the role of stakeholder involvement in IWRM.

Comparative Analysis of IWRM Implementation

In this section, we examine the selected elements of a water system, as presented in Appendix A, which are included in the country reports for measuring IWRM progress in 2017 and 2020. These elements have been organized into five major components of the AIMF: Institutions, Management Approach, Goals and Policies, Collaboration and Participation, Learning and Information Sharing, and Evaluating Outcomes. Appendix B offers a detailed overview of these elements in the context of Australia and Uzbekistan.

Figures 17 and 18 show the implementation of IWRM across various organizational levels in Australia and Uzbekistan, respectively. Employing a scoring range of 0 to 100, the figures utilize color intensity to represent the performance of each country, with heightened intensity corresponding to higher scores. Within the figure, each cell represents specific elements or indicators, as well as the corresponding organizational level at which IWRM principles are implemented. Elements can span one or multiple organizational levels, illustrating the top-down, bottom-up, or middle-out structure of the water system. Transboundary matters encompass the international level of participation, involving adherence to agreements between countries or conventions of which a nation is a member.

Notably, Australia outperforms Uzbekistan in nearly all components based on the scoring, with the exception of the indicator assessing progress on transboundary issues (see Figures 17 and 18). In Uzbekistan's case, while the distribution of elements across various organizational scales is visible, the scores remain consistently lower compared to Australia. This disparity stems from the absence of effective mechanisms or frameworks to facilitate implementation. Although initial legal measures have been undertaken to assign responsibilities across organizational levels, there is a notable lack of practical contributions toward IWRM implementation. This analysis highlights the importance of developing suitable mechanisms and frameworks that consider the unique context of each country, fostering the creation of tailored strategies and best practices for efficient IWRM execution. The comparison summary for all components and sub-components involved in this case study can be found in Table 2. For a comprehensive understanding, please refer to Appendix 2 of the study. In the subsequent section, we will present a detailed analysis and comparison of each component.

Figure 17: IWRM Implementation in Australia Years 2017 and 2020

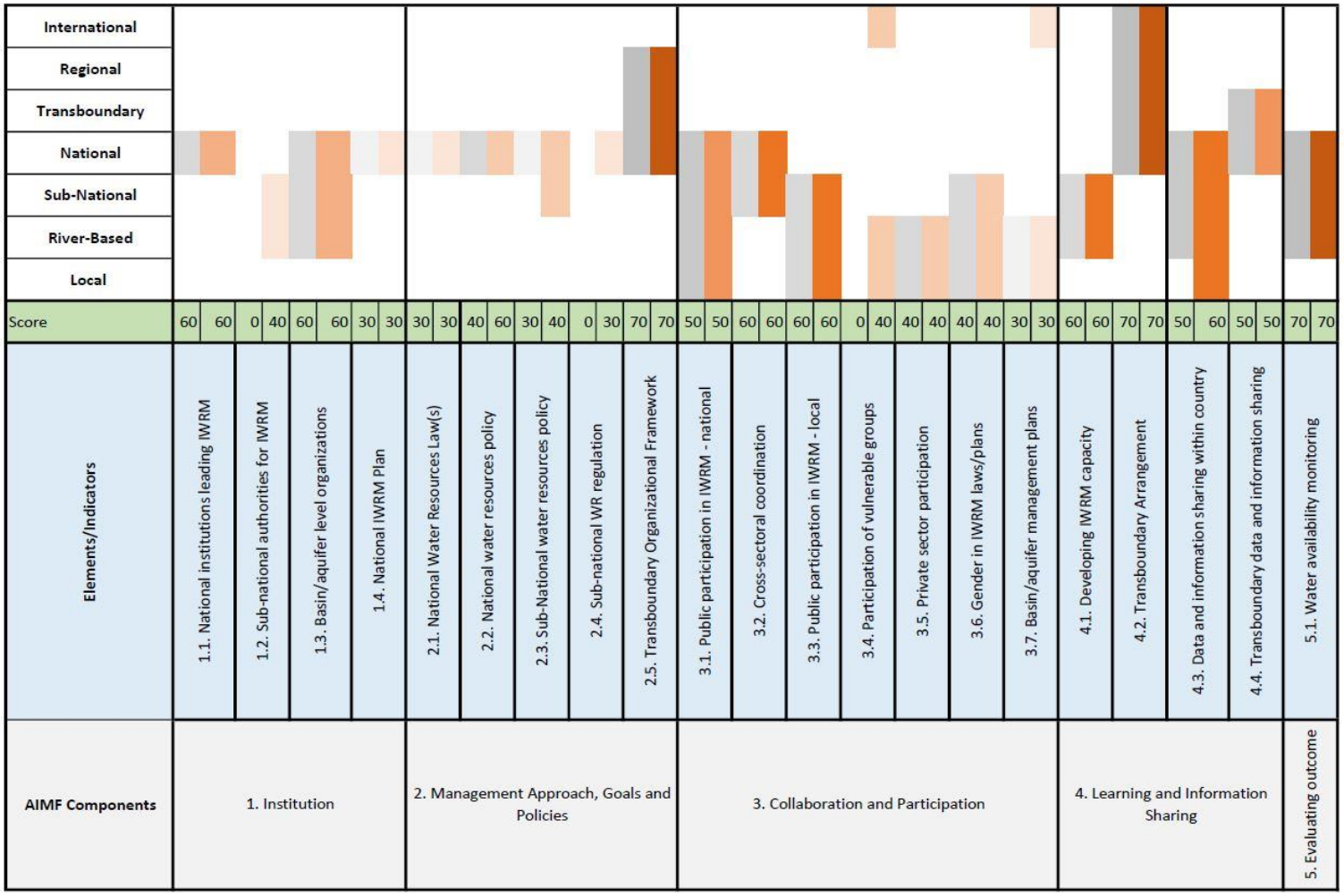

Figure 18: IWRM Implementation in Uzbekistan years 2017 and 2020

Table 2: Summary of Comparison of IWRM Implementation in Australia and Uzbekistan

Sub-Component	Australia	Uzbekistan
Institutions		
National Institution Leading IWRM	Decentralized with Multiple Authorities	Centralized, Ministry of Water Resources and Cabinet
Sub-National Authorities for IWRM	Clear Mechanism for vertical organization integration through water resources planning at state levels	Hierarchic Organizational Structure with limited power over major decision-making
Basin/Aquifer Level Organizations	Participatory (Horizontal Integration) by having councils	Only Basin Authority of Irrigation Systems (BAIS) (Top-down decision-making)
National IWRM Plan	Basin Plan as National IWRM (Practically implemented)	Roadmap of activities: Serves as prototype for national IWRM plan, Need more development
Management Approach, Goals and Policies		
National Water Resources Law	Water Act and reforms it introduced, Participatory revision	Law of the Republic of Uzbekistan on "Water and Water Use," Top-down approach
National Water Resources Policy	Strategies that are developed across sectors at national level	Only Country's Development Strategy National policy for the development of IWRM is lacking
Sub-National Water Resources Policy	Policies and plans vary across states and territories	Lacking Policy, relies on a decree by Ministry of Water Resources
Sub-national water resources regulations	states and territories have their own water resource laws.	Relies Law of the Republic of Uzbekistan on "Water and Water Use,"
Transboundary Organizational Framework	No Transboundary water issues	Interstate Commission for Water Coordination of Central Asia
Collaboration and Participation		
Public Participation in IWRM -National	Public Participation in Practice and legal documents through mechanisms	Public participation emphasized in legal documents
Cross sectoral Coordination	Cross-sectoral coordination through various committees	Cross-sectoral but hierarchic

Public Participation in IWRM – Local	Clear mechanism for public participation	Lack of mechanism for public participation
Participation of Vulnerable Groups	Actively included – through programs and funds	Ministry for Support of Mahalla and Family Participation remains moderate
Private Sector Participation	Private sector actively involved for years	Recent partnership allows private sector participation
Gender in IWRM laws/Plans	Specific policies ensure women participation at various levels	Participation encourages in legal documents, lack mechanisms
Basin/Aquifer management Plans	33 plan areas	Relies on national regulations for water management without regional or sub-basin plans
Learning and Knowledge Sharing		
Development IWRM Capacity	Social learning by collaboration and Participation	Learning through scientific trainings
Transboundary Arrangements	No transboundary arrangement	Various international agreements and conventions, addressing shared water resources and fostering stronger relationships
Data and Information Sharing – National	Carious agencies collecting, sharing, and making water information publicly available	Limits transparency and public access to essential water resource management data.
Transboundary level data sharing	No Transboundary level data sharing	Sharing data through International Fund for Saving the Aral Sea, and the Interstate Coordinating Water Commission
Evaluating Outcome		
Water Availability Monitoring	The Bureau of Meteorology manages national and regional water assessments, the National Water Account, and online portals for water data. Has online platform for data sharing and monitoring	The National Water Cadastre is maintained by Uzhydromet, the State Committee on Geology and Mineral Resources, and the Ministry of Agriculture and Water Resources, with each responsible for specific water resource aspects. Lacks online platform

1. Institutions

National government authorities for leading IWRM implementation:

In comparing the water systems of Australia and Uzbekistan, we see that both have their own unique organizational structures for water management at the national level. The water system in Australia is more decentralized, as it includes multiple authorities such as the Murray-Darling Basin Authority (MDBA), the Commonwealth Environmental Water Holder (CEWH), the Australian Bureau of Meteorology (BoM), the Australian Competition and Consumer Commission (ACCC), and the National Water Grid Authority (NWGA). Such a polycentric structure promotes the inclusion of stakeholders at national and sub-national levels of decision-making, implementation, financing, and monitoring.

On the other hand, the water system in Uzbekistan is managed by a hierarchical structure that includes the cabinet of the Ministry of the Republic of Uzbekistan, particularly the Ministry of Water Resources. The Ministry of Water Resources develops state policies by coordinating related entities, establishing procedures for the formation and use of the water fund, and developing regulations for water use. Such a centralized approach precludes the inclusion of various stakeholders at various levels, such as local communities, regional authorities, and national institutions that are affected by decision-making. The Ministry of Water Resources of Uzbekistan may promote a more inclusive water management system by enabling authorities in river basins and at local levels and embracing multiple perspectives and participation among various sectors.

Sub-National Authorities for IWRM

This section includes the provincial, state, county, local government area, and council levels of government. In Australia's water system, subnational authorities are responsible for managing and implementing water resource plans. Basin states conduct water resource planning to meet legislative obligations and maintain consistency with the Basin Plan. For example,

Victoria's statutory water corporations and catchment management authorities, which are run by independent boards, create, implement, evaluate, and change plans for managing water resources in their own districts and catchments. On the other hand, in Uzbekistan's water management system, regional, district-level, and local authorities are responsible for determining the main direction of water use and protecting water resources on their territory. They ensure compliance with regulations, control water use, and construct and restore damaged infrastructure. Both systems emphasize the role of local authorities in water resource management. In Australia, subnational governments are in charge of putting water resource plans into action. In Uzbekistan, however, local governments are in charge of protecting water resources and keeping track of how much water is used. Australia has clear mechanisms for vertical organizational integration that impose control over each other, while such mechanisms are not seen in the case of Uzbekistan.

Basin/aquifer level organizations

While discussing water systems at this level, countries have formal institutions at the basin/aquifer level. This variable refers to those institutions that implement IWRM. Basin- or aquifer-level organizations in Australia are managed through top-down government structures. The National Federation Reform Council (NFRC) later took the place of the Council of Australian Government (COAG), which had previously been in charge. The national cabinet is at the core of the NFRC, while COAG was comprised of the Prime Minister, State Premiers, Territory Chief Ministers, and Presidents of the Australian Local Government Association. The goal is to initiate, develop, and monitor the execution of nationally significant policy reforms, necessitating collaborative efforts from the government to implement IWRM at basin or aquifer level. In contrast, in Uzbekistan, the Basin Authority of Irrigation Systems (BAIS) forms the organizational structure responsible for water management and use at this level. The Water-Management Council, which operates under BAIS and includes various officials and experienced personnel, is responsible for managing BAIS regulations.

Australia has separate management mechanisms for each basin, e.g., the Murray-Darling Basin Ministerial Council, established by the Murray-Darling Basin Agreement, oversees policy and decision-making for state water shares and natural resource management programs. These basin councils are monitored by MDBA. The MDBA possesses various capabilities and resources to identify and address non-compliance, such as conducting audits and investigations and employing modern technologies like remote sensing. The Independent Assurance Committee (IAC) for Compliance offers expert guidance on the development, execution, and sufficiency of MDBA's Basin Plan compliance program. Australia allocates budget for research programs to enhance the Basin's scientific understanding, supporting informed decisions and outcomes. This approach fosters knowledge and research collaborations, creating a solid evidence base for evaluations and addressing complex basin water management challenges.

In the case of Uzbekistan, the BAIS oversees the development and implementation of water management and usage policies. Operating under BAIS, the Water-Management Council consists of various officials, such as the department head (Chairman of the Council), heads or deputy heads of regional agriculture and water management departments within BAIS's jurisdiction, managers of main channel offices (systems), irrigation systems, and other pertinent organizations. The Ministry of Agriculture and Water Resources of Uzbekistan initiated a restructuring process to effectively implement IWRM according to local conditions. This involves strengthening communication between the water management and agriculture sectors, hydrographic distribution and demand-based water supply, improving water use efficiency, supporting Water Users Associations/farmers through district-level irrigation departments, enhancing water productivity assessments, and involving key stakeholders. However, the Ministry must approve the Council's personnel composition and regulations, which shows the centralized final decision-making process.

National IWRM Plan

This section refers to plans, progress reports, and the status of IWRM implementation, The 2012 Basin Plan in Australia, and the roadmap of activities for the transition to IWRM in Uzbekistan both aim to improve water management and ensure sustainable resource usage. The Australian Basin Plan sets management objectives and outcomes, sustainable diversion limits, an environmental watering plan, a water quality and salinity management plan, and requirements for basin state water resource plans. It undergoes regular reviews to balance environmental improvements with socio-economic impacts on dependent communities. In contrast, the Uzbekistan roadmap focuses on developing the water sector by creating a concept for IWRM implementation. This concept serves as a prototype for a national IWRM plan. While the Australian approach emphasizes a comprehensive, multi-faceted plan with regular reviews, the Uzbekistan roadmap aims to establish a foundation for a national IWRM plan, focusing on practical implementation. Australia has taken many steps in the practical implementation of IWRM that include multiple aspects of water management, are inclusive, meet the specific requirements of the basin, and provide a regular basis for monitoring at three levels (see Figure 17). In the case of Uzbekistan, the action plan for the practical implementation of the principles of IWRM was approved in 2020, which requires more development in terms of strengthening the vertical channels of communication and interaction between water management and agricultural wings at all levels. The action plan is developed only at national scale (see Figure 18), which represents the absence of both vertical and horizontal integration and inclusion.

2. Management Approach, Goals and Policies

National Water Resources Law

A national water law in any country serves as a comprehensive legal framework that governs the sustainable management, allocation, and preservation of water resources while considering the diverse needs of the environment, agriculture, industry, and communities. Water management reforms were introduced in Australia in 2008 through the Water Act, which

established the MDBA, national water frameworks, and rules for water charges, information, and enforcement. It also enacted the Basin Plan in 2012, which became law and set out management objectives, including sustainable diversion limits, water quality and salinity management plans, and rules for trading and transferring water rights. The Water Act and Basin Plan enable adjustments and enhancements through periodic reviews and requests from basin jurisdictions, while also fulfilling Australia's obligations under international agreements like the Ramsar Convention on Wetlands of International Importance. In contrast, the main national legislative act is the Law of the Republic of Uzbekistan on "Water and Water Use," which was established in 1993 with some amendments in 2009 and defines principles for water management and use. While a national working group was established in 2016 to prepare for a new water code, its implementation process has been slow. Uzbekistan still relies on international support programs such as the United Nations Development Program and European Programs, but taking into account the current realities and ongoing reforms in the country, Uzbekistan needs to improve the current legislation and codify the existing legal norms related to water and water use, ensuring consistency with the legislation in the fields of agriculture, environmental protection, utilities, and the industrial sector. Uzbekistan follows a top-down approach in developing and reviewing the law, focusing on the single national law and neglecting the contribution of sub-national and river-based organizations (see Figure 18).

National Water Resources Policy

In Australia, the National Water Initiative and National Water Quality Management Strategy serve as important policy frameworks at the national level, with the federal and state/territory governments having primary responsibility for water management. The Australian government provides national leadership, coordination, and support for water reform. Local governments also play a role in managing water resources (see Figure 17). In contrast, the second text is about Uzbekistan and discusses the State Water Management Policy as a component of the country's Development Strategy. While there is no other national-level policy for

implementing IWRM, its principles have been elaborated in the responsibilities of the Ministries of Agriculture and Water Resources and the roadmap for water resource development from 2020–2022. In Australia, the national policy was developed across sectors and implemented at various scales, while in Uzbekistan, most of the reforms should be approved by the President of the Republic of Uzbekistan, which may create challenges at various scales and stages (see Figure 18).

Sub-National Water Resources Policy

Refers to the status of policies, laws, and plans in a water system that are required at the sub-national (state, province, county, and prefecture) level. In comparing the water resource management policies in Australia and Uzbekistan, both reports highlight frameworks in place to address various aspects of water management regulations at the subnational level. Australia's approach includes policies for evaluating and planning water resources, rules for obtaining and using water, and environmental protection measures, but the legal status of these plans varies across states and territories. For example, Tasmania’s State Policy on Water Quality Management, Western Australia’s Waterwise Perth Action Plan, a two-year action plan with a ten-year strategy to transform Perth into a Waterwise city at multiple levels, and the Australian Capital Territory Water Strategy 2014–2044. In contrast, Uzbekistan does not have specific policies, but the Ministry of Water Resources has issued decrees for improving water resource management, promoting efficient water use, enhancing land reclamation, and regulating water at the sub-national level, with these decrees being approved after 2017 (see Figure 18).

Sub-National Water Resources Regulations

This section points out the laws, decrees, and ordinances at the state, province, or county level. When comparing the water resource management regulations at this level in Australia and Uzbekistan, we can see that the legal frameworks in the two countries take different approaches. In Australia, various states and territories have their own water resource laws, such

as New South Wales with the Water Management Act 2000 and the Water Act 1912, and Victoria with the Water Act 1989 and the Catchment and Land Protection Act 1994. In contrast, Uzbekistan does not have separate subnational legal acts; instead, it relies on a single fundamental legislative act for water regulation: the Law of the Republic of Uzbekistan on "Water and Water Use," which dates back to 1993. This distinction highlights the decentralized nature of water management in Australia compared to the centralized approach taken in Uzbekistan.

Transboundary organizational frameworks

Water systems can be either exclusive to a single country or span across multiple nations, with the geographical boundaries of a river basin or the rivers within a system being shared among countries. While Australia does not face any international transboundary water issues, Uzbekistan shares two river basins with three neighboring countries. The Interstate Commission for Water Coordination of Central Asia represents an agreement between the Republic of Kazakhstan, the Republic of Tajikistan, Turkmenistan, and Uzbekistan, aimed at managing the Amu Darya and Syr Darya river basins cooperatively (see Figure 18).

3. Collaboration and Participation

Public Participation in IWRM - national level

Australia and Uzbekistan both emphasize the importance of public participation and collaboration in managing water resources. In Australia, the Water Act sets out multiple mechanisms for public participation and legislated consultation processes, involving stakeholders in basin planning, water act review, basin plan assessment, and water resource plans. Additionally, the Efficiency Measures Program and Water Efficiency Program were developed in consultation with various stakeholders, and the Commonwealth Environmental Water Officer works with six local representatives.

In contrast, Uzbekistan's approach involves Water Users Associations (WUAs), non-governmental organizations (NGOs), and individual citizens working together with public

authorities to promote the efficient use of water resources and the protection of water and water bodies. Public authorities in Uzbekistan take into account suggestions from WUAs, NGOs, and citizens when implementing water management activities. Both countries recognize the value of stakeholder involvement in ensuring effective water resource management. However, Australia involves the public in practice during decision-making, execution, and monitoring, while Uzbekistan confirms public participation in legal documents.

Cross-Sectoral Coordination

Both Australia and Uzbekistan have established various bodies and committees to facilitate collaboration in water resources policy, planning, and management. In Australia, multiple working groups and committees focus on different aspects of water management, such as the Murray-Darling Basin Community Committee, the National Water Reform Committee, and the Great Artesian Basin Coordinating Committee. Geoscience Australia is also involved in groundwater-related projects and national water resource coordination activities (see Figure 17) the level of cross-sectoral coordination). In contrast, Uzbekistan centralizes its water management efforts under the Cabinet of Ministers, which coordinates the activities of several ministries, state committees, departments, and legal entities. The 2017 presidential decrees led to further organizational changes, including the creation of the Ministry of Housing and Communal Services and the reassignment of responsibilities for groundwater use and emergency situations.

While both countries emphasize collaboration in water resource management, their approaches differ. Australia focuses on various committees and working groups with specific mandates, while Uzbekistan consolidates its efforts under a centralized authority. Nevertheless, both nations involve grassroots organizations, NGOs, and other stakeholders in water resource management to ensure a comprehensive approach.

Public participation in WRM - local level

In both Australia and Uzbekistan, public participation is an essential aspect of water resource management. In Australia, the Water Act and Basin Plan mandate consultation processes for the development of state Water Resource Plans, environmental watering plans, and annual environmental watering priorities, with sub-national governments engaging in various public consultation methods. Examples of these methods include consultations on proposed changes to water legislation, draft water resource plans, and water quality objectives in different states and territories.

On the other hand, Uzbekistan's approach to public participation is driven by the Ecological Movement of Uzbekistan, and the new water code legislates the regulation of these aspects. A presidential decree incentivizes farmers to actively participate in water management for efficient land use in agriculture. Both Uzbekistan and Australia want the public to be involved in how water resources are managed, but Australia's approach is more formal and involves multiple consultations at different levels of government. Uzbekistan, on the other hand, focuses on getting grass-roots groups like the Ecological Movement and WUAs involved, with the goal of giving local communities more power over water management decisions, but no clear mechanism is discussed for its realization.

Participation of Vulnerable Groups

Vulnerable groups refer to those experiencing economic, political, or social marginalization or exclusion. These may consist of, but are not limited to, indigenous populations, ethnic minorities, migrants (including refugees, internally displaced persons, and asylum seekers), remote communities, subsistence farmers, impoverished individuals, and residents of slums or informal settlements. They are also known as 'marginalized' or 'disadvantaged' groups.

In Australia, the National Water Initiative and the Water Act promote Indigenous Australians' involvement in water planning and management, with organizations like the Murray-Darling Indigenous Nations and Northern Basin Aboriginal Nations representing Aboriginal

interests. The Australian Government also provides financial support through the Murray-Darling Basin Aboriginal Water Entitlements Program and funds research on Aboriginal water values. In contrast, Uzbekistan enables vulnerable groups, such as low-income families and persons with disabilities, to address water-related issues via the Ministry for Support of Mahalla and Family. However, their participation in water management regulation remains moderate. The comparison highlights the proactive measures taken in Australia to include Indigenous communities in water management, while Uzbekistan's efforts appear to be less comprehensive and are part of the responsibilities of a ministry that is not included in any water management efforts or decision-making. Figures 17 and 18 show that no data was reported in 2017 for participation of vulnerable groups.

Private Sector Participation

In Australia, government agencies frequently collaborate with private sector stakeholders through peak bodies involved in water resource policy and management. Stakeholders participate in public and private meetings, and infrastructure programs often seek industry feedback for improvement. The Water Efficiency Program partners with state governments to manage projects through delivery partners, and multiple government initiatives involve consultation with various business organizations, local groups, and communities to ensure efficient water use, alternative water supply development, and support for market and investment opportunities. Figure 17 shows that the private sector is included at multiple levels of decision-making and contribution to IWRM implementation in Australia.

In Uzbekistan, the decree after 2017 allows the transfer of the Ministry of Water Resources' management functions for water facilities on cluster lands based on direct negotiations. The Ministry and the Agency for the Development of Public-Private Partnerships are required to submit a list of water facilities to the Cabinet of Ministers for transfer to the private sector. The private sector is included in local and river-based organizations (see Figure 17). This introduction of public-private partnerships and outsourcing aims to enable farms, clusters, and

other organizations to use individual water management facilities, directing saved funds towards modernizing water facilities and incentivizing staff. For example, the creation of cotton and textile clusters in Uzbekistan indicates the involvement of the private sector in organizing a production cycle, including raw cotton cultivation, processing, and textile production.

The comparison shows that Australia has been working together with the private sector to manage water for a long time, while Uzbekistan is just starting to use public-private partnerships and outsourcing to get the private sector involved in water management. The focus in Uzbekistan is on transferring management functions for water facilities to cluster lands and modernizing water facilities, with the potential to significantly change agriculture and water management systems in the country.

Gender in IWRM Laws/Plans

The Australian government is dedicated to respecting, protecting, and fully realizing human rights, including gender equality, and emphasizes the importance of women's participation in the development and implementation of water policies. Although the Water Act and Basin Plan do not mandate gender considerations, the Victorian Government's Water for Victoria policy supports gender equality and promotes women in leadership roles. In 2019, a one-year program was initiated to empower and mentor women in the water industry and associated sectors, with the goal of enhancing their leadership abilities and preparing them for potential executive positions. Since the start of the program, the number of women in different roles, such as chair and executive positions, has gone up by more than 50%. Currently, women hold 20% of managing director and chief executive officer positions in water corporations and catchment management authorities. In contrast, in Uzbekistan, the Law on Guarantees of Equal Rights and Opportunities serves as the sole basis for addressing gender concerns in water-related matters at local, basin and state levels while there is no mechanism for their practical inclusion in decision-making.

Basin/aquifer management plans

In Australia, there is a comprehensive approach to water resource management, with 33 water resource plan areas in the Basin and various state and territory allocation plans. These plans address climate change, protect natural systems, and promote sustainable resource use. Community consultation plays a role in the development of these plans. In contrast, Uzbekistan does not have individual regional or sub-basin plans for water resource management. Instead, water use and consumption are governed by national regulations. A new Water Code draft, prepared in 2018, aims to introduce local planning regulations, but it has not yet been implemented.

4. Learning and Information Sharing

Developing IWRM Capacity

The aim of developing IWRM capacity is to improve the implementation of IWRM by enhancing skills, instruments, resources, and incentives at all levels for individuals and institutions. Australia demonstrates a commitment to long-term capacity development programs for water management, focusing on Indigenous communities' involvement and sharing knowledge on IWRM domestically and internationally (see Figure 17). Programs like Indigenous Rangers and the MDBA's Aboriginal Waterways Assessment Program empower Traditional Owners to participate in water planning and management. Furthermore, sub-national governments and regional authorities contribute by engaging with local communities on natural resource management.

On the other hand, Uzbekistan's Concept for the Development of Water Resources for 2020-2030 emphasizes strengthening IWRM capacity through measures such as personnel training, professional development, and fostering collaboration between education, science, and production. The concept also aims to improve design organizations' capacities for developing

modernized irrigation systems, preparing estimates, and procuring relevant documents while ensuring effective execution and implementation of scientific research in the water sector.

In Chapter 3, we discussed four types of social learning in a water system that are improved through the active collaboration and participation of stakeholders at various levels. Overall, both countries focus on capacity-building and knowledge-sharing in their respective water management sectors, with Australia placing more emphasis on Indigenous community involvement and the active participation of stakeholders, while Uzbekistan concentrates on technical expertise and scientific research integration.

The mechanisms employed by both countries to build capacity for IWRM implementation vary significantly. Enhanced social learning is achieved through stakeholder participation and collaboration, allowing for the exchange of knowledge and experiences. Continuous involvement in the operation of the water system each year enables stakeholders to gain experience, adapt to changing circumstances, and transform the system when the current approach fails to meet requirements.

Australia promotes social learning through programs like Indigenous Rangers and the MDBA's Aboriginal Waterways Assessment, which provide platforms for stakeholder’s active engagement in planning, execution, and evaluation. Conversely, Uzbekistan focuses on developing the scientific capacity and technical responsibility of stakeholders through training programs. However, this approach does not take into account the perspectives of non-technical stakeholders and ignores the need to develop their capacity to manage water systems in the face of change.

Transboundary Arrangements

Australia does not have transboundary arrangements, as its water resources are managed within its borders. On the other hand, international water treaties are integral to Uzbekistan's water legislation. The country has acceded to two key global conventions related to

transboundary water resources, namely the UNECE Convention and the UN Convention on Non-Navigational Uses of International Watercourses. These conventions necessitate legal measures and improvements in Uzbekistan's water legislation. Furthermore, Uzbekistan's water relations in Central Asia are regulated by various international agreements that involve shared water resources, such as the Aral Sea and interstate water resources. Uzbekistan also participates in several environmental conventions and adheres to international "soft" environmental law. In 2017, the country prioritized addressing shared water resources and fostering stronger relationships with its neighbors.

Data and Information Sharing Within the Country

In Australia, various Commonwealth and state agencies collect, share, and make water information publicly available through different portals and systems, ensuring transparency and informed decision-making in water resource management. The BoM, MDBA, and sub-national governments, as well as Geoscience Australia, are involved in providing water data to the public.

In contrast, Uzbekistan's 1993 "On Water and Water Use" law outlines state registration and planning for water resource use and protection but does not make much of the environmental information publicly available. This limits transparency and public access to essential data in water resource management in the country.

Transboundary Data and Information Sharing

While international transboundary data sharing is not applicable to Australia, Uzbekistan actively engages in water resource management cooperation based on its foreign policy and adherence to international law norms. Uzbekistan exchanges data at the transboundary level through the International Fund for Saving the Aral Sea (IFAS) and the Interstate Coordinating Water Commission (ICWC), though neighboring countries have shown limited interest in openness since 2017. The Uzbek-Kazakh joint working group on environmental protection and

water quality in the Syrdarya river basin has been more successful in data exchange and collaboration.

5. Evaluating Outcome

Water availability monitoring

The Australian Bureau of Meteorology (BoM) is responsible for national and regional water assessments, the National Water Account, and online portals for water data in Australia. The BoM also provides daily simulations of landscape water balance components as well as forecasts, outlooks, and projections to support water-related decision-making. On the other hand, the State Water Cadastre (SWC) in Uzbekistan is a system established under the "On Water and Water Use" Law that aids in water resource management, regulation, and evaluation of economic activities and environmental concerns. The National Water Cadastre in Uzbekistan is maintained by three distinct entities: Uzhydromet, the State Committee on Geology and Mineral Resources, and the Ministry of Agriculture and Water Resources, each responsible for specific aspects of the country's water resources. Australia has an online data portal for storing and sharing the data, while Uzbekistan lacks such an online platform.

Conclusion

Water Management Systems of Australia and Uzbekistan exhibit multiple key differences in their organizational structure, institutions, approaches to governance, stages of IWRM implementation, and stakeholders' practical inclusion. With a decentralized system, Australia has separate mechanisms, laws, policies, and regulations for river basins, states, and public participation. There is an emphasis on the practical involvement of stakeholders and authorities at all levels, as shown in their progress reports. In contrast, Uzbekistan mainly relies on a top-down, centralized approach with a single fundamental legislative act dating back to 1993, governed by the Ministry of Water Resources. Some progress has been made to develop and empower river-based organizations and share decision-making power among various authorities.

Australia's decentralized water management system is managed through national-level authorities, including the Murray-Darling Basin Authority (MDBA), the Commonwealth Environmental Water Holder (CEWH), the Australian Bureau of Meteorology (BoM), the Australian Competition and Consumer Commission (ACCC), and the National Water Grid Authority (NWGA). The above authorities ensure the inclusiveness of multiple stakeholders at national and subnational levels to take part in decision-making, planning, implementation, financing, and monitoring while at the same time meeting the legislative obligations of the Basin Plan.

The Ministry of Water Resources in Uzbekistan develops state policies, coordinates related entities, and enacts regulations for water use. In legal documents, regional, district-level, and local authorities are responsible for determining the main direction of water use and protecting water resources on their territory. They ensure compliance with regulations, control water use, and construct and restore damaged infrastructure. Such a centralized approach shows the exclusion of various stakeholders at various levels, such as local communities, regional authorities, and national institutions that are affected by decision-making.

Australia manages its basins in different ways, such as through the Murray-Darling Basin Ministerial Council, which is in charge of programs that manage policy and resources. The MDBA monitors these councils, utilizing tools like audits, investigations, and remote sensing to address non-compliance. Another committee, the Independent Assurance Committee, provides expert guidance on MDBA's compliance program. Additionally, Australia allocates a budget for research to improve basin understanding, foster collaborations, and support evidence-based decision-making to tackle complex water management challenges.

In contrast, in Uzbekistan, the Basin Authority of Irrigation Systems (BAIS) forms the organizational structure responsible for water management and use at this level. The Water-Management Council, which operates under BAIS and includes various officials and experienced personnel, is responsible for managing BAIS regulations. The Ministry of Agriculture and Water

Resources of Uzbekistan started a restructuring process to implement IWRM. The process focuses on communication, hydrographic distribution, water use efficiency, farmer support, productivity assessments, and stakeholder involvement. Despite these efforts, the process of making decisions is still centralized because the Ministry has to approve the Council's staff and rules.

In managing water resources, both Australia and Uzbekistan emphasize public participation, collaboration, and coordination across sectors. Australia utilizes various committees and working groups with specific mandates, while Uzbekistan consolidates efforts under a centralized authority. Public participation is essential in both countries, but Australia has a more formal approach involving multiple consultations, while Uzbekistan involves grass-roots groups with no clear mechanism for realization. Australia proactively includes Indigenous communities in water management, whereas Uzbekistan's efforts for vulnerable groups are less comprehensive. The private sector plays a significant role in Australian water management, while Uzbekistan is just starting to use public-private partnerships. Gender considerations are more prominent in Australia's water policies, while Uzbekistan's efforts are limited. Australia has a comprehensive approach to basin management, while Uzbekistan currently relies on national regulations.

In the area of learning and information sharing, both Australia and Uzbekistan prioritize capacity building, knowledge sharing, and information sharing in the water system. Programs like Indigenous Rangers and the MDBA's Aboriginal Waterways Assessment Program in Australia empower traditional owners to participate in water planning and management. Various Commonwealth and state agencies collect, share, and make water information publicly available through different portals and systems, ensuring transparency and informed decision-making in water resource management. The BoM, MDBA, and sub-national governments, as well as Geoscience Australia, are involved in providing water data to the public. As Uzbekistan moves towards implementing IWRM, the country places emphasis on building its capacity by adopting measures such as personnel training, professional development, and promoting collaboration

among the education, science, and production sectors. The goal of these efforts is to make it easier for design organizations to make modern irrigation systems and make estimates, as well as to make sure that scientific research in the water sector is carried out and used effectively. Uzbekistan lacks an open platform to share information and data with the public, which limits transparency and public access to data.

5. CONCLUSION

Water resources management is undergoing a paradigm shift towards more integrated and participatory approaches and collaborative decision-making due to growing uncertainties, including climate change, nexus strategies for integrated landscape management, and the function and growing recognition of indigenous peoples and their knowledge in the stewardship of natural resources. The new paradigms consider the importance of stakeholders' engagement and the uncertainties that include lack of knowledge, system behavior, climate change, and our understanding of the system. Consequently, IWRM and an adaptive water governance paradigm have emerged.

Various articles in the literature point out the shortcoming of IWRM, specifically the vagueness in its conceptualization that allows managers to avoid making significant changes in approach while asserting that they are adapting to global perspectives. IWRM has led to new centralized, large bureaucratic organizations that are in charge of managing water in river basins. It opposes community-based planning and management at the local level, which leads to disappointments, a lack of ownership among stakeholders, and a failure of collaboration. Although it may help with coordination across interrelated hydrological and ecological systems within a river basin, it presents certain challenges; for instance, the boundaries of river basins or catchments might not match other critical ecological borders. Additionally, newly established authorities could face legitimacy issues if they disregard jurisdictional boundaries, potentially worsening coordination difficulties.

IWRM encourages shared dialogue that is expected to encourage equality and fairness among stakeholders, but the power imbalance among stakeholders is a barrier to achieving this objective. This means that some stakeholders may have more influence and decision-making power than others, making it difficult to achieve true integration and rational decision-making

through dialogue. Another challenge lies in the insufficiencies of top-down management structures in relation to decentralization and IWRM, coupled with the complexities of decision-making in water management under uncertain conditions while employing adaptive management strategies.

Similarly, adaptive water management, despite its potential advantages, also faces challenges and limitations. The transition to adaptive water management is slow because of limited empirical evidence, and shifting from a top-down to a more participatory approach without altering information and risk management practices is not straightforward. The lack of empirical evidence and knowledge makes it difficult to predict outcomes and leads to resistance from stakeholders who are used to traditional management methods. Inherent barriers also emerge as this approach requires significant changes to existing structures, policies, and regulations. The complex social dynamics, institutional rigidities, and financial constraints make adopting this approach more challenging. Despite this shortcoming, adaptive management contributes toward addressing some of the challenges in IWRM.

Adaptive management calls for an open and comprehensive process that involves a wide range of stakeholders at different levels. It focuses on ongoing stakeholder engagement and collaboration for the management of human and water resources. It empowers stakeholders, even marginalized groups, enhances their skills and knowledge, and fosters transparent and accountable governance.

Stakeholder engagement in adaptive governance is a dynamic process that promotes social learning, empowers individuals, fosters relationships, builds trust, and promotes collaboration. Success in participatory efforts relies on trust, which requires time, patience, and transparency. Literature suggests that collaborative modeling is an effective technique that brings together diverse perspectives, promotes discussion, identifies problems, and develops consensus-based strategies to address water resource issues. This process improves group

dynamics, builds relationships and trust, and explores potential futures for enhancing long-term resilience.

In contrast to the IWRM, stakeholder knowledge in adaptive governance can democratize and improve decision-making efficiency. Informed stakeholders are better equipped to make decisions, while broader stakeholder involvement strengthens adaptive capacity by engaging individuals with diverse skills and experiences and fostering knowledge exchange. Capacity building for stakeholders, including government agencies, NGOs, and local councils, ensures informed and effective decision-making. This governance system allows individuals and groups to experiment with new ideas, adapt approaches to specific situations, and develop innovative collaboration methods. Stakeholders also participate in regular monitoring of water systems to identify successes, challenges, and ways to improve them.

The concept of adaptive water governance is developed to address the growing number of uncertainties, such as climate change, socio-economic development, and globalization, challenging the management of water resources. The literature review alluded to numerous uncertainties that can be categorized into three major groups. The first category is uncertainty due to limited knowledge or data availability. The second type is our understanding of the system's components, nonlinearities, feedback loops, and delays that generate trends. It is especially relevant to the socioeconomic system, human behavior, and ecosystems, where multiple interpretations of the same phenomenon may exist. The third type is the unpredictability of the factors that are inherent in the system's behavior. The interactions of rules and regulations with human preferences and mental models that influence the behavior of the system.

Social learning plays an important role in stakeholder capacity building, institutional development, and strengthening collaboration among stakeholders. It promotes shared comprehension and joins efforts among different yet interconnected groups that enable them to effectively handle the intricacies and unpredictability of the system through past management actions and adaptation to the changes. Enabling flexible and responsive decision-making is

crucial for addressing the complexity and uncertainty of water resource management. The literature suggests that a shift from IWRM to adaptive water management is necessary to incorporate a structured learning process that effectively handles this complexity and uncertainty.

In light of the findings of the literature review, the Adaptive and Integrated Management Framework was developed in this study keeping in mind the IAD framework and Transition and Management Framework as the theoretical foundation. The AIMF serves as a shared language for analyzing various water governance regimes, offering a deeper understanding of the interactions among the components of a water system. It situates water systems at the intersection of social, technological, and ecological domains and highlights action situations within the social domain, emphasizing stakeholder inclusion. The framework identifies types of social learning: collaborative and participative, experiential, adaptive, and transformative, and examines falling under the single, double, and triple loop learning categories and how the learning process affects components and action situations.

Experiential learning that falls under double loop learning occurs through social interactions and stakeholders' experiences in action situations. This type of learning helps build trust and foster collaboration without formal monitoring and evaluation processes. Adaptive learning involves continuous amendments in management practices and policies based on new information from the system, ensuring sustainability, resilience, and efficiency. Transformative learning focuses on fundamental changes after evaluating the outcomes of continuous action situations, leading to institutional change and new approaches and management. This learning involves challenging deeply rooted assumptions and taking a systems-thinking approach to water management. Learning from collaboration and participation emphasizes the active involvement of stakeholders in an inclusive, multi-disciplinary environment. This approach promotes trust, conflict resolution, and a sense of ownership over the water management system by ensuring diverse perspectives are heard and considered in decision-making.

We employed the AIMF to examine the implementation of IWRM in both Australia and Uzbekistan, focusing on national water systems. The framework facilitated an analysis at various organizational levels in each country despite data limitations, encompassing five key components: institutions, management approach, goals and policies, collaboration, and participation, learning and information sharing, and evaluation of outcomes. This allowed for a comprehensive examination of water systems, including the identification of specific institutions, legislation, and policies. Furthermore, it provided insights into the hierarchical, bottom-up, and participatory nature of water management systems. Of particular importance was the discernment of strategies and mechanisms employed in Australia to incorporate diverse stakeholders at multiple levels, as well as the facilitation of collaboration among stakeholders and institutions.

Australia established agencies at the national level, including the MDBA (implementing the Basin Plan), CEWH (managing environmental water assets), BoM (providing meteorological, hydrological, and oceanographic services), the ACCC (overseeing the water market and pricing), and the NWGA (developing the National Water Grid and investing in water infrastructure projects with state and territory governments). These agencies support sub-national authorities in implementing basin plans and meeting legislative obligations. Policy frameworks exist, such as the National Water Initiative (NWI) and the National Water Quality Management Strategy (NWQMS), at the national level, that play an active role in water management at various levels. Every state and territory, in accordance with these policy frameworks, has specific plans for water resources. Various stakeholders, including the public and private sectors and vulnerable communities, are engaged in all these agencies and frameworks through various committees, programs, and consultation procedures. Legal frameworks, the development of organizational structures at multiple levels, and programs for specific goals, all while abiding by the Water Act, are the mechanisms in Australia that support the implementation of IWRM.

Despite the limitations of the data, the framework helped to analyze the institutional, legislative, participatory, and learning structures in both countries. To better assess the

framework's utility in future research, it is recommended that case studies at any level of a water system be conducted, evaluating a series of action situations over a 5–10-year period. This will allow for the assessment of learning, capacity building, collaboration, adaptation, and institutional arrangements within each case study.

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APPENDIX

LIST OF COMPONENTS, SUB-COMPONENTS AND ATTRIBUTES OF AIMF

Water System	
Title	Description
Geographical Location	The geographical location of the water system (longitude and Latitude)
Hydrological Boundaries	Size of the river basin of the main river of the basin
Hydrological Characteristics	It includes the volume of water (maximum and minimum), quality of water, and more
Environmental Condition	The climatic variation of the water including precipitation, flooding, and droughts defines whether the system is water-abundant or water-scarce
Population	The population that the system cover
Social Domain	
Human Development Index	determines a society's level of development by taking into account GDP per capita, life expectancy, literacy, and educational achievement.
Values and Culture	Social norms that are important for water management are referred to as culture. It contains: Individualism against collectivism environmental awareness attitude towards risk-taking
Demography	Size of the community, number of inhabitants in the system
Governmental Regimes	The governmental regimes might have impacts on the overall water system, from being democratic the is based on inclusion to dictatorship with a high level of centralized decision-making
Social Development	The process of improving the quality of life and well-being of people by providing access to safe and reliable water resources.
Economy	Economic growth of the society (GDP per capita)
Role of Institutions	The strength of formal institutions (formal laws, rules) and the possibility that they are put into practice and carried out rather than existing simply on paper
Equity	refers to how wealth is distributed in society and how unequally it is distributed.
Ecological Domain	
Water Availability	The availability of water in the system
Water Quality	The water quality meets the need of a system
Natural Storage Capacity	The storage capacity of the basin to store water
Human Impacts	This is about how humans change the water and its surroundings. It's important to compare these changes
Biodiversity	It refers to the variety of species and ecosystems within aquatic environments.

Water System	
Title	Description
Environmental Hazards	It refers to harmful conditions that can negatively impact the health of aquatic ecosystems and their inhabitants. It is also the likelihood of the occurrence of any natural disaster that adversely impacts the water system.
Environmental Services	The inclusion and exclusion of water use and the availability of services
Technological Infrastructures	
Scale	A geographical region that is affected by the infrastructure
Lifetime	The life cycle of physical infrastructures of the system
Maintenance	The infrastructure is maintained based on the infrastructure life cycle and technical support by responsible bodies
Ownership	Who owns the physical infrastructure? (Government, or community)
Institutions	
Legal Formality	Degree of Formality and Documentation (Formal, informal but documented, informal and undocumented)
Normative Uncertainty	Refers to the degree of interpretation that is allowed by an institution.
National institutions leading IWRM	Discuss the institutions that focused on implementing IWRM at the country level.
Basin/aquifer level organizations	While discussing water systems at the country level, countries have formal institutions on the basin/aquifer level. This variable refers to those institutions that implement IWRM
Transboundary organizational frameworks	Water system can be shared among countries, or the geographical boundaries are within a river basin or rivers of a system is shared between countries
Rules	
Rules	Rules vary according to the water system but could be at constitutional, collective choice, or operational level as described in IAD Framework.
Management Approach and Strategic Management Goals	
Management Paradigm	Management paradigm is the dominating frame of water management issues in a group of stakeholders. It could be Integrated, Participatory, Adaptive, or Hierarchal.
National IWRM Plan	It refers to plans, progress reports and the status of IWRM implementation
Management Goal	Strategic management goal varies in water systems, for example, Ensuring water Availability, promoting water use efficiency, Protecting water quality, and promoting stakeholders' participation and collaboration.

Water System	
Title	Description
National Water Law	A national water law in any country serves as a comprehensive legal framework that governs the sustainable management, allocation, and preservation of water resources while considering the diverse needs of the environment, agriculture, industry, and communities.
National water resources policy	the status of policies, laws, and plans to support Integrated Water Resources Management (IWRM) at the national level
Sub-National water resources policy	Refers to the status of policies, laws, and plans in a water system that is required at the sub-national (state, province, county, prefectures) level.
Basin/aquifer management plans	It refers to the plan at a river basin or aquifer level
Transboundary arrangements	Transboundary arrangements are formal commitments between riparian countries on the management of transboundary water. It could be interstate, intergovernmental, regional, or interagency.
Sub-national WR regulation	Refers to the laws, decrees, and ordinances at state, province, or county levels
Stakeholders	
Formal	National water agencies, Public sector agencies, Sub-national water agencies, Basin/Aquifer agencies, Transboundary expertise, and Academia or research groups
Informal	Water User Associations, Civil society, the Private sector, Vulnerable groups, Gender expertise, Research/academia
Individual Or Collective	A stakeholder can contribute as individuals or group to any water system
Evaluating Outcome	
Water quality and quantity	The quality and quantity of water before and after an action situation in a water system
Water access	Changes in the access to water for different stakeholders, including households, industries, and ecosystems, can be assessed.
Economic impact	The economic impact of the action taken can be evaluated, including the costs and benefits associated with the action. This includes assessing changes in water-related industries, such as agriculture, tourism, and energy production.
social impact	The social impact of the action taken can be evaluated, including changes in people's quality of life and well-being.
Environmental Impact	The environmental impact of the action taken can be evaluated, including changes in the ecosystem's health and biodiversity.
Institutional and Governance impact	The impact of the action taken on the institutional and governance structures in the water system can be evaluated.
Collaboration and Participation	

Water System	
Title	Description
Level of Decision-making	It depends on the action situation and the level of stakeholders involved. Any decision-making that leads to transformation in a water system requires a higher level of decision-making
Inclusivity	All stakeholders, including marginalized groups, have an equal opportunity to participate and be heard.
Transparency	Information be openly shared and decisions be made based on shared information
Communication	It refers to providing timely and accurate information, facilitating dialogue and discussion among stakeholders, and using communication channels that are accessible to all.
Trust building	Demonstrating integrity, openness, and a willingness to listen and respond to feedback during the phase of collaboration.
Capacity Building	Providing training and support to enhance knowledge and skills and building networks and partnerships to facilitate cooperation.
Flexibility	Willingness to modify plans and strategies based on new information or feedback.
Accountability	Making stakeholders responsible for their actions and decisions and includes clear roles and responsibilities and monitoring and evaluating the outcomes of collaboration and participation.
Cross-sectoral coordination	Coordination between national government authorities representing different sectors 13 on water resources, policy, planning, and management.
Public participation in WRM - national	All interested parties or stakeholders who may be affected or may affect by any water resources issues or interventions that include civil society, academia, NGOs, or individuals
Private sector participation	Inclusion of for-profit businesses and groups of people in various levels of decision-making, plan development, and policies.
Developing IWRM capacity	The aim is to improve the implementation of IWRM by enhancing skills, instruments, resources, and incentives at all levels for individuals and institutions.
Public participation in WRM - local	All interested parties, including organizations, institutions, academia, civil society, and individuals who may be affected by any water resources issue or intervention, are considered the public. However, government organizations are not included.
Participation of vulnerable groups	This refers to groups of people who experience economic, political, or social marginalization or exclusion. Such groups may include indigenous people, ethnic minorities, migrants, remote communities, subsistence farmers, people living in poverty, and those residing in slums and informal settlements.
Sub-national authorities for IWRM	This encompasses various levels of government, such as provincial, state, county, local government areas, and councils.
Gender in IWRM laws/plans	Mechanisms that are responsive to gender can comprise a range of measures, including laws, policies, plans, strategies, or other frameworks or procedures intended to accomplish gender objectives associated with women's participation, voice, and influence.

Water System	
Title	Description
Learning (Social Learning)	
Collaborative and Participatory	Involving stakeholders in identifying and defining water-related issues, recommending strategies and actions, and observing outcomes.
Experiential	The learning by stakeholders through experimenting or contributing to actions and reflecting on the outcome.
Adaptive	Stakeholders learn from the outcome and adapt to the changing conditions for the next action.
Transformative	Stakeholders understand the challenges and challenge the underlying assumption including institutional structure and paradigm and perceive a fundamental change.
Water availability monitoring	The status of management instruments to support the implementation of IWRM at the national level is being investigated/evaluated.
Data and information sharing within the country	This involves establishing more structured data and information-sharing agreements among users, and making such data accessible to the general public, as deemed appropriate.
Transboundary data and information sharing	The presence of institutional and technical mechanisms that enable the exchange of data in accordance with agreements made between riparian parties.
Outcome	
Operational	The operational outcomes of water management are the tangible, physical, and measurable effects of water management. Behavioral changes or technical or infrastructural actions.
Knowledge	The knowledge outcome after an action situation could be technical, scientistic, institutional, and social
Cost and Benefits	Such outcome is the direct and indirect costs associated with an action situation and the direct and indirect benefit made out of an action situation.
Action Arena, Action Situations, and Positions	
Action Arena varies in water systems but can be related to water supply, irrigation, water pollution control, fishery management, agriculture, energy generation, industrial water use, tourism development, nature protection, aquatic ecosystem management and etc. The action situation and positions depend on the action arena. IAD guidelines are the main source to refer to for further development of these classes.	

IWRM Implementation			
Title	Description	Country	
Institutions		Australia	Uzbekistan
National institutions leading IWRM	Discuss the institutions that focused on implementing IWRM at the country level.	The Australian Government Department of Agriculture, Water, and Environment provides national leadership in water resource management. Key agencies include MDBA (implementing the Basin Plan), CEWH (managing environmental water assets), BoM (providing meteorological, hydrological, and oceanographic services), ACCC (overseeing water market and pricing), and NWGA (developing the National Water Grid and investing in water infrastructure projects with state/territory governments).	The Ministry of Water Resources in Uzbekistan is responsible for creating a unified state policy for integrated and sustainable water resource use, management, and protection. Key tasks include coordinating relevant entities, establishing water fund procedures, maintaining state accounting and control, monitoring water cadaster, disaster prevention, and mitigation, setting payment procedures for water use, and developing inter-state relations.
Sub-national authorities for IWRM	This encompasses various levels of government, such as provincial, state, county, local government areas, and councils.	All Australian subnational authorities possess the ability to manage and implement water resource plans. Basin states conduct water resource planning to meet legislative obligations and maintain consistency with the Basin Plan.	In Uzbekistan, regional, district-level, and local authorities are responsible for determining the main direction of water use and protecting water resources on their territory, ensuring compliance with regulations, water use control, and the construction and restoration of damaged infrastructure.

IWRM Implementation			
Title	Description	Country	
Institutions		Australia	Uzbekistan
Basin/aquifer level organizations	While discussing water systems at the country level, countries have formal institutions on the basin/aquifer level. This variable refers to those institutions that implement IWRM	The Council of Australian Governments was Australia's top governmental form, and National Federation Reform Council (NFRC) has replaced it. The national cabinet is at the core of NFRC	The Basin Authority of Irrigation Systems (BAIS) is responsible for conducting policy in water management and use. The Water-Management Council, which functions under BAIS and is composed of various officials, including the head of department (Chairman of the Council), heads (or deputy heads) of the regional departments of agriculture and water management within the coverage area of BAIS, managers of offices for main channels (systems), irrigation systems, and other relevant organizations, as well as experienced and highly qualified employees, is responsible for managing BAIS.
National IWRM Plan	It refers to plans, progress reports and the status of IWRM implementation	The basin plan became law, setting out management objectives and outcomes for the basin. The Water Act along with the basin plan provide mechanisms to review the basin plans regularly, and the Great Artesia Basin Strategic Management Plan outlines how communities, businesses, traditional owners, and governments in the basin can use the resources sustainably.	A roadmap of activities on the transition to IWRM assisted in creating the concept for the development of the water sector in Uzbekistan that provides for the development and implementation of action programs for the practical implementation of IWRM. It will become a prototype of the National IWRM Plan.
Management Approach and Strategic Management Goals			

IWRM Implementation			
Title	Description	Country	
Institutions		Australia	Uzbekistan
National Water Resources Law	National water law in any country serves as a comprehensive legal framework that governs the sustainable management, allocation, and preservation of water resources while considering the diverse needs of the environment, agriculture, industry, and communities.	The Water Act commenced in 2008, and reforms for water management have been made in Australia, including the development of the Basin Plan, which becomes law in 2012 and sets out the management objectives and outcomes to be achieved for the basin.	The main national legislative act in the field of regulations is the Law of the Republic of Uzbekistan on "Water and Water Use," dated 1993. Some changes have been made to it in 2009 to define the principles of water management and the use of water. In 2016, a national working group was established under the Ministry of Agriculture and Water Resources to prepare for a new water code, supported by the EU Program "Sustainable management of water resources in rural areas of Uzbekistan, but the process of its implementation is not significant.
National water resources policy	the status of policies, laws, and plans to support Integrated Water Resources Management (IWRM) at the national level	The National Water Initiative (NWI) and National Water Quality Management Strategy (NWQMS) are among the policy frameworks at the national level that play a crucial role in water management. The federal system and state and territory governments hold primary responsibility for regulating and managing water resources. Local governments also play a vital role, especially in stormwater management and sometimes in water supply and wastewater treatment. The Australian Government offers national leadership, coordination, and support to advance water reform.	State Water Management Policy is a component of Uzbekistan's Development Strategy. There is no other national-level policy to implement IWRM, but IWRM principles have been elaborated in the responsibilities of the Ministries of Agriculture and Water Resources and the roadmap for the development of water resources from 2020–2022.

IWRM Implementation			
Title	Description	Country	
Institutions		Australia	Uzbekistan
Sub-National water resources policy	Refers to the status of policies, laws, and plans in a water system that is required at the sub-national (state, province, county, prefectures) level.	Australia has policies and plans for water resources in every state and territory, but the legal status of these plans and policies varies from place to place. These frameworks include policies for evaluating and planning water resources, rules for getting and using water, and ways to protect the environment.	Ministry of Water Resources under the decree on measures for further improvement of the water resources management system and on urgent measures for efficient use of water resources and improvement of the reclamation state of land management and regulation of water at the sub-national level. These decrees were approved after 2017.
Sub-national WR regulation	Refers to the laws, decrees, and ordinances at state, province, or county levels	All states and territories with jurisdiction over Australia have water resources laws, e.g., New South Wales has the Water Management Act 2000 and the Water Act 1912, and Victoria has the Water Act 1989 and the Catchment and Land Protection Act 1994.	There are no separate subnational legal acts in Uzbekistan. The fundamental legislative act regulating water is the Law of the Republic of Uzbekistan "On Water and Water Use, " which dates from 1993.
Transboundary organizational frameworks	Water system can be shared among countries, or the geographical boundaries are within a river basin or rivers of a system is shared between countries	Not applicable in Australia	The Interstate Commission for Water Coordination of Central Asia is an agreement between the Republic of Kazakhstan, the Republic of Tajikistan, Turkmenistan, and Uzbekistan on the management of the Amu Darya and the Syr Darya.
Collaboration and Participation			

IWRM Implementation			
Title	Description	Country	
Institutions		Australia	Uzbekistan
Public participation in WRM - national	All interested parties or stakeholders who may be affected or may affect by any water resources issues or interventions that include civil society, academia, NGOs, or individuals	Australia has multiple mechanisms for public participation and legislated consultation processes that are set out by the Water Act. Participation in basin planning, water act review, basin plan assessment, and water resource plans are all part of it. The efficiency Measures Program and Water Efficiency Program were developed in consultation with different stakeholders. The Commonwealth Environmental Water Officer has six local representatives.	Water Users Associations (WUAs), non-governmental organizations (NGOs) in line with their missions, and individual citizens collaborate with public authorities to promote the efficient use of water resources and the protection of water and water bodies. Public authorities may consider suggestions from WUAs, NGOs, and individual citizens when implementing these activities.
Cross-sectoral coordination	Coordination between national government authorities representing different sectors on water resources, policy, planning, and management.	There are multiple working groups and committees where government officials representing different sectors participate in water resource policy, planning, and management. It includes the Murrah-Darling Basin Ministerial Council, the National Water Reform Committee and its sub-committees, the Great Artesian Basin Coordinating Committee, the Lake Eyre Basin Community Advisory Panel, the National Roundtable, the Independent Expert Scientific Committee, and Geoscience Australia.	The Cabinet of Ministers of the Republic of Uzbekistan is in charge of the state policy for integrated and sustainable use, management, and protection of water resources. It does this by coordinating the work of different ministries, state committees, departments, and legal entities. Key players include the Ministry of Agriculture and Water Resources, the Ministry of Healthcare, State Committee on Geology and Mineral Resources, State Committee on Ecology and Environmental Protection, State Inspectorate for the Geological Condition of Subsoil, and the State Inspection for Control of Drinking Water Use.

IWRM Implementation			
Title	Description	Country	
Institutions		Australia	Uzbekistan
Public participation in WRM - local	All interested parties, including organizations, institutions, academia, civil society, and individuals who may be affected by any water resources issue or intervention, are considered the public. However, government organizations are not included.	The Water Act and Basin Plan outline consultation guidelines for creating state Water Resource Plans (WRPs), the environmental watering plan, and yearly environmental watering priorities. This includes particular provisions for consulting on Indigenous values and water resource utilization. Sub-national governments engage in public consultation and involvement through a variety of methods.	The Ecological Movement of Uzbekistan drives public participation in the water sector, with the new water code legislating the regulation of these aspects.
Participation of vulnerable groups	This refers to groups of people who experience economic, political, or social marginalization or exclusion. Such groups may include indigenous people, ethnic minorities, migrants, remote communities, subsistence farmers, people living in poverty, and those residing in slums and informal settlements.	Australia, through the National Water Initiative and National Water Reform, recognizes the needs of indigenous people and includes them in planning that meets their values and objectives.	Vulnerable population groups can participate in water-related issues through appeals to the Ministry for Support of Mahalla and Family. The ministry is responsible for developing and implementing a unified state policy for supporting families, women, and the elderly, protecting their rights, and fostering cooperation with citizens' self-government bodies.

IWRM Implementation			
Title	Description	Country	
Institutions		Australia	Uzbekistan
Private sector participation	Inclusion of for-profit businesses and groups of people in various levels of decision-making, plan development, and policies.	Australian agencies collaborate with private sector stakeholders through peak bodies involved in water resource policy and management. Infrastructure programs often seek industry feedback for improvement, and the Water Efficiency Program partners with delivery partners to manage projects. Multiple government initiatives involve consultation with various business organizations, local groups, and the community to ensure efficient water use, alternative water supply development, and support for market and investment opportunities.	In 2017, the private sector was not part of water management due to the high cost of infrastructure and maintenance but was obliged to follow the laws. In 2020, through the development of public-private partnerships by the Ministry of Water Resources and the Ministry of Finance, the public-private sector can manage the small water facilities.
Gender in IWRM laws/plans	Mechanisms that are responsive to gender can comprise a range of measures, including laws, policies, plans, strategies, or other frameworks or procedures intended to accomplish gender objectives associated with women's participation, voice, and influence.	There is no requirement under Water Act or the Basin plan to include gender considerations. The Victorian Government's Water for Victoria policy emphasizes gender equity and supports women in leadership roles.	The Law on Guarantees of Equal Rights and Opportunities is the only base for gender consideration in water issues.
Basin/aquifer management plans	It refers to the plan at a river basin or aquifer level	Across the Basin, 33 water resource plan areas exist, encompassing both groundwater and surface water regions. These plans outline area-specific management strategies in accordance with the Basin Plan.	There are no individual regional or sub-basin plans for the management of water resources in Uzbekistan.

IWRM Implementation			
Title	Description	Country	
Institutions		Australia	Uzbekistan
Learning (Social Learning) and Information Sharing			
Developing IWRM capacity	The aim is to improve the implementation of IWRM by enhancing skills, instruments, resources, and incentives at all levels for individuals and institutions.	Australia has programs for long-term capacity development such as Indigenous Rangers, MDBA's Aboriginal Waterways Assessment, and more.	The development of the water resources of the Republic of Uzbekistan is to build the capacity for IWRM, improve the system of training, increase the capacity of design organizations, and ensure the effectiveness of the conduct and implementation of scientific research.
Transboundary arrangements	Transboundary arrangements are formal commitments between riparian countries on the management of transboundary water. It could be interstate, intergovernmental, regional, or interagency.	Transboundary matters are not applicable to Australia	International water treaties play an integral role in the water legislation of Uzbekistan. The country has acceded to two key global conventions: the UNECE Convention on the Protection and Use of Transboundary Watercourses and International Lakes (Helsinki, 1992) and the UN Convention on Non-Navigational Uses of International Watercourses (New York, 1997).
Data and information sharing within the country	This involves establishing more structured data and information-sharing agreements among users, and making such data accessible to the general public, as deemed appropriate.	Various Commonwealth and state agencies collect and share information as well as make data publicly available. The data includes water flow, quality, groundwater, licensing, water user accounts, and river flows. and the data is publicly available.	State Water Cadaster under the Law on "Water and Water Use" is responsible for data maintenance. But the data is not available to the public

IWRM Implementation			
Title	Description	Country	
Institutions		Australia	Uzbekistan
Transboundary data and information sharing	The presence of institutional and technical mechanisms that enable the exchange of data in accordance with agreements made between riparian parties.	This does not apply to Australia	Uzbekistan's international cooperation in water resource management is based on its foreign policy, adhering to international law norms. Data exchange at the transboundary level occurs through the International Fund for Saving the Aral Sea (IFAS) and the Interstate Coordinating Water Commission (ICWC).
Evaluating Outcome			
Water availability monitoring	The status of management instruments to support the implementation of IWRM at the national level is being investigated/evaluated.	The Australian Bureau of Meteorology (BoM) offers national and regional water assessments, a National Water Account, and online portals for various water data	State Water Cadaster and National water cadaster are the entities for monitoring the water availability in Uzbekistan