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Commons vs. Commerce – managing water resources between pineapple production and nature conservation

Bien común vs. comercio: gestión de los recursos hídricos entre la producción de piña y la conservación de la naturaleza

Bem comum vs. comércio: gestão dos recursos hídricos entre a produção de abacaxi e a conservação da natureza

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Abstract

Water is pivotal for the growth of pineapple plants throughout their life cycle. In Costa Rica's rural areas, water is often provided as a common good by community-based water organizations (CWOs). Due to their reliance on locally available water resources, they are vulnerable to the water-related actions exerted by other users of their resource systems, such as water contamination through utilization of agrochemicals in pineapple production. In this article, we look more closely at the ongoing spatial fragmentation and the pressure for resource use through pineapple expansion in Costa Rica in the context of the Sustainable Development paradigm. We highlight the resulting consequences for common-pool resource (CPR) systems, exemplified by water contamination for CWOs in the northern Costa Rican canton of Río Cuarto. Drawing on insights from eight semi-structured interviews with different stakeholders, we analyze how the situation affects local CWOs, how these stakeholders address the consequences, and how they strive to improve the situation. We found that the situation accentuates power imbalances between CWOs and powerful private actors, jeopardizing the CWOs' economic viability. However, their proposed long-term strategies may exacerbate water scarcity and resource conflicts. Instead, we argue that effective solutions would comprise regulatory instruments, accountability of the contaminators for their actions, as well as a stronger involvement of CWOs in decision making. Calls for a balanced development model that prioritizes community interests and environmental conservation over economic growth underscore the need for a paradigm shift in national policy frameworks.

Keywords: Community-based water organizations; contamination; pineapple; power; sustainable development; water governance; water.

Resumen

El agua es fundamental para el crecimiento de las plantas de piña a lo largo de todo su ciclo de vida. En las zonas rurales de Costa Rica, el agua suele ser provista como un bien común por organizaciones comunales de agua (OCAs). Debido a su

dependencia de los recursos hídricos disponibles localmente, estas organizaciones son vulnerables a las acciones relacionadas con el agua por parte de otros usuarios de los sistemas de recursos, como la contaminación del agua por el uso de agroquímicos en la producción de piña. En este artículo, analizamos más de cerca la fragmentación espacial en curso y la presión sobre el uso de recursos generada por la expansión piñera en Costa Rica, en el contexto del paradigma del desarrollo sostenible. Resaltamos las consecuencias resultantes para los sistemas de recursos comunes, ejemplificadas por la contaminación del agua que afecta a las OCAs en el cantón norteño de Río Cuarto. A partir de ocho entrevistas semiestructuradas con diversos actores, analizamos cómo la situación impacta a las OCAs locales, cómo estos actores enfrentan las consecuencias y qué esfuerzos realizan para mejorar la situación. Encontramos que la situación acentúa los desequilibrios de poder entre las OCAs y actores privados con gran influencia, lo que pone en riesgo la viabilidad económica de estas organizaciones. Sin embargo, sus estrategias propuestas a largo plazo podrían agravar la escasez de agua y los conflictos por los recursos. Sostenemos, en cambio, que las soluciones efectivas deberían incluir instrumentos regulatorios, la rendición de cuentas por parte de los contaminadores, así como una mayor participación de las OCAs en la toma de decisiones. Los llamados a un modelo de desarrollo equilibrado que priorice los intereses comunitarios y la conservación ambiental por encima del crecimiento económico subrayan la necesidad de un cambio de paradigma en los marcos de política nacional.

Palabras clave: agua, contaminación, desarrollo sostenible, gobernanza del agua, organizaciones comunales de agua, piña, poder

Resumo

A água é essencial para o crescimento das plantas de abacaxi ao longo de todo o seu ciclo de vida. Nas áreas rurais da Costa Rica, a água é frequentemente fornecida como um bem comum por organizações comunitárias de água (OCAs). Devido à sua dependência de recursos hídricos locais, essas organizações são vulneráveis às ações de outros usuários desses sistemas, como a contaminação da água pelo uso de agroquímicos na produção de abacaxi. Neste artigo, examinamos

mais de perto a fragmentação espacial em curso e a pressão sobre o uso dos recursos decorrente da expansão do cultivo de abacaxi na Costa Rica, no contexto do paradigma do desenvolvimento sustentável. Destacamos as consequências para os sistemas de recursos de uso comum, exemplificadas pela contaminação da água que afeta as OCAs no cantão de Río Cuarto, no norte da Costa Rica. Com base em oito entrevistas semiestruturadas com diferentes atores, analisamos como a situação impacta as OCAs locais, como esses atores enfrentam as consequências e como buscam melhorar a situação. Constatamos que a situação acentua os desequilíbrios de poder entre as OCAs e os atores privados influentes, colocando em risco a viabilidade econômica dessas organizações. No entanto, as estratégias propostas por elas a longo prazo podem agravar a escassez de água e os conflitos pelo uso dos recursos. Argumentamos, em vez disso, que soluções eficazes deveriam incluir instrumentos regulatórios, responsabilização dos poluidores por suas ações e uma maior participação das OCAs nos processos de tomada de decisão. Os apelos por um modelo de desenvolvimento equilibrado que priorize os interesses comunitários e a conservação ambiental acima do crescimento econômico ressaltam a necessidade de uma mudança de paradigma nas políticas públicas nacionais.

Palavras-chave: abacaxi, água, contaminação, desenvolvimento sustentável, governança da água, Organizações comunitárias de água, poder

Introduction

Water's pivotal role in agriculture and its significant environmental importance underscore the complex interplay between water resources, farming practices, and the environment (Redman et al, 2004). For example, it plays a key role in supporting the growth of pineapple plants throughout their life cycle. At the same time, water is a socially constructed object that is often subject to competing interests (Alpízar-Rodríguez, 2019). Within this nexus, water is broadly referred to as a common-pool resource (CPR). CPR was identified by Vincent and Elinor Ostrom as a distinct fourth category of goods, in addition to private, public, and club goods (Ostrom & Ostrom, 1977). According to E. Ostrom, a CPR is "[…] a natural or man-made resource system that is sufficiently large as to make it costly (but not impossible) to exclude potential

beneficiaries from obtaining benefits from its use" (Ostrom, 1990, p. 30). Being substractable at the same time, competition over the resource can increase as a result (Pahl-Wostl, 2015). In her seminal work *Governing the Commons* (Ostrom, 1990), she challenged Hardin's *Tragedy of the Commons* (1986), which argued that CPR-regimes would generally result in overuse of the resource. In contrast, Ostrom showed that many examples of successful co-management have and had already existed, especially regarding water (Dobbin, 2013).

For example, in Costa Rica's rural areas, water is often provided as a common good by community-based water organizations (CWOs), known as ASADAs (Associations for the Administration of Aqueduct and Sewerage Systems, Spanish acronym), serving almost 60% of the country's rural population with drinking water (Madrigal-Ballestero et al., 2013). Currently, ASADAs fulfill a broader range of functions beyond merely supplying water to their communities: they play a pivotal role in Costa Rica's water governance framework. Typically, ASADAs depend on locally available water resources, such as groundwater or spring water, making them not only vulnerable to local climate variations (Kuzdas et al. 2015; Suárez-Serrano et al. 2019), but also to the water-related actions exerted by other users of their resource systems. Consequently, ASADAs often emerge as environmental stewards (Monge et al., 2013). For instance, in areas experiencing rapid residential growth, they have undertaken regulatory roles by granting or withholding water-use permits to safeguard aquifers (Cuadrado-Quesada et al., 2018; Cuadrado-Quesada, 2021). Being the most participative mechanism in Costa Rican water governance (Cuadrado-Quesada, 2021; Freshwater Action Network-Central America [FANCA], 2006; Monge et al, 2013), ASADAs advocate for their communities in water-use conflicts. This is particularly evident in the province of Guanacaste's coastal zones, where aquifers face risks such as salinization caused by urban development and tourism pressures (Alpízar-Rodríguez, 2019; Cuadrado-Quesada, 2017; Cuadrado-Quesada, 2022; Stefan et al., 2019). Nevertheless, Cuadrado-Quesada (2022, p. 114) indicates prevailing power imbalances between ASADAs and the public and private sectors, as epitomized by real estate developers and hotels. Similar challenges can be observed in Costa Rica's northern zone, where rural ASADAs are affected by pineapple expansion and activities by influential transnational producers, as this article further explores. In the introduction to this special issue, it became evident that as a reaction to the

surge of the Sustainable Development paradigm, Costa Rica has begun to present itself through an image of *excepcionalismo verde* (Ramírez-Cover, 2020), wherefore it underwent a geographic transformation under neoliberal terms. Creating 'sustainable' protected areas through national parks for natural conservation and the promotion of sustainable tourism on the one hand, and production-oriented exclusive economic zones, such as the ones with intensive agro-industrial activity, e.g. pineapple plantations, on the other hand, resulted in the fragmentation of national space (Herrera-Rodríguez, 2013; León-Araya, 2022; Ramírez-Cover, 2020). Amid these national interests asserted by powerful state and private actors, the needs of local communities are often neglected (Cuadrado-Quesada, 2022). This becomes observable especially in Costa Rica's rural landscapes, where the isolated ecosystems and production systems intersect, with CWOs and their communities being situated within these impact zones. Detailed analyses show that, especially in Costa Rica's northern zone, extensive grasslands and forests have been replaced by expanding pineapple plantations (Fagan et al, 2013). In these areas, pineapple is often cultivated under heavy usage of agrochemicals, which drift into nearby communities, contaminate households and fields, and thus impair not only other agricultural activities, but especially the livelihoods of rural communities (Ballestero & Reyes, 2006; Bower, 2014; León-Araya, 2022). This represents just one of many ways through which "pineapple production creates the conditions of possibility for its own expansion" (León-Araya 2022, p. 109).

In this article, we will look more closely at the effects of the expansion of agro-industrial production systems and the resulting fragmentation of Costa Rican rural areas into zones of either agroeconomic production or environmental protection with a focus on CPR regimes. Through the example of the case of aquifer contamination caused by pineapple cultivation in the canton of Río Cuarto in northern Costa Rica, we highlight power imbalances between state and private actors on the one hand, and local CWOs as entities dependent on intact local resources on the other. Furthermore, drawing from eight semi-structured interviews with local stakeholders, we analyze how these consequences are addressed and how stakeholders seek to improve the situation. By contextualizing the results with the theoretical background to be introduced, we highlight possible improvements to the process of problem-solving applied in the case study of Río Cuarto cantón. Correspondingly, our

objective is to investigate the socio-environmental impacts of expanding pineapple agro-industry on CWOs and the ways in which those impacts are being addressed in the Río Cuarto canton of Costa Rica. More specifically, we aim to:

- Understand the effects of pineapple cultivation and resulting aquifer contamination on local CWOs.
- Analyze how different organizations (state, private, and local CWOs) are responding to these challenges.
- Identify potential improvements to the problem-solving process related to this type of agro-industrial expansion and its environmental consequences.

Our research is guided by the following set of questions:

Q1: How does the expansion of pineapple cultivation and resultant aquifer contamination affect local CWOs?

Q2: How do the involved organizations address the challenges posed by agro-industrial activities?

This article is structured as follows: First, we explain in detail the spatial manifestations resulting from policies influenced by the Sustainable Development paradigm in Costa Rica. Second, we introduce the case study of the canton of Río Cuarto. Third, we explain the approach and methods utilized to examine it. Fourth, we present the results, before fifth, discussing the process of problem action in the context of water governance research. Lastly, we draw conclusions by answering the research questions, formulate actionable recommendations, and cast an outlook for further research.

The sustainable development paradigm's spatial manifestation in Costa Rica

The implementation of the Sustainable Development paradigm often favors economic growth over natural conservation (Barrios-Napurí et al., 2007; Rivera-Hernández, 2017). This comprises the conversion of nature into commodities and services, which is not only promoted as a means of advancement but also perceived

as environmentally benign and sustainable (McAfee & Shapiro, 2010), shifting the focus away from the destructive to the productive outcomes (León-Araya, 2022).

This conversion becomes observable through the resulting transformation of landscapes. Costa Rica, often celebrated as a model for sustainable development, exhibits a complex spatial transformation marked by the interplay of neoliberal economic policies and environmental conservation efforts. The Costa Rican self-portray of excepcionalismo verde is especially focused on the implementation of Sustainable Development in rural areas (Ramírez-Cover, 2020), promoting the country's green image through its national parks, while invisibilizing rural realities of social-ecological conflict (León-Araya, 2022).

From the quick embracement of the Sustainable Development agenda by the Costa Rican governments of the 1980s onwards, degrading and extractive activities have been banned from biodiversity hotspots, while actively endorsing outside of these new National Park areas (Herrera-Rodríguez, 2013). While on the one hand, these conservation efforts safeguard habitats and ecological niches that sustain numerous life forms, this approach has two essential, interlocking drawbacks: First, nature and society get artificially separated (Herrera-Rodríguez, 2013), decoupling social and ecological system components and, thus, threatening natural conservation and impeding resources management, exacerbating societal vulnerabilities (Cumming et al., 2006). Second, natural conservation is limited to certain areas outside of manmade environments, where ecological degradation is often accepted, and can grow exponentially. This is exemplarily observable through the expansion of export-oriented agroindustrial production, such as pineapple plantations (Blanco-Obando, 2020; Consejo Nacional de Rectores [CONARE], 2023; Cuadrado-Quesada, 2018; León-Araya, 2022).

This expansion epitomizes the spatial fragmentation through its numerous environmental impacts, such as deforestation, erosion, and water contamination through the heavy usage of agrochemicals, which, in turn, endangers not only natural ecosystems, but also rural populations (Cuadrado-Quesada, 2018). Furthermore, pineapple production is characterized by its rapid expansion. León-Araya (2022) explains the pineapple expansion through four steps: First, the acquisition of devalued lands. Second, the transition from other agricultural practices

to pineapple production. Third, the creation of dependencies and indebtedness (Acuña, 2006; Rojas, 2006; Solera and Porras, 2017; Valverde Salas et al., 2016). Lastly, pineapple production creates "toxic landscapes" (León-Araya, 2022, p.109), comprising the very circumstances for its own expansion through numerous ways, only one of which is the drift of agrochemicals into neighboring communities, contaminating nearby households and fields, and thus harming other agricultural activities (León-Araya, 2022). In this context, rural drinking water provision by CWOs is similarly threatened.

Relying on the locally available water resources, these organizations are especially vulnerable to contaminating practices of their neighbors. In consequence, CWOs situated in pineapple production intensive areas are threatened to be excluded from access to safe drinking water. This exclusion of one social actor from the ecological system by another actor produces social-ecological conflicts (Blanco-Obando 2020). Accordingly, in the past, ASADAs, as well as environmental and development associations, have taken legal action against pineapple plantations for violating environmental and water laws (Cuadrado-Quesada, 2018). Still, public institutions have failed to solve these conflicts, which is attributed to several reasons: First, the Costa Rican water governance system itself is fragmented, comprising legal loopholes, self-profiling public organizations, poor coordination, as well as unclearly defined responsibilities (Blomquist et al., 2007; Cuadrado-Quesada et al., 2018; Cuadrado-Quesada, 2017; Kuzdas et al., 2015; Kuzdas et al., 2013). Second, pineapple production is an important source of income for the country, generating approx. $ 806 million of income and 28.000 jobs (Arguedas-Ortiz, 2016). Pineapple producing corporations promise local development and environmental conservation, justified through employment generation and local and national economic dynamism. They present themselves willing to incorporate environmental measures as part of a freely acquired commitment, without recognizing their responsibility within these conflicts (Chacón, 2017). According to León-Araya (2022), this focal shift to economic growth allows plantation owners to present themselves as promoters of development, as opposed to backward-minded opponents, such as community-based organizations. Third, the spatial fragmentation distances policy-makers from the consequences of destructive actions, which fosters ongoing unreflective

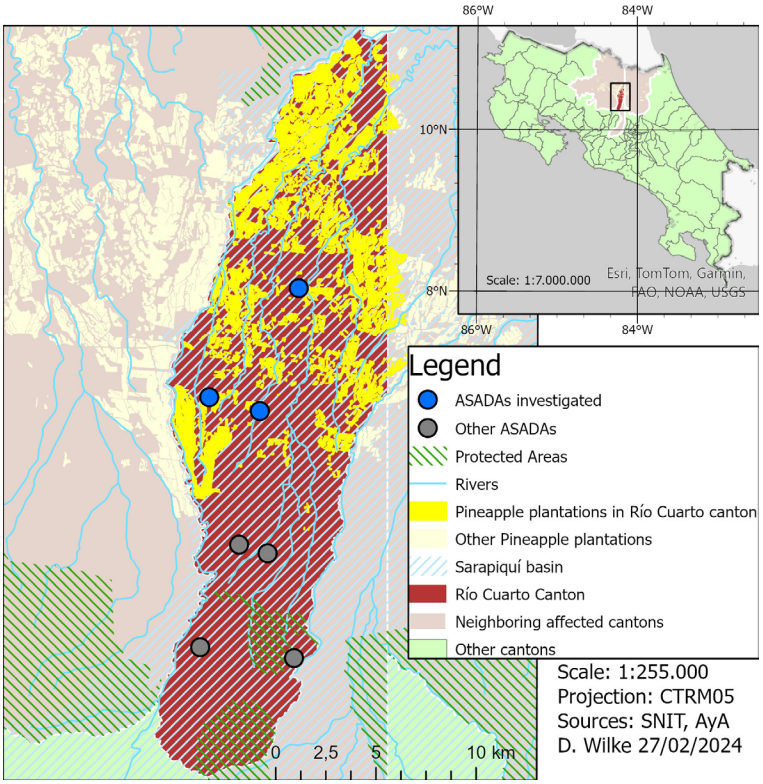
practices instead of public discourse that scrutinizes the desirability of pursuing the objectives implicit in this place-making agenda (Herrera-Rodríguez, 2013).

Río Cuarto Case Study

Our study focuses on the case of drinking water contamination in the canton of Río Cuarto, which became evident in 2018 (Ávalos Rodríguez, 2018; Díaz-Zeledón, 2020; Lara Salas, 2019). Figure 1 shows a map of the canton.

Figure 1.

Pineapple crop distribution map in the canton of Río Cuarto, Alajuela, Costa Rica



Source: own elaboration (2024).

The canton is rich in water resources. Hydrologically, the entire canton is located in the watershed of Sarapiquí river and belongs to the Caribbean drainage slope (Instituto de Desarrollo Rural [INDER], 2024). In the canton's north, vast agriculturally utilized spaces determine the landscape. Agriculture is the activity with the greatest socioeconomic impact in the area and in terms of crops, pineapple is predominantly cultivated (Municipalidad Río Cuarto, 2024). As pineapple significantly influences local economies and land use, territories dedicated to its cultivation often experience transformations in their landscape and land use distribution. Additionally, the socio-environmental impact of pineapple cultivation in these territories is subject to debate, as it can lead to issues such as deforestation, water pollution, and depletion of natural resources (Guevara, 2021).

Drinking water is provided by a total of seven local ASADAs, four of which in the southern, and three in the northern zone (Santa Rita, La Tabla, and Santa Isabel). Since 2016, groundwater contamination in the canton has been documented. Three water sources were affected by the presence of the herbicide bromacil, leading to their disconnection from the Santa Rita, La Tabla-Pinar, and Santa Isabel-San Rafael aqueducts, affecting 13,000 users of potable water (Ávalos-Rodríguez, 2018). Therefore, the ASADAs affected filed a complaint with the Constitutional Chamber, which issued a judgment against six state institutions to initiate cleaning the affected sources. This happened after it was established that all the involved institutions had been aware of risks of contamination for years. According to the Constitutional Chamber, the lack of institutional attention caused a crisis in the drinking water provision in the area due to the deactivation of the contaminated springs (Díaz-Zeledón, 2020; Lara Salas., 2019).

As a result of this action, a figure known as the *Plan Único Interinstitucional* (Single Interinstitutional Plan) was created, within the framework of which various Costa Rican state institutions coordinate their actions in response to water source pollution problems. These actions include field visits by the Health Ministry (MINSA) to take samples from the sources and by the Ministry of Environment and Energy (MINAE) to verify that the protection areas of watercourses and springs are respected, as well as the correct implementation of the environmental commitments by the farms around the affected areas. On the other hand, the Ministry of Agriculture and Livestock (MAG) would

support improvements in agricultural practices and reinforce training and supervision in the use of agrochemicals (Ministerio de Salud [MINSA], 2018). The problem of groundwater contamination has caused a series of measures by the State; however, the responsible party of the contamination has not yet been identified, leading to uncertainty and environmental conflict in the area (Surcos, 2023).

Approach and Methods

We investigated the two research questions introduced within the case study of Río Cuarto canton in Costa Rica's northern zone by applying a qualitative approach. There, we analyzed the process of problem resolution regarding the case of groundwater contamination, focusing especially on three affected CWOs. To do so, we selected relevant community, state, and private actors to interview. Among these, the three affected ASADAs of La Tabla, Santa Rita, and Santa Isabel were crucial. State actors from Costa Rican water governance comprised the Regional Offices of Rural Aqueducts (ORAC), which is the governing body of ASADAs and belongs to the Costa Rican Institute of Aqueducts and Sewerage (AyA), the National System of Conservation Areas (SINAC), which plays a key role in nature conservation, and the Health Ministry (MINSA), which controls water quality for human consumption (Araújo-Resenterra & Umaña-Mayorga, 2021). In order to also grasp a perspective likely to be opposing, we also selected a transnational pineapple corporation that operates plantations in the area. We conducted a total of eight semi-structured interviews the stakeholders. Before conducting the interviews, we created interview guidelines utilizing Hellferich's (2009) SPSS method. The guidelines comprise several open questions along three main parts: Problem Awareness, Problem Action, and Governance. In creating the guidelines, we chose an explorative approach and therefore structured the guidelines as open as possible and only as structuring as necessary (Hellferich, 2009). However, this still allowed formulating questions at the stage of guideline creation (Bogner et al., 2014).

Except for the interview with the ASADA Santa Isabel representatives, which was the only interview with two interviewees, we conducted all of the interviews via video conference. Afterwards, we utilized Whisper AI on the servers of Osnabrück University

(Snoflake Inc., 2025) to transcribe the interview recordings. When reviewing and correcting the interview transcripts, we applied Dresing and Pehl's (2018) rules for semantic content-based transcription. For the analysis, we conducted structuring qualitative content analysis (QCA) according to Kuckartz and Rädiker (2023). Within the first coding cycle, we applied consensual coding under utilization of MAXQDA 2024 (VERBI Software, 2023) in order to improve coding reliability (Kuckartz & Rädiker, 2023).

Regarding limitations of the study, not all of our interview requests got answered, which is why we could not incorporate other relevant organizations, such as MAG and Development Associations. Also, it would have been interesting to involve affected CWOs from neighboring cantons into the study to compare approaches on a cantonal level.

Results

Impact of Pineapple Cultivation on Local CWOs

The qualitative analysis of interviews with various stakeholders in the canton of Río Cuarto sheds light on the multifaceted impact of pineapple cultivation on local community-based water organizations (CWOs). In this chapter, we present the synthesized results based on the perspectives provided by the different actors involved. Due to the diversity of the empirical material, we focus only on the most noteworthy outcomes.

First of all, it is notable that all of the participants, except for the pineapple corporation representative, who identified soil erosion as the primary environmental impact of pineapple production, attributed the problems of water contamination to pineapple production. Though, the ASADA representatives do not identify pineapple production itself, but rather inadequate management practices, such as the inappropriate use and application of agrochemicals as guilty for the contamination issues. Moreover, the encroachment of pineapple plantations into protected areas further compounds environmental concerns, emphasizing the

urgent need for control and regulation to prevent ongoing and future problems associated with water contamination.

Furthermore, the ASADA representatives reflect on the profound social impacts of water-related challenges exacerbated by pineapple cultivation. In the case of Santa Rita, community perceptions have attributed blame to the ASADA for their inability to deliver potable water, and thus, the contamination problems: "[...] y la gente de la comunidad, y la gente del distrito decía, 'es culpa de la ASADA, culpa de la ASADA'" (representative of ASADA Santa Rita, personal communication, February 08, 2024 20). The closure of water sources poses significant economic challenges for ASADAs. In order to keep supplying their communities with water, ASADAs had to raise considerable additional expenditure for buying clean water from neighboring ASADAs, posing substantial risks in their viability: "[...] gracias a eso hubo que hacerle punta al lápiz, porque si no, la ASADA hubiera, hubiera quebrado" (representative of ASADA Santa Rita, personal communication, February 08, 2024, 28). However, the representative also states that this economic limitation increased efficiency of the ASADA, repairing leakages more quickly due to the cost of water. The organizations face pressure to upgrade infrastructure to adapt to the posed challenges in numerous ways. Approaches to connect to clean water sources in the southern part of the canton are especially costly, which, in turn, reinforces economic struggles. Other efforts to address the challenges comprise legal actions against pineapple companies for environmental violations. Still, ASADAs face ongoing struggles to maintain social cohesion and address community needs effectively.

The interviews underscore the complex regulatory landscape surrounding water resource management in the face of private property rights and commercial interests. The dominance of international agricultural enterprises poses a challenge to the communal interest in water resources, exacerbating tensions between private investments and the common good, as stated by the ORAC representative. Regulatory efforts by public institutions are hindered by the intricate web of stakeholders involved, including the state, local communities, and private enterprises. Accordingly, the ASADA representatives express governmental actions to be imposing, rather than supporting, highlighting bureaucratic obstacles. Furthermore, there are concerns about economic repercussions if regulatory actions were to negatively impact local employment

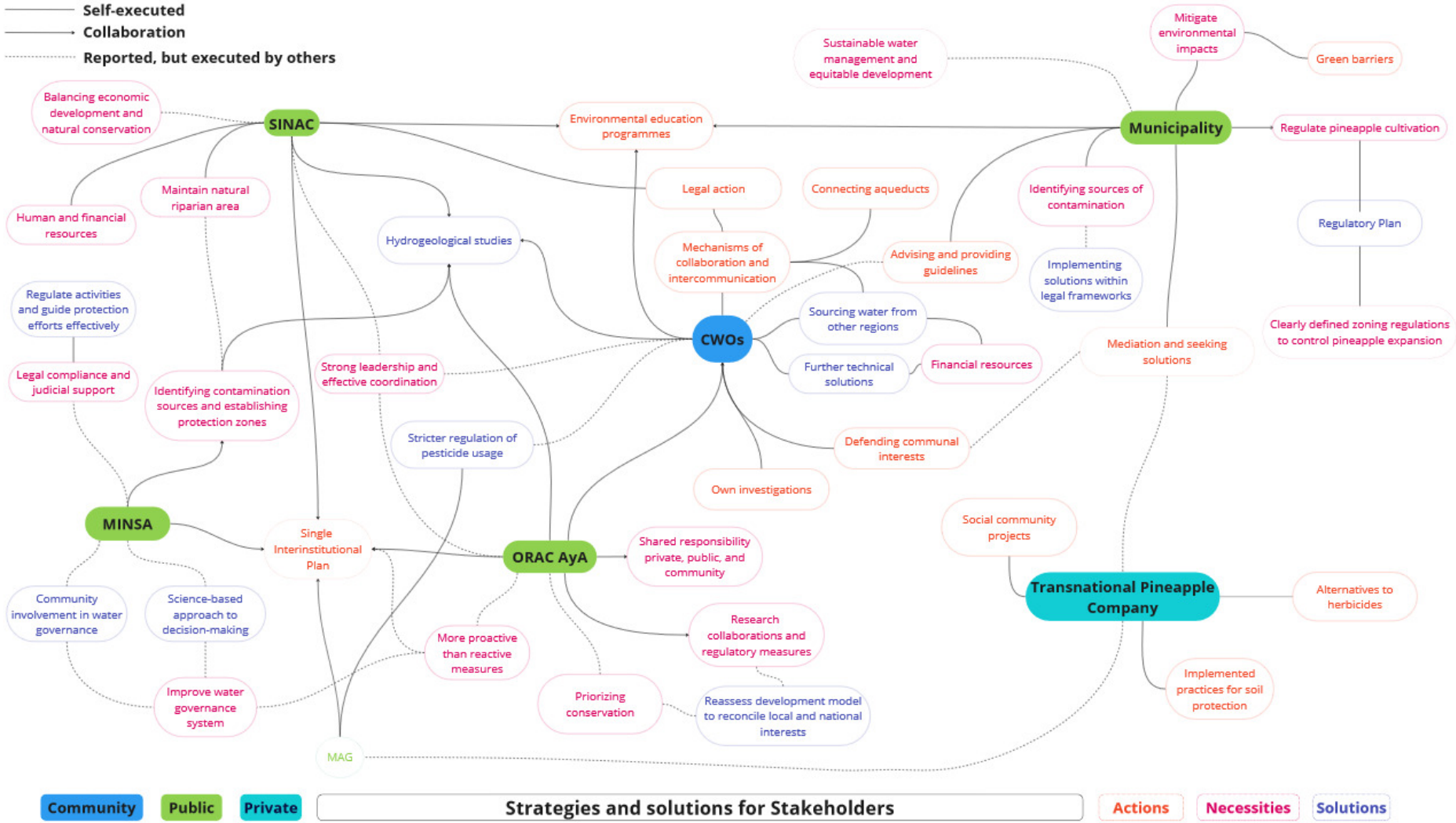
generated by pineapple cultivation. According to the ORAC representative, reconciling these competing interests necessitates a reassessment of the current development model to safeguard local resource management while accommodating foreign investments and alternative economic activities.

Addressing the challenges

In this part, we elucidate how the interviewed actors address the challenges posed by pineapple cultivation to strive for improvement in water management. Furthermore, we analyze the alternative solutions the interviewed actors suggest, as well as necessary improvements to address the problem. Figure 2 visualizes the actions, proposed solutions, and necessities expressed by the interviewed actors in the process of problem resolution. Due to the complexity of the case, however, we will only summarize the most central findings.

Figure 2.

Actions, proposed solutions, and necessities expressed by the interviewed actors in the process of problem resolution.



Source: own elaboration (2024).

Being directly affected by water contamination in the area, ASADA representatives have taken various forms of action, starting from their own investigations of destructive practices related to pineapple production, such as deforestation. Furthermore, the three ASADAs similarly state to have taken joint legal action, filing complaints regarding deforestation and drinking water contamination. In this context, they emphasized having won a writ of amparo against the government. Short-term actions taken by ASADAs to guarantee drinking water supply of their communities include connections of their aqueducts to neighboring CWOs. For long-term problem resolution, they propose technical solutions like sourcing water from uncontaminated sources in the mountainous south of the canton, instead of relying on threatened downstream sources, as in the case of ASADA Santa Isabel. For this, they emphasize the need for sufficient financial resources, attesting a lack of government support. The CWOs have established mechanisms of collaboration and intercommunication. All of the interviewed ASADA representatives attest a lack of governmental oversight over agricultural activities. For example, the Ministry of Agriculture (MAG), should regulate pesticide usage and ensure compliance with environmental standards. The representatives expressed frustration with the perceived neglect of rural communities' water needs by decision-makers. They call for greater awareness and collaboration between municipal authorities and ASADAs to ensure sustainable water management and equitable development.

The municipality representative, on the other hand, states the responsibility of the same municipality to regulate pineapple cultivation and mitigate its environmental impacts. Taken actions include establishing green barriers and community education programs. Within the existing conflict, they see themselves primarily as interveners, offering mediation and reacting to problems. The representative emphasized the necessity of a regulatory plan, as is the case in many Costa Rican cantons, which would allow for clearly defined zoning regulations to control pineapple expansion. They call for interdisciplinary collaboration to tackle the complex issue effectively.

According to the SINAC representative, for its conservation-focused role, SINAC serves as a strategic ally for ASADAs, delivering joint environmental education programs. Stating the problem of contaminated water dwelling into areas designated for natural conservation, they highlight the significance of sufficient research, such as

hydrogeological studies, to delineate aquifer recharge areas and thus, be able to regulate activities and guide protection efforts effectively. They also emphasize the need to maintain natural riparian areas as mandated by law, mentioning other successful experiences in the Río Cuarto area where conservation efforts were prioritized and destructive activities regulated by several government agencies, such as MAG, MINSA, SINAC, and MINAE.

The ORAC representative emphasizes the shared responsibility among private, public, and community-based stakeholders in addressing environmental challenges. The organization's primary role in the conflict consists in supporting and advising CWOs. The participant classifies the establishment of the *Plan Único Interinstitucional* as reactive, and questions decisions taken by the government, obliging AyA to resolve the situation, without any implication for the contaminating actors. Instead, they indicate a need for more proactive measures, such as raising awareness among communities and agricultural actors, research collaborations, and regulatory measures. Most centrally, the participant formulates a need for improved governance mechanisms to harmonize the interests between private property rights and communal right to access to safe potable water. Pointing out the risk of economic repercussions if regulatory actions were to negatively impact local agriculture, they call for reassessing the current development model to reconcile local and national interests.

The MINSA representative highlights the relevance of ongoing collaboration through the *Plan Único Interinstitucional*. However, the interviewee criticizes fragmentation of the national water governance system, lacking a centralized governing body to better integrate the competencies of the three superior water governance bodies, namely AyA, MINAE, and MINSA. Additionally, they proposed strengthening the role of ASADAs and enhancing community involvement in water governance. The representative stressed the importance of hydrogeological studies in identifying contamination sources and establishing protection zones. However, the participant states this to be challenging the past due to resistance from landowners towards fieldwork.

Transversing the statements of all other participants, for the pineapple company's representative, the main environmental impact of pineapple production lies in soil erosion. They state to have implemented practices for soil protection, as well

as alternatives to herbicides for eliminating old pineapple plants. Instead, the representative highlights the company's socially sustainable actions, such as their social involvement in communities through information centers and social community projects through a Fair Trade Association established with their assistance.

Generally, regarding the responsibility to address the problem, most of the actors acknowledge the requirement of collaborative efforts between several governmental organizations. However, some participants see certain organizations as primary coordinators or regulators of problem action, namely MAG or the Phytosanitary Service. Additionally, MINSA and ASADAs call for greater involvement of local organizations in decision-making processes.

Discussion

Based on the empirical results, we can finally answer the first research question 'How does the expansion of pineapple cultivation and resultant aquifer contamination affect local CWOs?' We observed that groundwater contamination through bromacil in the case of Río Cuarto threatens rural communities' water supply (Cuadrado-Quesada, 2018; León-Araya, 2022), producing a social-ecological conflict epitomized by the legal actions of the affected ASADAs (Cuadrado-Quesada 2018; Blanco-Obando, 2020). The community, in turn, blaming their supplier for their inability to guarantee safe potable water, as in the case of ASADA Santa Rita, is an indicator for downward accountability of the provider towards their community (Madrigal-Ballestero et al., 2013; Madrigal-Ballestero & Naranjo, 2015). Also, it underscores the associations' role as defenders of communal interests, as opposed to powerful private and public actors (Cuadrado-Quesada 2021). On the one hand, in contrast to other uses, drinking water supply is defined as a priority in Costa Rica, despite being a Fundamental Human Right (Hidalgo et al. 2019, United Nations, 2010). On the other hand, though, the studied CWOs state a lack of governmental prioritization and support, attributing for the fragmentation of the national water governance framework, which can be exemplified through the absence of a regulatory plan, hindering the municipality to control land use activities (Blomquist et al., 2007;

Cuadrado-Quesada et al., 2018; Cuadrado-Quesada, 2017; Kuzdas et al., 2013 ; Kuzdas et al., 2015).

The situation also threatens the affected ASADAs in economic terms, having to buy water from neighboring CWOs, which, in turn, increases their efficiency in responding to technical failures and strengthens cooperation with other ASADAs. This mutual support of CWOs is crucial for their navigation of the situation. The quick actions taken by the affected ASADAs, rapidly connecting to the aqueducts of neighboring CWOs, indicates a high adaptive capacity of the affected associations (Madrigal-Ballestero & Naranjo, 2015; Pahl-Wostl, 2015). However, the approach the ASADAs choose for long-term problem resolution, namely sourcing water from the mountainous south of the canton, although solving the problem of water contamination for community supply, ultimately decouples the social system from their local resource system and therefore, further exacerbates water scarcity. In the words of León-Araya (2022), instead of preventing the toxification of the ecological realm, the communities adapt for survival in a toxic landscape.

This leads to the second research question 'How do the involved organizations address the challenges posed by agro-industrial activities?' The Interinstitutional Commission consisting of MINSA, MINAE, MAG, and AyA in charge of executing the Plan Único Interinstitucional is criticized to be created as a reactive measure to the contamination situation and prioritizing less contaminated areas. Regarding governmental action, ASADAs criticize the governmental sluggishness, as the referenced water quality studies by University of Costa Rica (UCR) had already been realized in 2015, long before becoming public in 2018. This delay could be attributed to the general fragmentation of the Costa Rican water governance framework (Blomquist et al., 2007; Cuadrado-Quesada et al., 2018; Cuadrado-Quesada, 2017; Kuzdas et al., 2015; Kuzdas et al., 2013), the lack of affectation of policy makers from the consequences (Herrera-Rodríguez, 2013), or the responsible actors trying not to jeopardize the regional economic benefit created through pineapple production, favoring economic growth over natural conservation. This, in turn, would correspond to the growth orientation of the national Sustainable Development framework (Barrios-Napurí et al., 2007; Rivera-Hernández, 2017).

Regarding the stated lack of affectation of governance entities as well as the fact that several participants emphasized the lack of community involvement in water governance, we argue that a stronger involvement of CWOs in decision-making would not only help to secure community interests against the practices of powerful private actors, but also contribute increasing the importance of ecological conservations in governance. After all, CWOs are important actors in national water governance, functioning as communal leaders in socio-environmental conflicts (Cuadrado-Quesada, 2017). Being the most participative mechanism in national water governance (FANCA, 2006), their involvement in decision-making would contribute significantly to democratization of the water sector (Astorga, 2016; Suárez-Serrano et al., 2019). From a regulatory perspective, participants from the public domain expressed the need for instruments for territorial regulation, such as hydrogeological studies, or a cantonal regulatory plan that would allow for defining zones more clearly. Given the youth of the canton, such instruments are still absent (Municipalidad Río Cuarto, 2024). However, delineating aquifer recharge areas would allow for banishing destructive activities from these zones.

In terms of responsibility to address the problem, surprisingly none of the participants attested need for action to the pineapple corporations themselves. However, the ORAC representative criticized that the contaminating actors were not sanctioned for their actions. As pineapple production is an important income source nationally and locally, economic repercussions through the loss of jobs pose a risk for local development (Arguedas-Ortiz, 2016). Instead, the pineapple company's representative highlights the company's contributions towards social sustainability, exemplified through their own Fair-Trade Association and social community projects, presenting themselves as promoters of Sustainable Development (León-Araya, 2022), while avoiding the topic of drinking water contamination. Concludingly, the ORAC representative called for a reassessment of the national development model to balance private and community interests, as well as economic growth with environmental conservation, unlike in the current model (Barrios-Napurí et al., 2007; Rivera-Hernández, 2017).

Conclusion & Outlook

The examination of the spatial mismatches arising from the expansion of pineapple cultivation in Costa Rica, particularly exemplified by aquifer contamination in the canton of Río Cuarto, offers profound insights into the challenges faced by local CWOs and underscores the inadequacies of the current development model and the national water governance framework to tackle such issues effectively.

Water contamination resulting from bromacil use in pineapple cultivation poses a significant threat to rural communities' water supply, highlighting the vulnerability of CWOs to external socio-economic activities. This contamination not only triggers social-ecological conflicts but also accentuates power imbalances between CWOs and powerful private and public actors. The affected ASADAs, as defenders of communal interests, face economic strains due to the need to request drinking water service from neighboring CWOs, as well as, in some cases, blame from their communities for the situation. The studied ASADAs managed to adapt quickly technically and intensifying inter-ASADA collaboration. However, their proposed long-term strategies, namely sourcing water from other areas, may exacerbate water scarcity and resource conflicts.

The results show how the actions of powerful private actors can disrupt CPR management regimes. On the one hand, due to power imbalances, CWOs are limited in their actions upon the problem, while on the other hand, governmental responses fail to address the root causes of contamination promptly. We argue that a stronger involvement of CWOs into decision-making processes would contribute to democratizing the water sector, balancing community and private interests, and increasing relevance of environmental conservation in governance processes. At the same time, the presence of an overseeing ministry would mitigate fragmentation of the water governance framework. Instruments for territorial regulation, such as hydrogeological studies and regulatory plans are essential for delineating aquifer recharge areas and safeguarding against destructive activities. However, we observed an absence of stringent sanctions for contaminating actors and the reluctance to hold pineapple corporations accountable for their actions. While the corporations themselves emphasize their contributions to social sustainability, the

absence of acknowledgment of their role in contamination raises questions about their commitment to environmental conservation. Calls for a balanced development model that prioritizes community interests and environmental conservation over economic growth echo the necessity for a paradigm shift in national policy frameworks. This study exemplifies the challenges faced by community-based organizations in their efforts to safeguard communal interests and natural resources against the destructive actions of powerful actors from diverse sectors. This struggle is a recurring theme in Costa Rica and other countries, where community organizations face similar challenges. Therefore, the study emphasizes the significance of CWOs in protecting resources and contributes to a broader understanding of how to build more equitable and resilient local water resource management systems in the face of increasing water-related threats, with implications for communities worldwide. Further research is required to assess the potential for alternative water management strategies to prove more effective in such circumstances and to identify methods for enhancing the resilience of CWOs in the face of destructive actions by powerful entities through improved governance.

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Supplementary materials

Supplementary material, such as the codebook of the qualitative analysis and high-quality versions of the figures can be downloaded at https://myshare.uni-osnabrueck.de/d/2a93cfcbec5145a1bef9/