Adapting to Scarcity

Community-based water management and climate adaptation: Insights from Santa Cruz canton, Guanacaste, Costa Rica

Master's thesis – master SUSD-IDS (GEO4-2321)

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Cover photo: Hills of Santa Cruz in the dry season (author's own)

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Summary

As climate change increasingly affects water management systems, in regions like Guanacaste, Costa Rica the impact of hydrometeorological events is becoming incrementally more significant. This research aims to examine water scarcity and climate adaptation, in the context of a community-based water management system (CBWM). Academic gaps include a lack of understanding of the specific enablers and barriers to climate change adaptation, the effectiveness of climate adaptation interventions and the management of freshwater resources within Santa Cruz's CBWM organisations, the ASADAS. This research applied a conceptual framework based on climate adaptation, principles of community-based natural resource management and water conflict.

A systematic literature review was conducted to identify barriers and enablers, and a stakeholder analysis was done to assess previous water sector interventions on the aforementioned principles and water conflict. Finally, water sector stakeholders were interviewed to explore their perceptions of water scarcity. The aim of which was to answer the following research question:

How can the community-based water management system and its climate change adaptation be improved, for the sector's stakeholders in the Santa Cruz canton of Guanacaste, Costa Rica?

Findings show that enabling factors, like secondary forest plantings and community-based monitoring, can address barriers such as irrigation inefficiencies and data scarcity. Interviews revealed that some stakeholders recall more abundant water in the past, whilst many now perceive increased shortages due to tourism pressures. Several principles of CBWM, for example the monitoring of water systems, were found in need of strengthening. Stakeholders' influence over water sector interventions varies, with community members having less power compared to higher-level institutional stakeholders. Evaluating such interventions revealed partial adherence to CBWM principles, and highlighted the importance of participatory, bottom-up approaches to increase community buy-in.

Improving community-based water management in Santa Cruz and subsequent climate change adaptation involves applying CBWM design principles to address weaknesses and leveraging respective barriers and enablers. Addressing issues such as corruption and streamlining water concessions can prevent first-order conflicts, whilst strengthening the community-based water management system through adaptation can prevent maladaptive and unintended consequences.

Keywords: Water scarcity, climate adaptation, community-based water management, maladaptation, water conflict

Resumen

A medida que el cambio climático afecta cada vez más los sistemas de gestión del agua, en regiones como Guanacaste, Costa Rica, el impacto de los eventos hidrometeorológicos se está volviendo incrementalmente más significativo. Esta investigación tiene como objetivo examinar la escasez de agua y la adaptación climática en el contexto de un sistema de gestión comunitaria del agua (CBWM). Las lagunas académicas incluyen una falta de comprensión de los habilitadores y barreras específicos para la adaptación al cambio climático, la efectividad de las intervenciones de adaptación climática y la gestión de los recursos de agua dulce dentro de las organizaciones CBWM de Santa Cruz, las ASADAS. Esta investigación aplicó un marco conceptual basado en la adaptación climática, los principios de la gestión comunitaria de los recursos naturales y el conflicto del agua.

Se realizó una revisión sistemática de la literatura para identificar barreras y habilitadores, y se hizo un análisis de actores para evaluar intervenciones previas en el sector del agua sobre los principios antes mencionados y el conflicto del agua. Finalmente, se entrevistó a actores del sector del agua para explorar sus percepciones sobre la escasez de agua. El objetivo de esto fue responder a la siguiente pregunta de investigación:

¿Cómo se puede mejorar el sistema de gestión comunitaria del agua y su adaptación al cambio climático para los actores del sector en el cantón de Santa Cruz de Guanacaste, Costa Rica?

Los hallazgos muestran que factores habilitadores, como las plantaciones de bosques secundarios y el monitoreo comunitario, pueden abordar barreras como las ineficiencias en la irrigación y la escasez de datos. Las entrevistas revelaron que algunos actores recuerdan que antes había más abundancia de agua, mientras que muchos ahora perciben un aumento de la escasez debido a las presiones del turismo. Se encontró que varios principios del CBWM, como el monitoreo de los sistemas de agua, necesitan fortalecerse. La influencia de los actores sobre las intervenciones en el sector del agua varía, con los miembros de la comunidad teniendo menos poder en comparación con los actores institucionales de nivel superior. La evaluación de tales intervenciones reveló una adherencia parcial a los principios del CBWM y destacó la importancia de enfoques participativos y ascendentes para aumentar la aceptación de la comunidad.

Mejorar la gestión comunitaria del agua en Santa Cruz y la posterior adaptación al cambio climático implica aplicar los principios de diseño del CBWM para abordar las debilidades y aprovechar las respectivas barreras y habilitadores. Abordar cuestiones como la corrupción y simplificar las concesiones de agua puede prevenir conflictos de primer orden, mientras que fortalecer el sistema de gestión comunitaria del agua a través de la adaptación puede prevenir consecuencias no deseadas.

Palabras clave: Escasez de agua, adaptación climática, gestión comunitaria del agua, maladaptación, conflicto hídrico.

List of Abbreviations

ASADAS	Asociaciones Administradoras de Sistemas de Acueductos y Alcantarillados Comunales (Communal Administrative Associations of Aqueducts and Sewage)
AyA	Instituto Costarricense de Acueductos y Alcantarillados (Water and Sewage Institute)
CADC	Central American Dry Corridor
CBNRM	Community-Based Natural Resource Management
CBWM	Community-Based Water (resource) Management
ENSO	El Niño-Southern Oscillation
MINAE	Ministerio de Ambiente y Energía (Ministry of Environment and Energy)
NGO	Non-Government Organisation
OECD	Organisation for Economic Co-operation and Development
PAACUME	Proyecto Abastecimiento de Agua para la Cuenca Media del río Tempisque y Comunidades Costeras (Project for Water Supply to the Middle Basin of the Tempisque River and Coastal Communities)
SENARA	Servicio Nacional de Aguas subterráneas, Riego y Avenamiento (National Groundwater, Irrigation and Drainage Service)
UNDP	United Nations Development Programme
WASH	Water, Sanitation, Hygiene

Contents

1. Introduction

As the dry season in Guanacaste, Costa Rica comes to an end, yellow and brown are the dominant colours of the landscapes affected by the season's namesake. During this time, water shortages and outages become more common as the groundwater levels eagerly await replenishment. Forest fires are likewise a threat, evidenced by the frequent piles of carbon found in the tropical dry forests. These issues are exacerbated by the burning of farm waste in the agricultural sector, throngs of tourists flocking to the pristine coastal areas, and some locals' habit of incinerating household trash in ditches along the road. In the hills of Santa Cruz canton lies a small village named Las Pilas. As quoted by one of its community members:

"*They do not have water, they have dust.*"

The above is an example of what is occurring in many tropical regions of the world (Bellprat et al., 2015; Hund et al., 2021; Lacambra S et al., 2024; Powers et al., 2020). Instead of the four seasons in regions with a temperate climate, regions with a tropical climate have two. The dry season is characterised by severely diminished, or lack of, precipitation. Whilst during the rainy season precipitation is a daily occurrence, with a relatively large amount of rainfall in short periods (Bellprat et al., 2015). Climate change is increasing the number of weather extremes in such climates, with as a result a prolongation of the dry season, and a decreased duration of the rainy season (Hund et al., 2021). These hydrometeorological effects are exacerbated throughout Latin America, in places affected by the El Niño-Southern Oscillation (ENSO). This phenomenon further intensifies the variability of weather patterns, leading to more severe droughts and unpredictable rainfall. In ENSO positive periods (El Niño) a prolonged dry season occurs with less rainfall in the rainy season, leading to droughts, whilst in ENSO negative periods (El Niña) rainfall increases exponentially, leading to floodings or crop failure (Hund et al., 2021; Pérez-Bertozzi et al., 2024). The Central American Dry Corridor (CADC) worsens the effects of El Niño as it is relatively drier. The CADC is a specific region in the isthmus starting in Mexico and ending in Guanacaste, in the northwest of Costa Rica. With the drought recurrence in this region displayed in Figure 1, it can be observed that the CADC mostly includes coastal zones along the Pacific Ocean (Quesada-Hernández et al., 2019). Even during extremely wet years, the Guanacaste province is at high risk of drought recurrence, which is why the water sector in this area is of particular importance to academia (Quesada-Hernández et al., 2019).

Especially the increasing number of droughts has a profound impact. Human health is affected, with water scarcity leading to shortcomings in drinking water, sanitation and hygiene (WASH) and increased incidence of water-borne diseases (Deshpande et al., 2020; Talukdar et al., 2023). Additionally, the risk of food insecurity increases exponentially during periods of drought seeing as livelihoods, particularly those reliant on agriculture, are similarly affected as crops fail and livestock suffer from inadequate water supplies (Cerdas-Ramírez & Espinoza-Sánchez, 2018; Magliocca & Gonzalez-Jimenez, 2020). Not only human systems are impacted, however, but already dry ecosystems become further stressed, leading to a loss of biodiversity and ecosystem services that are also crucial for local communities (Cosens, 2013; Srivastava et al., 2020a). Since local and rural communities are heavily impacted, community-based water management (CBWM), a derivative of community-based natural resource management (CBNRM), has emerged over the past few decades as a strategy for addressing challenges socially equitably. CBNRM involves the local communities in decision-making regarding their environment, in this case, hydrological resources (Day, 2009; Delgado-Serrano et al., 2017). This approach is based on the idea that these populations directly interact with, and are best placed to protect their resources.

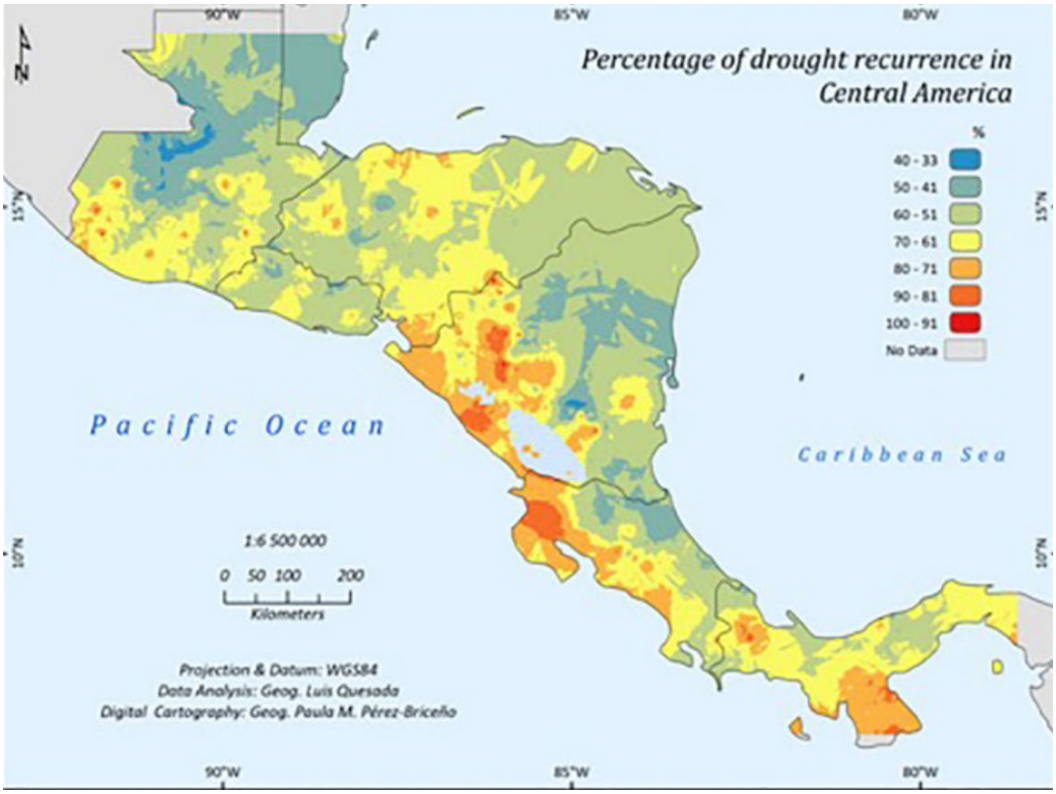

Figure 1: Drought recurrence in the CADC (Quesada-Hernández et al., 2019)

However, despite its potential to enhance water resource management, these systems often struggle to improve their resilience due to limited resources. Many community-based initiatives lack the technical expertise, financial resources, and institutional support needed to effectively manage their water resources, particularly in the face of escalating climate events such as during ENSO-positive periods (Madrigal-Ballestero & Naranjo, 2015; Measham & Lumbasi, 2013a, 2013b). Climate adaptation, which includes human actions or economic structural adjustment measures taken to reduce vulnerability to climate change, is essential to combat these adverse impacts and strengthen CBWM systems (Agrawal & Perrin, 2001; Ishiwatari & Sasaki, 2023). Adaptation measures can range from infrastructural improvements, like building resilient water supply systems, to policy interventions that promote sustainable water use and conservation practices (Bartlett & Dedekorkut-Howes, 2023; Jia et al., 2021; Morataya-Montenegro & Bautista-Solís, 2020). However, many adaptation interventions fail to target the root causes of water scarcity and the gaps in CBWM effectively. Instead, they often focus on short-term solutions that do not address underlying issues such as insufficient funding (Bailey et al., 2024; Ley et al., 2023; Measham & Lumbasi, 2013). Both water scarcity in and of itself, and subsequent adaptation can lead to another problem: an increased risk of water conflict (Gleick & Shimabuku, 2023; Ohlsson, 2000). Exploring the complex dynamics related to (the absence of) water in different contexts is therefore vital for the societal well-being of communities in the face of climate change.

An exemplary case where all these topics converge is the Santa Cruz canton, located in the Guanacaste Province of Costa Rica as seen in Figure 2. Santa Cruz faces a comparatively large number of climate-related problems. Much like in the rest of Guanacaste province, the first of which is water scarcity. This not only impacts its communities' drinking water availability but also agricultural productivity and ecosystem health (Stan et al., 2020). Additionally, the rising sea level threatens livelihoods, and both the tourism and real estate sectors due to the loss of beaches and salification, exemplifying the need for climate adaptation and sustainable water resource

management in the region (Schatan et al., 2010). Through the canton flows the Cañas River, a tributary of the larger Tempisque River, whilst the coastal zones have their aquifers and streams. These water resources are managed by the Communal Administrative Associations of Aqueducts and Sewage (*Asociaciones Administradoras de Sistemas de Acueductos y Alcantarillados Comunales*, ASADAS). ASADAS are CBWM organisations that play a vital role in the distribution and management of water resources, specifically in rural areas where governmental water services are limited. They operate under the institutional framework of Costa Rica's national Water and Sewage Institute *(Instituto Costarricense de Acueductos y Alcantarillados*, AyA). The ASADAS' effectiveness in upholding the human right to water has been scrutinised when faced with hydrometeorological events such as drought, raising broader questions about inclusivity and sustainability in water governance (Serrano et al., 2019a). This highlights the need for comprehensive and context-specific approaches to address the challenges faced by ASADAS and other stakeholders in the water sector (Oxfam Novib, 2009). The canton boasts several industries that contribute to its socio-economic landscape. Historically renowned for its agricultural sector, Santa Cruz has diversified its economy over the years to encompass various other industries. Agriculture remains a significant contributor, with sugarcane and cattle farming playing pivotal roles in the local economy (Cruz et al., 2011; OECD, 2017). Additionally, tourism has emerged as a cornerstone of its people's livelihoods. Fuelled by the region's pristine beaches, the coast attracts visitors from around the globe (Cruz et al., 2011). Amidst this economic landscape, stakeholders in Santa Cruz are diverse. They encompass several communities, local businesses, real estate agents, agricultural cooperatives, tourism and other private sector actors, municipal authorities, government agencies, non-government organisations (NGOs), and academics. These stakeholders play integral roles in shaping the canton's development trajectory, collaborating on initiatives related to sustainable growth, but with existing and historical frictions related to water resources (Cañada, 2019; Cover, 2007a; Edelman, 1987; Herrero Amo & De Stefano, 2019).

Figure 2: Map of Santa Cruz canton and its rivers (Author's own)

1.1 Academic gap

The Anthropocene has brought significant shifts in the dynamics of global hydrological cycles, with human activities playing a central role in reshaping these systems (Cuadrado-Quesada et al., 2018). Groundwater governance has emerged as a critical focus area, particularly in climate variability and increasing demands from agriculture and urbanisation (Bouroncle et al., 2017). Meanwhile, existing studies have provided valuable insights into the functioning of ASADAS and other institutional bodies in Costa Rica and their role in rural water governance (Cuadrado-Quesada et al., 2018; Serrano et al., 2019a). However, there remains a gap in understanding the specific enabling factors or barriers to climate change adaptation implementation in the Guanacaste province, specifically in support of its community-based system (Piggott-McKellar et al., 2019; Steg et al., 2022). Limited research has been conducted on the problems related to water usage faced by different stakeholder groups, hindering the development of targeted strategies (Babcock et al., 2016; Stanghellini, 2010). While some implementation reviews of climate adaptation have examined intervention effectiveness, there is a need for more comprehensive research to understand the underlying factors contributing to their varying levels of impact on supporting the community-based water management systems, as well as the monitoring of them (Karres et al., 2022). Despite the large amount of literature on the topic of CBNRM, relatively little research has gone out to the management of freshwater resources in a community-based system, nor have the ASADAS been assessed from this literature's perspective (Dekker et al., 2020; Karres et al., 2022; Pino-Gómez et al., 2021; Syabri et al., 2014). Finally, social-environmental vulnerability has also been identified as a knowledge deficit affecting climate policy in Costa Rica (Ryan & Bustos, 2019). Addressing these gaps is essential for developing context-specific and community-based solutions to enhance water resource management for Guanacaste's rural communities.

This research aims to examine water scarcity in the context of CBWM, addressing academic gaps and providing a comprehensive analysis of the strengths and weaknesses of this management approach. By investigating the specific challenges faced by CBWM systems and evaluating their capacity to adjust to change, this research seeks to reveal the shortcomings of current practices and propose strategies for strengthening these systems (Eakin et al., 2014). This includes exploring how climate adaptation measures can better support the CBWM system, ensuring that interventions are not only effective in the short term but also sustainable in the long run. By highlighting the role of local communities in Santa Cruz's water sector and identifying pathways for enhancing their resilience, this research aims to contribute to more equitable water management strategies. In doing so, it addresses a pressing global challenge: ensuring that all communities have access to safe and reliable water resources in an era of climate uncertainty.

1.2 Outline

The introduction emphasised the importance of this research in exploring the CBWM system since it is integral to Costa Rica's institutional framework. Next, the theoretical framework will focus on climate adaptation needed due to the impacts of climate change on Latin American water systems, the role of CBWM, and the distinction between resource-based and maladaptation-based water conflicts. The research framework elaborates on the main and sub-questions, methodology, and stages of research, including literature review, analysis of previous interventions, and semi-structured interviews. The results chapters outline the context of Santa Cruz, examining the history and institutional framework and identifying barriers and enablers to climate adaptation. The second results chapter analyses stakeholder perceptions of the water sector, and the final evaluates interventions by the National Groundwater, Irrigation and Drainage

Service (*Servicio Nacional de Aguas Subterráneas, Riego y Avenamiento*, SENARA) and United Nations Development Programme (UNDP), and perceptions of interventions and future water access by the sector's stakeholders. The discussion interprets interview data to discern what barriers and enablers can be leveraged, analyse water conflict causes, and suggest improvements for CBWM, whilst also providing limitations and suggestions for future research. The conclusion summarises key findings and their implications for enhancing the CBWM system and its subsequent adaptation.

2. Theoretical Framework

In the literature related to climate adaptation in the water sector, a few concepts are central to the discussion. The first of which is adaptation itself, and its antonym maladaptation. Although one of the main arguments for climate change adaptation is reducing the likelihood of impacts occurring after extreme weather events such as drought or heavy rainfall, some adaptation strategies have adverse effects (Antoci et al., 2024; Schipper, 2020; Work et al., 2019) Another concept is based on a potential solution for the water sector touted by scholars, focusing on the specific governance system used in the Costa Rican water sector, where ASADAS serve as a form of CBWM. Water in this context is the natural resource mentioned in the literature on common-pool resources, which will be discussed in this section (Day, 2009; Syabri et al., 2014). Finally, the last sub-question relates to water conflict itself and how climate adaptation can give rise to conflict, which is likewise relevant due to the history and context of Guanacaste (Gleick & Shimabuku, 2023).

2.1 Climate change adaptation

Climate adaptation is aimed at minimising the adverse impacts of climate change on both communities and ecosystems (Ishiwatari & Sasaki, 2023; Jia et al., 2021; Quesada-Román, 2023). Climate adaptation focuses on adjusting human and natural systems to cope with external factors. In the context of dry tropical climates, this can mean climate issues such as rising temperatures, changing precipitation patterns, and increased frequency or intensity of extreme weather events (Quesada-Hernández et al., 2019; Quesada-Román, 2023). Adaptation involves implementing measures to reduce vulnerabilities and increase resilience to such climate-related risks, thereby safeguarding livelihoods (Agrawal & Perrin, 2001). For example, building a robust infrastructure that can withstand extreme weather events like heatwaves, as well as restoring natural ecosystems such as mangroves that provide essential services like flood protection (Sovacool et al., 2015). By incorporating climate resilience into decision-making processes, governments can enhance the effectiveness of development interventions while minimising future risks (Dessai & Hulme, 2004). It is important, however, that barriers and enablers to climate adaptation are considered (Steg et al., 2022).

Disaster risk reduction complements climate adaptation efforts by focusing on reducing the underlying drivers of disaster risks and enhancing preparedness for natural hazards like flooding. Such strategies encompass community-based disaster preparedness initiatives, or utilising remote sensing, all aimed at minimising the impacts of disasters such as drought on livelihoods (Hori & Shaw, 2012; Morris, 2008). Effective climate adaptation requires collaboration among multiple stakeholders, including governments, civil society organisations, the private sector, academia, and the affected communities. This includes fostering participative processes to increase the resilience of such communities. Furthermore, empowering communities to participate in climate adaptation efforts and integrating local knowledge into risk reduction strategies is essential for promoting socially equitable solutions (Nkombi & Wentink, 2022). Climate adaptation and disaster risk reduction are essential components of resilience-building strategies. They are aimed at minimising the adverse impacts of natural hazards on communities and are therefore at the core of water sector interventions in the Guanacaste province. By integrating climate considerations into development planning processes, investing in resilient infrastructure and ecosystems, and promoting collaborative and inclusive approaches to risk reduction, livelihoods in the Santa Cruz canton can be safeguarded.

2.1.1 Maladaptation

There are always uncertainties when planning for the impacts of climate change, however. Many strategies to protect ecosystems and livelihoods are not successful in adapting to adverse impacts. In some instances of maladaptation, the planned strategies can make the targeted population more vulnerable (Schipper, 2020). An example would be overdrafting,using too much groundwater, due to increasing the number of wells to provide sufficient water for a growing population. Impacts in the dry season are then exacerbated due to the recharge rate of groundwater not being sufficient to replenish the aquifers (Antoci et al., 2024; Jasechko et al., 2024). Especially in cases where adaptation is combined with industrial development, with the mention of climate targets used as a way to legitimise the project, the risk of maladaptation is present (Work et al., 2019). Simultaneously, inaction can also lead the additional vulnerabilities, as the example in Figure 3 displays. No response to climate vulnerabilities is therefore likewise not an option. Coping strategies can also become maladaptive through short-term solutions that do not allow the target populations to adapt fully. Merely increasing the supply of water with a growing population and risk decreasing groundwater levels in the future might only give temporary relief, if the root causes of scarcity are not adapted to or mitigated. Finally, in climate adaptation policy, non-governmental organisations and communities are often included in multilateral development initiatives but not always in government-driven processes. This might create strategies that are too one-sided and, likewise, maladaptive (Ley et al., 2023).

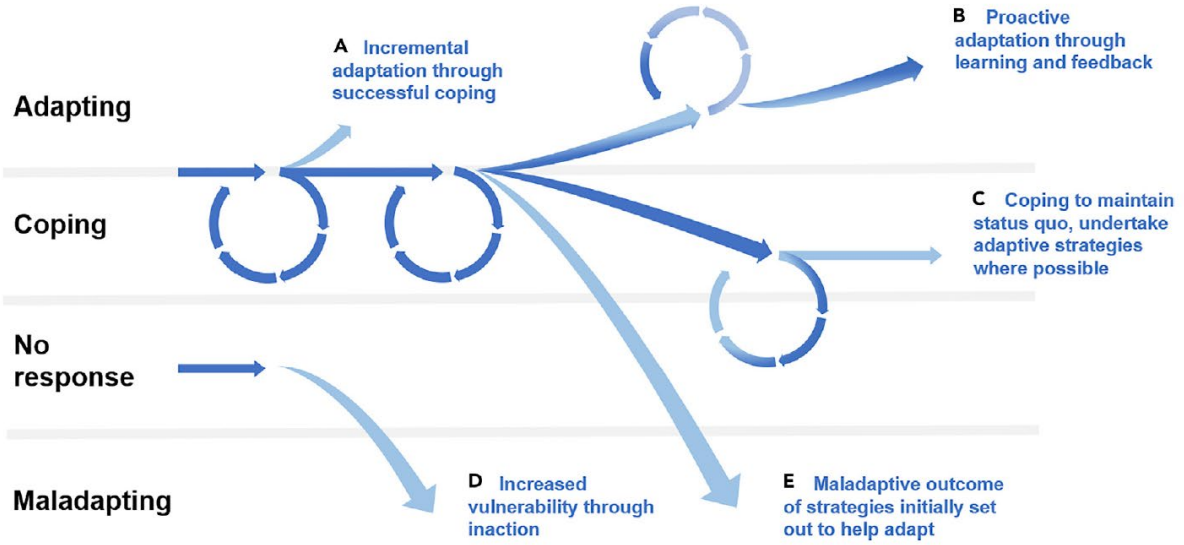

Figure 3: Adaptation outcomes over time (Schipper, 2020)

2.2 Community-based resource management

2.2.1 General concept

Community-based natural resource management (CBNRM) is a management approach that involves local communities in the conservation or administration of relevant resources within their areas of residence. The importance of including local peoples and their context-specific knowledge is acknowledged as essential for decision-making regarding these resources. Inclusion increases social justice and legitimacy stemming from services related to the water resources (Dekker et al., 2020; Measham & Lumbasi, 2013). The concept stems from the literature on common-pool resources, although formalisation of institutional structures in the

water sector can transition the natural resource towards being a public good instead of a commodity, this is not necessarily the case in the context of Costa Rica (Cuadrado-Quesada, 2020; Ostrom, 1990). Including communities in water administration is important as the human right to water means that all peoples should have access to sufficient facilities for WASH, essential to livelihoods (Kornfeld, 2012). It has the potential to foster a sense of involvement among community members, encouraging them to participate in resource conservation efforts (Ferrol-Schulte et al., 2014). CBNRM also emphasises the importance of equitable benefit-sharing mechanisms. Scholars propose that the system should aim to ensure that benefits derived from natural resources are distributed fairly among community members, which can help address socioeconomic inequalities (Measham & Lumbasi, 2013). Moreover, CBNRM promotes adaptive management strategies that leverage the communities' connection to their local environments (Measham & Lumbasi, 2013). By incorporating local knowledge, CBNRM enables communities to adapt to environmental challenges such as climate change and the changing patterns of hydrometeorological events more effectively (Delgado-Serrano et al., 2017). Overall, it represents an approach to natural resource management that recognises the interconnectedness of social, economic, and environmental factors. By empowering communities and promoting their ownership, CBNRM can contribute to enhancing livelihoods (Measham & Lumbasi, 2013).

Despite the potential benefits of CBNRM systems, not all literature lauds the solutions it can offer. The effects of CBNRM are not always positive or can have unintended consequences (Dekker et al., 2020). Perceived benefits to the community members of such a system, for example, are at times low (Shereni & Saarinen, 2021). Concretely, whilst some positive health outcomes have been shown by Riehl et al. (2015), wealth outcomes were inconclusive whilst education outcomes were negative. Outcomes become less ideal when the design of a CBNRM system is reconfigured during its lifespan or becomes too institutionalised (Dressler et al., 2010).

2.2.2 Community-based Water Management

Water is a fundamental natural resource that plays a crucial role in sustaining life. In many regions, such as the CADC, water resources are under increasing pressure due to climate factors. Community-based water resource management (CBWM), derived from the CBNRM literature, offers a promising approach to addressing water resource challenges while promoting local participation (Serrano et al., 2019a; Syabri et al., 2014). Like in the CBNRM literature, it calls for involving local peoples in decision-making processes related to water allocation. They often have valuable knowledge about water sources or usage patterns which can inform more effective water management strategies (Dobbin & Sarathy, 2015). CBWM also encourages establishing community-led water management institutions responsible for overseeing water resources within their territories, such as the ASADAS (Day, 2009). Furthermore, it promotes the development of water-related livelihood opportunities within the managed area. This may include initiatives like community-based ecotourism, sustainable fisheries management, and water-efficient agriculture practices. By diversifying livelihood options, CBWM helps reduce dependency on water resources while promoting economic resilience (Cinner & Bodin, 2010).

One of the key benefits of CBWM in water management is its ability to foster social cohesion and collective action among community members. Essential for this, however, is the downward accountability of the organisations to the community in which they operate. Reporting to a central government is irrelevant to the perception of the locals towards the quality of the water system,

whilst more accountability towards fellow community members was found to impact the perception positively (Madrigal-Ballestero et al., 2013). In recent years assessing water governance or climate interventions based on Ostrom's (1990) design principles (Table 1) has been done among scholars in Global South contexts, but these principles have yet to be applied to the system or interventions in Guanacaste (M. Delgado-Serrano et al., 2017; Dell'Angelo et al., 2016; Seward & Xu, 2019). Strengthening these principles in the context of climate change adaptation can empower local peoples, and support participatory processes (Reid et al., 2013).

	Design Principle	*Explanation*
1	Clear boundaries	Individuals, households and sectors who have the right to use water resources are clearly defined
2	Congruence with local conditions	Rules restricting time, place, technology, and quantity of water use are well adapted to local conditions
3	Collective-choice arrangements	Most individuals affected by the rules can participate in modifying them
4	Monitoring	Water resource conditions and use are monitored by the users themselves or by people accountable to the users
5	Graduated sanctions	Users who violate water-related rules are likely to be assessed penalties that correspond to the seriousness and context of the offense
6	Conflict-resolution mechanisms	Users and officials have rapid access to low-cost local arenas for resolving conflicts among water users and conflicts between water users and officials
7	Recognition of the right to organisation	The rights of water users to devise their own institutions are not challenged by external governmental authorities
8	Nested governance	Appropriation, provision, monitoring, enforcement, conflict resolution, and governance are organised in multiple, nested layers

Table 1: Eight design principles for community-based water management (Adapted from Dell'Angelo et al. (2016))

2.3 Water Conflict

The last concept essential to the context of this research is water conflict and the reasons for its occurrence. Water is a natural resource essential to human existence and in the face of climate change, conflict related to the commodity has become increasingly frequent in recent years (Gleick & Shimabuku, 2023; Stålgren, 2006). Although international conflict might also become more frequent in the long term, the possibility of conflict within countries over shared resources is greater (Ohlsson, 2000). Many such events do not occur due to disputes over the resource itself (a first-order conflict) but instead occur when trying to adapt to water scarcity in the first place (a second-order conflict) (Ohlsson, 2000). This distinction makes it especially relevant in the context of climate adaptation in Guanacaste, as water conflict is at risk of arising by the very means of preventing further scarcity, such as institutional change. As such, maladaptation must be prevented in order to avoid water second-order conflict or an exacerbation of first-order conflict. One way that this has been assessed in the literature is by researching power dynamics by classifying stakeholders as beneficiaries or adversely affected. The influence and involvement of relevant stakeholders were mapped to get a picture of these dynamics (Maheshwari et al.,

2004; Stanghellini, 2010). Other literature focuses on strengthening the existing system to increase its capacity to combat adverse climate effects, under the banner of leaving no one behind (M. del M. Delgado-Serrano et al., 2017; Madrigal-Ballestero & Naranjo, 2015; Measham & Lumbasi, 2013; Syabri et al., 2014).

Addressing issues that give rise to water conflict requires collaborative approaches between different stakeholders. Participatory decision-making processes are essential for ensuring that the different needs of local communities will be on the agenda. Communities being empowered to participate in fostering resilience to climate impacts can contribute to more equitable development outcomes (Otsuki et al., 2021). This includes fostering partnerships between communities and governments, non-government organisations, academia, and the private sector at all relevant levels. These partnerships can facilitate knowledge sharing, and avoid the reoccurrence of water conflict in the face of common challenges.

The conceptual framework that follows from the aforementioned theory can be seen in Figure 4.

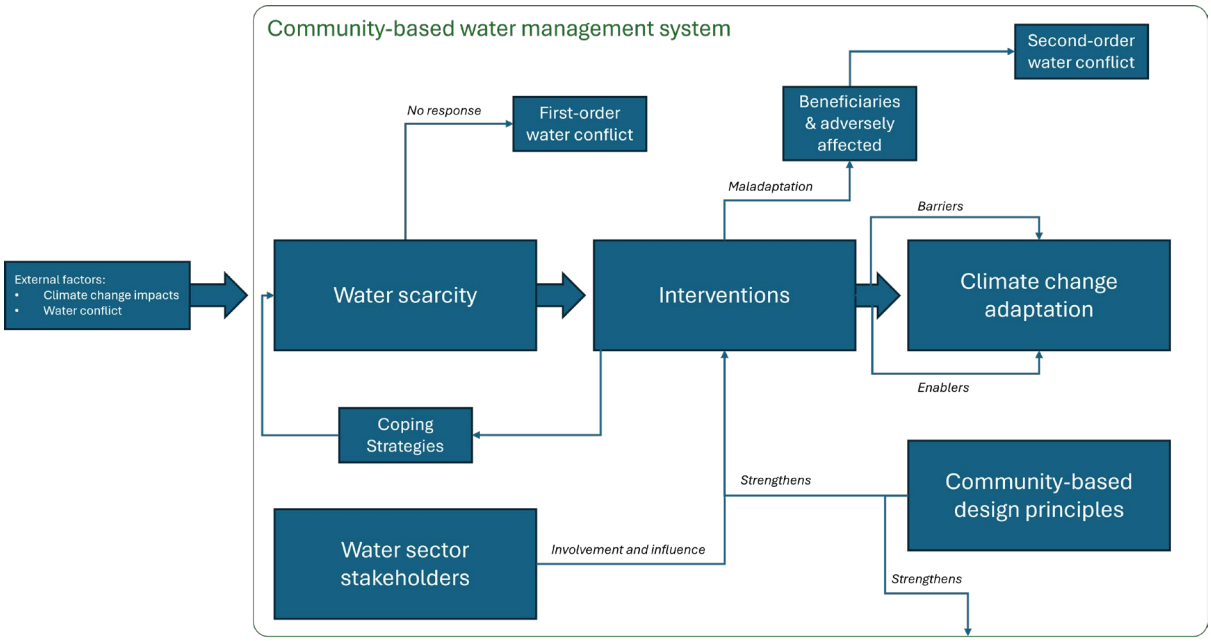

Figure 4: Conceptual framework (Author's own)

3. Research Framework

3.1 Research Questions

The aforementioned introductory background and theoretical framework led to the following research question:

How can the community-based water management system and its climate change adaptation be improved, for the sector's stakeholders in the Santa Cruz canton of Guanacaste, Costa Rica?

Improving the community-based water management of the sector is of the utmost importance for strengthening resilience to climate change impacts. ASADAS play a crucial role in rural water management, as 28,6% of the population is administered by these CBWM organisations, yet they face numerous challenges towards adaptation (UNDP, 2020). This thesis seeks to identify effective approaches for enhancing the resilience of the water sector. Understanding the factors influencing stakeholders' perceptions of water scarcity can inform the development of targeted interventions and policy recommendations to support CBWM in the Santa Cruz canton.

- *SQ1: What are the barriers and enablers for climate change adaptation in Santa Cruz?*

Understanding the barriers and enablers to the implementation of climate change adaptation in the canton is crucial for identifying factors that hinder effective adaptation. Firstly, when answering this question, the context of the Santa Cruz canton will have to be elaborated upon. This will provide insights into the institutional framework shaping the water sector. By identifying barriers such as lack of resources or institutional constraints, methods of overcoming these barriers can be identified. Simultaneously, whilst the goal is not generalisability, identifying enablers can help replicate successful adaptation initiatives in other localities.

- *SQ2: How do different stakeholder groups experience water scarcity, and how does this equate to involvement and influence over interventions?*

Exploring the contexts of each group involved in water governance provides a better understanding of the challenges of interventions. Different stakeholders, such as ASADAS, the private sector or community members, may have differing priorities regarding water management, as well as different degrees of power in combatting their respective water-related anxieties. By examining these stakeholders-specific problems, the research can identify areas of conflict among different groups, to prevent maladaptation. This information is essential for developing democratic adaptation strategies that address the concerns of all, thereby enhancing the legitimacy of adaptation efforts (Cosens, 2013).

- *SQ3: What aspects of the community-based water management system need to be strengthened?*

Effective CBWM systems are essential for ensuring equitable distribution of potable water by the rural ASADAS. In the context of Santa Cruz, specific aspects of the existing system that require reinforcement will be identified. This involves assessing the CBWM principles of the system and climate adaptation intervention, and identifying weaknesses. Strengthening these areas can enhance the system's resilience (Day, 2009; Measham & Lumbasi, 2013).

- *SQ4: How have previous climate adaptation interventions in the water sector contributed to community-based water management of Santa Cruz and its adaptation?*

Assessing the impact of previous interventions on the adaptive capabilities of Santa Cruz is essential for understanding the effectiveness of such interventions in enhancing resilience. Capacity-building initiatives such as the UNDP or the SENARA have aimed to strengthen ASADAS' or the AyA's financial and technical capacities to adapt to changing environmental conditions (Ricardo et al., 2018; SENARA, 2022). By evaluating the goals and outcomes of adaptation efforts, this research can identify gaps in current interventions and to which extent they adhere to the community-based intentions with which the ASADAS were initially founded.

3.2 Study Area

Guanacaste province, including the Santa Cruz canton, is characterised by a mix of flatlands along the coast, giving way to rolling hills and mountains more inland. This topography influences local climate patterns, with the coastal areas experiencing hot and dry conditions most of the year, in contrast to the slightly cooler, more humid conditions in the higher altitudes (Hurtado-de-Mendoza & Alvarado, 2021). The Nicoya Peninsula, a significant part of Guanacaste, has coastal landscapes and is known for being one of the Blue Zones, areas where people live significantly longer than the world's average (Rosero-Bixby et al., 2014). The region's geological features support a variety of ecosystems, from dry tropical forests to mangroves and coral reefs along the coast, and wetlands in the river basins. The Rio Tempisque, one of the most important water bodies in the province, plays a crucial role in the hydrology of Guanacaste, affecting both human and natural systems (Hurtado-de-Mendoza & Alvarado, 2021). Being situated in both the CADC and ENSO, Guanacaste is an exemplary case of how tropical countries can face increasing water scarcity in the dry season if precipitation in the rainy seasons is not efficiently managed or groundwater efficiently utilised (Quesada-Hernández et al., 2019; Quesada-Román, 2023). Santa Cruz particularly is an exemplary case due to the presence of Guanacaste relatively large urban centres and the traditional *ganaderos*. These predominantly cattle-raising agricultural stakeholders, in combination with the *cañeros* of the sugar industry, a large tourism sector, the AyA and ASADAS, and potentially underrepresented stakeholders in the rural communities, resulting in a diverse landscape. The diversity of land use can be seen in Figure 5 below. The region's history of water conflict combined with the current need for climate adaptation due to impending losses and damages, whilst leveraging the community-based water management system, make this relatively populous canton with a large coastline and forests an important research area in the Guanacaste province for this research (Edelman, 1987).

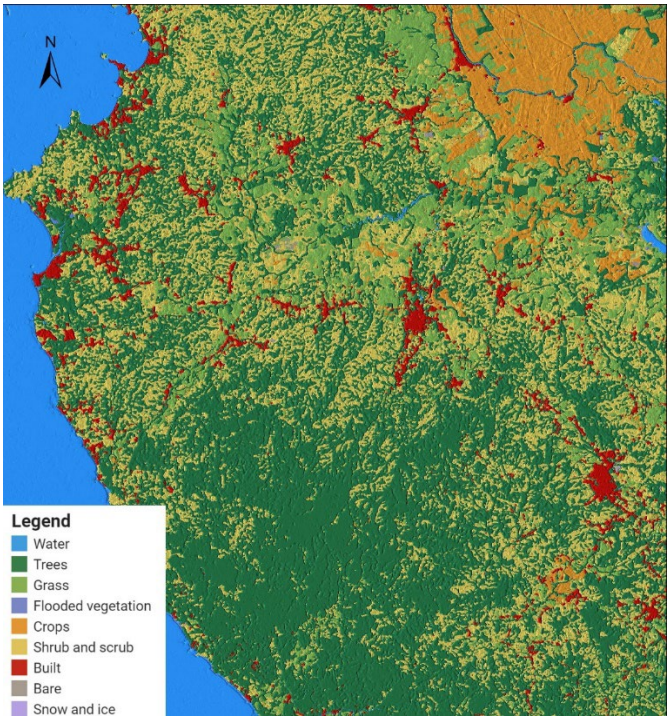

Figure 5: Land use map of Santa Cruz (Brown et al., 2022)

3.3 Methodology

3.3.1 Literature Review

The methodology for addressing SQ1 involves conducting a systematic literature review, whilst this information assists in answering SQ3 and SQ4. This review encompasses academic sources, as well as policy documents to assess previous and ongoing interventions. Firstly, and before the systematic review, the context of Santa Cruz canton has been explored, such as its institutional framework and history of water conflict. Then, the review helps to identify existing barriers and enablers for climate change adaptation implementation in the region. Conducting a systematic literature review to identify barriers and enablers of climate adaptation is a method applied by scholars for other sectors and regions (Bailey et al., 2024; Bartlett & Dedekorkut-Howes, 2023). Additionally, the review assesses how various water sector interventions have contributed to enhancing the community-based water management system and its adaptation, whilst avoiding water conflict between the targeted stakeholders. Key themes emerging from the literature inform subsequent stages of the research, including the semi-structured interviews. Databases used for the literature review are World of Science and SciELO, the latter is included to increase the amount of Spanish and Latin-American literature in the review. An initial screening has been done to identify keywords used across each database (Bailey et al., 2024; Bartlett & Dedekorkut-Howes, 2023). This screening resulted in the following keywords and their Spanish equivalents, as each database was assessed for both English and the official language of Costa Rica:

> *(Costa Rica AND (Guanacaste OR Santa Cruz) AND (clima* OR adapt* OR mitig*) AND (water* OR groundwater OR freshwater OR hydro*))*

The focus of the literature review is climate adaptation in the water sector of the Costa Rican canton Santa Cruz, located in the region of Guanacaste, which the above keywords were found to encompass. The resulting records were screened to ensure they adhere to the above criteria, whilst organism-specific ecological studies have been excluded.

3.3.2 Stakeholder Analysis

To help address SQ2 and SQ3, a stakeholder analysis has been conducted to understand the impact of interventions on different stakeholder groups. Data used for this purpose was sourced from policy documents and implementation reviews of the relevant interventions. Stakeholder mapping techniques were utilised to identify the relationships, interests, and power dynamics among different groups. The type of stakeholders were identified, using the template in Figure 6, to assess whether these actors are likely beneficiaries or adversely affected (Maheshwari et al., 2004; Stanghellini, 2010). The stakeholders were further divided into social and non-social, as well as primary and secondary groups. An example of a primary social beneficiary would be farmers, whilst the agricultural industry is a secondary stakeholder and the flora and fauna they manage are non-social actors. Finally, for this research, power is described as a combination of influence and involvement, based on the framework of Stanghellini (2010), which has been assessed based on the supplemental data collected during the interviews. The analysis provides insights into the diverse perspectives within the water sector, facilitating the identification of areas of conflict.

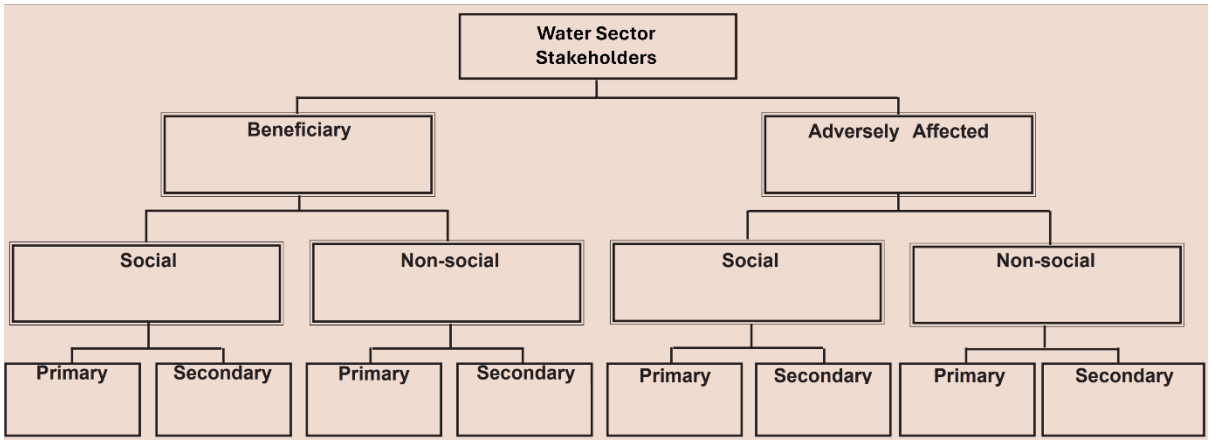

Figure 6: Template for stakeholder analysis mapping, adapted from Maheshwari et al. (2004)

3.3.3 Interviews

Semi-structured interviews were conducted with key stakeholders representing the various groups in the Santa Cruz canton that were identified in the stakeholder analysis. Key interviewees may include representatives from ASADAS, municipal authorities, or NGOs. Interviews with all stakeholders helped in discussing SQ1 whilst it assisted in answering SQ2, SQ3 and SQ4. Semi-structured interviews allow for an in-depth exploration of participants' experiences, perspectives, and insights related to water scarcity and interventions in Santa Cruz or water systems within the canton. This focused on perceptions of water scarcity, observed impacts and the CBWM system, as well as perceptions of interventions (Iñiguez-Gallardo & Tzanopoulos, 2023). An overview of the operationalisation of the conceptual framework can be seen in Table 2 below. Interview questions were designed to talk about the experiences with water scarcity of stakeholders, and overlooked opportunities for adaptation, as well as their perceptions of the CBWM systems and involvement in water sector interventions.

Conceptual framework	*Operationalisation*	*Interview Questions*
Climate (mal)adaptation	Water sector problems	Experiences with water scarcity Views on future access
	Previous interventions	Perceptions of water sector projects (influence, involvement)
CBWM	Community-based design principles	Perceptions of ASADAS (Representation, monitoring, sanctions, conflict resolution)
Water conflict	-	Perceptions of water sector projects Perceptions of conflict (first-/second-order) Conflict resolution mechanisms

Table 2: Operationalisation of conceptual framework

The interviews utilised open questions to encourage participants to share their experiences and opinions. 11 interviews were conducted in Spanish for this research. The interview guide was adjusted to apply to each stakeholder group, and said guides can be found in Appendix C.

3.4 Data Analysis

3.4.1 Literature Review

The literature review lays the foundation for understanding the context within which climate change adaptation takes place in Costa Rica, the Guanacaste province and the Santa Cruz canton. It serves as a critical source of secondary data. In the data analysis phase, information and topics identified in the literature are utilised with primary data collected through interviews. This comparison enables the validation of findings or uncovering of context-specific insights that might not have been apparent in the existing literature (Steg et al., 2022). Existing capacities are clarified and potential barriers and enablers of climate adaptation confirmed with literature from the systematic literature review. An overview of the literature found through a keyword-based systematic search can be seen in the below PRISMA statement (Figure 7). After screening, a relatively low number of Spanish or Latin-American studies were found. The records were therefore supplemented with an additional Google Scholar search utilising the same keywords. Of the 38 studies included in the literature review, 11 (28,9%) are written in Spanish, and a further 8 (21,1%) have Latin-American authors.

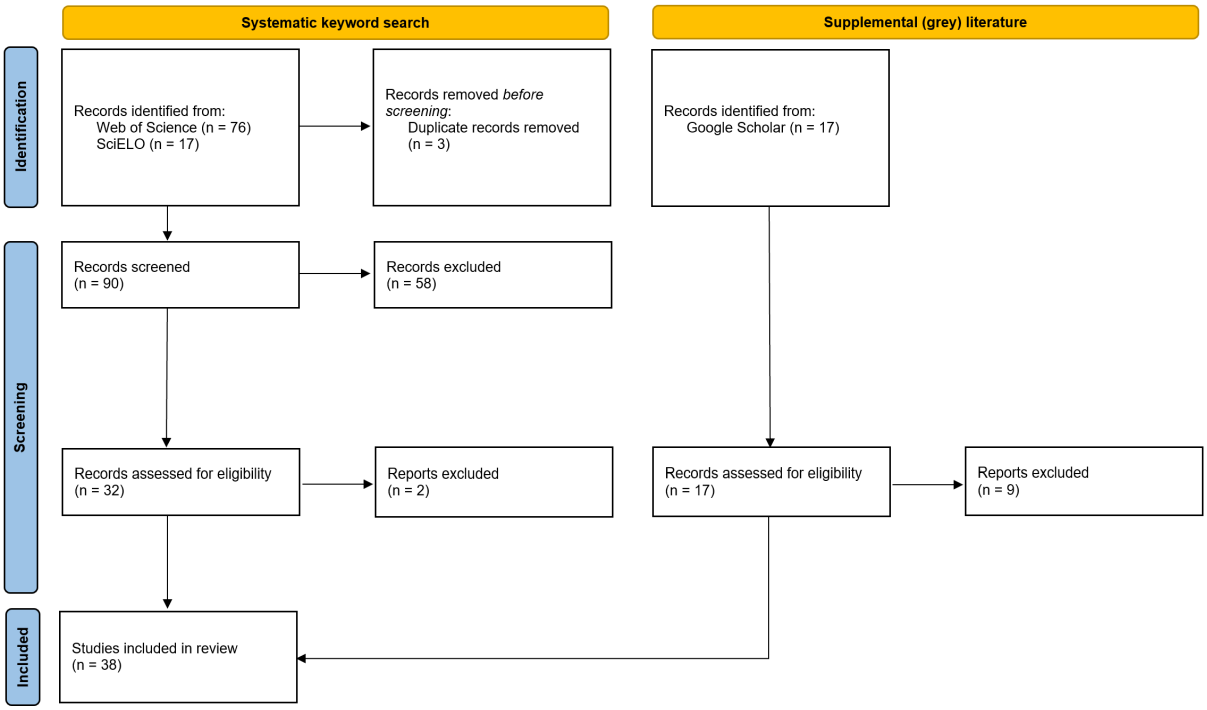

Figure 7: PRISMA statement of the systematic literature review (Adapted from Page et al., 2021)

3.4.2 Interviews

Interview data has been analysed thematically to identify common themes regarding the CBWM system. An inductive approach has been taken to gain new insights into stakeholders' perceptions and experiences, rather than a deductive approach to test a specific concept from the literature (D. R. Thomas, 2006). The findings provide valuable insights into the community-based system, informing decision-making processes across multiple ASADA jurisdictions in the Santa Cruz canton. The collected data has been organised and coded using the qualitative data analysis software NVivo, and the codebook can be found in Appendix D. Table 3 provides an overview of all interviewed stakeholders, their descriptions, and the identifiers by which they have been referred to hereafter. Interventions and other methods of climate adaptation were also examined to understand the influence and involvement of these stakeholders in such projects. This, and insights into future water access and the interviewees' perceived priorities for preventing adverse outcomes, will be discussed in the final results chapter.

#	*Stakeholder Group*	*Identifier*	*Area*	*Description*
1	Community Members	C1	Veintisiete de Abril	Community member with a working history at ASADA Tamarindo
2	Community Members	C2	Paraiso	Representative of community organisation
3	Community Members	C3	Los Pargos	Community member that has experienced water outages
4	Public Sector	Pu4	Santa Cruz (town)	Representative of the municipality
5	Public Sector	Pu5	Paraiso	Representative of ASADA
6	Public Sector	Pu6	Rio Seco	Representative of ASADA
7	Private Sector	Pr7	Los Pargos	Tourism industry: Hotel and restaurant owner
8	Academia	A8	Liberia	Researcher of HIDROCEC (Water Resources Centre for Central America and the Caribbean)
9	Academia	A9	San Jose	Geologist

10	NGO	N10	Paraiso	Activities related to ecosystem-based solutions
11	NGO	N11	Santa Cruz (canton)	Activities related to human health impact of water scarcity, and community resilience

Table 3: Interviewed water sector stakeholders

Appendix A shows the research framework, and how each of the methods contributes to answering the main research question.

3.5 Limitations

First, the reliance on existing literature to identify barriers and enablers for climate change adaptation creates a limitation related to the availability of Latin American sources. There is a risk of bias towards English and peer-reviewed sources, potentially overlooking valuable grey literature, local reports, or studies published in Spanish. Additionally, the literature review might be constrained due to studies or projects with positive outcomes being more publicly available, therefore diminishing the understanding of what interventions may have given rise to second-order water conflict. Second, the interviews rely heavily on my ability to access and engage with a representative sample of stakeholders from different groups. There is a risk of excluding groups or under-representing certain perspectives, especially if these stakeholders are less visible in public discourse or I am unable to contact them through snowball sampling. To make this study as complete as possible, it is of the utmost importance to prevent exclusion from happening by enquiring about under-represented perspectives with interviewees. Finally, whilst the use of semi-structured interviews is valuable for gaining in-depth insights, it introduces limitations related to the representativeness of the data collected. Language barriers might be encountered that prevent interviewees from sharing their perspectives effectively. The quality of information gathered is also heavily dependent on the participant's willingness to share and their perception of the research's sensitivity. Finally, the analysis of interview data can be influenced by biases in my interpretations, affecting the accuracy of the findings.

3.6 Ethical Considerations

Due to the potentially personal nature of information shared during interviews as well as conducting research with the positionality of a Global North student, ethical aspects need to be considered. Firstly, the thesis research adheres to principles of informed consent, ensuring that all participants are aware of the research purpose, and methods, and can withdraw their interview at any time without consequence. This has been explained at the start of an interview, with recordings only starting after giving their consent, at which time a confirmation of said consent has been requested. Confidentiality has been maintained, safeguarding the identities of interviewees and potentially sensitive information shared. This research has also been conducted in partnership with- and supported by consultants of the Costa Rican University for Peace (UPeace), who are themselves grantees of a capacity-building project in Guanacaste's water sector. Whilst this gave valuable insights and access, it also required reflection on the potential influence that may have had on the research. Transparency about this collaboration was essential in how potential interviewees viewed me as the interviewer, ensuring fair and non-exploitative practices (Drolet et al., 2023). The sharing of findings with stakeholders has also been committed to, thereby fostering a South-North exchange rather than extractive practices. Recognising my positionality as an external researcher and the power dynamics this and the partnership entails, I strived for an approach that emphasises listening and learning, ensuring that the research process was inclusive to all stakeholders involved.

4. Water in the context of Santa Cruz

The context of the Santa Cruz canton is further outlined in this results chapter. The problems faced by rural communities in the past and the organisation of the ASADAS are examined. The ASADAS are supported by various institutions on the local, regional and national levels which will be elaborated upon. Preliminary barriers and enablers to climate change adaptation in Santa Cruz are delineated following the systematic literature review, giving an overview of the canton's governance, and socio-cultural or economic stumbling blocks to climate adaptation, among others.

4.1 History of water scarcity

Climate change will heavily affect human systems for water management (Rosenzweig et al., 2007). Even regions that were previously not drought-prone, will be increasingly reliant on groundwater and seasonal surface water ponds. Effective management of water resources will be crucial for livelihoods, productive sectors and local communities alike (Day, 2009). In Costa Rica, the management of water resources exemplifies the country's ambition for community-based sustainability. Rural communities have faced significant challenges, primarily due to deficiencies in conventional state or private water systems (Serrano et al., 2019a). This catalysed the emergence of community-driven solutions, such as the ASADAS, which aim to address rural water exclusion, enhance local water governance and improve water quality (Shahady & Boniface, 2018). ASADAS represent a form of co-management, providing a platform for collective decision-making regarding water systems at the local level (Cuadrado-Quesada et al., 2018). However, despite their potentially pivotal role, the ASADAS face various management challenges in certain contexts. As Guanacaste is simultaneously located in both the ENSO and CADC, the impact of hydrometeorological events is incrementally more significant (Quesada-Hernández et al., 2019; Quesada-Román, 2023). The vulnerability is particularly evident during events such as the 2014-2016 drought in Guanacaste, which led to severe water shortages threatening human health and livelihoods (Morataya-Montenegro & Bautista-Solís, 2020). Low administrative capacity, ageing infrastructure, and inadequate maintenance practices exacerbated vulnerabilities (Serrano et al., 2019a). Water insecurity not only undermines community well-being by compromising access to safe drinking water but also has adverse impacts on the canton's economic stability (Cuadrado-Quesada et al., 2018).

The province of Guanacaste has a long history of both first- and second-order water conflict. Edelman (1987) has written extensively about the rise of such conflicts, due to the overexploitation of water resources for irrigation in the second half of the 20th century by cattle ranchers in the area. These *ganaderos* were a powerful lobby group that successfully participated in political affairs to become beneficiaries of water interventions. During the 1970s, these large-scale farmers practically eliminated most competition from smallholders to be the sole cattle raisers in the province. Afterwards, many of the original objectives, such as the regional development of a hydroelectric project in the Arenal area, were minimalised due to lobbying in favour of more concessions to irrigation. As a result, entire communities around the site of construction had to be relocated. (Edelman, 1987). Additionally, damming for energy production or water retention can exacerbate scarcity in downstream communities (Boelens et al., 2023; SENARA, 2022). To this day, agricultural cooperatives hold significant power in Guanacaste. Much of this power has transitioned to the increasingly dominant *cañeros,* or sugarcane farmers, due to the presence of sugar mills and large multinationals such as FIFCO (Sanabria, 2016). Although the economic value of the crop is high, its water usage does not err on the side of efficiency in an

already water-scarce region (Chico et al., 2022). In the context of the SENARA project PAACUME, for instance, provisions for additional water inputs for irrigation in the province are included, potentially allowing for agricultural expansion. Such provisions, and the potential of forest conversion for agriculture, increase the risk of maladaptation and second-order water conflict (SENARA, 2022; Work et al., 2019). The agricultural sector is not the only one that is at the origin of water conflict in Santa Cruz, however. Tourism, specifically over-tourism due to residential tourists, has become an increasingly large issue in coastal areas of the canton Tamarindo, Playa Potrero and Playa Negra (Cañada, 2019). The development of water-intensive tourism such as large hotels or golf courses, in addition to investment in residential tourism by foreign nationals, supported by the state, exacerbates existing tensions in rural communities (Cañada, 2019; Cruz et al., 2011). Based on the literature, the existing stakeholder groups can be broadly subdivided into the public sector, private sector, academics, NGOs and communities (Hernández & Picón, 2013; Kuzdas et al., 2016; Magliocca & Gonzalez-Jimenez, 2020; SENARA, 2022; UNDP, 2020). The public sector is vital for new interventions, as problems in the existing water systems are often identified for adaptation by organisations such as the UNDP or SENARA. Since the ASADAS are part of the public administration of the water resources, they are also included in this sector despite being a community-based organisation. Academics are also important to initiating adaptation processes, as geological or meteorological studies are often used as sources to inform the necessity of adaptation. NGOs are active in the Guanacaste water sector in a variety of capacities, from environmental organisations protecting flora and fauna to organisations preventing the exacerbation of human impacts. The private sector is often included in considerations of projects, and cooperatives such as the *ganaderos* have a relatively large amount of power. Irrigation and water usage for (residential) tourism and its development are likewise large consumers. Whilst communities are not often involved in participative processes for water sector projects, they and their rural development associations are impacted by such interventions. Appendix B shows a system map by Kuzdas et al. (2015) for the Hojancha & Nicoya cantons, where the Upper Rio Nosara watershed shows many similarities with the aforementioned stakeholders of Santa Cruz.

4.2 Institutional framework of the water sector

In the Santa Cruz canton, water management is predominantly handled at the local level through ASADAS. They are responsible for managing local water resources and maintaining infrastructure, thus water distribution to community members. They operate on a nonprofit basis, with funding primarily sourced from user fees, and, occasionally, grants (Kuzdas et al., 2015). The community-driven nature of ASADAS means that they are locally organised by electing board members from the community, thus residents have a direct stake in the management of their water resources (UNDP, 2020). The ASADAS often face significant challenges. Limited financial resources can impede the maintenance and expansion of water infrastructure, leading to inefficiencies and potential service interruptions (Cuadrado-Quesada et al., 2018). Technical capacity is another critical issue, as many ASADAS lack access to modern water management technologies and expertise, which are essential for addressing complex water scarcity and quality issues (UNDP, 2020). The institutional framework of the water sector also involves a significant role for the AyA, which provides oversight and technical support. However, the interaction between AyA and ASADAS can sometimes be strained, with issues arising from the occasional misalignment of priorities between national policies and local needs, seeing as investment plans are often not community-based (UNDP, 2020).

Additionally, the involvement of the Ministry of Environment and Energy (*Ministerio de Ambiente y Energía*, MINAE) is crucial in the broader context of water resource management. MINAE oversees the conservation and sustainable use of natural resources, including water, through policies that aim to protect watersheds and promote environmental sustainability (Kuzdas et al., 2015). Complementing MINAE's efforts, the SENARA is tasked with managing groundwater resources and developing irrigation and drainage infrastructure. SENARA's role is particularly vital in agricultural regions, where efficient water use and irrigation systems are essential for maintaining agricultural productivity and mitigating the impacts of drought (Kuzdas et al., 2015). In recent years, there has been an increasing emphasis on integrating climate adaptation strategies into the institutional framework governing water systems in Costa Rica (Arias & Alvarado, 2013; Smith & Oelbermann, 2010; Stan et al., 2022). Collaborative projects involving local communities, governmental agencies, and international organisations have been initiated to address the pressing challenges of water scarcity and to ensure a sustainable water future in some regions (SENARA, 2022; UNDP, 2020). Santa Cruz's municipality, however, has focused most of its investments in recent years on developing infrastructure such as roads. Although a working group has been created to promote the economic development of the canton within a framework of sustainable water use (Universidad para la Paz, 2023).

4.3 Barriers and enablers to adaptation

The barriers and enablers for climate adaptation in the water sector that were identified with the systematic literature review have been placed in categories adapted from Bartlett & Dedekorkut-Howes (2023). The six resulting categories of barriers and enablers are: Governance and institutional, Ecological, Knowledge and Technology, Geophysical, Socio-cultural, and Economic.

4.3.1 Governance and institutional

The water-use framework utilised by Costa Rica is quota-style water allocation, which can be problematic during dry seasons due to senior licensees potentially filling their quotas first (K. D. Stan et al., 2022). Additionally, water in Guanacaste was not adequately checked by responsible entities in the period from 1997 to 2006, giving rise to second-order water conflict stemming from the different degrees of power by institutions in the water sector (Cover, 2007). Water resources in the area need to be checked or enforced by responsible actors to avoid irreversible impacts such as overuse of groundwater (Cover, 2007). Many ASADAS display a low level of management and development capacity, thus is such instances, support and additional resources may be required (Serrano et al., 2019b).

Participative processes in the planning of governance scenarios are seen as a way to reduce the aforementioned water conflict (Kuzdas & Wiek, 2014). Active community-based groups help avoid conflict and address disputes with government agencies (Kuzdas et al., 2016). Such social innovation was cause for more mobilisation in Juan Castro Balance National Water Park in Guanacaste, giving rise to empowerment, effective socio-political arrangements and satisfaction of stakeholder interests (Castro-Arce et al., 2019).

4.3.2 Ecological

Alterations to soil characteristics might be a necessary adaptation strategy. Forest productivity and biomass growth will be limited with decreased precipitation (Poorter et al., 2017; Stan et al., 2020). This is exacerbated by periodical forest fires growing more intense each year (Pérez-

Bertozzi et al., 2024). Mangrove stands will likewise decrease with rising sea levels due to their inability to migrate further inland given the land elevation along the Guanacaste coast (Samper-Villarreal et al., 2012). Broader biodiversity in said forests is also threatened, due to macrofauna such as large mammals and some bird species' reliance on seasonal waterholes that are likely to disappear under climate change scenarios (Montalvo et al., 2019). Ecosystem functioning would be affected by the collapse of flora and fauna populations.

These forests are necessary to maintain, as they display lower risks of water scarcity in comparison to grassland and improve ecosystem response to drought (Cooley et al., 2019). Water availability is the largest limiting factor for tropical dry forests such as in Santa Cruz canton. Plantings of secondary forests will therefore increase water retention and contribute to maintaining the existing ones (Werden et al., 2020). Not all biodiversity will be threatened by decreased precipitation either, as invertebrates display resilience to changes in rainfall (Srivastava et al., 2020b).

4.3.3 Knowledge and technology

Hydrologic monitoring is limited in many rural areas. Integration of monitoring programs into the local community has been key in informing both water resource management and academia. Leveraging principles of CBWM by engaging the community in monitoring has developed low-cost alternatives to hydrological studies in data-scarce regions (Hund et al., 2016). Those responsible for water management do not have accurate indicators for groundwater levels, the primary water source in many regions of Guanacaste (Hund et al., 2018). Additionally, indicators are necessary to measure the changing conditions due to hydro-climatic events in different localities such as the status of sanitation infrastructure or water supply (Esquivel-Hernández et al., 2018).

Newer technologies, such as water system modelling, are successfully utilized in the planning and designing of distribution projects to improve infrastructure management and provide a potential avenue to reduce data scarcity (González-Ramírez & Bejarano-Salazar, 2019).

4.3.4 Geophysical

Guanacaste will likely experience droughts in the future even in high precipitation years. Some areas will change climate classification to arid and will have to be planned for accordingly. Otherwise, damages to housing, infrastructure and agriculture due to flooding will become more frequent after extreme weather events following long droughts (Hidalgo et al., 2021; Quesada-Hernández et al., 2019). This is exacerbated partly due to the decreased water discharges coming from the province's mountain ranges under climate change scenarios. These catchments will not replenish the Tempisque watershed at the same rate by 2050 due to decreased precipitation (Gutiérrez-García et al., 2023; Jiménez-Rodriguez et al., 2015). This barrier is highlighted further by the projected groundwater recharge rates, which are set to decrease by up to 28%, if demand does not increase, whilst decreasing in quality (Hund et al., 2021; Pérez-Castillo et al., 2013; Zhen-Wu, 2010).

Soil conditions can be leveraged to reduce the likelihood of such events, by planting native trees that improve secondary forest growth and water retention. Although anthropogenic land use has depleted soil in the more populated areas, these can be restored through carbon-rich additions such as biochar to increase water retention (Lyon et al., 2022; Powers et al., 2009).

4.3.5 Socio-cultural

The natural and protected areas in the Costa Rican context are socio-ecological systems and contested spaces. As Guanacaste has a history of water conflict, the human-nature relationships in each area's context need to be considered for effective water management (Castro-Arce et al., 2019; Cover, 2007). Due to ineffective rural stakeholder engagement, there is a sense of distrust toward water-related information used in decision processes (Kuzdas et al., 2016).

If the necessity for water efficiency is integrated into the canton's social systems and per-capita water demand can be decreased, it could reverse the worsening situation around groundwater (Hund et al., 2021). Community-based monitoring has been trialled as a cost-effective method of decreasing groundwater aquifer extraction as well as improving user satisfaction and the quality of potable water, the latter often being of a high standard for human consumption in Costa Rica (Bernedo Del Carpio et al., 2021a; Sánchez-Gutiérrez et al., 2020).

4.3.6 Economic

The agricultural sector of Guanacaste is intensifying and expanding despite the increasing dryness of the region. Inefficiencies contribute to irrigation using 50% more water than necessary for some crops and polluting aquifers with the utilisation of certain pesticides (Morillas et al., 2019; Pérez-Castillo et al., 2013). Despite agriculture having relatively large water availabilities, the sector still experiences shortages during the dry season and damages during the rainy season. Increasing efficiencies and closing such yield gaps is a vital precedent for agricultural intensification (Benavides et al., 2021). The potential decrease in food security can also be a threat to livelihoods in rural areas, since as much as 10,1% of the households surveyed in the Santa Cruz canton experienced moderate to severe food insecurity in recent years (Cerdas-Ramírez & Espinoza-Sánchez, 2018). Other sectors, such as tourism with its coastal developments and utilities with hydroelectric power generation, leave increasingly little water for environmental flows and communities (Hernández & Picón, 2013; Magliocca & Gonzalez-Jimenez, 2020).

Whilst the drinking water supply of Santa Cruz is under pressure, the operating cost is lower than the households' willingness to pay. The actual economic value of water remains above both the operating cost and the willingness to pay, showing that economic incentives for potable water are not necessary (Merayo Calderón, 2004).

4.4 Conclusion SQ1

The ASADAS, supported by local, regional, and national institutions, encounter barriers and enablers to climate change adaptation, with governance, socio-cultural, and economic issues impacting their effectiveness. Additionally, the history of water conflict in the region emphasises the significant role of agricultural and tourism sectors, and the institutional framework involving AyA, MINAE, SENARA and municipal authorities underlines the need for integrated climate adaptation strategies. Figure 8 summarises the barriers and enablers based on the literature review. Notably, many barriers can be resolved or circumvented by leveraging their enabling counterparts. For instance, water conflict in Guanacaste and rural stakeholders' distrust towards water authorities can be reduced by integrating social networks and involving communities in hydrological monitoring, thereby improving user satisfaction. The next section will assess notable projects and interventions in the water sector to determine if they have targeted the most prominent barriers and leveraged relevant enablers.

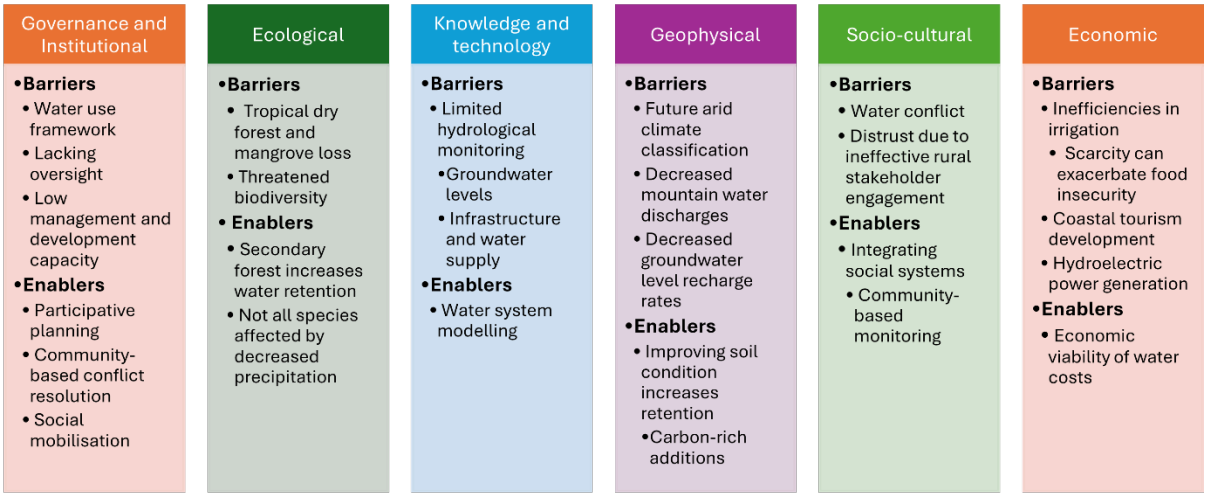

Figure 8: Summary of barriers and enablers of climate change adaptation

5. Perceptions of the water sector

In this second results chapter, a part of the findings from semi-structured interviews are outlined, focusing on the perceptions of different stakeholders regarding water scarcity. The problems related to water scarcity and the causes of such pressures faced by this sector are discussed, as well as perceptions of the current management system to elaborate on CBWM principles.

5.1 Perceptions of scarcity

Water scarcity is perceived differently by various stakeholders, influenced by day-to-day impacts and past experiences. Personal history and knowledge play a crucial role in shaping whether individuals perceive current water availability as an exacerbation of past conditions. Important to note, however, is that differences between the perceived problems, impacts and causes related to water scarcity did not differ between stakeholder groups as significantly as anticipated.

5.1.1 Area changes

The Santa Cruz canton has seen significant changes over the past two decades. Historical water conflicts in Guanacaste have been discussed in the theoretical framework, but interviewees have noted considerable changes in their communities during their lifetimes. Urbanisation in Santa Cruz began in the 1980s, followed by a real estate boom up to the 2008 financial crisis. This development stagnated until after the COVID-19 pandemic, when the economy, particularly the tourism sector, entered a recession due to restrictions and reduced visitors to Guanacaste's coastal areas:

> *In recent years we saw a big change. After 2020, let's say, after the COVID moment, even in the year of COVID, a lot of foreigners have arrived here. Many people arrived in that area (...) and people began to invest, to buy land, to build, and in that last year we saw a great development, positive perhaps, by whoever sold properties and by whom construction permission was given, but not very positive for the area and for the locals who live here. – C3, Los Pargos*

This sentiment is echoed by many interviewees, who believe water scarcity has increased due to pressures from new inhabitants and residential tourists, among other factors:

> *So, I can tell you, trade has increased, in terms of the commercial part, the tourism part has increased, it has grown, it has continued to increase, and the pressure on water resources has increased. – A8, Liberia*

Two stakeholders did not believe there was a water scarcity issue, as water has always been available to them. Both were involved with the public sector. Another public sector actor refrained from labelling the situation as scarcity due to insufficient data. However, eight interviewees felt that water availability has decreased in the past decade due to various impacts. Although Guanacaste is Costa Rica's driest province, accessing water hasn't always been difficult. Some interviewees recalled an abundance in the region's rivers before the severe droughts of the past decade:

> *I remember 30, 40 years ago when you still had rivers and you went fishing in the river. Yes, I was going to bathe in the rivers. Today you can't do that. Yes, there is not so much water in this river (...). – Pu5, Paraiso*

5.1.2 Problems

Those experiencing water scarcity recalled incidents like outages or interruptions in service. Problems and impacts were not as differentiated between stakeholder groups as initially hypothesised. Besides quantity, water quality is impacted in the dry season by lowered water tables, contamination, and saline intrusion:

> *(...) those that were closer to the beach [the wells], on the side of Los Pargos, and they were filled with sea water, salt water. - C2, Paraiso*

Another common perceived problem was the overexploitation of water resources and aquifers.

5.1.3 Impacts

Water scarcity impacts daily life in various ways. Some impacts are relatively low, such as water-saving methods due to lower availability:

> *I think there are many people who no longer wash cars or water plants because we know there is less water, right? So we avoid doing it. – Pu4, Santa Cruz*

However, decreased water flow at the end of the dry season in Costa Rica has more far-reaching consequences. Essential services, including electricity, are interconnected with the water supply:

> *(...) the other week, there was a power outage, because here 60% of the electricity is produced by hydroelectric plants. (...) If there is no water, they cannot produce electricity. – C3, Los Pargos*

In reality, 70% of electricity is produced by hydroelectric plants. Rationing was ordered in May 2024 due to one of the longest droughts in Costa Rica in 50 years, influenced by El Niño (Murillo, 2024). Productive sectors and livelihoods are also threatened by scarcity and outages, affecting tourism and irrigation systems:

> *Because it has drastically decreased or affected some crops. Then, and the rainy season delays primary plantings. – NGO11, San Jose*

Whilst most interviewees experienced adverse impacts due to water scarcity to some extent, it was noted that gender comparisons are disparate due to the differing consumption rates:

> *Women need more water. For example, for menstrual hygiene. Women need more water if they are pregnant. They then become a vulnerable group that needs a greater amount of water. – NGO11, San Jose*

Men consume more water overall, but women potentially consume more due to personal hygiene needs (Balado-Naves & Suárez-Fernández, 2024; Talukdar et al., 2023). This is an exemplary case that within the existing water systems, there are groups that are more vulnerable to adverse impacts. Rural communities, and areas with costly water infrastructure maintenance, like higher altitudes, are more adversely impacted.

5.1.4 Causes

The issues and causes of water scarcity, as perceived by interviewees, can be broadly categorised into climatic issues, productive sectors, and water governance. Academic stakeholders noted CADC and ENSO as major reasons for decreased precipitation in Guanacaste over the past decades. Affected area residents have also observed these changes:

We have seen a change, it's never been that hot. – Pr7, Los Pargos

Higher temperatures, prolonged dry seasons, and decreased precipitation have lowered aquifer recharge rates:

The aquifer drops very, very, very much, and basically, at least in that sector, in that sector of Santa Cruz, I do relate it a lot to precipitation, right? – A9, San Jose

A9 also noted that aquifer recharge in Santa Cruz is immediately measurable after heavy rainfall. However, increasing forest fires in recent years have disrupted this recharge. While Pu4 noted the creation of volunteer firefighting forces, fires continue to hinder the watershed's ability to direct water towards aquifers:

There is the foliage, the trees play a very important role, the topography plays a very important role, that is, if you remove the trees, the water will no longer be retained, right? Because they call it retention due to the foliage, so it is very important, the trees, everything that is the foliage, the topography, what is the, that is, the waterproofing of the land is too important, if you take it away, it begins to build everywhere, um, infrastructure, already there, where the water is going to infiltrate, right? – A9, San Jose

Tourism, construction, real estate, and agriculture contribute to decreased water availability in Santa Cruz. Although agriculture has historically been dominant in Guanacaste, the impact of current *cañeros* in Santa Cruz is relatively low. More significant is the influx of people, leading to increased trade and activity in real estate and tourism:

For example, in my community it happens a lot that there are constant water cuts because they are doing some giant projects in Avellanas. – C1, Veintisiete de Abril

These projects, mainly large condominium parks for residential tourists, strain the already limited water resources. Additionally, the consumption habits of non-native residents differ vastly from locals:

Regarding water consumption in hotels, I think there is a standard of people who are very extractivist (…) there are two factors at the same time, it is the end of the dry season, it is much hotter, and we have the time when water is most scarce and people from cold places can perfectly take 3 showers a day. – NGO10, Paraiso

Different lifestyles and lack of education further strain water availability. Finally, governance is also seen as a potential cause of water scarcity in Santa Cruz. ASADAs are central to rural water management, but the laws creating the current system are outdated, with no significant changes expected:

And they've tried to bring bills in a bunch of times. But every time they are rejected because they are pure privatisation of water. For example, the last bill, the word ASADA is not mentioned even once in the entire document. – C1, Veintisiete de Abril

The governance framework is outdated and ill-equipped for the socio-economic and environmental challenges of Guanacaste. Additionally, resources for water governance have decreased over time:

So all of this weakens and weakens and weakens [the public institutions], or they cut the budgets, for example a colleague who works with the MINAE in the forest fire section was given 60 thousand colones a month for fuel, so he is a person who cannot go out every time.

They ask you to go out to do an inspection, go see a complaint, it is not possible, that is why the entire system is weakened and then we as citizens are also losing faith and trust in that system. – NGO10, Paraiso

5.2 Conclusion SQ2

Different stakeholder groups in the Santa Cruz canton experience water scarcity in varied ways, influenced by both historical context and daily impacts, although perception did not differ between the groups as significantly as anticipated. While some residents remember a past where the dry season was less impactful, many now perceive increased scarcity due to urbanisation and an influx of tourists. These pressures have exacerbated existing water problems, with impacts such as service outages to compromised water quality. Insufficient technical capacity and a lack of adequate knowledge of water levels are issues that hinder the effectiveness of the ASADAS' CBWM. Perceptions of water scarcity also reflect the influence and involvement in interventions. Influence over water sector interventions varies significantly among stakeholders, with community members' participation mostly being limited to local assemblies, while higher-level institutional stakeholders exhibit more substantial influence. Those with more influence, notably the public sector, perceived scarcity to a lesser extent than other interviewees.

5.3 Perceptions of CBWM

Interviewees shared their views on the institutions responsible for water management and the problems they experienced with water governance. Satisfaction is crucial, as it reflects how well consumers feel represented within CBWM bodies. Other questions aimed to identify gaps in CBWM principles to strengthen these factors, preventing climate maladaptation. This assisted in answering SQ4. Water governance in Costa Rica involves multiple, nested layers, each with specific responsibilities. In practice, these institutions often operate independently. ASADAS fall under AyA, which also handles sewage treatment and potable water:

There are three, let's say. The SENARA and the MINAE Water Directorate (...) And also AyA. Let's say that AyA already gives up a little to those two institutions, but they are always related. – A11, San Jose

ASADAS primarily manage community administration of water resources and maintain infrastructure, focusing on projects related to wells, pipes, and pumps:

Maintain infrastructure. That is, preventative. – Pu6, Rio Seco

These organisations often face infrastructure-related problems. Water pipes (Figure 9) are glued together, and due to heat, fires, and occasionally inadequate installation, leaks occur frequently. Pump failures and leaks are particularly troublesome, as treated potable water is lost:

So, there's a lot of leaks. But that's already a problem with the municipality every year. They sleep [ignore it] every year. – Pu5, Paraiso

Figure 9: Water pipes stored in an ASADA warehouse (Author's own)

To improve technical capacities, ASADAS receive training from other stakeholders, such as UNDP projects and academics. However, due to the democratic nature of community organisations, trained individuals on the board of directors are sometimes replaced:

> *We have been working, as I mentioned, on the issue of water quality in the ASADAS, evaluation of water quality, the risk index for human consumption and a lot of strengthening of technical capacities, because they have that particularity of the ASADAS that they rotate [their members] many times. So, if there is training, sometimes a board of directors is maintained, but many times they also change. – A10, Liberia*

Infrastructure problems are not always quickly resolved, leaving consumers without water services. While community responsibility for water management is recognised as positive, technical capacity shortcomings are evident:

> *So, in some things, in many things, perhaps they fail, as I told you. – C3, Los Pargos*

> *They do a good job, but training is always welcome. – A10, Liberia*

5.3.1 CBWM Principles

Most principles were discussed during the semi-structured interviews. Existing barriers to improving the CBWM system will be outlined for each principle. Nested governance is excluded, as the governance framework was previously outlined and not discussed in detail during the interviews.

5.3.1.1 Boundaries

Most districts in Santa Cruz are assigned to either AyA in larger urban centres or rural ASADAS. However, this is not always consistent. Some users lack any water services, affecting human health due to unmanaged water quality. Communities sometimes join growing ASADAS, such as ASADA Paraiso and Junquillal, showing that boundaries are not always clear:

But at least ASADA is the one that provides water to everyone, there is someone responsible, they should measure the quality of the well. There is no one in that sector [Los Vasques]. – Pu4, Santa Cruz

5.3.1.2 Congruence with local conditions

In areas where water is managed for mostly Costa Rican households, without the large presence of productive sectors, as is the case in Rio Seco, water scarcity is not observed, and management aligns with local conditions. However, as ASADAS grow and stakeholder-needs diversify, maintaining these conditions becomes challenging. Residential tourists often build homes with pools and non-native gardens requiring large amounts of water:

That is, you can use so much water per month. So, there is already a group of people here who buy the big villa with the huge pool and want to see everything green on the border in the summer. That is water that is thrown away. – C3, Los Pargos

5.3.1.3 Collective choice

Community participation is vital in ASADAS, as board members are elected during assemblies. However, not all water users feel represented by their water administrators:

I think there is a lack of much more representation of young people between 20 and 35, so to speak, generally the people who most represent community organisations are more between 30 and 40, 50, so yes, and sometimes there is also a lack of female representation, or even if there is, at the end of the day, many times the presidents are men (...) – NGO9, Paraiso

5.3.1.4 Monitoring

Monitoring is a principle observed to be lacking by many interviewees. While the amount pumped from wells and consumed is measured, there is no clear overview of groundwater levels in the aquifers. Water quality is periodically reviewed in many ASADAS:

No, here every six months, every six months, a water study is done. – Pu6, Rio Seco

Although water treatment quality is maintained, there is no clear overview of quantity over the years, making it difficult for some stakeholders to realise the urgency of climate adaptation measures:

Baseline, that is, you go to measure the levels of the wells month by month, for several years, then you can know what is the baseline, what is the baseline of that aquifer. When you already establish a baseline, you can know when the balance of that aquifer, and when it goes down, if it goes down from that balance, you can already know that it is water stress, that it has water stress, that is, it is being overexploited, or if it went down due to the drought, but, let's say, at least in Santa Cruz right now, since there is not so much development (...) – A9, San Jose

5.3.1.5 Graduated sanctions

There are no sanctions for overexploitation, but a graduated scale is used for water consumption, with the maximum rate reached above 60 cubic meters per month. Bills are still relatively low compared to high-income countries, and fines for illegal usage are low and difficult to enforce:

Yes, there is a fine for illegal connections, but the amount to pay is ridiculous, (...) it is super low. So a lot of people do it. What people do is they go to build, they connect illegally, they hide, they build the house and then when they see what was put there illegally, a fine must be issued. It's nonsense. – Pu5, Paraiso

5.3.1.6 Conflict resolution

Conflicts typically occur between water users and administrators, and between different water institutions. Resolution is often challenging:

> *I think that, let's say, there are moments in which people have empowered themselves and have filed complaints in the right place and followed up on them, because filing the complaint by itself many times is of no use, right? You have to follow up, you have to insist, you have to face it. – NGO10, Paraiso*

Institutional conflicts are difficult to resolve due to changes in government, leadership of AyA, and ASADA board of directors, hindering trust-building:

> *Yes, because the problem is changes in government and it becomes very political. And then there is a government, which was what happened with the AyA, then the ASADAS complained, they put restrictions on us to provide water availability and suddenly a luxury condominium appears with approved water availability from San José. – A8, Liberia*

5.3.1.7 Right to organisation

The right to organise in the current CBWM system is not always stimulated between communities. While internal community projects can be created through commissions, collaboration is difficult since ASADA cooperatives must be recognised by AyA:

> *The ASADAS, to the extent possible, who can work alone, do so alone. When did they have to join together? When they have serious problems. So, for example, the ASADAS of the coastal zone, for a long time they had created the union of ASADAS of the coast (...) but more are not created legally because they are not interested in being legalised before AyA as a union because they do not want AyA closer. – A8, Liberia*

Such unions still exist in other cantons, like ORAC Chorotega of Nandayure and Hojancha, but no longer in Santa Cruz districts.

5.4 Conclusion SQ3

The interviewees expressed varying levels of satisfaction with the ASADAS and other water management institutions, highlighting gaps in representation and technical capacities within the CBWM system. Service interruptions due to infrastructure problems, and lack of effective monitoring were key issues identified. CBWM principles that need strengthening were outlined, such as graduated sanctions, with only the AyA giving fines, and conflict resolution, due to the strenuous process involved with complaints. To conclude, SQ3 has been answered through data collected and the aforementioned participants' responses. Ways of strengthening the CBWM system based on the shortcomings will be further assessed in the discussion section.

6. Climate adaptation in Santa Cruz

Climate change adaptation and interventions are analysed in this results chapter based on desk research and semi-structured interviews. Interventions by SENARA and UNDP will be analysed to see if a risk of maladaptation—and a subsequent second-order water conflict—exists. They have also targeted several barriers as identified in the systemic literature review and will be assessed on how they support the existing CBWM system. The final data from the semi-structured interviews are also presented, including how some stakeholders have adapted to water scarcity on a local level and their perceptions of future access.

6.1 Beneficiaries and adversely affected

Figure 10 provides an overview of the UNDP project's stakeholder mapping. Within the beneficiary group, primary social beneficiaries include ASADAS and end users who will benefit directly from improved water management practices, as most capacity-building efforts are aimed at these stakeholders. The public sector is identified as a secondary social beneficiary, gaining through enhanced coordination and support structures (Araujo et al., 2021; UNDP, 2020). Primary non-social beneficiaries encompass livestock and crops that will benefit from more efficient water use practices in the long term from water-saving practices implemented in the project. Farmers are secondary non-social beneficiaries, benefiting through improved agricultural conditions (Araujo et al., 2021; Ricardo et al., 2018).

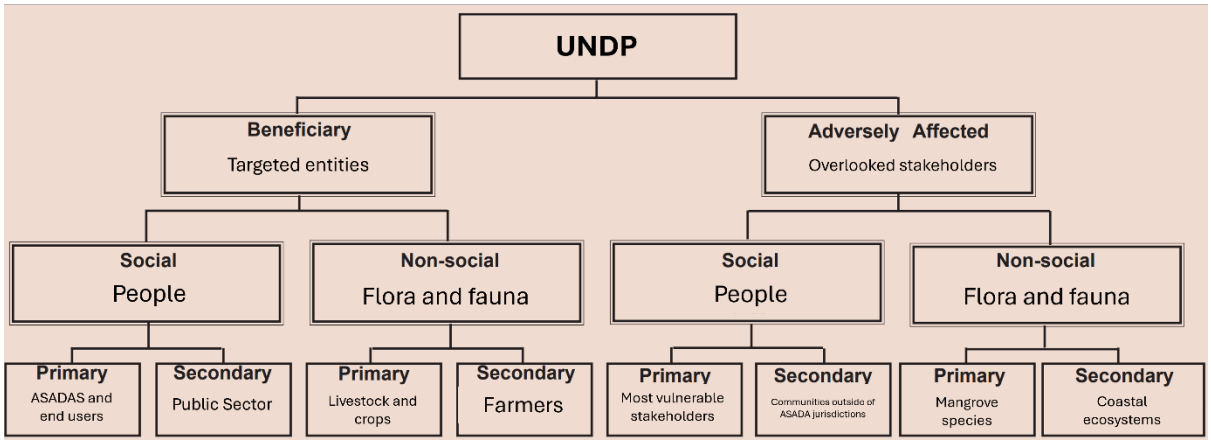

Figure 10: Stakeholder mapping of the UNDP climate adaptation project

As this project does not involve construction or other activities that could impact ecosystems, the adversely affected stakeholders are those potentially overlooked in the project's scope. As such, the potential for unintended consequences to the adversely affected stems from the fact there is no adaptation response targeted towards these entities. Primary social adversely affected groups are the most vulnerable rural stakeholders who currently face challenges due to not being administered by any ASADAS. Communities outside ASADA jurisdictions are the secondary social adversely affected group, potentially missing out on direct project benefits (Pasquier et al., 2020). For non-social entities, primary adversely affected groups include species in mangroves, which may suffer due to capacity building strategies that mainly focus on secondary forests and reforestation outside these coastal zones (Lacambra S et al., 2024; UNDP, 2020). Secondary non-social adversely affected stakeholders are therefore coastal ecosystems.

The stakeholder mapping for the PAACUME project, as illustrated in Figure 11, likewise categorises stakeholders into beneficiaries and adversely affected groups. The primary social

beneficiaries include farmers and tourism operators who directly benefit from the increased water availability for irrigation and tourism activities. Secondary social beneficiaries, such as the private sector, indirectly gain from improved economic opportunities resulting from better water management (SENARA, 2022). On the non-social side, primary beneficiaries include cattle and sugarcane that will have a more reliable water supply, while secondary beneficiaries are the *caneros* and *ganaderos* who benefit indirectly through the increased provisions for their farms.

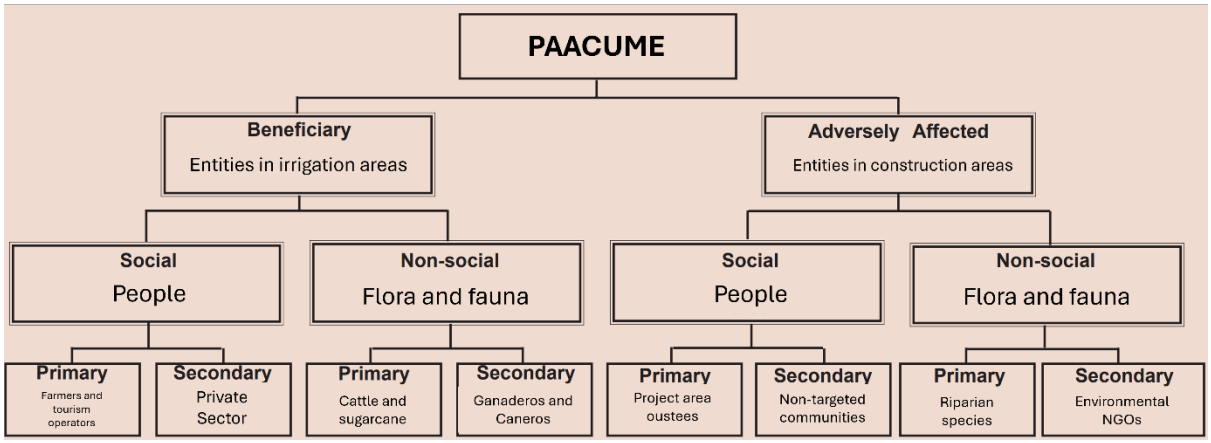

Figure 11: Stakeholder mapping of PAACUME, climate adaptation project

The adversely affected groups comprise entities in construction areas, as there are many similarities between PAACUME and previous infrastructure projects. Primary social groups adversely affected include project area oustees, who can potentially experience displacement or other disturbances due to construction activities, while secondary social groups include non-targeted (downstream) communities that may experience changes in water distribution and provisions for surrounding ecosystems indirectly (Chacon Soto, 2018; Edelman, 1987). Among the non-social stakeholders, riparian species are primarily adversely affected groups as their habitats face direct disruption or loss due to construction along water bodies, as indicated by environmental impact assessments (SENARA, 2017). Secondary non-social adversely affected stakeholders are environmental NGOs, which are indirectly impacted as they work to address and mitigate the environmental consequences of the project.

6.2 Assessing water sector interventions

The two water sector interventions have also been evaluated to determine how effectively they have addressed the identified barriers and enablers of climate adaptation and its subsequent implementation. Additionally, an analysis has been conducted to assess the extent to which these initiatives have adhered to the principles of CBWM. This evaluation is aimed to help address SQ3, which aims to determine whether maladaptation has occurred due to the neglect of key barriers and enablers or if there has been a violation of the CBWM principles essential to the functioning of the community-based system in Santa Cruz, potentially resulting in unintended consequences. Two such interventions, which have the potential for significant impacts, have been implemented by the UNDP and the Costa Rican government institution SENARA. The latter is a planned project, whilst the UNDP has already finalised their project.

6.2.1 UNDP

Guanacaste and the Santa Cruz canton were a target area of the UNDP's *Strengthening Capacities of Rural Aqueduct Associations' (ASADAS) to address climate change risks in water stressed communities of Northern Costa Rica* project, in collaboration with the Global

Environment Facility (GEF). The goal of this project was to improve the water supply and its sustainability for end users through ecosystem- and community-based adaptation measures (Araujo et al., 2021; Ricardo et al., 2018; UNDP, 2020).

6.2.1.1 Barriers and enablers

Some governance and institutional aspects are somewhat addressed by the UNDP intervention through focusing on enhancing the technical capabilities of ASADAS through training, aimed at addressing gaps in management capacities. While the project does not directly tackle the ecological barrier of mangrove loss, it emphasises ecosystem-based adaptation measures through bottom-up reforestation efforts of tropical dry forests. These measures could support the ecosystems that contribute to water retention, thus enabling the maintenance of the hydrological balance. The project also integrates the need for more advanced hydrological monitoring and technology. By aiming to improve the infrastructure, some inadequacies in the water supply networks are addressed. Additionally, monitoring capabilities have been improved through the creation of a framework for an early-warning system. This should also help with the adaptation to changing geophysical conditions in future scenarios, although not explicitly targeted through this project. The intervention fosters social inclusion and community-based monitoring, aiming to build trust through increased stakeholder engagement. This approach not only enhances the CBWM capacity but also promotes social cohesion. Economically, the project aligns with cost management by integrating financial incentives into the agricultural sector to adopt water conservation practices.

6.2.1.2 CBWM Principles

First and foremost, the boundaries of the project and the intended water users are identified, but not explicitly outlined in the implementation documents (Ricardo et al., 2018). It is well adapted in congruence to local conditions since quantities of water provided to users are well adapted. Risk management for the project is also integrated into the ASADA system through GIRA, a vulnerability analysis, identification, assessment, administration and communication tool about the risks that may affect the provision of services provided (UNDP, 2020). Attention is also given to the participation of communities in the project, specifically female and youth participation. A significant gap in the adherence to CBWM principles exists when it comes to monitoring, sanctions and conflict resolution. The end users are not involved in monitoring the progress of the project, and the implementation review is done by the UNDP or GEF, therefore not including entities representing the end users. It is also not clear whether, and what, sanctions exist for violations or illegal water usage related to the project. Finally, as a project strengthening ASADA capacities, the same conflict-resolution mechanisms are likely utilised in comparison. This, however, is not clearly outlined. Although the right to organisation is recognised by supporting the community-based system of the ASADAS, the project can still be seen as an imposition by a supranational organisation such as the UNDP. It is unclear to what extent the right to self-organisation of the local water users is recognised in defining the targets of this intervention, and which capacities have been increased. Advocacy spaces have been created as a result of the project, thus the organisation of multiple nested layers of governance has been supported. The aforementioned is summarised in Table 4.

	Design Principle	*UNDP Intervention*
1	Clear boundaries	The project boundaries and intended water users are identified but not outlined
2	Congruence with local conditions	The project is adapted to local conditions, especially in terms of the quantities of water provided to users, benefiting both productive sectors and livelihoods.
3	Collective-choice arrangements	Attention is given to community participation, specifically emphasising female and youth involvement in the project.
4	Monitoring	Users are not involved in monitoring and reviewing the project's progress.
5	Graduated sanctions	It is unclear whether sanctions for violations or illegal water usage exist.
6	Conflict-resolution mechanisms	Conflict-resolution mechanisms are likely similar to those used by ASADAS, though they are not clearly outlined in the project documentation.
7	Recognition of the right to organisation	The project supports the community-based system of ASADAS, but the project is predominantly top-down, making the right of local users' self-organisation unclear.
8	Nested governance	Advocacy spaces have been created as a result of the project, supporting the organisation of multiple nested layers.

Table 4: Application of CBWM principles to the UNDP intervention

6.2.2 PAACUME

Another recent project, with the first stages still under consideration to be initiated, is the Proyecto Abastecimiento de Agua para la Cuenca Media del río Tempisque y Comunidades Costeras (PAACUME) by SENARA in collaboration with MINAE and AyA. Initially, this project was intended to provide additional hydro-electric energy production, and irrigation for farms situated in the Tempisque River basin (SENARA, 2022). After critique from the Guanacaste communities, who require more resources to combat water scarcity, an additional phase was added to PAACUME, named Water for Guanacaste (Chacon Soto, 2018). This provision is intended to add 2 cubic meters per second to the water availability of coastal Guanacaste communities, where water scarcity is greatest. The intended construction for the infrastructure project can be seen in Figure 12 below.

Figure 12: Planned PAACUME infrastructure (SENARA, 2020)

6.2.2.1 Barriers and enablers

Under the governance and institutional aspect, the program establishes coordinating bodies and frameworks, such as the High-Level Commission and Technical Secretariat, to oversee and manage water-related projects effectively. It aims to enhance management capacity and ensure oversight. Ecologically, the program recognises the importance of ecosystem preservation and sustainable practices. While not directly addressing issues like tropical forests and mangrove loss or threatened biodiversity, it emphasizes the need for sustainable ecosystem management and indirectly contributes to water retention and ecological health. The environmental assessment of the interventions, however, projects many adverse impacts as a result of the construction of its infrastructure (SENARA, 2017). Geophysically, it aims to mitigate decreased water discharges and groundwater recharge rates by providing additional water inflow from the Arenal area, artificially combatting the geophysical barriers. Socio-culturally, the program aims to foster stakeholder engagement and community involvement through a community relationship plan, although participative processes are not explicitly mentioned. Economically, the program seeks to promote efficient water use practices and ensure the economic viability of water costs. The designated amount of water for agriculture is, however, far higher than the amount designated for the coastal communities, with 16,5 cubic meters of water per second for irrigation and 2 cubic meters per second designated for drinking water. Whilst 70% of all water consumption in Guanacaste is agriculture, for this project it is closer to 80% (OECD, 2015; SENARA, 2022). Similarly, whilst the tourism sector only consumes 1% of the annual inflow of Costa Rica's water, in PAACUME they have received a concession of around 7,5% of the total water inflow gained from the project (OECD, 2015; SENARA, 2022). Therefore, whilst barriers from

both sectors are considered in the project, they are likewise both given larger water concessions raising questions about the equitability of its water access.

6.2.2.2 CBWM Principles

SENARA (2022) has given a clear overview of the amount of people PAACUME will service, and the quantities of water they will receive. Additionally, temporal and spatial scopes are clearly outlined as further boundaries in the local conditions. Energy generation is not solely for the Guanacaste context, however, and impacts are likely to extend beyond the immediate localities affected by the construction of PAACUME's infrastructure. Participation of the people in the Tempisque River basin, including communities in Guanacaste, is central to the project. Although social participation is mentioned, the scope and manner of it are not. The monitoring of the project is carried out by government institutions such as SENARA, which, in theory, are accountable to the water users. In practice, however, it is difficult for rural communities to provide feedback to institutions at a higher level besides the ASADAS in case the social participation framework is not suitably structured (Nkombi & Wentink, 2022). Sanctions are omitted in the PAACUME reports; thus, it is unclear to what extent overexploitation is penalized. Resulting conflicts are resolved through a *Plan de Relación con las Comunidades* (Community Relationship Plan), predominantly consisting of assemblies with affected communities. Despite water being provided to communities administered by the CBWM bodies, ASADAS are not involved in the implementation of PAACUME. It is unclear whether they have a direct say in the project, and the right to self-organisation can therefore be deemed questionable. The same is true for the nested governance, as all agencies involved in the project are accountable to the national government. The aforementioned is summarised in Table 5.

	Design Principle	*SENARA Intervention*
1	Clear boundaries	Clear temporal and spatial scopes and quantification of water provisions.
2	Congruence with local conditions	Benefits and impacts extend beyond target areas.
3	Collective-choice arrangements	Participation of the people in the Tempisque River basin, including Guanacaste communities, is central to the project, though the specifics of social participation are not detailed.
4	Monitoring	Project monitoring is conducted by government institutions like SENARA, accountable to water users.
5	Graduated sanctions	PAACUME reports omit sanctions, making it unclear how overexploitation is penalised.
6	Conflict-resolution mechanisms	Conflicts are resolved through the Community Relationship Plan, mainly through assemblies with affected communities.
7	Recognition of the right to organisation	It is unclear whether ASADAS have a direct say in how to distribute the assigned water concessions or can organise such distribution.
8	Nested governance	Most agencies involved in PAACUME are accountable primarily to the national government.

Table 5: Application of CBWM principles to PAACUME

6.3 Perceptions of water sector climate adaptation

In some respects, the necessity of projects to support the future of the water sector has been recognised. There are climate adaptation projects at the local level conducted by communities themselves, as well as at the municipal or national level. Some interventions are supported by supranational organisations, as is the case with the UNDP project. Others are supported by national government institutions such as SENARA. This section will discuss the power in projects, to the extent that stakeholders are knowledgeable about them, and the extent to which institutions cooperate to improve the water management system.

6.3.1 Power of different stakeholders

Most stakeholders can exert some influence over projects. For community members, it is important to participate in assemblies, as there are few other opportunities to have their voices heard at a local level:

> *They [the ASADA] pretty much keep it to their own, they have their own circle of people. Okay, and… No, I don't think they will include me, I will tell them too much. – Pr7, Los Pargos*

Although ASADAS sometimes participate in larger-scale projects, the influence of the interviewed stakeholders seems limited. At the municipal or higher institutional level, this influence seems to increase:

> *In this Water Table project, we even managed to involve the Emergency Committee, which I am on the Committee and I promoted it, then there are my colleagues, and there are many other institutions, and the idea is to be able to carry out specific projects, specific needs. For example, AyA tells us, I need infrastructure for this sector, then see how private partners or other institutions can collaborate to bring water to a community, to be able to expand the network, to be able to control the extraction, the quality of the water, in short. – Pu4, Santa Cruz*

While influence seems to be reserved for individuals at a higher level, most interviewees aware of water sector problems were involved in projects to some extent. Larger projects, such as those analysed during this study, were not known to most interviewees except at the municipal level and above, suggesting either a lack of participation—or inclusion. Stakeholders from all groups were involved to some extent, although problems occur in such projects due to a lack of resources:

> *So, the lack of long-term planning. We think it won't affect me, but then there are a lot of problems. Also, with the issue of infrastructure and others that we have due to a lack of investment in infrastructure, not a lack of water, but that the investments have not really been made on time and we have a delay in that regard. – A8, Liberia*

6.3.2 Cooperation by responsible institutions

The aforementioned example highlights that not all stakeholder groups work together to solve translocal water problems. Private or public sector investments are necessary to address issues identified predominantly by academia and NGOs, while community participation is necessary to identify said problems. Collaboration between different institutions and cooperation among different stakeholder groups are not always a given:

The problem is that sometimes the SENARA does things that the AyA does again. In other words, they do not provide for each other, the information is not provided between them. So, it's a problem because the functions are repeated. – A11, San Jose

Fragmentation and difficulties with representatives are mentioned as reasons why collaboration with ASADAS is sometimes troublesome:

Yes, because there are many of them and they do not have a single representative, so talking to all of them and working with all of them is complicated. For forest fire policy, we called the ASADAS to the worktable and there were many and very, very few arrived. There is no fluid communication with the ASADAS because we do not see them as a single organisation, but rather many organisations. – Pu4, Santa Cruz

6.4 Perceptions of future water access

All stakeholders are concerned about the future of water availability in Guanacaste to some extent. Even those whose current situation is not a reason for concern see that with the progressively shorter rainy season, their water supply could be at risk. Some stakeholders have already undertaken measures to prepare for such scenarios, which will be briefly highlighted. Then, the perceived priorities to combat water scarcity and the interviewees' views on who is responsible for implementing these measures will be discussed.

6.4.1 Climate adaptation by stakeholders

Both academics and NGOs emphasised the importance of capturing rainwater to supplement water availability. To some extent, this is already being done in communities instead of using public water for purposes such as watering gardens:

We are recycling the water, the rainwater into tanks and we use it to do the flowers, you know, for two, we can almost flower the yard without one drop of water for over five to six weeks during the drought. So we are doing what we can to do that, to save water, which is a good thing. And many, many people I know are doing it too. – Pr7, Los Pargos

6.4.2 Priorities

Most interviewees expressed different priorities to resolve the challenges facing the water sector. Many are concerned about the immediate increase of water availability through capacity-increasing interventions such as additional wells, improving waterlines, and other infrastructure improvements. Two factors related to the long-term functioning of the water systems were also discussed. The first was improving governance and increasing the priority of water scarcity as a political topic since crime is currently perceived to be higher on the national government's agenda. Secondly, supporting the community-based systems involves increasing water-related education and social cohesion:

The most serious concern or forward-looking concern is that people are not seeking to participate in community solutions. So there is less and less community participation. So, if people's interest and participation increases, they can find joint solutions. But that, well, that impacts the water, it impacts local governments, it impacts the economy. So social cohesion is important. – NGO 8, San Jose

6.4.3 Responsibility

When it comes to increasing water availability, most people look to the ASADAS and hold them responsible for providing services to the communities. Underlying problems and priorities are

deemed to be under the government's authority. Collaboration between AyA, SENARA, and MINAE was emphasised here:

> *I don't know, due to the lack of information, because there may be better ones, there may be campaigns at the government level, at the national level, on climate issues, on raising awareness about saving water. – A10, Liberia*

6.5 Conclusion SQ4

The interventions by UNDP and SENARA, have played, or will play, important roles for the CBWM system of Santa Cruz. The UNDP project, aimed at enhancing the technical capacities of ASADAS, focused on community-based and ecosystem-based adaptation, and social inclusion. It addressed some barriers to climate adaptation, such as governance barriers, by providing training to increase management capacity. However, it lacked clear involvement of end-users in monitoring and conflict-resolution mechanisms. SENARA's PAACUME project, although still in its initial stages, has established clear boundaries for the increase of water availability through building additional infrastructure. Unlike the intervention by the UNDP, this does not classify as community-based adaptation as it is mostly top-down, with most water concessions intended for systems other than the CBWM ones. Despite promoting community participation and efficient water use, it faces challenges in ensuring equitable water distribution. Both interventions have partially adhered to CBWM principles, yet gaps remain in areas such as monitoring and sanctions. Whilst the intentions of such interventions are surely to decrease climate risks in vulnerable areas, the fact remains that these projects are imposed upon communities instead of planned in a participatory manner with the communities. Whilst investments in the water sector are of the utmost importance, and CBWM is supported by some aspects of the beforementioned projects, a bottom-up approach would result in much more buy-in from the targeted and at-risk communities.

7. Discussion

7.1 Leveraging the existing capacities

The semi-structured interviews in combination with the literature review on barriers and enablers for climate adaptation reveal several capacities that can be leveraged in subsequent interventions.

Governance and institutional challenges, such as outdated frameworks and insufficient resources, are evident in both the literature and interviews, aligning with the interviewees' calls for more inclusive governance and better coordination between the various institutions like AyA, MINAE and SENARA. Ecological factors, like the impact of forest fires and the importance of maintaining forested areas for water retention, have been mentioned in the interviews, with additional concerns about such events not being adapted to by the local populace. There are, however, existing organisations in the Santa Cruz canton whose knowledge of the local ecosystem can be utilised in the ecosystem-based adaptation of secondary forests. The emphasis on the importance of hydrologic monitoring aligns with interviewees' concerns about the lack of accurate indicators for groundwater levels. Recommendations such as year-by-year monitoring of aquifers were given. Geophysical challenges, such as the projected decrease in groundwater recharge rates and the impact of climate change, are consistent across both the literature and interviews, with interviewees highlighting the need for proactive planning to mitigate these impacts. Although monitoring and ecosystem-based solutions are part of the solution to address these challenges, adjusting the outdated governance framework could generate the institutional capacity necessary to address further geophysical climate adaptation barriers. Socio-cultural barriers, such as distrust towards water authorities and the need for community engagement, as mentioned by both primary and secondary data sources, emphasise the importance of further involving the community in matters such as monitoring, participative processes or increasing education related to water as a human right. Frequently discussed economic barriers such as inefficiencies in the agricultural sector and the pressures from tourism, underscore the need for improving water use efficiency. In the context of Santa Cruz, especially when it comes to large-scale residential tourism. All in all, there are considerable capacities that can be leveraged for climate change adaptation. Addressing these barriers and leveraging the aforementioned enablers can enhance disaster preparedness.

7.2 Water concession conflict

In contrast to what was found by Ohlsson (2000), most water conflict in Santa Cruz is in fact first-order and about the resource itself. Although adaptation is occurring to some extent, as demonstrated by the analysed interventions, the scale is not extensive enough to give rise to widespread second-order water conflicts. However, large-scale interventions such as PAACUME could potentially lead to future conflicts. Although historically the agricultural sector has been a dominant force in the political system of Guanacaste, in the study area, the development of the tourism sector was thought by interviewees to be the most impactful (Cañada, 2019; Sanabria, 2016). The current system for obtaining water concessions and construction permits, as outlined during the data collection, involves multiple authorities and a lengthy bureaucratic process. This fragmentation contributes to significant inefficiencies and opportunities for corruption, as discussed during the interviews, which exacerbates water conflict in the region. Streamlining this system by providing clear boundaries and oversight, as well as implementing more rigorous

barriers for large-scale projects, especially for those situated in aquifers designated as vulnerable by SENARA, can potentially mitigate these issues around construction and water concessions for the residential tourism sector (Cruz et al., 2011).

The existing process for obtaining water concessions and construction permits involves interactions with several entities from the institutional framework, including the municipality, MINAE, the AyA or ASADAS, with decisions being informed by data made available by SENARA. Each of these bodies has its own set of requirements, procedures, and timelines, leading to a cumbersome process with little transparency. This complexity not only frustrates applicants but also provides fertile ground for corruption and inefficiencies, as is apparent to most interviewees and residents. Instances were referred to as large-scale luxury housing projects for residential tourists. An example would be NUMANDI near Playa Avellanas, where 80 luxury homes are being constructed in an area that has been indicated by SENARA as having a medium risk of groundwater vulnerability (Briones, n.d.; Engel & Volkers, n.d.). This entails that the aquifer is at a higher risk of being contaminated. As other risks are not actively monitored in areas outside of Tamarindo by most institutions, such as the risk of flooding or severe water scarcity, such assessments need to weigh more heavily in decision-making for water concessions or construction permits. Figure 13 shows this vulnerability assessment, as well as the location of NUMANDI, encircled in red.

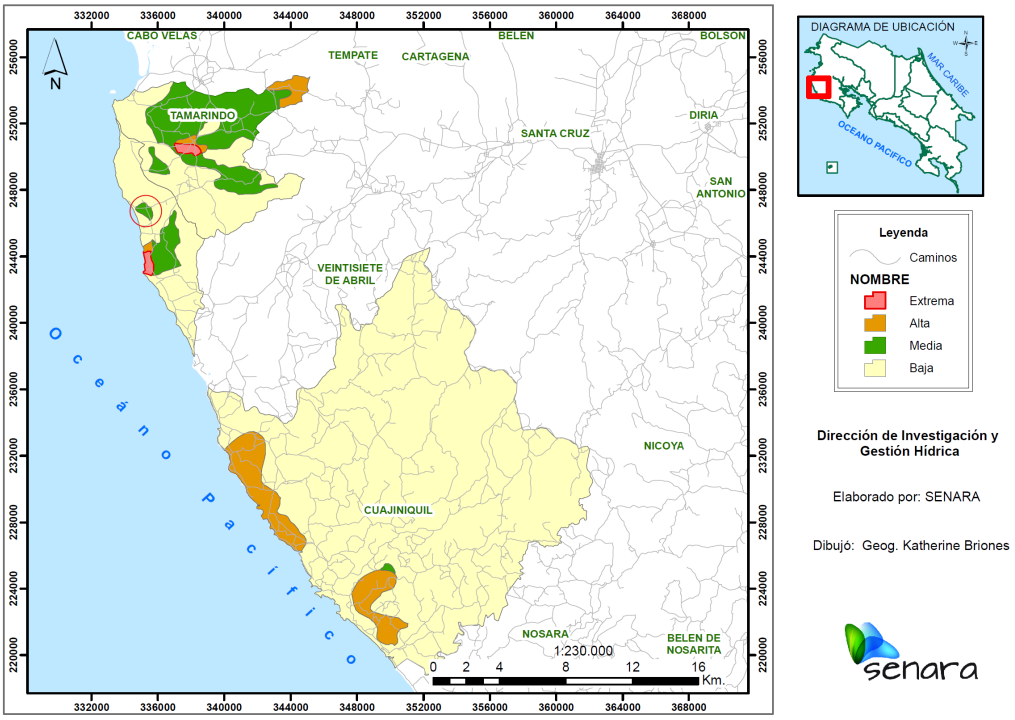

Figure 13: Vulnerability map of Santa Cruz coastal aquifers (Adapted from Briones (n.d.)

A key recommendation to address these challenges is the consolidation of all responsibilities related to giving water concessions into one body. This centralization could streamline the approval process, reduce bureaucracy, and enhance accountability as concessions were said to come from the ASADAS, AyA and some ministries, depending on the scope and location of the project. As the municipality conducts environmental assessments before construction, responsibility for the permits remains with this entity. There are, however, not enough resources available to maintain oversight over all construction projects to monitor compliance continuously. Additional resources should be allocated to municipal authorities for the

verification of building plans, ensuring that adequate scrutiny is applied during the approval and implementation process. The responsibility for periodic assessments of water quality at construction sites should be placed with the constructing entities themselves, with the ASADAs or AyA, whichever administers water in the project area, conducting audits and providing oversight of these assessments to ensure compliance. This distribution of responsibilities acknowledges the resource constraints faced by the public sector while maintaining rigorous standards for water management and construction practices (N. I. R. Thomas & Costa, 2017). It also aligns with the ideal of decentralization upon which ASADAS were founded. To further protect water resources, it is crucial to implement barriers for large-scale projects, particularly those that pose medium or higher risks as identified by SENARA. Projects such as NUMANDI, often involving significant water consumption and potential environmental impacts, require meticulous scrutiny to prevent over-extraction and degradation of water sources. Public participation and stakeholder engagement are also essential, as involving local communities and other stakeholders in the decision-making process can enhance the legitimacy and acceptance of large-scale projects. Currently, this acceptance is absent from community members of the study area.

In terms of combatting corruption, measures must align with national governance reforms on the topic and involve political support. Homogenous responses should be avoided since not all measures are certain to fit the water sector's specific needs (Stålgren, 2006). To recount the findings of Stålgren (2006) on corruption in Latin American water sectors, recognising corruption as a systemic issue rather than individual greed is crucial, requiring preventative measures instead of reactive responses. Building comprehensive networks across all levels of society and governance is essential, as no one involved in the process of permits and concessions should be deemed immune from corruption. Efforts should prioritise the needs of rural and marginalised communities, such as in the study areas, who are most affected.

7.3 Strengthening community-based water management and subsequent adaptation

As outlined by Reid et al. (2013), strengthening the community-based water management system can result in community empowerment and improve the effectiveness of bottom-up initiatives. To that extent, for each of the design principles for which data was collected, methods of strengthening community processes and the relevant institutions will be suggested in this section. These are based on the interviewees' insights and the literature reviewed for this research and aim to complement SQ3. First, boundaries between rural ASADAS are not always clearly defined, at times impacting the quality of potable water in the most remote communities. Assessing the existing capacities of ASADAS first allows for tailored management plans suited to each area's needs, instead of continuously trying to improve capacities in a one-size-fits-all manner (Anderson & Mehta, 2013). This approach ensures that water management is localised, reflecting the specific capabilities and resources of each ASADA and aiding the drawing of clearly defined boundaries. This division can improve water distribution efficiency. It also enables better monitoring and maintenance systems, ensuring the availability of water services to all.

Restricting water usage in the dry season from rainwater for non-WASH activities, such as watering gardens and filling pools, is an effective way to conserve potable and public water. This measure can be particularly impactful during dry seasons when water scarcity is most acute. By promoting the use of alternative water sources for non-essential purposes, or the installation of rainwater-harvesting infrastructure, communities can significantly reduce the strain on the primary water supply, groundwater. Such measures can be supported by public awareness

campaigns and incentives for installing rainwater harvesting systems, which align with principles of public participation and mobilisation. The fact that these measures are already being promoted by NGOs, and implemented by some community members aware of the recurrent scarcity, suggests that these are realistic measures. They would relieve the pressures on the aquifer recharge rates giving it additional time to replenish during the rainy seasons (Hund et al., 2021b; Pérez-Castillo et al., 2013; Zhen-Wu, 2010).

To increase representation, it is crucial to ensure that all stakeholders, including marginalised groups, are involved in decision-making processes. This can be achieved through more frequent member meetings and transparent elections for ASADA board members, to provide more opportunities to engage besides merely through social media. Education initiatives as suggested by interviewees can increase the involvement of underrepresented stakeholders and subsequently empower underrepresented groups, ensuring their voices are heard. This principle of empowerment enhances the legitimacy and effectiveness of water management practices, as decisions would reflect the diverse perspectives of the entire community.

Starting with coastal areas and those communities with a negative water balance, a comprehensive assessment of the water levels in aquifers year-by-year is essential. Sharing this information freely among different bodies fosters transparency and informed decision-making, as well as the collaboration that is currently missing between institutions. Community-based monitoring, supported by social systems like community WhatsApp groups, ensures real-time data collection and local engagement. This aligns with principles of communication and information dissemination, as well as public trust and legitimacy, as it promotes transparency and empowers communities with critical information (Bernedo Del Carpio et al., 2021b). Additionally, interventions could focus on utilising funds for technological solutions such as remote sensing. As Costa Rica is highly dependent on its groundwater for the water-food-energy nexus, investments could be made in this increasingly accurate field (Adams et al., 2022; Ibrahim et al., 2024).

Implementing exponential fines for illegal water usage and limiting water usage from private wells during dry seasons can effectively reduce water misuse (Klassert et al., 2023; Oljaca et al., 1998). These measures incentivise compliance and deter over-extraction, as the current measures in place do not sufficiently disincentivise illegal usage at, for example, construction sites. Monitoring and enforcement by local administrators, instead of fines only being given by the AyA, can ensure adherence, supported by clear communication about regulations and consequences.

By shifting oversight to district and municipal levels instead of relying solely on AyA, local responsiveness in conflict resolution can be enhanced. Local authorities are often more familiar with community-specific challenges and can implement tailored solutions more efficiently. This approach promotes co-management, as local governments could work closer with ASADAS. It would benefit communities, however, to address conflict during assemblies as well, as such mobilization was found to increase the satisfaction of local stakeholders (Kuzdas et al., 2015; Kuzdas et al., 2016).

Enabling ASADAS to create associations such as the ORAC without needing AyA recognition encourages inter-ASADA collaboration. This can foster knowledge sharing among ASADAS, enhancing overall water management. Collaboration with other institutions can also be more effective without bureaucratic delays due to the plethora of ASADA representatives currently

present in the Santa Cruz canton, making collaborative consultations cumbersome at times. The right to organisation can be strengthened in this respect.

7.4 Limitations

A few limitations, that were previously delineated in the research framework, need to be reiterated. This research relies heavily on qualitative data from interviews, as many insights were gained from these. Some perspectives, such as the non-human perspectives present inside the community-based system, were omitted in this. Whilst there are NGOs in the study area advocating for the tropical dry forest ecosystems, matters such as animal welfare and biodiversity are not as well represented. Due to the nature of semi-structured interviews, a different set of interviewees can therefore lead to different outcomes and findings, making generalisability difficult. The proficiency in Spanish of the interviewer is also not native, meaning that a native speaker might have been able to engage with the interviewees better, or would have been able to ask more in-depth follow-up questions, although no significant issues were encountered during the interviews.

Response bias in interviews could likewise lead to incomplete or overly optimistic portrayals of water management practices. Those involved with the ASADAS or other water management institutions tended to have a more positive outlook on common practices, reflecting this limitation. With more time, focus group discussions that combined insights from interviewees of multiple stakeholder groups could have alleviated some of this bias.

Although the geographic focus on Santa Cruz canton is warranted due to the plethora of problems that converge in the study area, it again limits the generalisability of the findings to other cantons in Guanacaste. Not only because the populations' demographics and socio-economic landscapes differ across cantons, but also because the focus of each municipality has a profound impact on whether investments are made in the water sector or elsewhere, such as was the case in Santa Cruz.

The research captures a snapshot in time, so the relevance of interventions and the frameworks in which they operate may change depending on the timing of data collection. For example, interviewees may have provided different insights pre-Covid or even during the rainy season, as data collection was predominantly conducted during the dry season.

7.5 Future Research

This research has contributed to the extensively researched CBNRM, by applying the Ostrom's (1990) principles to the context of Santa Cruz community-based water resource management. The ASADAS are one of the few examples of institutionalised CBWM, but this framework has been applied to its context remarkably little prior to these insights. Furthermore, parallels between historic hydroelectric projects in Costa Rica and future climate adaptation interventions clarify the need for bottom-up processes to prevent maladaptive outcomes. Finally, and opposed to Ohlsson (2000), it has shown that even in relatively advanced economies such as Costa Rica, the risk of first-order water conflict still exists in the absence of institutional change or climate adaptation.

Future research should expand on the findings and perspectives of this research, and address its limitations. Including a wider range of stakeholders with ecosystem-based perspectives, would provide a more comprehensive understanding of water management systems. Additional perspectives could be added to this research from academics that specialise in ecology or other

natural sciences. This would increase the transdisciplinarity of this research for a more holistic understanding of the Santa Cruz social and environmental systems. Additional insights gained from other cantons in Guanacaste could provide a more holistic overview of how the CBWM in the province could be strengthened. Comparative analyses across Costa Rica's regions would help identify common barriers and enablers of climate adaptation for the national context, and help prevent maladaptive outcomes.

Integrating quantitative data would give more concrete insights into the impact of water scarcity on livelihoods, by for example conducting household surveys. This would also make the standardisation of longitudinal studies more feasible, as qualitative data collection is time-consuming when done in large numbers. As this research was a snapshot in time and predominantly conducted in the dry season, insights might also differ when stakeholders are impacted by other hydrometeorological problems such as flooding. Therefore, more interviews should be conducted during a more expansive timeframe.

Exploring the role of technology in water resource management could reveal new opportunities for improvement of the CBWM system and more concrete applications of technology for monitoring such as remote sensing could be piloted through additional academic research.

8. Conclusion

As the adverse effects of climate change that affect human systems for water management are slowly mounting, regions such as the Santa Cruz canton are facing the consequences. Through climate adaptation, resilience can be built toward the impacts of increasingly extreme hydrometeorological events This research aimed to decrease the existing knowledge gap regarding the specific enabling factors and barriers for climate change adaptation in Guanacaste's community-based systems, and the subsequent social-environmental vulnerability. Addressing these gaps is crucial for developing context-specific solutions for Santa Cruz's rural ASADAS that prevent maladaptive outcomes through excessive coping strategies or the creation of second-order water conflicts. This was done by applying the conceptual framework to several stages of research, most importantly Ostrom's (1990) CBNRM design principles. A systematic literature review was conducted to identify barriers and enablers, and a stakeholder analysis was done to assess previous water sector interventions on the aforementioned principles and water conflict. Finally, water sector stakeholders were interviewed to explore their perceptions and experiences with water scarcity. The aim of which was to answer the following research question:

How can the community-based water management system and its climate change adaptation be improved, for the sector's stakeholders in the Santa Cruz canton of Guanacaste, Costa Rica?

This research has demonstrated that applying design principles to a CBWM system can help identify shortcomings to prevent unintended second-order water conflict or other maladaptive outcomes to climate adaptation.

To answer the first sub-question, the barriers and enablers identified in the systematic literature review were allotted to six categories: governance and institutional, ecological, knowledge and technology, geophysical, socio-cultural, and economic. Examples of enabling factors were secondary forest plantings or community-based monitoring, whilst barriers such as irrigation efficiency and data scarcity were likewise identified. Notably, many barriers can be resolved by leveraging their enabling counterparts. Water conflict in Guanacaste and rural stakeholders' distrust towards water authorities can be reduced by integrating social networks and involving communities in hydrological monitoring, thereby improving user satisfaction.

The semi-structured interviews further highlighted diverse perceptions of water scarcity, influenced by personal experiences, answering the second sub-question. While some stakeholders recall a time when water was more abundant, many now perceive increased scarcity due to (residential) tourism. These pressures have exacerbated existing water problems, leading to issues like service interruptions. Stakeholders' influence over water sector interventions varies, with community members mostly participating in local assemblies having relatively little power and higher-level institutional stakeholders having more substantial influence. The public sector perceives scarcity to a lesser extent, possibly due to playing a key role in interventions.

The third sub-question was likewise answered through the analysis of interview data and assessed further in the discussion. Clear boundaries between rural ASADAS are crucial for water quality in remote areas. Restricting non-essential water usage in the dry season to rainwater can conserve potable water, supported by education campaigns. Ensuring representation in decision-making processes through inclusive forums and transparent elections enhances legitimacy. Comprehensive, annual assessments of aquifer levels, especially in coastal and

water-stressed areas, promote both transparency and collaboration between the various national water management institutions. Implementing exponential fines for illegal water usage, shifting oversight to local levels for conflict resolution, and enabling ASADAS to collaborate with less bureaucratic hurdles are key strategies, whilst maintaining a level of oversight essential for the functioning of ASADAS with limited capacities. These approaches, aligned with CBWM principles, can strengthen Santa Cruz's community-based water management system.

The final sub-question was answered by evaluating two water sector interventions to determine their effectiveness in addressing barriers and enablers of climate adaptation in Santa Cruz, as well as the alignment with CBWM principles. The UNDP project aimed to enhance the technical capacities of ASADAS through community-based and ecosystem-based measures. It focused on governance and technological barriers but lacked clear end-user involvement in, for example, monitoring. SENARA's PAACUME project plans to increase water availability through additional infrastructure, whilst promoting efficient water use. However, it faces challenges in ensuring equitable water distribution. Both interventions adhered partially to community-based water management principles, highlighting the importance of a participatory, bottom-up approach to increase community buy-in. The stakeholder analysis of the UNDP and PAACUME projects in Guanacaste revealed important insights into the beneficiaries and adversely affected groups of these interventions, an exemplary case of how different stakeholder groups can experience water scarcity and its subsequent adaptation.

The literature review, combined with the conducted interviews, also highlights several capacities that can be leveraged. For example, ecological factors can be leveraged by utilising the knowledge of local actors concerning ecosystems, for ecosystem-based adaptation of secondary forests. The emphasis on the importance of hydrologic monitoring also aligns with interviewees' concerns about the lack of accurate indicators for groundwater level, yet another barrier that was mentioned in both the literature and interviews. Streamlining water concessions and construction permits, especially for residential tourism, is critical since most conflicts are first-order and about resource access, in contrast with the literature. The current complex process for permits and concessions contributes to inefficiencies and corruption, particularly for large-scale projects like NUMANDI. Recommendations include centralising responsibilities for water concessions, enhancing accountability, and involving local communities and stakeholders in decision-making. Combating corruption requires national governance reforms and comprehensive networks across governance levels, prioritising rural communities.

In conclusion, this research has shown that improving community-based water management in the Santa Cruz canton of Guanacaste, Costa Rica, through climate change adaptation involves applying CBWM design principles and the identification of relevant barriers and enablers. Leveraging enabling factors like community-based monitoring and secondary forest plantings can help overcome barriers. Projects like the assessed interventions, while partially aligned with CBWM principles, highlight the importance of participatory approaches and equitable water distribution. Addressing complex issues like corruption and streamlining water concessions for residential tourism projects is crucial for preventing first-order water conflict. By involving local communities and promoting bottom-up approaches, Santa Cruz can strengthen its community-based water management system and adapt to the challenges it will be facing in the foreseeable future whilst the system gains legitimacy and social equitability. Although water scarcity in the current system was widely recognised, future water availability was not always met with pessimism. As one interviewee aptly put their perspective:

I don't allow myself to think that everything is going to be bad or that there is going to be a [water] shortage. I firmly believe that this can manifest itself, so I really work every day so that the future is prosperous, abundant and full of life and I believe in it. I am an idealistic person. I believe that nature teaches us many things. The planet is not going to die because of the ego of human beings. Saving the earth is the most egocentric thing that can come from a human being because the earth is too gigantic and strong for us little creatures who appeared in the last 30 seconds of an entire hour of the planet's evolution to believe that we are going to kill it.

Perhaps, amidst the many future challenges delineated in this research, the yellow and brown of Santa Cruz's riparian forests in the dry season will once more be predominantly verdant.

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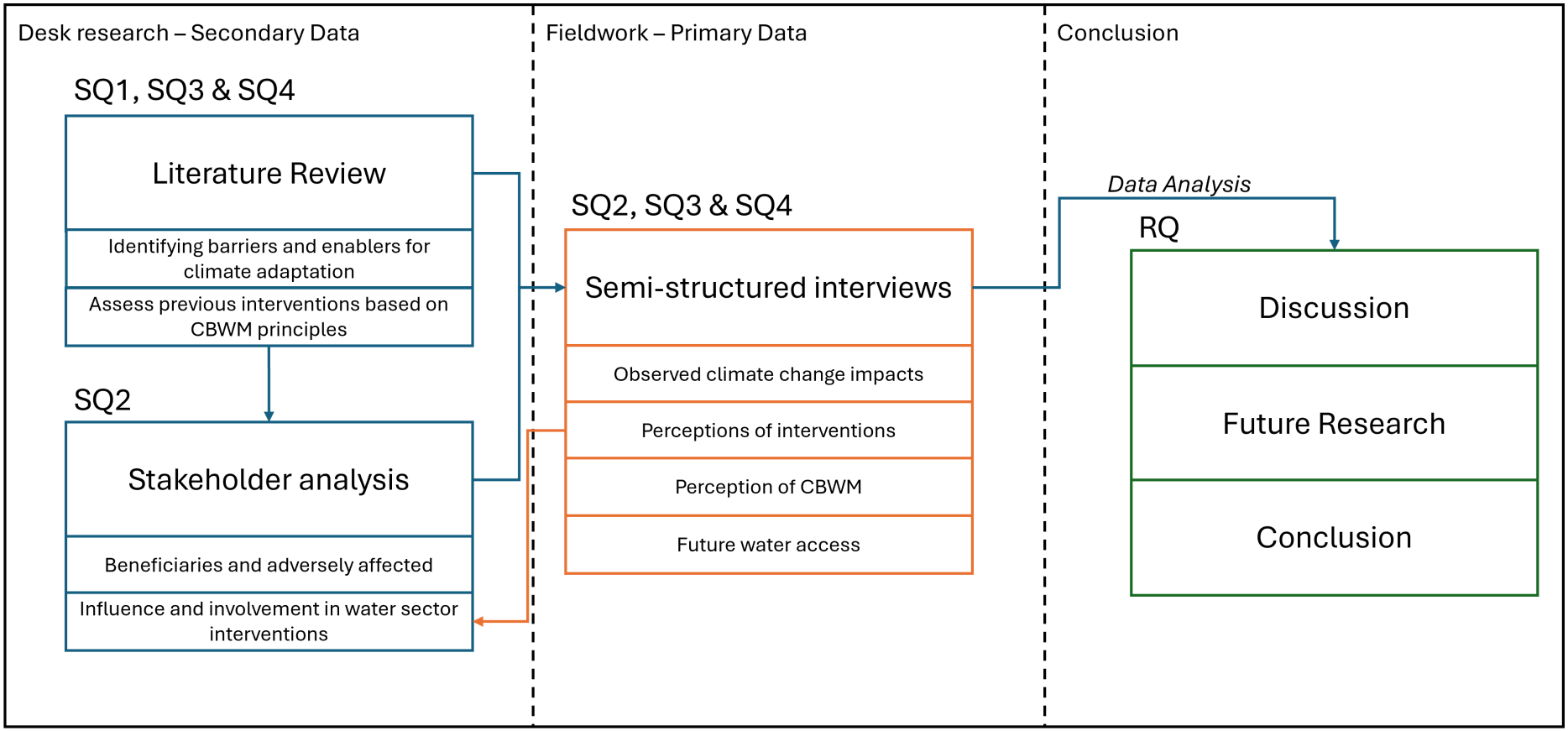
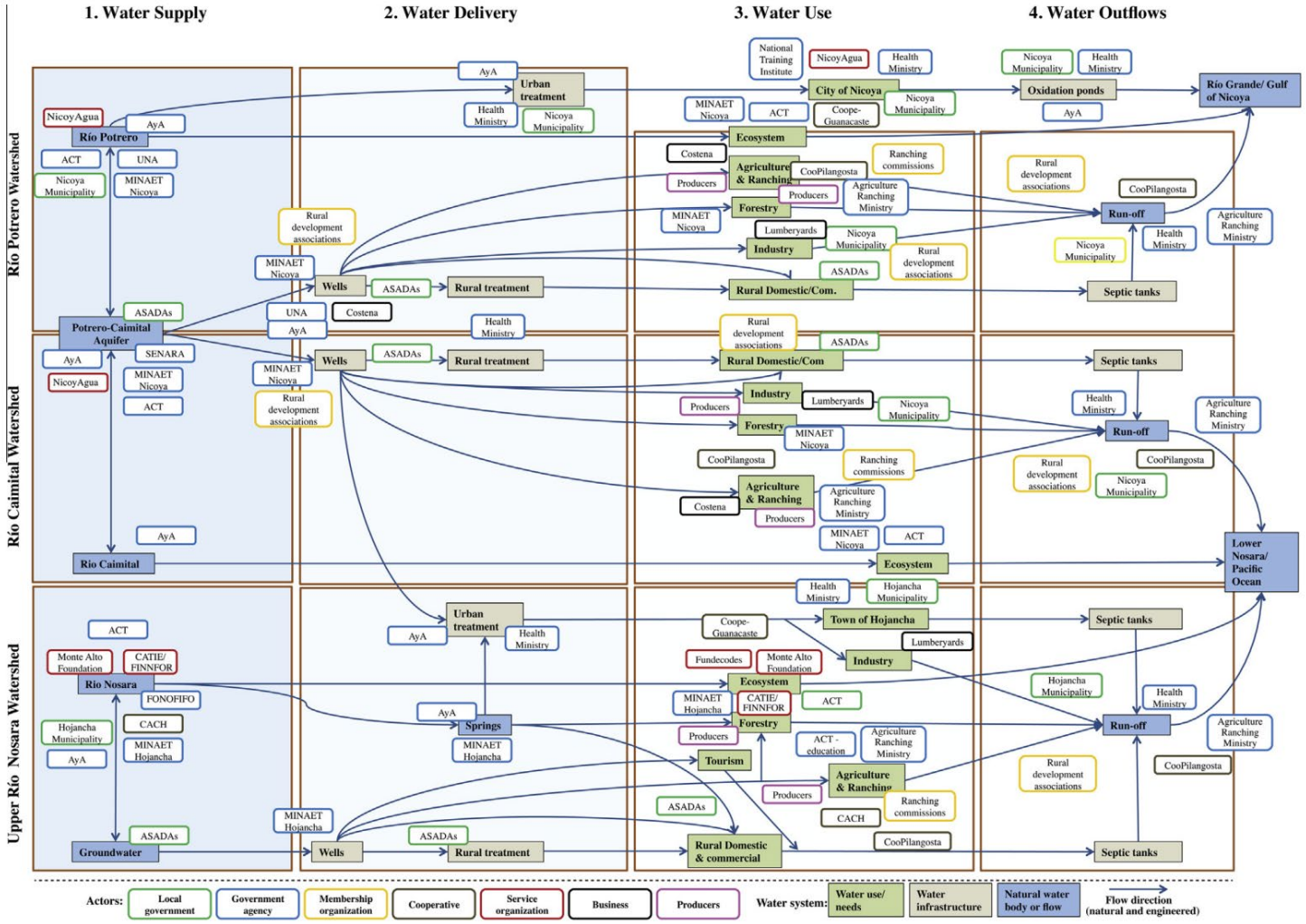
10. Appendices

Appendix A – Research Framework



Appendix B – The combined water system and stakeholder map of Hojancha & Nicoya (Kuzdas et al., 2015)



Appendix C – Interview Guides

Objective:

The objective of these interviews is to understand the respective problems experienced by different stakeholder groups regarding water (scarcity), particularly in the dry season. Do they experience any problems, and if so, what are they and do they have the power to change said situation. What are their experiences with community-based management and the ASADAs and finally, what are their perceptions of future water availability. Hearing the answers to the questions from the respective stakeholders should contribute to answering SQ2, 3 & 4, as well as the main research question. Ultimately these findings should lead to concrete recommendations on how to strengthen the (community-based) water system and its subsequent adaptation, in the Santa Cruz canton.

Introduction:

- Soy un estudiante de maestría holandés en la Universidad de Utrecht. Que apoya a un proyecto de la Universidad para la Paz, relacionado con el agua y el cambio climático en Guanacaste. Decidí apoyar este proyecto sobre la creciente escasez de agua en la región, específicamente en Santa Cruz, y espero proporcionar ideas que puedan ayudar en este proyecto o en su implementación posterior.
- Tendré preguntas sobre usted y las experiencias de su organisación con el agua (escasez), su trabajo en la ASADA/AyA/Municipalidad y proyectos relacionados con el agua, así como también cómo ve el futuro de la escasez de agua en la zona. (Para terminar, empecé aprender español hace un mes para poder hablar contigo y con otros entrevistados, así que a veces podría pedirle a usted que me explique algunas palabras o frases. Y le agradezco sea paciente conmigo por favor.)
- La información de esta conversación es confidencial y si hay algo que no desees que se mencione en el informe final, lo eliminaré del texto. Además, no mencionaré su nombre en el informe final. Por último, me gustaría grabar esta conversación para analizarla más tarde, pero primero me gustaría saber si está de acuerdo con eso. Si no lo está, por supuesto, no lo haré. La conversación tomar alrededor una media hora, más o menos.
- ¿Tiene alguna pregunta antes de que comience la grabación?
- Comenzaré a grabar y primero me gustaría saber si está de acuerdo en participar en esta conversación y si cuento su consentimiento para grabarlo.

Community Members

Opening questions:

1. ¿Puede decirme acerca de usted por favor?
    a. ¿Cuántos años tiene usted? ¿A qué se dedica?
2. ¿Cuánto tiempo tiene usted de vivir en esta área?
    a. ¿Donde vivía usted antes? ¿Su familia vive en esta área también?
3. ¿Qué tanto ha cambiado esta zona en los ùltimos … años,
    a. ej: infraestructura, economía, turismo, entre otros. ?

Experiences with water and impact:

1. ¿Valora usted que en los años recientes exista una escasez del agua en el cantón y o en su comunidad?
    a. Si: ¿Es peor que en el pasado?
    b. No: ¿Es mejor que en el pasado?
2. ¿Cuáles son las incidencias de los servicios de agua, si hay mencione algunas en la comunidad?
    a. Interrupción del servicio, escasez de agua, deficiencia en la calidad de agua, contaminación, mal servicio al cliente
3. Cuales cree usted que son los orígenes de estos problemas o incidencias
    a. Cambio climático, sectores productivos, permisos de construcción, mal manejo
4. ¿Si tiene escasez de agua como afecta a su comunidad día a día?
    a. Altos costos, dificultadas relacionadas a trabajo, problemas al preparar los alimentos, higiene personal
5. ¿Ha habido algunos cambios en la calidad del agua potable, durante los últimos años?

Perceptions of ASADAs:

1. ¿Qué piensa usted del trabajo que realisa la ASADA sobre el manejo del agua en su comunidad?
2. Está de acuerdo con de ASADA/AyA (y su actual manejo del agua)?
    a. ¿Estas a menudo en contacto con ellos? ¿Hay alguna forma de expresar su opinión con ASADA/AyA? ¿Considera usted que ellos proveen un buen servicio?
3. Existen mecanismos para brindar su opinión a la ASADA/AyA sobre los problemas del agua?
    a. En línea, Llamar/Whatsapp, en persona, entre otros
4. ¿Siente que usted y la comunidad están bien representadas dentro de las organisaciones que gestionan el agua en su comunidad?
    a. ¿Están también representadas las generaciones más jóvenes y las mujeres?
5. ¿Cómo se monitorea el uso del agua?
    a. ¿Y hay penalidades por sobrepasar el uso o por mal uso? ¿Hay algún uso ilegal también?
6. ¿Hay alguna vez conflictos sobre el uso del agua en la comunidad/cantón?
    a. Uso ilegal, incendios porque quema de basura, deforestación por agricultura
    b. ¿Cómo se resuelve esto?
    c. Si es así, ¿cómo se resolvería?

Influence/involvement in water-related projects:

1. Usted sabe sobre algunos proyectos de agua relacionados a prevenir o disminuir los problemas antes mencionados
    a. PAACUME, UNDP, Universidad para la Paz
2. ¿Ha participado en proyectos o iniciativas relacionadas con la gestión del agua en su comunidad o cantón?
    a. ¿Podría indicar ejemplos?
3. ¿Usted está dispuesto a participar o a portar colaboración en algunos proyectos de agua en la comunidad o cantón?
    a. Particípate: ¿Qué le podría motivar a participar y o colaborar? ¿Qué rol podría jugar usted? ¿Qué posibles desafíos u obstáculos ve usted para poder participar?
    b.

Perceptions of future access:

1. ¿Cómo piensa usted que será el acceso del agua en el futuro en su comunidad?
    a. ¿En el cantón? ¿Qué tan lejos en el futuro? ¿Algunas otras preocupaciones en el futuro?
2. ¿En su opinión cuales problemas debería ser prioritarios de atender?
    a. ¿Por qué? ¿Porque esto no se ha hecho? ¿A quién responsabiliza por esto?

Academics

Opening questions:

1. ¿Puede decirme acerca de usted por favor?
    a. ¿Cuánto tiempo lleva en la organisación (HIDROCEC)?
2. ¿Puede decirme un poco más sobre (HIDROCEC) su organisación?
    a. ¿Cuál es el propósito? ¿Cómo se relaciona con el tema de agua?
    b. ¿Cuáles son ejemplos de proyectos de investigación recientes? Dado que la SEDE está ubicada en Guanacaste, ¿muchos proyectos de investigación se centran en la región?
3. ¿Qué tanto ha cambiado en Guanacaste (o el país) en los últimos ... años,
    a. ej: infraestructura, economía, turismo, entre otros. ?
    b. ¿Ha afectado eso la perspectiva de la investigación de [organización]?

Experiences with water and impact:

1. ¿Valora usted que en los años recientes exista una escasez del agua en Guanacaste/ el cantón Santa Cruz y o en las comunidades allá?
    a. Si: ¿Es peor que en el pasado?
    b. No: ¿Es mejor que en el pasado?
2. ¿Cuáles son las incidencias de agua, si hay mencione algunas en Guanacaste/Santa Cruz?
    a. Interrupción del servicio, escasez de agua, deficiencia en la calidad de agua, contaminación, infraestructura obsoleta, sobrepoblación.
3. Cuales cree usted que son los orígenes de estos problemas o incidencias
    a. Cambio climático, sectores productivos, permisos de construcción, mal manejo, incendios
4. ¿Cómo ha afectado la escasez de agua a usted o a su organización en el día a día?

a. Más interés por parte de las instituciones/comunidades, mayor carga de trabajo, más proyectos.

5. ¿La escasez de agua afecta por igual a todos los miembros de las comunidades?
    a. Comunidades más afectadas: rurales, agrícolas, de menores ingresos.
    b. Comunidades menos afectadas: desarrolladas, servicios/turismo, mayores ingresos
6. ¿Ha habido algunos cambios en la calidad del agua potable, durante los últimos años?
    a. ¿Cómo ha afectado esto a las comunidades?
7. ¿Qué métodos de adaptación climática ve que se aplican en Guanacaste/Costa Rica?
    a. Racionamiento de agua, educación, aumento de capacidades, reducción de la deforestación

Perception of CBWM:

1. ¿Cómo ve el rol (o el apoyo) de la académica en la gestión de los recursos hídricos en las comunidades?
    a. Participación comunitaria, educación, impacto en la ambiental/salud humana (investigaciones)
    b. ¿Y usted colabora a veces con las ASADAS para ese trabajo?
        i.¿Cómo ve usted el rol de los ASADAS?
            1. Prestación de servicios de agua, administración, mantenimiento de infraestructura, participación comunitaria,
2. Está de acuerdo con la gestión de recursos hídrico actual en Guanacaste (ASADAS/AyA (y su actual manejo del agua))?
    a. ¿Estas a menudo en contacto con ellos? ¿Considera usted que ellos proveen un buen servicio a las comunidades? ¿Ellos solicitan aportaciones del HIDROCEC también?
3. Existen mecanismos para brindar sus perspectivas a las instituciones de gobierno como ASADA/AyA sobre los problemas del agua?
    a. En línea, Llamar/Whatsapp, en persona, entre otros
4. ¿Siente que las comunidades están bien representadas dentro de las organisaciones que gestionan el agua en Guanacaste/ Santa Cruz?
    a. ¿Están también representadas las generaciones más jóvenes y las mujeres?
5. ¿Usted sabe, cómo se monitorea el uso del agua, o el nivel de agua en las cuencas/acuíferos?
    a. ¿Ha tenido algún proyecto de investigación para medir los niveles de agua subterránea de los acuíferos o monitorear los niveles de agua?
    b. ¿Y hay penalidades por sobrepasar el uso? ¿Hay algún uso ilegal también?
6. (¿Hay alguna vez conflictos sobre el uso del agua en las comunidades?)
    a. Leí que HIDROCEC también hace investigaciones relacionadas con disputas por el agua. ¿Ha habido casos similares en Guanacaste?
    b. ¿Con, AyA, otras comunidades, los sectores productivos (agricultura, ¿turismo)? ¿Cómo se resuelve esto?
    c. Si es así, ¿cómo se resolvería?

Power in water-related projects:

1. Usted sabe sobre algunos proyectos de agua relacionados a prevenir o disminuir los problemas antes mencionados
    a. PAACUME, UNDP (Naciones Unidas para el Desarrollo), Universidad para la Paz
    b. ¿Alguno de estos proyectos ha ayudado los objetivos de su organisación?
2. ¿Su organisación ha participado en proyectos o iniciativas relacionadas con la gestión del agua en su comunidad o cantón?
    a. ¿Podría dar ejemplos? ¿Qué desafíos u obstáculos ha enfrentado al participar?
3. ¿Su organisación está dispuesto a participar o a portar colaboración en algunos proyectos de agua en la comunidad o cantón?
    a. Particípate: ¿Qué le podría motivar a participar y o colaborar? ¿Qué rol podría jugar su organisación? ¿Qué posibles desafíos u obstáculos ve usted para poder participar?

Perceptions of future access:

1. ¿Cómo piensa usted que será el acceso del agua en el futuro en las comunidades en Santa Cruz/Guanacaste?
    a. ¿Qué tan lejos en el futuro? ¿Algunas otras preocupaciones en el futuro?
2. ¿En su opinión cuales problemas debería ser prioritarios de atender?
    a. ¿Por qué? ¿Porque esto no se ha hecho? ¿A quién responsabiliza por esto?

NGOs

Opening questions:

1. ¿Puede decirme acerca de usted por favor?
    a. ¿Cuántos años tiene? ¿Cuánto tiempo lleva en la organisación?
2. ¿Puede decirme un poco más sobre su organisación?
    a. ¿Cuál es el propósito? ¿Cómo se relaciona con el tema de agua?
3. ¿Qué tanto ha cambiado en Guanacaste (o el país) en los ùltimos … años,
    a. ej: infraestructura, economía, turismo, entre otros. ?
    b. ¿Cómo ha afectado eso el trabajo de la [NGO]?

Experiences with water and impact:

1. ¿Valora usted que en los años recientes exista una escasez del agua en Guanacaste/ el cantón Santa Cruz y o en las comunidades allá?
    a. Si: ¿Es peor que en el pasado?
    b. No: ¿Es mejor que en el pasado? Z
2. ¿Cuáles son las incidencias de agua, si hay mencione algunas en las comunidades?
    a. Interrupción del servicio, escasez de agua, deficiencia en la calidad de agua, contaminación, infraestructura obsoleta, sobrepoblación.
3. Cuales cree usted que son los orígenes de estos problemas o incidencias
    a. Cambio climático, sectores productivos, permisos de construcción, mal manejo

5. ¿Cómo ha afectado la escasez de agua a usted o a su organisación en el día a día?
    b. Más interés por parte de las comunidades, mayor carga de trabajo, más proyectos.

5. ¿Ha habido algunos cambios en la calidad del agua potable, durante los últimos años?
    a. ¿Cómo ha afectado esto a las comunidades?

Perception of CBWM:

1. ¿Cómo ve el rol (o el apoyo) de su organisación en la gestión de los recursos hídricos en las comunidad?
    a. Participación comunitaria, educación, impacto en la salud humana (investigación)
    b. ¿Y usted colabora con las ASADAS para ese trabajo?
        i.¿Cómo ve usted el rol de los ASADAS?
            1. Prestación de servicios de agua, administración, mantenimiento de infraestructura, participación comunitaria,
2. Está de acuerdo con las ASADAS/AyA (y su actual manejo del agua)?
    a. ¿Estas a menudo en contacto con ellos? ¿Hay alguna forma de expresar su opinión con ASADA/AyA? ¿Considera usted que ellos proveen un buen servicio a las communidades? ¿ Ellos solicitan aportaciones del [NGO] también?
3. Existen mecanismos para brindar su opinión a la ASADA/AyA sobre los problemas del agua?
    a. En línea, Llamar/Whatsapp, en persona, entre otros
4. ¿Siente que usted y la comunidad están bien representadas dentro de las organisaciones que gestionan el agua en su comunidad?
    a. ¿Están también representadas las generaciones más jóvenes y las mujeres?
5. ¿Tu sabes, cómo se monitorea el uso del agua?
    a. ¿Y hay penalidades por sobrepasar el uso? ¿Hay algún uso ilegal también?
6. ¿Hay alguna vez conflictos sobre el uso del agua en las comunidades?
    a. ¿Con los sectores productivos (agricultura, turismo)? ¿Cómo se resuelve esto?
    b. Si es así, ¿cómo se resolvería?

Power in water-related projects:

1. Usted sabe sobre algunos proyectos de agua relacionados a prevenir o disminuir los problemas antes mencionados
    a. PAACUME, UNDP (Naciones Unidas para el Desarrollo), Universidad para la Paz
    b. ¿Alguno de estos proyectos ha ayudado los objetivos de su organisación?
2. ¿Su organisación ha participado en proyectos o iniciativas relacionadas con la gestión del agua en su comunidad o cantón?
    a. ¿Podría dar ejemplos? ¿Qué desafíos u obstáculos ha enfrentado al participar?
3. ¿Su organisación está dispuesto a participar o a portar colaboración en algunos proyectos de agua en la comunidad o cantón?
    a. Particípate: ¿Qué le podría motivar a participar y o colaborar? ¿Qué rol podría jugar su organisación? ¿Qué posibles desafíos u obstáculos ve usted para poder participar?

Perceptions of future access:

1. ¿Cómo piensa usted que será el acceso del agua en el futuro en las comunidades en Santa Cruz/Guanacaste?

a. ¿Qué tan lejos en el futuro? ¿Algunas otras preocupaciones en el futuro?

2. ¿En su opinión cuales problemas debería ser prioritarios de atender?
    a. ¿Por qué? ¿Porque esto no se ha hecho? ¿A quién responsabiliza por esto?

Public Sector

Opening questions:

1. ¿Puede decirme acerca de usted por favor? (y su rol dentro de la ASADA/AyA/Municipalidad)?
    a. ¿Cuánto tiempo lleva en la organisación?
2. ¿Vive usted también en esta área?
    a. ¿Por cuánto tiempo? ¿Su familia también vive en esta área?
3. ¿Qué tanto ha cambiado esta zona en los ùltimos … años,
    a. ej: infraestructura, economía, turismo, áreas naturales, entre otros. ?
    b. ¿Cómo ha afectado eso el trabajo de la ASADA/AyA/Municipalidad?

Experiences with water and impact:

1. ¿Valora usted que en los años recientes exista una escasez del agua en el cantón y o en su comunidad?
    a. Si: ¿Es peor que en el pasado?
    b. No: ¿Es mejor que en el pasado?
2. ¿Cuáles son las incidencias de agua, si hay mencione algunas en la comunidad/canton?
    a. Interrupción del servicio, deficiencia en la calidad de agua, contaminación, infraestructura obsoleta, sobrepoblación.
3. Cuales cree usted que son los orígenes de estos problemas o incidencias
    a. Cambio climático, sectores productivos, permisos de construcción, mal manejo, deforestación
4. ¿Cómo ha afectado la escasez de agua a usted o a su organisación en el día a día?
    a. Mayor carga de trabajo, desafíos técnicos, desafíos de asignación de recursos/financieros (como reparar infraestructura, implementar iniciativas de ahorro de agua o gestionar la distribución de agua en áreas afectadas), relaciones con la comunidad.

Perception of CBWM/ Work at ASADAs:

1. ¿Cómo ve el rol de su organisación en la gestión de los recursos hídricos en la comunidad?
    a. Prestación de servicios de agua, administración, mantenimiento de infraestructura, participación comunitaria,
    b. Es que en colaboración con el ASADA/AyA?
2. ¿Está con el funcionamiento actual de la ASADA/AyA/Municipalidad?
    a. Sí: ¿Será así si estos problemas continúan/empeoran?
    b. No: ¿Qué necesita su ASADA para poder hacerlo?
3. ¿Tienen las comunidades y usuarios oportunidades para proporcionar retroalimentación o aportes a su organisación sobre temas relacionados con el agua también, (o es solamente las ASADAS o AyA)?
    a. ¿Cómo: En línea, por teléfono, en persona, ¿de otra manera?

4. ¿Cómo percibe el nivel de participación y representación comunitaria en los procesos de toma (satisfecho) de decisiones relacionados con los servicios de agua dentro del área/canton?
    a. Participación comunitaria, representación comunitaria, involucramiento comunitario.
5. ¿Cómo se monitorea el uso del agua?
    a. ¿Y hay penalidades por sobrepasar el uso o por mal uso? ¿Hay algún uso ilegal también?
6. ¿Hay alguna vez conflictos sobre el uso del agua en la comunidad/canton?
    a. Uso ilegal, incendios por que quema de basura, deforestación por agricultura
    b. ¿Cómo se resuelve esto?
    c. Si es así, ¿cómo se resolvería?

Power in water-related projects:

1. Usted sabe sobre algunos proyectos de agua relacionados a prevenir o disminuir los problemas antes mencionados
    a. PAACUME, UNDP, Universidad para la Paz
    b. ¿Alguno de estos proyectos ha ayudado a su organisación?
2. ¿Su ASADA ha participado en proyectos o iniciativas relacionadas con la gestión del agua en su comunidad o cantón?
    a. ¿Podría dar ejemplos? ¿Qué desafíos u obstáculos ha enfrentado al participar?
3. ¿Su ASADA está dispuesto a participar o a portar colaboración en algunos proyectos de agua en la comunidad o cantón?
    a. Particípate: ¿Qué le podría motivar la ASADA a participar y o colaborar? ¿Qué rol podría jugar su organisación? ¿Qué posibles desafíos u obstáculos ve usted para poder participar?

Perceptions of future access:

1. ¿Cómo piensa usted que será el acceso del agua en el futuro en su comunidad?
    a. ¿En el cantón? ¿Qué tan lejos en el futuro? ¿Algunas otras preocupaciones en el futuro?
2. ¿En su opinión cuales problemas debería ser prioritarios de atenter?
    a. ¿Por qué? ¿Porque esto no se ha hecho? ¿A quién responsabiliza por esto?

Private Sector

Opening questions:

1. ¿Puede decirme acerca de usted por favor? (y su organisación)?
    a. ¿Cuánto tiempo lleva en la organisación?
2. ¿Vive usted también en esta área?
    a. ¿Por cuánto tiempo? ¿Su familia también vive en esta área?
3. ¿Qué tanto ha cambiado esta zona en los ùltimos ... años,
    a. ej: infraestructura, economía, turismo, áreas naturales, entre otros. ?
    b. ¿Cómo ha afectado eso el trabajo a su organisación?

Experiences with water and impact:

1. ¿Valora usted que en los años recientes exista una escasez del agua en el cantón y o en su comunidad?
    a. Si: ¿Es peor que en el pasado?
    b. No: ¿Es mejor que en el pasado?
2. ¿Cuáles son las incidencias de agua, si hay mencione algunas en su organisación?
    a. Interrupción del servicio, escasez de agua, deficiencia en la calidad de agua, contaminación, infraestructura obsoleta, sobrepoblación.
3. Cuales cree usted que son los orígenes de estos problemas o incidencias
    a. Cambio climático, sectores productivos, permisos de construcción, mal manejo, deforestación
4. ¿Cómo ha afectado la escasez de agua a usted o a su organisación en el día a día?
    a. Menos ingresos (menos visitantes/peores rendimientos), ha afectado la a la satisfacción de sus clientes, mayor carga de trabajo, desafíos técnicos, relaciones con la comunidad.
5. ¿Hace algo para prepararse para la escasez de agua?
    a. Suficiente agua potable (tanques), protocolo para el ahorro de agua, otros.
    b. ¿Qué medidas específicas ha implementado su organisación para conservar agua?
6. ¿Cómo ha afectado la escasez de agua los costos operativos de su organisación?
    a. ¿Ha tenido que invertir en soluciones alternativas, como la compra de agua en cisternas o la perforación de pozos?

Perception of CBWM:

1. ¿Cómo ve el rol de ASADAS en la gestión de los recursos hídricos en la comunidad?
    a. Prestación de servicios de agua, administración, mantenimiento de infraestructura, participación comunitaria,
2. ¿Está feliz con el funcionamiento actual de la ASADA/AyA/Municipalidad?
    a. Sí: ¿Será así si estos problemas continúan/empeoran?
    b. No: ¿Qué necesita su ASADA para poder hacerlo?
3. ¿Tiene oportunidades para proporcionar retroalimentación o aportes a las ASADAS sobre temas relacionados con el agua también?
    a. ¿Cómo: En línea, por teléfono, en persona, ¿de otra manera?
4. ¿Cómo percibe el nivel de participación y representación de su sector (turismo/agricultor) en los procesos de toma (satisfecho) de decisiones relacionados con los servicios de agua dentro del área/cantón?
    a. Participación de sectores, representación de sectores, involucramiento de sectores.
5. ¿Cómo se monitorea el uso del agua?
    a. ¿Y hay penalidades por sobrepasar el uso o por mal uso? ¿Hay algún uso ilegal también?
6. ¿Hay alguna vez conflictos sobre el uso del agua?
    a. Con la comunidad, ASADAS, otros sectores/hoteles
    b. Uso ilegal, incendios porque quema de basura, deforestación por agricultura
    c. ¿Cómo se resuelve esto?
    d. Si es así, ¿cómo se resolvería?

Power in water-related projects:

1. Usted sabe sobre algunos proyectos de agua relacionados a prevenir o disminuir los problemas antes mencionados
    a. En la comunidad/con la ASADA, PAACUME, UNDP, Universidad para la Paz
    b. ¿Alguno de estos proyectos ha ayudado a su organisación?
2. ¿Su organisación ha participado en proyectos o iniciativas relacionadas con la gestión del agua en su comunidad o cantón?
    a. ¿Podría dar ejemplos? ¿Qué desafíos u obstáculos ha enfrentado al participar?
3. ¿Su organisación está dispuesto a participar o a portar colaboración en algunos proyectos de agua en la comunidad o cantón?
    a. Particípate: ¿Qué le podría motivar usted a participar y o colaborar? ¿Qué rol podría jugar su organisación? ¿Qué posibles desafíos u obstáculos ve usted para poder participar?

Perceptions of future access:

1. ¿Cómo piensa usted que será el acceso del agua en el futuro en su comunidad?
    a. ¿En el cantón? ¿Qué tan lejos en el futuro? ¿Algunas otras preocupaciones en el futuro?
    b. ¿Cuál será el impacto para su sector?
2. ¿En su opinión cuales problemas debería ser prioritarios de atender?
    a. ¿Por qué? ¿Porque esto no se ha hecho? ¿A quién responsabiliza por esto?

Final questions:

1. ¿Hay algún tema que discutimos del cual le gustaría volver y desarrollar más?
2. ¿Hay algo más que le gustaría mencionar?
3. ¿Hay amigos, familiares o personas conocidas suyas que también tengan experiencia en estos temas y que podrían estar dispuestos a discutir esto conmigo? ¿Conoce usted un representante de la comunidad, (o de la [organización]) que puedo entrevistar?

Conclusion:

- Muchas gracias por su tiempo y perspectivas. Si está interesado, también me gustaría compartir el informe final con usted.

Appendix D – Codebook

Themes	Sub-themes	Topic	Sub-topic
Perceptions of CBWM			
Perceptions of CBWM	ASADAS		
Perceptions of CBWM	ASADAS	Problems	
Perceptions of CBWM	ASADAS	Role	
Perceptions of CBWM	ASADAS	Satisfaction	
Perceptions of CBWM	Principles		
Perceptions of CBWM	Principles	Collective choice (participation and representation)	
Perceptions of CBWM	Principles	Conflicts	
Perceptions of CBWM	Principles	Conflicts	Conflict resolution
Perceptions of CBWM	Principles	Monitoring	
Perceptions of CBWM	Principles	Right to organization	
Perceptions of CBWM	Principles	Sanctions	
Perceptions of water			
Perceptions of water	Area changes		
Perceptions of water	Water Scarcity		
Perceptions of water	Water Scarcity	Causes	
Perceptions of water	Water Scarcity	Causes	(Residential) Tourism
Perceptions of water	Water Scarcity	Causes	Agriculture
Perceptions of water	Water Scarcity	Causes	Climate
Perceptions of water	Water Scarcity	Causes	Construction & development
Perceptions of water	Water Scarcity	Causes	Corruption
Perceptions of water	Water Scarcity	Causes	Deforestation (fires)
Perceptions of water	Water Scarcity	Causes	Education and ways of living
Perceptions of water	Water Scarcity	Causes	Governance
Perceptions of water	Water Scarcity	Causes	Malmanagement
Perceptions of water	Water Scarcity	Causes	Malmanagement
Perceptions of water	Water Scarcity	Compared to the past	
Perceptions of water	Water Scarcity	Future Access	
Perceptions of water	Water Scarcity	Future Access	Priorities
Perceptions of water	Water Scarcity	Future Access	Responsibility
Perceptions of water	Water Scarcity	Impacts (day to day)	
Perceptions of water	Water Scarcity	Problems	
Perceptions of water	Water Scarcity	Problems	Contamination
Perceptions of water	Water Scarcity	Problems	Infrastructure
Perceptions of water	Water Scarcity	Problems	Livelihoods
Perceptions of water	Water Scarcity	Problems	Outages
Perceptions of water	Water Scarcity	Problems	Overexploitation
Perceptions of water	Water Scarcity	Problems	Quality
Perceptions of water	Water Scarcity	Problems	Quantity
Perceptions of water	Water Scarcity	Solutions	
Projects and interventions			
Projects and interventions	Initiatives		
Projects and interventions	Initiatives	Cooperation	
Projects and interventions	Initiatives	Influence	
Projects and interventions	Initiatives	Involvement	
Projects and interventions	Initiatives	Willingness to participate	