



Article

The Types of Water Conflicts in an Irrigation System in Northern Mexico: Conflict as a Negative Link in Social Network Analysis

Ixtoc Marlo Rivera-Nuñez ^{1,*}, Diana Luque Agraz ¹, Arthur D. Murphy ², Eric C. Jones ³ and Martha Alejandra Flores-Cuamea ¹

¹ Centro de Investigación en Alimentación y Desarrollo A.C., Hermosillo 83304, Mexico; dluque@ciad.mx (D.L.A.); martha.flores@ciad.mx (M.A.F.-C.)

² Department of Anthropology, The University of North Carolina at Greensboro, Greensboro, NC 27402, USA; admurphy@uncg.edu

³ School of Public Health, University of Texas Health Science Center at Houston, Houston, TX 77030, USA; eric.c.jones@uth.tmc.edu

* Correspondence: irivera421@estudiantes.ciad.mx

Abstract: We used social network analysis (SNA) to identify the types of water-related conflicts between the users and members of the institutional arena of the Rio Mayo Irrigation District (RMID) within the ancestral territory of the Yoreme Mayo indigenous group in Sonora, northeastern Mexico. We combined ethnography with an analysis and visualization of bimodal networks that consisted of 118 users and their connections to the institutional arena's 30 identified social actors who influence water management. Using a clustering algorithm, we identified four types of conflicts: (1) disputes between small- and large-scale farmers over (i) irrigation water and (ii) payments for water rights and land rental; (2) the struggle by large-scale farmers against the upper level of the water hierarchy, to obtain more water; (3) struggles by rural indigenous women against water providers, to conserve indigenous vernacular systems of managing water for domestic use; and (4) a "conflict" that turned out to be merely a structural remnant of the algorithm. We conclude that land- and water-grabbing in the RMID mainly affect indigenous small-scale farmers and that the combination of SNA and a clustering algorithm can identify the types of natural resource-related conflicts that might go undetected by other methodologies. However, SNA should in some cases be accompanied by a qualitative methodology.



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Keywords: social network analysis; water-related conflicts; indigenous people; Yoreme Mayo; irrigation districts; Rio Mayo; irrigation systems; water insecurity; land tenure; gender

1. Introduction

This study is based upon the following central question: what are the types of conflict between users and actors that influence the water management of an irrigation district in northwest Mexico? Based on social network analysis, conflicts were conceptualized as a type of negative link, and a community detection algorithm was applied to identify the types of conflicts. This information was triangulated with ethnographic fieldwork.

According to the Environmental Justice Atlas ([EJAtlas 2023](#)), 13% of environmental conflicts are directly related to water management. Agriculture is a potential contributor to such conflicts because it uses more water (e.g., for irrigation) than any other economic activity ([United Nations 2023](#)). Thus, it is vital to study conflicts that arise from irrigation systems ([Yacoub et al. 2015](#)).

Irrigation systems have three major components: (i) the physical system, composed of rivers, wells, dams, canals, and other infrastructure; (ii) the users; i.e., the people with access to irrigation for their agricultural plots; and (iii) the institutional arena, including state agencies and/or users' organizations. The institutional arena is charged with maintaining the physical system, distributing water among users, supervising compliance with existing

informal agreements and formal regulations, and resolving conflicts (Ostrom and Gardner 1993). To distribute sufficient clean water equitably year-round among all users, there must be water distribution mechanisms that are considered fair by the users (Trawick 2008). In most irrigation systems, water is a common-use resource available to all users (Ostrom 1990; Trawick 2008).

Users vary in their subjective perspectives, the size and quality of their landholdings, and their capital (economic, social, cultural, and symbolic).¹ Conflicts over access to the irrigation system's water and infrastructure are disputed in the institutional arena.

These conflicts have been investigated via a range of theoretical–methodological approaches. Zwarteveen (2010) used analyses of gender and power/knowledge. Ricart et al. (2019) studied the participation by interested parties in the governance of water. Rocha-López et al. (2019) noted the multiple languages of legitimizing irrigation water rights. Other investigators studied the conflicts through the lens of rural development (Köpke et al. 2019), game theory (Salazar et al. 2007), field experiments with farmers (Janssen et al. 2012), water-grabbing as a form of dispossession by accumulation (Birkenholtz 2016), collective action and socioecological resilience (Hellin et al. 2018), and planned behavior theory (Mohammadinezhad and Ahmadvand 2020).

In this article, water conflict in irrigation systems as a negative link in environmental governance is studied. This approach has rarely been used to study this specific type of conflict or even environmental governance in general (Bodin et al. 2020).

The concept of a negative link—used in social network analysis (SNA)—captures negative judgments, intentions, and/or actions among the parties involved (Harrigan et al. 2019). SNA is a theoretical–methodological tool for analyzing the ways in which agents of a delimited system relate to each other. Social networks consist of nodes (e.g., individuals, institutions, places) and links (e.g., interactions, flows, friendships, and conflicts; Borgatti et al. 2009; Wasserman and Faust 1995). Irrigation systems can be treated as having two distinct types of nodes: users and members of the institutional arena. The links in an irrigation system are of many types and can be positive or negative. Water conflicts are by definition negative. SNA has developed various tools that are suitable for identifying networks of water conflicts among the users of an irrigation system and the members of its institutional arena. For example, algorithms for community detection and clustering can identify underlying groups in the network. More specifically, a community detection algorithm can be used to identify which user profile (i.e., combination of capital, landholding, and perspectives) has a conflict with which members of the institutional arena. In this way, SNA can reveal an irrigation system's structural conflicts.

In this article, SNA was applied in addition to the concept of a negative link to the Rio Mayo Irrigation District (RMID), a common resource irrigation system that has been managed by users for over 30 years. Located in the state of Sonora, in northeastern Mexico, the RMID is part of the ancestral territory of the Yoreme Mayo indigenous group (Luque et al. 2016; Murphy et al. 2022). Sonora divides irrigated lands into irrigation units (IUs) and irrigation districts (IDs) (CONAGUA 1992). Both are managed by the users, but IUs generally have a smaller infrastructure that was constructed by the government and/or farmers and is managed by individuals or small groups. In contrast, IDs have large-scale infrastructures that were constructed by the state under presidential decree and are more formally organized. Like IUs, IDs are managed by the users and are subdivided into irrigation modules.² For these purposes (because of the potential differences between the types and sources of conflict in IDs versus IUs), it is important to note that ID users are more diverse than IU users in terms of ethnicity, class, land tenure, etc. In addition, IDs have more complex institutional arenas—not only because IDs are geographically larger and have more users but also because they went from being state-managed to user-managed in the 1990s (Rap et al. 2004; Wilder and Romero Lankao 2006). Details about the diversity of social actors in the RMID—and how that diversity came to be—are provided by several sources, for example Banister (2015), Lorenzana-Durán (2015), Luque et al. (2016), Murphy et al. (2022), and Rivera-Núñez et al. (2023).

The objective of the present study was to identify the types of structural water-related conflicts that exist among the RMID's different types of users and its various members of the institutional arena. This study goes beyond the topic of irrigation systems, to provide a theoretical–methodological framework for identifying the types of conflicts that occur in the context of managing common-use resources. Additionally, this is one of the few studies to conceptualize conflict as a negative link in environmental governance and one of the few SNA studies that addresses IDs in Mexico.

The remainder of this article is divided as follows. Section 2 describes the socio-environmental history of the RMID. This section focuses on the sociopolitical processes involved in three important developments: the restriction of access to the Mayo River's water; the increasing complexity of the institutional arena; and the formation of a large, diverse group of users, with correspondingly distinct profiles. Section 3 describes the methodology employed. Sections 4 and 5—respectively—present and discuss the results. The final section presents conclusions.

2. The Rio Mayo Irrigation District: The Enclosure of the Commons, Creation of User Profiles, and Evolution of the Institutional Arena

In prehispanic times, the Mayos lived in settlements (later called *rancherías* by the Spanish, who arrived in 1513) along the Mayo River (Doolittle 2015). This river provided material and symbolic conditions for the development of Mayo culture. The Mayo cultivated crops including maize, beans, and squash in soils whose fertility was maintained by the river's periodic flooding. To complement their diet, the Mayo hunted, fished, and gathered. At that time, the territory had little sociocultural diversity or stratification, and the land and river were common-use resources to which the population had free access.

These social and environmental conditions changed after the Jesuits arrived in 1614 (Luque et al. 2016; Radding 2023). The Jesuits introduced new agricultural practices and crops such as wheat and grapes. The populations of the *rancherías* were now concentrated in mission villages, and religious syncretism began. Although the land began to be privatized, and the society became more stratified, the river continued to be a common-use, free-access resource.

During Mexico's colonial period (1521–1821), the economy was based on mining precious minerals such as gold, silver, and copper. The lack of such mineral deposits in the lower Mayo watershed—where the RMID is located—caused that area to be of little interest to the Spanish. Instead, mining took place in the mid-watershed. The large mining fortunes that were made thereby gave rise to a regional bourgeoisie centered in the city of Alamos. The region's ethnic complexity increased at the same time that the native Mayos continually fled the strict rules of the mission villages to earn money working in the mines (Clark-Valenzuela 2016; Cramausse 2012).

When mining decreased in the mid-watershed after the Mexican War for Independence (1810–1821), the bourgeoisie of Alamos diversified their economic activities by investing in the lower watershed's incipient but promising agriculture (Clark-Valenzuela 2016). An agricultural landscape was created by clearing scrubland and constructing irrigation canals (Lorenzana-Durán 2015). By the start of the 20th century, the Mayo River was no longer a free-access resource: close to 20 irrigation enterprises existed, which together had been granted concessions to almost three-quarters of the Mayo River's flow (Banister 2016). The ensuing agricultural boom led to the increase and diversification of the lower Mayo River Valley's population, by attracting mestizos and indigenous people from the mining center of Alamos and the northern region of the state of Sinaloa, south of Sonora.

In the Mayo Valley, as in much of Mexico, socio-territorial transformations resulting from the Mexican Revolution (1910–1917) were not implemented until the presidential administration of General Lázaro Cárdenas (1934–1940; Banister 2015). In 1938, land in the Mayo Valley was redistributed to landless peasants as *ejidos*.³ Many recipients were Mayo families. Cultural diversity again increased as the possibility of obtaining land attracted new waves of migrants from parts of Mexico where *ejidos* had not yet been implemented

(Almada Bay 2009). The majority of *ejido* land in the Mayo Valley was scrubland, which the families cleared to establish agricultural plots. Meanwhile, more canals were constructed to irrigate the new agricultural land.

In 1943, the Mayo Valley was one of the sites of origin of the Green Revolution. The resulting agricultural boom caused the federal government to create the RMID in 1951, including the Mocuzari dam (built in 1955, with a storage capacity of 1286 million m³). One goal was to double the Valley's cultivated surface area from 35,000 to 70,000 hectares (Durán Lorenzana 2019). At the same time, the creation of the RMID led to the enclosure of the commons.⁴ Now, the only parties with access to water within the RMID were those who had land tenure and used the land for agriculture.

The state took charge of delimiting the borders of the RMID and deciding which land would be irrigated, thus determining the membership of the ID. In addition, the state administered and maintained ID infrastructures for almost 40 years.⁵ Together with the *ejidos*, the federal government formed the backbone of the RMID's institutional arena from the mid-1950s to the late 1980s.

More specifically, the RMID was administrated by the state from the district's creation in 1956 to 1988. Then, due to the influence of a World Bank report that advocated decentralization and government divestment or privatization, the federal government began to transfer the management of the RMID to the users (Rap et al. 2004; Wilder and Romero Lankao 2006). The users then organized themselves to form two types of entities. The first was a limited liability company,⁶ in order to obtain the entire concession of the ID, which included 290 km of the network of principal canals, 809 km of the drainage network, and 38 wells. The users also formed 16 groups (called irrigation modules IMs), to which the federal government concessioned 992 km of secondary canals (Distrito de Riego del Rio Mayo 2023). The RMID's institutional arena includes—but is not limited to—these 16 IMs. Within that institutional arena, a previous study (Rivera-Núñez et al. 2023) identified 30 “social actors influencing water management”, to whom we refer hereinafter as “actors in the institutional arena”.

The present-day complexity of the RMID's institutional arena resulted not only from the history described above but also from actions at the federal level during the 1990s:

1. Land reforms: The redistribution of land to peasants⁷ ended by an amendment to Mexico's Constitutional Article 27 (1992) and by the passage of the National Agrarian Law (1992) and its concomitant regulation (1993). *Ejido* members were allowed to sell their landholdings by the Certification Program of *Ejido* Rights and Titles of Urban Lots (PROCEDE, according to its Spanish initialism). As a result of PROCEDE, most *ejido* land in Mexico went from being collective to individual property (similar to private property) which the owners were free to rent or sell (Assies 2008; Torres-Mazuera 2019). Many RMID users—especially the Mayo users—did sell or rent their land, thus in effect dissolving the *ejido* structure (Luque et al. 2016; Murphy et al. 2022).
2. Water reforms: The 1992 National Water Law and its concomitant regulation (1994) treated water as an economic asset subject to market dynamics. These measures made it difficult for indigenous and peasant communities to access water while also permitting water-grabbing by a few companies and individuals (Ávila-García 2016; Gómez-Arias and Moctezuma 2020). For example, in the RMID, the law affected groundwater—private users now own 72 wells, while the RMID controls only 32 wells (Distrito de Riego del Rio Mayo 2023). The appropriation of groundwater increased the inequality of access to water among users, as well as the influence of water-grabbers over the members of the institutional arena.
3. Market reforms: The 1992 North American Free Trade Agreement (NAFTA) put Mexican farmers in direct competition with large-scale United States farmers during a time of low support by the Mexican government to farmers. The results were especially harmful for producers of basic grains. Furthermore, rural lifeways changed as out-migration increased, and the transmission of agricultural knowledge to younger generations was interrupted (Barnes 2009). Out-migration was particularly attractive

to young people in the RMID and not only because of the RMID's proximity to the United States (only 600 km away). Wheat (which accounts for 45% by value of the RMID's harvests (CINA 2021)) cannot be produced competitively under a free market system except in large fields. Therefore, relatively few users in the RMID—principally non-indigenous private property owners—have managed to continue farming (Rivera-Nuñez et al. 2023). The rest are renting out their land.

As a result of the sociopolitical and territorial changes described above, the RMID currently has 11,452 users, 63% of whom have *ejido* land tenure and 37% of whom own private property (CINA 2021). The proportion of indigenous Mayo users is unknown, but seven of the eight traditional Mayo villages formed by the Jesuit missions are within the RMID, and the majority of *ejidos* have at least 40% Mayo users (see Figure 1). The RMID's total surface area is 114,000 ha, 83,510 of which is cultivated. An estimated 90% of *ejido* land (the exact figure is unknown) is being rented out or has been sold to large-scale farmers (Torregrosa and Kloster 2021).

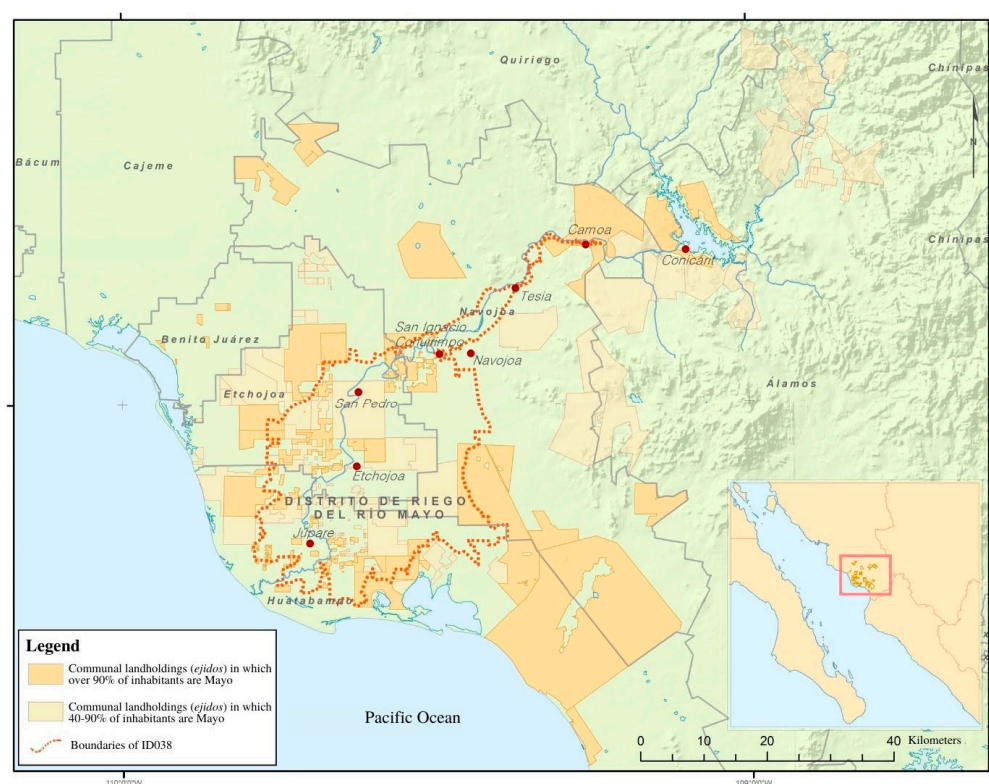


Figure 1. Rio Mayo Irrigation District (RMID), Sonora, Mexico. Red dots indicate traditional Mayo villages founded during the time of the Jesuit missions. Source: (Luque et al. 2016).

Table 1 describes the RMID's principal crops, most of which impact water management. Wheat has the greatest impact; it represents three-quarters of the cultivated area and half (by value) of the agricultural production. Wheat is grown mostly by large producers with more than 500 hectares. Potatoes account for 20% of production and represent 6% of the cultivated area, half of which is farmed by a single family. Celery and pumpkin are grown mainly by one family on less than 1% of the area but contribute (respectively) 1.8% and 1.4% of the economic value. Both of these crops have strict requirements regarding the quality of their irrigation water. Because of such requirements (which are not exclusive to celery and pumpkin), producers exert whatever influence they can in order to obtain the quantities and qualities of water needed by their respective crops.

Table 1. A description of the principal crops grown in the RMID during the 2021 season.

Crop	Cultivated Area (%)	Economic Value (%)	Water Requirement (Thousands of m ³ per ha)	Maximum Allowable Salt Content (ppm)	Size of Producers' Landholdings (ha)		
					Large	Medium	Small
Wheat	74.4	50.8	6.5	1000	4000–500	100–50	10–5
Potato	6.0	29.8	9–10 * 4.5–5	750–800	** 2000	300–50	-
Safflower	6.2	2.3	3	1000	200–100	40–60	20–15
Maize	4.5	3.4	6.5	1000	500–300	50–30	10–5
Bean	2.7	1.6	5	750–800	300–200	60–50	10–5
Tomatillo	0.5	2.3	10 * 4.5	600	150–100	30–20	10–5
Celery	0.1	1.8	* 4.5	400–500	** 150	-	-
Pumpkin	0.5	1.4	8 * 4.5–5	400–500	** 150	-	15–10

* Water consumption when grown with irrigation technology (usually drip). ** Grown by a single producer. Source: Prepared by the authors from [CONAGUA \(2024\)](#) data and field work.

3. Materials and Methods

The methodological strategy for the present study consisted of using social network analysis ([Borgatti et al. 2009](#); [Wasserman and Faust 1995](#)) to conceptualize water conflicts as a type of negative relationship between water users and institutional actors. A bimodal network ([Borgatti and Everett 1997](#)) was designed in which the two types of nodes are as follows: (1) the users and (2) institutional actors that influence water management. The water conflict between any individual user and any type of institutional actor (the latter is not always an individual) constitutes a negative tie or relationship. A community detection algorithm ([Girvan and Newman 2001](#)) was used in network analysis software to generate subgroups to identify the types of water conflicts occurring in the RMID.

3.1. Research Techniques Employed to Gather Data

The present study includes data gathered from March 2021 to August 2022. Figure 2 shows the methodological strategy, which consisted of three research techniques:

1. Six open interviews were carried out with key actors involved in water management. These actors were identified by the researchers as persons who might then be able to identify a sufficient list of members of the institutional arena.
2. A total of 118 structured interviews of RMID users, consisting of two sections. This information was later used to form the user profiles (see Table 2). Additionally, users were asked with which actors in the water institutional arena they had experienced conflict over water in the past two years and whether the conflict was over water for irrigation or for domestic use. These questions allowed for the differentiation between conflicts over the human right to water versus water rights associated with landholdings ([De Albuquerque 2014](#)).
3. Ethnography, in which users and RMID personnel guided the researchers on tours through the study area. In addition, different key actors were interviewed informally.

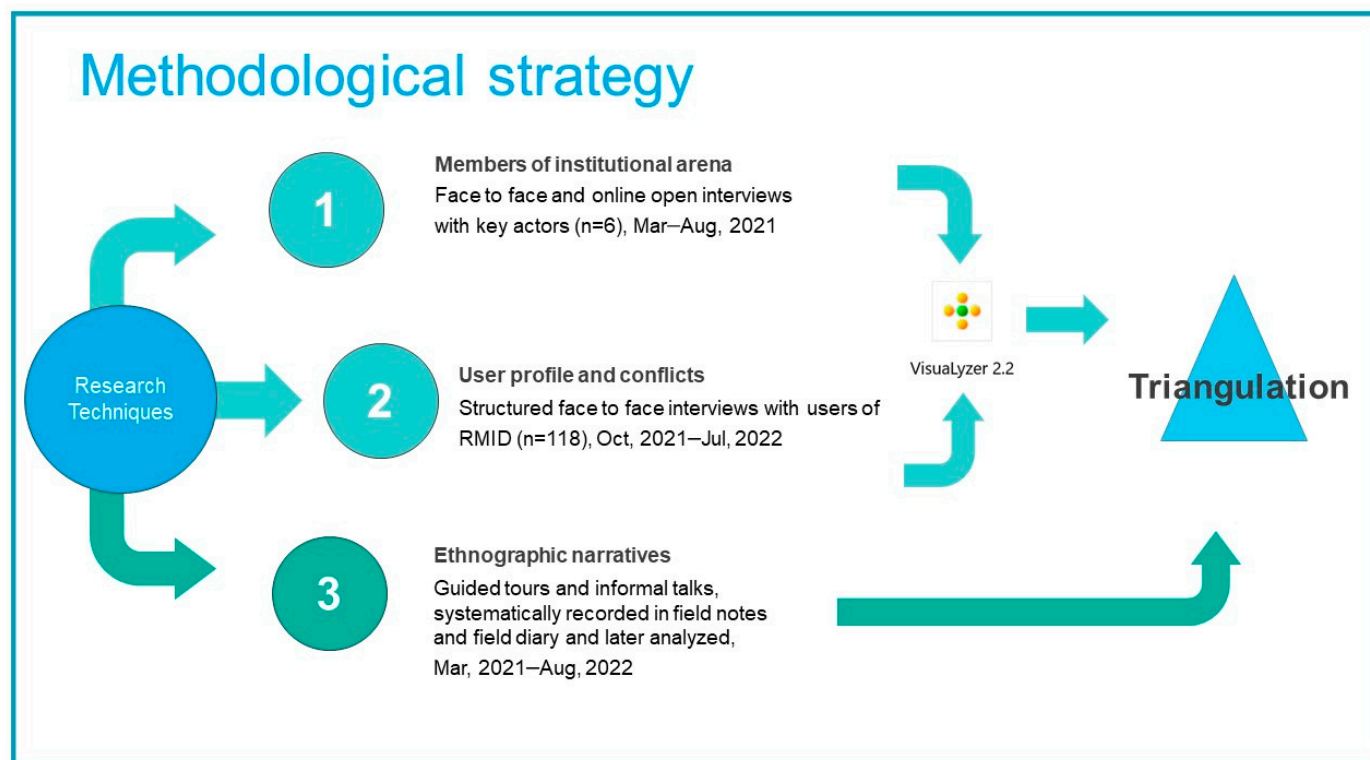


Figure 2. Methodological design for data collection via three research techniques. Source: Prepared by authors.

Table 2. The attributes of users in the RMID.

User Attribute	Description	Type
Gender	Sociocultural construct classifying people based on sexual differences to assign them different roles	Categorical
Formal education initiated	The final level of studies initiated	Categorical
Age	Age group (18–30, 31–45, 46–60, 61–75, 76+)	Categorical
Ethnicity	Self-adscription as a member of the Yoreme Mayo indigenous group	Categorical
Speaker of indigenous language	Ability to communicate in the indigenous Yoreme Mayo language	Categorical
Land tenure	The user's type of land tenure: <i>ejido</i> , private property, or both	Categorical
Land use	How the user uses the land: working it, renting it out, or both (working part and renting out part)	Categorical
Leadership position	Which—if any—leadership positions the user has occupied in the irrigation district or irrigation module or in a credit union, municipal government, state government, or <i>ejido</i>	Categorical

Source: Prepared by authors.

Information gathered via the first two techniques was processed with the Visualizer 2.2 software for social network analysis (MDLogix 2014). Ethnographic data were systematically recorded in a diary and field notes.

3.2. Data Analysis: The Formation of Subgroups Using the Girvan–Newman Community Detection Algorithm

The Girvan–Newman community detection algorithm is based on the concept of modularity (Girvan and Newman 2001). The modularity evaluates how well the network nodes are separated into distinct communities compared to a situation where the nodes would be distributed randomly. It measures the level of division of a network into subgroups—in this case, these would be the users and institutional actors involved in different types of water conflicts. Within each subgroup or type of conflict, the connections are denser, while fewer connections exist between one type of conflict and another. In this study, the Visualizer 2.1 software (MDLogix 2014) was used to form subgroups objectively with a partition level of 4, that is, selecting the algorithm to form 4 subgroups. The resulting modularity was high (0.897); zero is the minimum value, and one is the maximum. A visual examination of the subgroups is necessary to assess whether the subgroups are reasonable, i.e., whether the mathematical solution denotes reasonable subgroups. Selecting more than 4 groups could generate one or two sets of individuals unto themselves in a conflict, which does not help us to understand the patterns of conflict. Each subgroup generated consists of users as well as members of the RMID's institutional arena. To explain each type of water conflict, the following information was triangulated: (1) subgroups formed by the community detection algorithm; (2) the users' sociodemographic data; (3) each institutional actor's role in water management; and (4) ethnographic data (see Appendix A).

4. Results

4.1. Agrotitanes, Overdrafting, Blocks, and Canal Workers

Before describing the types of water conflicts of RMID users, three central topics that emerged from ethnographic fieldwork must be explained to comprehend the context.

First, two types of users may be distinguished, independently of the type of land tenure they possess, which affects their participation in water management: those who work the land and those who rent out their plots. Two RMID users described the two types of users as follows: “The [users] who rent out the land, they don't care about [water management]. They just receive their money [from the renters] without doing anything. And the [users] that do work [the land]—those are very involved in everything [related to water management].” And “The [users] who plant are the ones who have [political] power [over water management]. Those who just rent out [their plots] don't care [about managing water]. They want their full check [from the renters]—that [the renters] don't [invent a reason to] discount them and that's all”.

A second observation emerging from fieldwork is that large-scale farmers of the RMID—locally known as *agrotitanes*—take advantage of the land and water market to consolidate larger holdings into units known locally as “blocks.” *Agrotitanes* rent multiple contiguous plots of land and work them as one large plot, thereby reducing costs. The formation of contiguous blocks also facilitates irrigation—potentially and dramatically because a user who rents 50 separate plots might otherwise receive irrigation water at 50 different times. This can occur because due to the nature of the irrigation infrastructure, the RMID programs the use of irrigation water. For a variety of reasons (e.g., pressure from powerful farmers, poor administration, misuse or theft of water by users, and water loss due to poor condition of infrastructure), this schedule is rarely complied with. Some plots receive less water than promised or receive it too late to salvage their crops. They might also receive lower quality well or drainage water. Therefore, renters form blocks of land in order to be able to irrigate all their plots at once. One *agrotitan* described this practice as follows:

“I just have *ejido* land, but I decided to take the leap and now I plant like 1000 ha. I've formed 4 or 5 blocks: the smallest of 40 [ha] and the biggest 400 [ha] [...] One has to work to maintain the block intact—to obtain plots that are next to each other so it will be more profitable. [...] One has to lobby—be very political to conserve [the block. . .] Working by blocks facilitates everything: transportation,

machinery, expenses. . . but above all irrigation. Once you have irrigation, now you don't let go of it and it's easier to work that way."

A third topic identified during fieldwork is that for many families, renting plots provides their principal source of income. As one user mentioned, "He who has land [an RMID user] is no longer a wage laborer. If he has around 6 hectares, that's enough [to satisfy his economic needs]". Rents range from MXN 6000 to 14,000 (USD 350–820) per hectare per year, and no legal procedure is involved. The economic dependence of many families on renting out their plots leads such families to ask the *agrotitanes* to pay in advance for plot rental, to cover, for example, a family emergency. This phenomenon of advance payment is locally known as "overdrafting" and has been one of the *agrotitanes*' principal strategies for accumulating land.

According to one interviewee, "Here in [one of eight traditional Mayo villages], there are four [users] that have the land controlled. That's how it is. . . [a few users] have money and can rent [land from others]. The inputs are very expensive, and therefore many people can't cultivate anymore [. . .] Here the renter sets conditions; the owner of the land normally doesn't have much in terms of criteria. There are no exact or general dates for paying rent; it's however they arrange it, and almost everyone is overdrafting, as the renters practically take the land away from them [. . .] Before, here no one rented land; it was very rare."

This interviewee refers to the common practice of landowners overdrafting several years' rent, after which the renter often offers to purchase the land, paying the difference between the land value and the overdrafted amount. In this manner, land ownership tends to become more concentrated, as another interviewee explains:

"They take [the land] away from [the owners] like it's nothing. They overdraft them with the rent, and when [the landowners] have a big debt, the rich ones [offer to purchase] and suddenly they've lost their land."

Canal workers⁸ play a prominent role: they are hired by the IM to operate canal gates and bring irrigation water to the plots. They may be fired if they do not act according to the interests of their employers. Canal workers are non-indigenous men from local communities who have formal education in engineering. Despite being prohibited from doing so, they cultivate small plots within the RMID. Canal workers are important to this analysis because they serve as intermediaries between farmers (or their stewards) and irrigation authorities. According to two water users, "Here, a lot of information goes from the bottom up, the Canal Worker is the intermediary" and "you go to the [IM] offices every year and you do see the Canal Worker more frequently". In addition, canal workers take advantage of their contacts by acting as intermediaries in the rental and/or sale of land and water rights (a service for which they charge a commission).

4.2. The Types of Water-Related Conflicts in the RMID

Of the 118 surveyed users of the RMID, 69 (58.5%) said they had not had any water conflicts in the past two years. The remaining 41.5% stated that they had had at least one water conflict during that period. As a whole, these conflicts were with 15 social actors who influence water management (i.e., members of the institutional arena, see Appendix A).

Three of the four types of water conflicts identified by the community detection algorithm appear reasonable and resonate with the fieldwork experience. The fourth was considered to merely be a structural remnant of the algorithm. It is likely that the same groups would not have been identified using only the ethnographic approach (see Figure 3 and Table 3). Below, each of the three "reasonable" types of water conflicts are described.

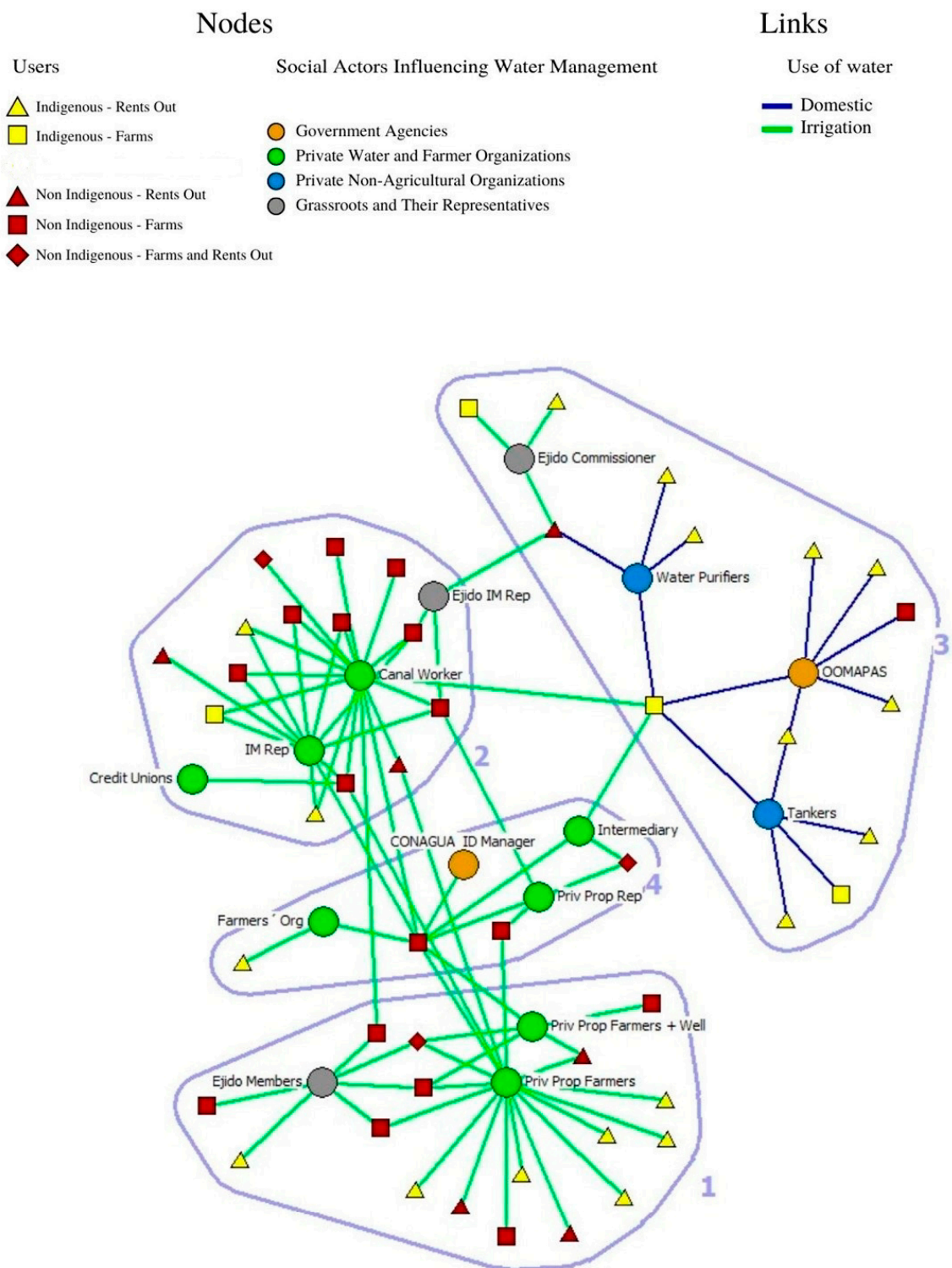


Figure 3. The types of water conflicts in which users of the Rio Mayo Irrigation District, Sonora, Mexico are involved, identified using the Girvan–Newman algorithm (Girvan and Newman 2001). Rents out = rents their land to others who cultivate it; Farms = cultivates their own land. Source: Prepared by authors.

Table 3. Members of the institutional arena (social actors who influence water management) and users with different profiles involved in each type of water conflict in the RMID.

		Subgroup 1	Subgroup 2	Subgroup 3	Subgroup 4
Social actors who influence water management		Priv prop farmers Priv prop farmers + well <i>Ejido</i> members	Credit unions IM Rep Canal worker <i>Ejido</i> IM rep	OOMAPAS Water purifier Tankers <i>Ejido</i> Commissioner	Intermediary CONAGUA ID manager Priv prop rep Farmers' org
Attribute of Users		(n = 17)	(n = 14)	(n = 14)	(n = 4)
Gender	Male	13	12	6	4
	Female	4	2	8	0
Formal education initiated	None	0	0	0	0
	Primary	8	2	7	0
	Secondary	2	3	2	2
	High school	1	1	4	0
	University	5	5	1	1
	Postgraduate	1	3	0	1
Age	18–30	0	0	2	0
	31–45	2	1	1	1
	46–60	7	6	5	2
	61–75	6	7	5	0
	76+	2	0	1	1
Ethnicity	Indigenous	7	3	12	1
	Non-Indigenous	10	11	2	3
Speakers of indigenous language	Yes	4	2	7	0
	No	13	12	7	4
Land tenure	Private property	4	3	1	0
	<i>Ejido</i>	10	8	11	4
	Private property and <i>ejido</i>	3	3	2	0
Land use	Rents out	10	4	10	1
	Farms	6	9	4	2
	Farms and rents out	1	1	0	1
Leadership positions (%)	Yes	5	7	2	3
	No	12	7	12	1

Source: Prepared by authors.

4.2.1. Water Conflict Type 1: “The *peces grandes* (Big Fish) Eat the Smaller Ones”

The parties to this conflict are *peces grandes* (big fish) and *peces pequeños* (small fish), as the people of the region tend to refer to them. The *peces grandes* are three types of water-influencing actors in the institutional arena: private property farmers who own wells, private property farmers without wells, and *ejido* members. These *peces grandes* are *agrotitanes* who cultivate enormous amounts of land under the system of blocks. Meanwhile, the *peces pequeños* are 17 users, with two different user profiles: (i) non-indigenous users (n = 13), with a high level of formal education (five undergraduate and one postgraduate degree) who work their land (n = 7) and have held leadership positions (n = 5); and (ii) indigenous users (n = 7) with a low level of formal education (n = 8 only primary school) who rent out their land (n = 10) and have not have held leadership positions (n = 12).

The first group of *peces pequeños* no longer work their land and interact with the *peces grandes* almost exclusively by renting out land to them. Conflicts between the two have little to do with water management: they are related mostly to the payment of rent, for example, regarding payment dates or how much has been overdrafted. Renting out land has become an intergenerational phenomenon. As one user mentioned, “Many new *ejido* members [who inherit land] don’t even know where their plots are; they just rent them out. The renters make their blocks and [the owner] doesn’t know where the[ir] land is anymore”.

The second group of *peces pequeños* have managed to adapt to changes in policies related to markets, land, and water (see Section 2) and continue to cultivate their land.

Conflicts between this group of *peces pequeños* and the *peces grandes* are related to access to water for irrigation, particularly with respect to timing, quality, and seasonality.

- **Timing:** Water is distributed according to weekly programming. However, *agrotitanes* use their influence to receive water outside of their time slots or for more plots than agreed upon. As one of the *peces pequeños* states, “Some farmers don’t respect their turns and the rest of us have to wait for them to finish watering. They’re very powerful”.
- **Quality:** The highest quality water in the irrigation district comes from the dam. Because there is not enough of this water for everyone, it is mixed with water from wells and drains. The latter source contains wastewater from plots and generally contains agrochemicals which over time lower the quality of the plots. One of the *peces pequeños* explains the following: “There are blocks of 100–200 hectares. When the water gets to us—to those with 3 to 5 hectares [. . .] they want to give us water from the drain, and it just ruins the crops and the land for us. They give us well water with good water and [the well water] is very salty. Once we lost all the tomatillo because of the water. It was \$100 thousand pesos [\$5900 USD] of loss from three hectares of crops”.
- **Seasonality:** Ideally, farmers of the region plant in November, but many users are not provided with water until months later. As one of the *peces pequeños* states, “They give preference to those who have more land and [money]. They skip those who have less land. We [begin to] plant [in] January. [We] have filed complaints, and they don’t get anywhere. We’ve never won”.

4.2.2. Water Conflict Type 2: The Hydrocracy: “The [Irrigation] Modules Are Just Another Middleman That They Set up for Us”

These water conflicts are of greater magnitude than are those of Group 1. They deal with the dates when water is released from the dam, the ID’s compliance with irrigation programming, and the management of private wells. These conflicts involve 14 users with a single user profile and up to four types of actors in the institutional arena: credit unions, canal workers, *ejido* members, IM representatives, and the elected irrigation module representative, who coordinates the entire irrigation module. Due to the role that these institutional arena actors play in managing the RMID, they may be considered a hydrocracy with which few users have contact (Molle et al. 2009; Soler and Roa-Avendaño 2015). The users involved in this conflict have a well-defined profile: they are non-indigenous ($n = 13$) men ($n = 12$) with a high level of formal education (five with undergraduate and three with postgraduate degrees) who work their plots ($n = 9$) and have occupied political positions ($n = 7$). This type of user has sufficient economic, cultural, and social capital (Bourdieu et al. 2001) to file their complaints with the hierarchy of the hydrocracy in order to protect their personal interests. As one user commented, “I went to speak with [the canal worker’s] boss and I filed a complaint so that [the problem] wouldn’t be repeated”. However, the majority of users do not have sufficient skills or connections to file their complaints with the irrigation district or module. Instead, they opt for a passive role. As another user stated, “Don’t even speak to me of that bastard [canal worker]. Because of him, I had to rent out the land this year. He didn’t release the water on time and I had the worst harvest. I ended up losing”.

Below, we provide interviewees’ comments as examples of the hydrocracy water conflict.

- **The date of the release of water from the dam and start of planting:** Because of the region’s desert climate, growers irrigate their land before planting. Each of the region’s wheat and vegetable growers must request from their IM the quantity of water they require and the dates on which they require it. The IM then requests (from the ID) the water for all of the IM’s users. This practice leads to conflicts that are rooted in plant physiology (of vegetables versus wheat) and the realities of providing water via open, unlined canals. For example, the growing season for wheat is longer than

for vegetables, but vegetables require water of higher quality. Vegetable growers have complained that water from wells and drainage canals—which the ID sends to growers once the dam water has been used up—ruins their crops. Therefore—in an attempt to be sure of obtaining high-quality water—vegetable growers pressure the ID to send them water before it is sent to wheat growers. However, once the dam is opened, a certain quantity of water is lost before reaching the crops due to filtration and evaporation. For that reason, sending water to all growers at once is more economical. If vegetable growers are successful in persuading the ID to send them water earlier, the resulting water losses lead to wheat growers being sent poorer quality water—especially toward the end of the wheat’s growing season, when vegetable growers have already harvested their crops. Thus, in contrast to vegetable growers, wheat growers attempt to persuade the ID to open the dam and send the first shipment of water to all growers on the same date. As one *agrotitan* who cultivates wheat says, “Those [who plant] vegetables always go around fighting for them to open the dam earlier, and—well—the wheat growers. . . it’s not in their interests. [The vegetable growers] always exercise pressure”.

- Compliance with irrigation programming: The ID sends water to the irrigation module, which in turn sends it to users, all of which is programmed according to available water. However, many irrigation module managers tend to give powerful users more water than is programmed. Upon running out of water, these managers ask the ID for more, resulting in less water for other irrigation modules. Less powerful users are the ones who are the most affected. As one user who is also a canal worker states, “The irrigation modules should develop strategies to make the water last—to be more efficient, because in the past three years—in which there’s been drought— [users have expressed] a lot of complaints. Something has happened that [the IM and ID] don’t comply with [their] programming. Some modules have water [programmed to deliver to users] and it turns out that the dam has already closed. The irrigation district lacks the balls to say to the [irrigation module administrators], “Your water’s up; face it”, but they don’t leave them without water. They give them more and in the end that water they take away from other [users]”.
- The management of private wells: In previous years, private property owners who also own wells sold well water to users in their irrigation module. However, due to the lack of water, more powerful users in other irrigation modules offered to pay more for that same water, leading to conflicts. Furthermore, the irrigation district allows the owner of a well to send water to powerful users through canals. This practice affects users in the irrigation module where the well is located, by interfering with the delivery of water that is programmed to reach them. As one user points out, “The well is in Navojoa [municipal seat] and the irrigation district helps make it arrive to the user in Huatabampo [municipal seat, 37 km. away]”.

4.2.3. Water Conflict Type 3: Water Insecurity: OOMAPAS versus Vernacular Systems of Water Management

This type of conflict includes all disputes over water for domestic use identified in this study and involves the three types of actors in the institutional arena who are charged with water management for domestic use: the OOMAPAS; a water purifier; tankers; an *Ejido* commissioner (who is also an institutional actor influencing water management); and 14 users. The profile of these 14 users is indigenous ($n = 12$), female ($n = 8$) with a low level of formal education (only 1 with undergraduate degree), possessing *ejido* land ($n = 11$), who rent out their plots ($n = 10$), and who have not occupied political positions ($n = 12$).

Users say that this central water conflict is due to OOMAPAS’ poor service and high fees. The communities have organized to seek alternatives involving self-management, of which two modalities were identified: community wells and artisanal wells. Based on experience elsewhere, as one user commented regarding community wells, “We don’t want OOMAPAS here [in the community]; it charges a lot of dough. The people don’t want it to

come. Here we have a committee to which community members pay for the water every month.” Regarding artisanal wells, as users commented, “Here I have [a contract for water for domestic use with] OOMAPAS, but it never comes, so I put in my well”, and “Here we all have a well like this [manually pumped with a sand filter]. All [community members] use this mechanism. No one uses piped water [from OOMAPAS] because they don’t want to send us water from Huatabampo [the municipal seat]. We use [well] water for everything in the house, but not for drinking; for that we buy [locally] purified water. Before we did drink from this [well water], but it was less salty. That’s why [the community] here is called Pozo Dulce [Sweet Well]. I don’t know what happened that the water began to [decrease in quality]”.

4.2.4. Group 4: Not a Conflict but a Structural Remnant of the Community Detection Algorithm

The Girvan–Newman algorithm forces the creation of groups that do not have an identifiable basis in the real world. It was determined that Group 4 is a structural remnant, and to verify this, the information supplied by members of this group with ethnographic information was triangulated. (Four users have no defined profile, and four social actors have diverse roles.) No type of conflict was found.

5. Discussion

Data regarding negative ties or relationships in general are difficult to obtain from interviewees, and the literature rarely addresses conflicts as ties with respect to natural resource governance (Bodin et al. 2020). Because of the lack of the literature that treats water conflicts as negative links, it was necessary to consult social network studies of other topics. Then, how the principal attributes of users influence the types of water conflicts that exist is discussed. For that purpose, political studies and studies of water conflicts whose authors did not use SNA are referred to.⁹

5.1. A Social Network Analysis of Conflict as a Negative Link

In the RMID, the conflictive ties or relationships between users and the relevant institutional entities follow structural patterns and operate on a system level as well as on an individual level (Bodin et al. 2020). An analysis of the network of water conflicts in the RMID generated four distinct subgroups with an overall modularity score of 0.897—considerably higher than the range of 0.300–0.700 typically used to indicate that the division of a network into four groups is structurally robust (MDLogix 2014).

In environmental governance, the principal factor contributing to the formation of positive links is homophily—the tendency of individuals to interact with others who are similar to them in some way that is considered relevant by the people involved (Bodin et al. 2020; Videras 2013). For example, people who have the same gender, ethnicity, age, or geographic location might tend to think or act similarly regarding a given situation. In society in general, ethnicity is the principal causal factor in positive and negative ties or relationships (Mcpherson et al. 2001). However, this pattern did not hold true in the network of water conflicts in the RMID. Specifically, the influence of ethnic homophily (or its converse) upon the formation of conflictive relationships in the RMID is indirect: it is only one factor in determining a user’s profile and thereby the type of water conflict in which the user becomes involved. As an example of two indirect effects of ethnic heterogeneity, we saw that indigenous users have conflicts in Group 1 related to the rental of their land, while in Group 3, they experience conflicts related to maintaining their vernacular systems of water management for domestic use. In addition, ethnic heterogeneity in water conflicts may be manifested in ethnic social stratification as well as in the localization of information flows (Mcpherson et al. 2001; Rivera-Núñez et al. 2023).

Relations of conflict may either impede or facilitate the implementation of policies. When power is concentrated in the hands of a few users, the consequences for implementing a policy may depend on how well the policy aligns with the interests of that small group of

powerful users (Brockhaus and Di Gregorio 2014). For example, in Group 1, the *peces grandes* (*agrotitanes*) readily implemented neoliberal reforms because the reforms gave *agrotitanes* opportunities to increase their profits by accessing more land and water. Although the *peces pequeños* understood that they would be harmed by the reforms, many *peces pequeños* decided not to enter into open conflict with the *agrotitanes*. This decision may be attributable to the *peces pequeños*' recognition that the *agrotitanes* had powerful allies as a result of having occupied political or leadership positions in the municipality, *ejido*, RMID, or IM. As Campbell et al. (2018) mention, the possibility of the enemy having powerful allies considerably influences people's decision to not enter into open conflict.

Group 3 is an example of how the structure of the system can be conducive to conflict if it requires a person to work with others whom he or she considers incapable or irresponsible (Bodin et al. 2020). Specifically, users in Group 3 responded to OOMAPAS's perceived inadequacies by opting for an alternative system to manage water for domestic use. This work-around reduces structural interactions, but a water conflict may still occur.

The increased scarcity of a needed resource may increase mutual support and cooperation among users (Basurto et al. 2016). In the RMID, the scarcity of water increased cooperation among large-scale farmers who—in order to work under the system of blocks—tend to exchange rented land, in some cases without the consent of the owner. As one large-scale farmer commented, “Sometimes among [farmers] we negotiate to complete our blocks and be able to work better”.

The results bear out Boucquey's (2016) observation that conflicts between actors do not need to hinder the actors' adoption of mutual agreements. For example, although (as mentioned above) the users in Group 3 would not allow OOMAPAS to supply the users' communities with water for domestic use, the users succeeded in demanding that OOMAPAS and tankers provide water when the communities' water pumps fail. Nevertheless, the party that wields more power typically obtains greater benefit from the conflict. For example, in Group 1, the *agrotitanes* and the users who rent out their plots agree on dates for the payment of rent, and—as explained in Section 4.1—the *agrotitanes* take advantage of this conflict to take ownership of the plots through the repeated reliance of landowners upon overdrafting when renting out their land.

5.2. The Influence of User Attributes on Water Conflicts in the RMID

5.2.1. Ethnicity

The RMID—which the state created to promote agroindustry—is markedly different from the indigenous vernacular irrigation system that dates back to prehispanic times. The principal difference is that RMID users do not have formal local organizations; rather, they merely elect representatives by vote (Palerm Viqueira 2020). The absence of formal local organizations along with the agroindustrial orientation of the RMID have reduced Yoreme Mayo participation to simply voting as individuals, leaving them with almost no collective influence as an indigenous people even though they inhabited the territory before formation of the nation-state.

The Yoreme Mayo users are involved in Group 1-type conflicts with the *agrotitanes* over the rental of Mayo lands and in Group 3 type conflicts with actors in the institutional arena who provide water for the Mayo's domestic use. As described above, the Group 3 conflict resulted from the Mayo opting to use their vernacular systems of water management for domestic use. Modifications to the hydrosocial territory affect different groups of people in different ways (Rocha-López et al. 2019). Group 1-type water conflicts may be understood as dissatisfaction over the restructuring of the RMID in response to neoliberal reforms. Those reforms benefited a small group of *agrotitanes* and harmed many Yoreme Mayo who were practicing traditional agriculture (Hartwig et al. 2022; Marlowe and Armstrong 2013). The reforms also exacerbated power asymmetries between the two user groups (Usón et al. 2017).

Although Mexico reformed its Constitution in 2012 to include the human right to water, Mexico has yet to modify its National Water Law and the corresponding regulations (Ávila-García 2016; Wilder et al. 2020). With respect to access to water for domestic use (the

root of the Group 3 conflict), indigenous communities have not received their water from the state, which has often instead supplied it—in exchange for political loyalty—to tankers that resell it to the general population (Herrera 2017; Meehan 2020; Pacheco-Vega 2020).

Indigenous groups in different regions of the world have resisted the entry of domestic water suppliers that make water inaccessible and expensive (Shiva 2003). The Yoreme Mayo, themselves, have organized to struggle for the human right to water, thereby achieving a practical authority that—although it was developed outside the law—has de facto recognition by the community and the state (Meehan 2020).

5.2.2. Ejido Land Tenure

In the RMID, users with *ejido* land tenure are more prone to renting their land than private landowners (Rivera-Núñez et al. 2023). The *ejido* structure influences water conflicts in ways that are related to the structural pressure of the above-described reforms/policies to markets and water and land and to the strategy of working by blocks and overdrafting. The *ejido* structure has other effects, as well. For example, one of the user profiles involved in Group 1 conflicts consists of elderly *ejido* members who have conflicts with *agrotitanes* over the rental of the elders' plots. The absence of state-run retirement programs for Mexican agricultural workers leads these elderly *ejido* members to rent out their land as a form of "old age insurance" rather than transferring their farms to their children (Barnes 2009). In the irrigation districts of northeastern Mexico, the chances of elders being cared for by family members are greater because the entire family economy often depends greatly upon renting out land (Lerma Rodríguez 2016). In addition, the chance of elderly *ejido* members passing on agrarian rights to their children is greater.

The other user profile involved in Group 1 conflicts consists of *ejido* members who are not large-scale farmers but continue working their land and have water conflicts with *agrotitanes* over access to sufficient high-quality water year-round. The *ejido* members' principal motivation for struggling for water and continuing to farm is not economic but rather the members' attachment to the territory and to an agrarian identity (Finger and Borer 2013). When asked about their occupation, many of these members responded "I'm an *ejido* member", even though being an *ejido* member in and of itself does not provide financial remuneration and is not considered a profession or trade. For these users, the struggle for irrigation water is a struggle to preserve their identity as *ejido* members and farmers. In addition to continuing to cultivate their own plots, some of these *ejido* members even rent additional plots from other users, in hopes of becoming *agrotitanes*.

The user profile involved in Group 2 conflicts consists of *ejido* members who are large-scale farmers and who—when attempting to defend their interests—have large-scale water conflicts with the hydrocracy or with those who control access to water. Thus, being an *ejido* member does not necessarily exclude one from cultivating on an agroindustrial scale. Instead, this attribute (being an *ejido* member) combines with others (such as gender, ethnicity, and educational level) to define the member's participation in the RMID's management. These large-scale *ejido*-member farmers form a local elite that takes advantage of historical and structural circumstances to favor their own interests. For example, they created "rules in use" to compensate for institutional gaps resulting from neoliberal reforms, thereby favoring the situations that would increase the elite's resilience to the detriment of other *ejido* members (see Sondershaus and Moss 2014).

5.2.3. Gender and Water

The Group 3 water conflict, involving vernacular water management systems for domestic use, is the only one that we detected that largely involves women and does not address water for irrigation. Eight of the fourteen users in this group are women. Agriculture in the region is a patriarchal activity, and women are generally prevented from being involved in the RMID system (Alston et al. 2018). Instead, they are in charge of the non-remunerated work of caring for other family members and the home. As a result, the aspects of water in which they are involved are principally related to its domestic use.

Historically, women's rights to water have existed only on paper. Women generally do not participate in decision-making regarding water (Zwarteveen 2010). There is a need to promote greater participation by women in the institutional arena of the RMID—also taking into account other aspects of their identity such as ethnicity, age, and educational level—in order to address the exclusion of women from water management from an intersectional perspective (Erwin et al. 2021).

Gender dynamics are also influenced by Mexico's policies regarding land tenure. From 1917 to 1971, *ejido* land in Mexico was provided exclusively to the male heads of the family. Thus, water management was their domain. Women could obtain land only through inheritance. Mexico law did allow widows who inherited *ejido* land, and had children, to rent the land out so that they could provide an income for the family while staying at home caring for the children (Vázquez García 2001).

Although women's rights are often not respected by national and local governments, women in many parts of the world are the principal organizers of collective action related to domestic water in their communities (Hernández Vidal et al. 2022). In the RMID, women are in charge of obtaining water for domestic use in their communities and are at the forefront of the resistance to OOMAPAS.

6. Conclusions

Social network analysis was used to identify conflicts between the members of the institutional arena and different kinds of water users in the RMID. In conclusion, it was possible to effectively identify structural conflicts, as a type of negative relationship, using a community detection algorithm, within this system of common-pool resource use. It is highly recommended to complement the use of this algorithm with a qualitative methodology such as ethnography in order to detect cases such as Group 4 (which was simply a structural remnant rather than a type of conflict) and Group 1, which consisted of two types of conflicts involving the same members of the institutional arena but different sets of users. This recommended complementary approach will help researchers to better understand different types of conflicts in highly stratified social contexts within complex institutional arenas.

Finally, three types of water conflicts exist in the RMID: two conflicts over the management of irrigation water and one over the management of water for domestic use. It was found that the conflicts over irrigation water were due to the *agrotitanes'* working by blocks—a practice that may be considered a small-scale form of land- and water-grabbing (Franco et al. 2013; Mehta et al. 2012; Rulli et al. 2013). This practice has structurally displaced those indigenous *ejido* members who have little formal education, from decision-making regarding the agricultural use of water. Meanwhile, the *agrotitanes*, from their high positions in the water hierarchy, strive to control even more water in order to increase their profits. Some small-scale farmers with a certain profile struggle to continue farming. Some do so because of their attachment to the agrarian lifestyle, while others hope to become *agrotitanes*. The cause of conflicts over water for domestic use is quite different: female indigenous *ejido* members have been structurally relegated to non-remunerated functions involving water for use in caring for the home and family. However, for precisely this reason, they are at the forefront of alternative systems (rather than the state's) for managing water for domestic use in their communities. They are also important in the struggle to get the government to ensure that indigenous communities have sufficient water (a human right).

One limitation of this study is that because of its transversal design, it is restricted to analyzing the structure of water conflicts that were present during the period in which data were obtained: this approach cannot study the evolution of conflicts. Additionally, the amount of detail in user profiles was limited because the possibility of retaliation from organized crime¹⁰ made RMID users reluctant to provide information. The field data were gathered during the COVID-19 pandemic—albeit during less critical periods—which may have modified the patterns of socialization during the period discussed in

interviews. Finally, this study could provide information about the critical issues that must be prioritized in policy and law design, considering that Mexico's water social actors have spent almost 15 years discussing a new national water law, derived from the introduction of water as a human right, and yet have not reached an agreement.

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Appendix A. Social Actors Involved in Conflicts in Water Management in the Río Mayo Irrigation District (RMID): IM = Irrigation Module; ID = Irrigation District

Agency	Representative	Scale of Influence	Principal Role	Conflict Group
1. Government agencies				
CONAGUA (National Water Commission) ID Manager	General Manager of the RMID	Regional	Programs and supervises the distribution of irrigation water to each IM of the RMID. There is one General Manager in the RMID.	4
OOMAPAS (Local Operating Organization of Potable Water, Sewage, and Sanitation)	OOMAPAS	Local	In charge of water supply and sanitation for domestic and non-agricultural commercial use. One OOMAPAS exists per county, for a total of three.	3
2. Private Water and Farmer Organizations				
IM Rep	Representative of Irrigation Module (IM) users	Local	Elected by users to coordinate and supervise the functioning of an IM of the RMID; supervises the management of channel gates to send water to users. There is one per IM, for a total of 16.	2
Canal worker	IM Canal worker	Local	An employee of an IM of RMID who opens and closes channel gates to provide water to users. There are two per IM, for a total of 32.	2
Priv prop rep	Representative of private property owners in the IM	Local	Represents users who have private property in the IM. Elected to procure their interests. There is one per IM, for a total of 16.	4

Agency	Representative	Scale of Influence	Principal Role	Conflict Group
Farmers' org	Farmers' organizations	Regional	Groups of farmers of the same crop (potatoes, other vegetables, wheat, safflower, etc.) organized to maximize political influence so that water is provided according to their crops' needs.	4
Priv Prop Farmers	Farmers with private property	Local	Farmers with private property who rent land and water rights.	1
Priv Prop Farmers + well	Farmers with private property and well-water use rights	Regional	Farmers with private property who rent out land and water rights. They own a private well and sell water to the ID and other farmers.	1
Intermediary	Intermediary	Local	Person hired by landholder to find people to rent or purchase land and water rights.	4
Credit unions	Credit unions	Regional	Financial services that provide money for farmers to purchase inputs (including water) according to the amount of land and water.	2
3. Non-Agricultural Businesses				
Water purifiers	Water purification plants	Local	Family-owned businesses that purify drinking water.	3
Tankers	Water tankers	Local	Trucks that transport water (from wells) to homes for domestic use in the case of water shortage.	3
4. Grassroots organizations and their representatives				
<i>Ejido</i> Commissioner	<i>Ejido</i> Commissioner	Local	<i>Ejido</i> member elected to be in charge of the legal representation of the <i>ejido</i> .	3
<i>Ejido</i> IM Rep	Representative of <i>ejido</i> members in the IM	Local	Representative of users with <i>ejido</i> property in the IM. Elected to procure their interests. One exists per IM, for a total of 16.	2
<i>Ejido</i> members	<i>Ejido</i> landholder	Local	<i>Ejido</i> members who farm and/or rent out their land and water rights.	1

Source: [Rivera-Núñez et al. \(2023\)](#).

Notes

- ¹ For a description of the three types of capital, consult [Bourdieu et al. \(2001\)](#).
- ² Official definitions may be consulted in Article 3, Fractions XXVa and LI of [CONAGUA \(1992\)](#). For some exceptions to the explanations provided above, see [Palerm Viqueira \(2009\)](#).
- ³ In Mexico, two types of rural land tenure exist (in addition to private property): communal landholdings and *ejidos*. Communal landholdings, which were granted by the state after the Independence in an attempt to return part of the indigenous groups' ancestral lands, are not formally divided into individual landholdings, although each family may use a small part of the territory. *Ejidos* are collective landholdings that were granted to groups of Mexicans after the Revolution (1910–1917). Each *ejido* member has an individual landholding. Before the passage in 1992 of a constitutional amendment (in conjunction with implementing the North American Free Trade Agreement (NAFTA)), these individual holdings could not be sold but only passed on to sons or widows.
- ⁴ For more information on the forms of enclosure of the commons, see [Peluso and Lund \(2011\)](#).
- ⁵ By the Ministry of Agriculture and Hydraulic Resources.
- ⁶ Members of a limited liability company pay dues without having to commit their personal assets.
- ⁷ From 1917 to 1992, almost four million Mexicans were provided with land, forming 30,082 *ejidos* and communal landholdings, consisting of a total of 103 million hectares or 51% of Mexico's surface area ([Torres-Mazuera 2019](#)).
- ⁸ In the U.S. context, they are called a "ditch tender".

- ⁹ In addition to the sociopolitical phenomena discussed here, some interviewees mentioned the increasing involvement of organized crime in the management of the region's water, land, and agriculture. Studies on other regions have reported the same (Ballvé 2012; Eman and White 2020; McSweeney et al. 2017; Salazar Barrón 2023).
- ¹⁰ According to World Atlas (2023), Ciudad Obregón, Sonora, located less than 70 km from the RMID, is the fourth most unsafe city in the world due to its high rate of drug and human trafficking.

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