Water Allocation and Social Unrest: Evidence from Chilean Water Rights

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Abstract

While existing research demonstrates that climate-driven reductions in water supply increase conflict, the role of rising water demand in reducing overall availability and fueling social discontent remains understudied. Human overdraft of freshwater for productive activities can deplete water endowments, leading to conflict between productive and domestic users. This paper examines how rising water demand and largely unrestrained water allocations in Chile drive disputes and protests. I combine geo-referenced surface and groundwater rights data for over 50,000 right-holders with yearly data on streamflows, water table depth, administrative and legal water disputes, and protest events. Using a spatial spillover design that exploits river flow directions, I find that a 10% increase in upstream groundwater allocations—equivalent to 0.7 m^3/s or the water rights of the 50th-largest user—produces a net reduction in downstream streamflow of 0.3 m^3/s and deepens water tables by 0.09-0.12 meters. This increase raises the probability of a water theft court case by 2.9 percentage points (pp) and generates 15% more filings of water-related administrative complaints. It further increases overall protest probability by 3.7 pp and results in 0.25 additional protest events per downstream municipality-year. These findings underscore the need for water allocation frameworks that promote efficient use while accounting for basin-wide hydrological and social impacts.

Keywords: water rights; water scarcity; groundwater; aquifer depletion; social conflict; legal disputes; protests; environmental regulation; Chile.

JEL codes: Q25, Q54, D74, O13

*Harvard Kennedy School of Government, Harvard University. Email: mlarreboure@fas.harvard.edu. Website: www.mlarreboure.com. **Acknowledgements:** This research was supported by the Vicki Norberg–Bohm Fellowship and the Joseph Crump Fellowship of the Belfer Center for Science and International Affairs, and by the SEHE Stipend of the Malcolm Wiener Center for Social Policy. Any remaining errors are my own. **PRELIMINARY VERSION, DO NOT CIRCULATE.**

1. Introduction

A large empirical literature links climate-induced reductions in water supply to spikes in conflict (McGuirk and Nunn, 2020; Hendrix and Salehyan, 2012; Hsiang et al., 2013; Harari and Ferrara, 2018; Unfried et al., 2022; Almer et al., 2017). Water scarcity, however, can also emerge from increased human demand for freshwater resources and consequent overdraft (AghaKouchak et al., 2021; Gleick and Cooley, 2021). When demand for water rises rapidly, unrestrained expansion of extraction rights can deplete water endowments throughout a basin. Large commercial users are typically able to adapt by investing in deeper wells, conveyance infrastructure, or on-farm storage, while smallholders and rural water utilities lack the capital to do so and therefore absorb a disproportionate share of the environmental damage. I argue that under weak governance and limited state intervention, this adaptation gap—by which some users experience scarcity while others do not—can ignite social unrest. Unlike exogenous climate shocks such as drought, heat anomalies, or shifting precipitation regimes, which are difficult to prevent, tensions arising from demand-side scarcity could in principle be avoided through appropriate policy intervention—such as adaptive allocation limits, cumulative impact assessments, or coordinated basin management.

Chile offers a unique setting for examining governance-driven water scarcity that arises precisely from the absence of such intervention in the face of mounting demand pressures. Over 100 distinct river basins flow from the Andes Mountains to the Pacific Ocean, each self-contained within a single country with a stable institutional context. The 1981 Water Code establishes water rights as constitutionally protected, perpetual, and freely tradable. Demand from agriculture, mining, and industry has grown exponentially since the 2000s, with the country becoming increasingly dependent on groundwater as surface water sources become depleted or unreliable for productive activities (Donoso et al., 2020). The National Water Authority has continued to expand extraction permits, disregarding long-term consequences while prioritizing productive value over conservation. This governance failure generates economically and politically consequential water scarcity, building tension between water users and local communities, and setting conditions conducive to conflict. My paper examines two central questions: (i) *How does water extraction for productive uses affect overall water availability?* and (ii) *When does increased water allocation provoke social conflict?*

To answer these questions, I implement a two-stage research design using comprehensive administrative, hydrological, and socio-political data. I first establish the hydrological relationship using a census tract-year panel (2005-2024) that combines geo-referenced water rights with seasonal streamflow and water table measurements. I then examine social consequences using a municipality-year panel (2015-2024) that links the same water rights data with legal disputes over water and protest events. My identification strategy follows a spatial spillovers design that exploits the unidirectional nature of hydrological flows within a basin. Only

upstream water allocations should impact downstream areas through hydrological connectivity; downstream and local allocations serve as controls for basin-wide allocation trends. By following each river flow from an area up to its source, I identify the specific water rights that might impact the area's access to water each year. Geographic unit and basin–year fixed effects isolate the causal impact of upstream allocation shocks while accounting for time-invariant heterogeneity and basin-specific shocks (Taylor and Druckenmiller, 2022; Duflo and Pande, 2007; Dias et al., 2023).

I first assess whether increased water allocation for productive activities is associated with reduced water availability. A growing body of research across geography, hydrology, and water resources has demonstrated that climate variables alone cannot explain observed water depletion patterns. These studies control for precipitation and temperature, then attribute unexplained residuals to human extraction, for which direct data is usually unavailable. Recent applications of this indirect attribution methodology have found human activities responsible for 46-77% of groundwater depletion in Indian aquifers (Mukherjee et al., 2024), over 100% of flow reductions in Chinese rivers (Xue et al., 2017), and a decoupling of water storage from precipitation patterns across 105,400 water bodies in global drylands (Zhao et al., 2025). In Chile specifically, scholars have similarly established that decreases in available water originate from factors beyond climatic conditions, pointing to intensive irrigated agriculture and the existing water management system as contributory factors (Muñoz et al., 2020; Duran-Llacer et al., 2020).

While this literature establishes the relevance of human extraction, it relies on inference rather than direct measurement. I provide direct evidence linking water extraction permits to downstream water availability. Using historical measurements of streamflows and water table depth, I find that a 10% increase in upstream groundwater allocations—equivalent to 0.7 m^3/s or the water rights of the 50th-largest user—produces a net reduction in downstream streamflow of 0.3 m^3/s and deepens water tables by 0.09-0.12 meters. Consistent with the premise of my identification strategy, I find null results for downstream allocations. Remarkably, these hydrological patterns are specific to groundwater rights: for surface water allocations, I find streamflow reductions from both upstream and downstream allocations, with no significant impact on water tables. This distinction may be explained by differences in local institutions; surface water systems foster collective management through shared infrastructure such as canals with user associations that coordinate proportional distribution and help internalize spatial externalities (Garcıa and Belmar, n.d.), while groundwater is typically exploited by individual users through private wells, operating with limited coordination or oversight (Donoso et al., 2020). Given that the spatial spillovers identification strategy relies on the upstream-downstream distinction—which holds only for groundwater rights—the remainder of this analysis focuses exclusively on groundwater allocations.

Once this relationship between water allocations and reduced availability is established, I turn to outcomes

related to social conflict. Most directly, reduced water availability can intensify competition among users, leading to disputes over water resources. Reports related to Water Code violations, such as unauthorized extraction of water, can be filed either through the local courts or administratively with the General Water Directorate (DGA).[1] I process public records of both georeferenced administrative complaints to the DGA and legal disputes over water theft at the court level, to measure water-related disputes (See Rivera et al. (2016)). The results show that a 10% increase in upstream groundwater rights ($\approx 1\ m^3/s$) raises the probability of water theft court cases by 2.9 pp and increases administrative complaints by 15%.

Finally, I test whether increased water allocation affects broader social conflict beyond direct water disputes. Local communities may experience grievances over depleted resources, particularly when they observe landscape changes, disruptions in domestic water supply, or disparities in access between large-scale operations and smallholder farmers. Most of the literature linking water scarcity and conflict focuses on drought and violent conflict in Africa, where prevalent food insecurity escalates fights over water (Unfried et al., 2022; McGuirk and Nunn, 2020). By contrast, I examine demand-driven water scarcity in a high-income democracy and its relationship to protest events, which are mostly peaceful but have potential to escalate. My results show that a 10% increase in upstream groundwater rights raises protest probability by 3.7 pp and generates 0.25 additional protest events per municipality–year, suggesting that water allocation decisions have consequences extending well beyond the water sector itself. Classifying protest events by issue and target reveals that the most significant increases occur in human rights and environmental protests, and those targeting the national government, consistent with Chile's centralized water management system and communities viewing water allocation decisions as failures of national policy.

The paper contributes to three strands of research. First, it broadens the climate–conflict literature —typically centered on exogenous weather shocks that reduce water supply—by documenting the social consequences of *anthropogenic* resource depletion. Second, it links political economy work on property-rights institutions with natural-resource economics, showing how rigid entitlements can impose negative externalities on non-owners under certain conditions (Ostrom et al., 1999; Wade, 1994). Third, by providing estimates from a high-income democracy, it enriches a literature so far dominated by African and South-Asian cases.

The remainder of the paper is organized as follows. Section 2 describes the context of the study. Section 3 describes the data and variable construction. Section 4 sets out the empirical strategy. Section 5 presents the main results. Section 6 concludes.

[1]The DGA provides online forms for administrative complaints, while legal action requires police attestation and involves lengthier court procedures.

2. Background and Context

2.1 Water governance in Chile

Chile's 1981 Water Code, implemented during Augusto Pinochet's military dictatorship (1973-1990), established a water governance system based on three core principles: privatization of water rights into permanent private property, marketization through tradable rights governed by price mechanisms, and self-regulation that transferred management from state agencies to private users associations (Budds, 2020). These principles receive constitutional protection under the 1980 Constitution, which treats water rights as real property modifiable only by super-majority vote. This legal framework has significantly constrained governmental administrative action over water resources, and few modifications have been implemented since then, with two major ones in 2005 and 2022 (Bauer (2004), World Bank, 2011a, 2021).

The 2005 reform established fees for maintaining unused water rights to discourage speculation and allowed the DGA to protect minimal environmental flows in rivers. However, this environmental protection was expected to have minimal effect in places where water had already been fully allocated to existing rights (Hearne and Donoso, 2014). The 2022 reform, passed after more than a decade in Congress amid extensive stakeholder lobbying and a failed constitutional process, introduced more substantial changes. It established a hierarchy that prioritizes human consumption, sanitation, and domestic subsistence over productive uses, and limited new rights to 30-year terms rather than permanent grants. The reform also mandates that user organizations in water-scarce areas develop redistribution agreements for proportional use reductions and implement real-time flow measurement systems to enable verification and monitoring of legal water use. However, the core structure of the 1981 system remains intact: existing rights retain their permanent status and constitutional protection, leaving the challenges linked to water rights over-allocation unresolved (OECD, 2025).

The system's underlying logic assumes that market transactions among water rights holders will achieve optimal allocation by directing water toward high-valued uses. In practice, however, water trading has remained limited outside of a few localized markets (Hearne and Donoso, 2014). Despite high competition for water use, the market has not actively reallocated water as expected; instead, water allocation continues to depend heavily on hierarchical administrative decisions (Prieto et al., 2022).

A Chilean water right specifies a flow rate (in liters per second), coordinates of a fixed intake point, and a time schedule—all determined at issuance (Garcıa and Belmar, n.d.). Rights are transferable, decoupled from land ownership, and recorded as real estate, making water right purchases similar to land transactions (Melo Jara, 2018). Initially, applicants can obtain rights at no cost by petitioning the General Water Directorate (Dirección General de Aguas, DGA), which assesses hydrologic availability and enforces the

Water Code. New rights are granted until the DGA declares a source exhausted, after which additional demand must be satisfied through purchasing existing rights (Biblioteca del Congreso Nacional, 1981).

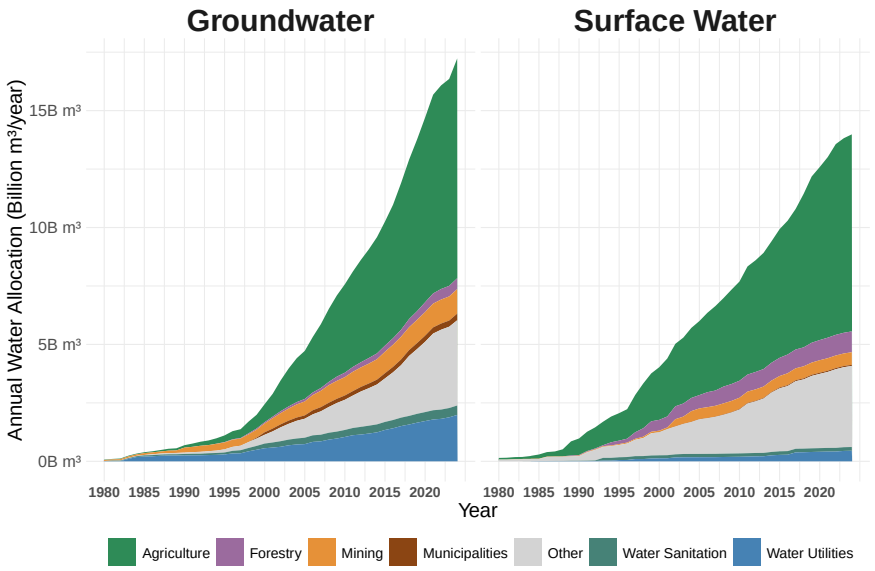
Several institutional constraints limit the system's adaptability and efficient water use. The market lacks formal mechanisms for trading partial rights—transfers typically involve entire rights rather than specific flow allocations. Relocating a right's intake point requires a bureaucratic process that may extend for years. Despite legal separation between land and water, many Chilean farmers maintain that water and land should not be separated and are therefore reluctant to sell water rights without also selling the land (Hearne and Donoso, 2014).

The pricing structure creates additional inefficiencies. Rights holders face no marginal cost for water volume obtained and, while they may pay fees to water user boards for infrastructure maintenance and cover electricity costs for groundwater pumping, the legal framework provides no incentives to account for water's scarcity value. Instead, as per the 2005 reform, users are expected to utilize their full yearly allocation or face non-use tariffs and risk losing their right.

Monitoring and enforcement capabilities are limited and largely delegated to private users. DGA inspectors measure intake infrastructure and confirm pipe diameters cap withdrawals at authorized flows only during permit issuance (Melo Jara, 2018). While this engineering check may deter over-pumping under normal conditions, it fails during droughts when the Water Code requires proportional reductions—fixed-diameter pipes provide no mechanism for scaling back extraction. Water user organizations coordinate reductions where they exist, but their authority and capacity vary widely across basins (Garcıa and Belmar, n.d.; Engler et al., 2021). Moreover, such coordination mechanisms are virtually non-existent for groundwater users, leaving monitoring to an under-resourced DGA (Hearne and Donoso, 2014).

Figure 1 presents the evolution of surface and groundwater rights granted nationally from 1980 to 2024 as per the Public Water Registry. Total water volumes granted increased at a rapid rate during the 2000s and 2010s, with groundwater driving much of this growth. This reflects both rising demand and the relative ease of obtaining groundwater rights in water-stressed regions, as the allocation system responded to scarcity by shifting toward groundwater extraction.

Figure 1: Cumulative water right volumes granted 1980-2024



Notes: Figure 1 shows cumulative water right volumes granted from 1980 to 2024, in Billion $m^3/year$. Groundwater rights are shown in the left panel and surface water rights are shown in the right panel. Colors indicate use type.

This shift created problematic consequences. Insufficient knowledge about groundwater dynamics enabled aquifer overexploitation in northern and central regions, complicating monitoring and sustainable management. The absence of groundwater user associations reflects this knowledge gap, as Hearne and Donoso (2014) suggest that users lack understanding of "the long term effects that uncontrolled exploitation of aquifers may cause."

2.2 Water scarcity and social conflict in Chile

Water scarcity results from the intersection of supply constraints and escalating demand (Gleick and Cooley, 2021). On the supply side, Chile experienced its worst drought on record during the 2010s—a decade-long sequence of dry years with annual rainfall deficits of 25–45 percent (Garreaud et al., 2017). Simultaneously, demand has surged due to the expansion of water-intensive industries, particularly mining in the north and large-scale agriculture and industry throughout the central and southern valleys. Both climatic stress and human pressure contribute to an unresolved crisis, which prompted the World Resources Institute to list Chile among the 33 countries projected to face severe water stress by 2040 (Maddocks et al., 2015).

The institutional response to water stress reveals the crisis severity through a succession of emergency measures that only offer temporary relief. By 2021, the General Water Directorate had declared 184 municipalities in extreme water shortage, placing nearly 47 percent of the population—more than eight million people—under rationing. Access to reliable drinking water has deteriorated, with the number of people with

access to clean water decreasing between the 2002 and 2017 Census (Amulén, 2019). Regional and municipal governments have increasingly relied on stopgap measures: tanker truck deliveries of drinking water, initially implemented as temporary drought relief, have become permanent fixtures in many localities, especially during summer months. This dependency extends even to traditionally water-rich southern regions experiencing water table declines. The scale of this emergency response is captured in Figure A.3, which shows government expenditure on tanker trucks rising from below 1 million USD in 2007 to over 10 million USD in 2023—a ten-fold increase that highlights the growing scope of water insecurity and the institutionalization of *emergency* water provision as the primary policy response.[2]

Water stress has also driven major infrastructure adaptations as traditional sources prove inadequate. Northern regions have turned extensively to desalination for mining operations and provisions for coastal cities, while deeper groundwater exploitation has become widespread nationwide, as evidenced by expanded groundwater rights and declining water table levels (Figures 1 and A.4). These technological responses, while providing short-term relief, often represent expensive and energy-intensive substitutes for sustainable water management.

In the past decades, there has been a surge in social resistance to the current water governance system. Water-focused organizations like *Modatima*, founded in 2010 in Petorca province, Valparaiso Region, emerged to challenge what they characterize as water appropriation by large-scale agricultural and mining operations (Bolados García et al., 2018).[3] These movements gained national prominence during Chile's 2019–20 mass protests, where access to water was among the most discussed topics against the backdrop of the historic drought (Macpherson et al., 2023). Demonstrators called for rewriting both the Water Code and the Constitution, popularizing the slogan "*No es sequía, es saqueo*" ("It's not drought; it's looting"). This framing reflects a broader critique that attributes water scarcity not to climate change but to political choices enabling over-extraction by powerful economic actors.

3. Data

For the first part of my analysis, I construct a census tract-year panel (2005-2024) combining geo-referenced groundwater rights with seasonal streamflow and water table measurements. I use census tracts rather than municipalities as the unit of analysis to maximize spatial precision—many municipalities contain multiple monitoring stations, and the finer geographic resolution allows me to better link each monitoring point to

[2]While tanker truck expenditures represent relatively modest government spending, they signal severe water stress as they constitute the last resort for ensuring basic water access. The crisis extends far beyond these emergency measures, with countless households independently digging deeper wells, installing private storage systems, and adopting other costly adaptation strategies not captured in official expenditures.

[3]See https://modatima.cl/quienes-somos/

its specific hydrological context. For the second part, I build a municipality-year panel (2015-2024) linking the same groundwater rights data with legal disputes over water and protest events. I use municipalities as the unit of analysis here, as these social outcomes naturally aggregate at the scale of local governance and population centers.

Table 1: Summary Statistics

	Mean (1)	Median (2)	Min (3)	Max (4)	Years (5)	N (6)
Groundwater rights						
Upstream GWA (m^3/s)	7.19	1.40	0.00	65	2005 – 2024	6820
	(11.12)					
Downstream GWA (m^3/s)	7.10	1.11	0.00	66	2005 – 2024	6820
	(11.17)					
Local GWA (m^3/s)	0.82	0.26	0.00	18	2005 – 2024	6820
	(1.38)					
Surface water rights						
Upstream SWA (m^3/s)	5.35	0.94	0.00	28	2005 – 2024	6820
	(7.24)					
Downstream SWA (m^3/s)	3.74	1.14	0.00	28	2005 – 2024	6820
	(5.48)					
Local SWA (m^3/s)	0.83	0.13	0.00	13	2005 – 2024	6820
	(1.57)					
Monitoring stations						
Winter Streamflow (m^3/s)	75.06	11.13	0.00	1691	2005 – 2017	4077
	(171.25)					
Summer Streamflow (m^3/s)	38.72	3.84	0.00	1496	2005 – 2017	4138
	(129.34)					
Average Water Table Depth (m)	12.71	7.59	0.01	101	2005 – 2024	3631
	(13.71)					
Summer Water Table Depth (m)	12.63	7.56	0.01	101	2005 – 2024	3206
	(13.38)					
Water disputes						
Administrative Complaints (DGA)	1.63	1.00	0.00	27	2018 – 2023	2046
	(2.84)					
Water Theft Court Cases	1.34	0.00	0.00	73	2015 – 2024	1337
	(3.68)					
Any Water Theft Court Case	0.40	0.00	0.00	1	2015 – 2024	1337
	(0.49)					
Protests						
Number of Protests (ACLED)	4.60	0.00	0.00	238	2018 – 2024	2387
	(14.85)					
Any Protest (ACLED)	0.48	0.00	0.00	1	2018 – 2024	2387
	(0.50)					
Number of Protests (COES)	2.50	0.00	0.00	253	2016 – 2021	2052
	(12.16)					

Notes: Means, medians, minima, and maxima are reported across municipality–year observations; standard deviations are in parentheses. GWA denotes Groundwater Allocation and SWA denotes Surface Water Allocation. Sample sizes (N) differ across panels because hydrological and protest data are not available for the same set of municipality–years.

Table 1 provides descriptive statistics; data-source details follow. There is substantial heterogeneity in water allocation and availability across Chile's municipalities. Winter streamflow averages 75 m^3/s but has a median of only 11 m^3/s, while well depths average 12.7 meters but range up to 101 meters, suggesting varying

degrees of water endowment and potential depletion. Disputes over water and protests remain relatively rare events, with most municipalities experiencing zero in most years.

3.1 Water allocation

Information on legally approved extraction comes from Public Water Registry maintained by the General Water Directorate (DGA).[4] Each record lists the water right holder, approval date, authorized flow rate, and the geographic coordinates of the intake point. The DGA has been mandated to maintain this public registry since 1997, with ongoing efforts to regularize and include all water rights ever granted. Water users must have their rights registered in this system to make official requests such as transfer applications, change of extraction points, or modifications to their allocations.

My analysis focuses primarily on groundwater rights for several reasons. First, groundwater allocations have grown substantially since the early 2000s, becoming the dominant form of new water rights as surface water sources have been declared exhausted. Second, groundwater extraction is inherently individualistic and less regulated, making it more prone to conflict. Unlike surface water systems that require common infrastructure like canals and naturally foster collective management through river boards and user associations, groundwater is typically exploited by individual users through private wells operated independently (Donoso et al., 2020). This individualistic extraction model, combined with the *invisible* nature of the resource beneath the surface, creates weak incentives for collective governance and makes monitoring and enforcement more challenging than surface water systems with organized user associations and visible infrastructure.

Third, groundwater rights present fewer data completeness concerns than surface water rights. As Boettiger (2012) documents, the Public Water Registry is incomplete, primarily due to older surface water rights granted before 1981 that require costly judicial *perfection* procedures for registration. Groundwater rights represent a smaller fraction of these problematic pre-1981 rights, and large-scale users most likely to drive the effects examined here have typically regularized their rights.

Finally, groundwater extraction provides better causal identification because pumping creates immediate, localized effects on both surface water flows and groundwater levels that are directly measurable, unlike surface water allocations which may be buffered by canal management, storage systems, or water user association decisions that complicate the causal chain from allocation to water scarcity.

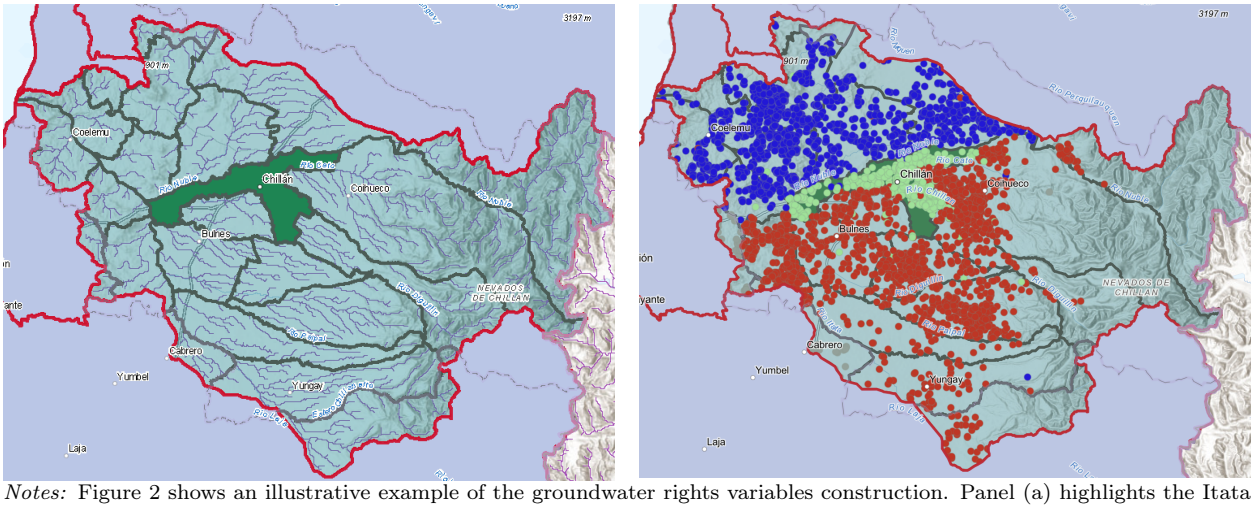
Using the global `HydroRIVERS` hydro-graphic network, I assign every intake point to a unique river segment and order all segments within each basin according to flow direction. Annual groundwater right volumes (L/s) are then cumulatively summed *upstream* of, *downstream* of, and *within* each municipality to obtain the three stock variables that enter equation (1). See Figure 2 for an illustrative example. Water rights

[4] Available at `https://dga.mop.gob.cl`.

authorized for domestic or municipal supply are excluded so that the measures reflect purely productive extraction.

Figure 2: Relative hydrological distribution of groundwater rights

(a) Municipalities in the Itata River Basin (b) Water rights hydrological location



Notes: Figure 2 shows an illustrative example of the groundwater rights variables construction. Panel (a) highlights the Itata River Basin (red boundaries), and within it, the municipality of Chillán (in dark green). Green boundaries delineate other municipalities within the basin. The river network is HydroRIVERS v1.0 (purple), and their water flows primarily from East (Andes Mountains) to West (Pacific Ocean). Panel (b) plots all registered groundwater-right intake points by holder. Colors denote the hydrological location relative to the municipality of Chillán: upstream (red), downstream (blue), and local (green).

3.2 Hydrological outcomes

Monthly discharge records from 367 gauging stations operated by the General Water Directorate—and processed by the *Center of Science and Climate Resilience* (CR2)—provide the streamflow series in m^3/s. I aggregate summer (January-March) and winter (June–August) observations to annual means and assign each station to its corresponding census tract polygon.

Water table levels come from 307 piezometric stations in the same monitoring network. Depth is measured in meters below static level. For these, I compute annual averages using all readings, and summer-season readings only (January–March). This maximizes variation because wells reach their lowest static level at the end of the dry season. Figure A.4 shows the evolution of these variables over time.

3.3 Social conflict

3.3.1 Water-related complaints and disputes

Chile's legal framework provides two primary avenues for addressing water-related violations. Administrative complaints may be filed with the General Water Directorate (DGA) for regulatory infractions under the Water Code, while criminal prosecutions for water theft proceed through the criminal court system as felony

offenses. I obtain water-related dispute data for each of these pathways. First, administrative complaints filed with the General Water Directorate (DGA) record violations such as unauthorized water extraction and unauthorized works in waterways, among other related infractions, from 2018 to 2023. These complaints are geo-referenced to municipality locations and collapsed to annual frequency. Given the higher density of administrative violations, I analyze the raw annual count of complaints per municipality.

Second, criminal court cases for water theft are obtained from publicly available data from the Chilean Judicial Power covering the period from 2015 to 2024. The data are extracted from the oral criminal proceedings database, specifically cases terminated under the water theft classification, which are mapped to the year they were filed. Cases are aggregated by court jurisdiction and assigned to municipalities, though only 141 out of 341 municipalities in the analysis maintain local courts. The analysis is therefore restricted to these units. These cases represent formal criminal prosecutions filed in tribunals for water theft offenses. Importantly, I focus on prosecutions rather than convictions as evidence of water-related conflict. The act of filing criminal charges indicates that users are actively disputing water access and resorting to legal mechanisms to resolve conflicts. Notably, less than 3% of water theft cases resulted in conviction throughout this period, while the vast majority ended without successful prosecution through various forms of dismissal or abandonment. Because criminal cases occur less frequently than administrative complaints, the main specification employs a binary indicator that equals one when at least one criminal case is filed in a municipality-year.

3.3.2 Protests

Protest outcomes are drawn from two complementary event data sets. First, the Armed Conflict Location and Event Dataset (ACLED) records daily, geo-referenced protests, riots, and episodes of violence for Chile from 2018 to 2024 (Raleigh et al., 2010). Event coordinates are spatially joined to 2017-census municipality polygons and collapsed to annual frequency. Because ACLED reports relatively few events per municipality–year, the main specification employs a binary indicator that equals one when at least one protest occurs.

Second, to extend temporal coverage and incorporate locally sourced reportage, I use the *Observatory of Social Conflict* (OCS) maintained by the Center for Social Conflict and Cohesion Studies (COES). The OCS systematically codes protest events appearing in national and regional newspapers between 2016 and 2021, following the standardized UNDP protocol described in *The Social Protest in Latin America*. Given the higher event density in this dataset, I analyze the raw annual count of protests per municipality rather than binary indicators. Building on the OCS's own event categorization, I classify protests by issue (environment, health, education, human rights), target (private companies, local government, national government),

and tactics (marches and manifestations, occupation of buildings or public spaces, roadblocks, strikes, and property destruction).

The two sources are used separately rather than merged: ACLED offers more recent coverage and uniform coding standards, while OCS provides a longer historical window and greater sensitivity to low-salience, local disputes. Results are robust across both measures.

3.4 Measurement error and coverage

A key source of measurement error warrants mention. Water-right volumes represent *legal entitlements*, not actual withdrawals; if water right holders under-pump, the estimated coefficients constitute lower bounds on the true impacts of extraction. Since 2005, however, unused rights have been subject to a non-use fee, initially enforced via on-site inspection of intake infrastructure and now complemented by real-time extraction monitoring. These institutional changes reduce—but do not eliminate—the gap between authorized and effective withdrawals. Conversely, over-extraction beyond authorized limits can occur and may bias results if this systematically occurs in places where more groundwater rights are granted.

The next section outlines the empirical strategy that links these data to the causal questions framed in Section 1.

4. Empirical Strategy

4.1 Conceptual outline

Empirically determining the impacts of increased water extraction on water availability and social unrest faces a fundamental challenge: new water users generate multiple local impacts beyond water extraction itself. These range from economic benefits—employment opportunities, infrastructure development, and local spending—to social disruptions such as migration flows and land use changes.

My identification strategy isolates the pure water scarcity effects by exploiting a fundamental hydrological principle: water flows downstream (Taylor and Druckenmiller, 2022; Dias et al., 2023; Duflo and Pande, 2007). While water users affect areas within the same municipality through various economic and social channels, upstream extraction can only reduce water endowments in downstream locations through hydrological connectivity. This creates plausibly exogenous variation in water availability for downstream municipalities, allowing me to separate water scarcity effects from the confounding local impacts of extractive activities.

The empirical approach examines how changes in upstream water extraction affect census tracts or

municipalities over time. Rather than comparing downstream to upstream areas, which might differ in significant ways, the identification strategy leverages within-unit variation by comparing each geographic unit to itself across different time periods. This within-unit comparison, combined with basin-by-year fixed effects, isolates the effect of upstream extraction from basin-wide shocks such as droughts or economic changes that affect all areas in a basin simultaneously. Geographic unit fixed effects control for time-invariant local characteristics, while basin-year fixed effects account for time-varying basin-level conditions. This specification follows established approaches in the spatial spillovers literature (Unfried et al., 2022; Harari and Ferrara, 2018).

4.2 Baseline specification

Let i index census tracts or municipalities, b river basins, and t years. The main estimating equation is

$$y_{ibt} = \delta_i + \alpha_{bt} + \gamma_1 \log\big(\text{WRA}^{\text{up}}_{ibt}\big) + \gamma_2 \log\big(\text{WRA}^{\text{down}}_{ibt}\big) + \gamma_3 \log\big(\text{WRA}^{\text{local}}_{ibt}\big) + X_{ibt} + \varepsilon_{ibt}, \tag{1}$$

where y_{ibt} represents the outcome of interest: streamflow, water table depth, water-related disputes, or protests. The variables $\text{WRA}^{\text{up}}_{ibt}$, $\text{WRA}^{\text{down}}_{ibt}$, and $\text{WRA}^{\text{local}}_{ibt}$ denote the liters per second of water rights allocated upstream, downstream, and locally, respectively. The coefficient of interest, γ_1, captures the causal impact of upstream extraction; γ_2 and γ_3 serve as a placebo and controls for basin-wide trends in water rights allocation. Unit fixed effects δ_i control for time-invariant heterogeneity (e.g., elevation, climate, long-run conflict propensity, political preferences), while basin–year fixed effects α_{bt} absorb basin-specific contemporaneous shocks such as precipitation, temperature, and snowmelt patterns. X_{ibt} includes controls for water rights restrictions and drought conditions (SPEI) in some specifications. Standard errors are clustered at the municipality level throughout.

5. Results

While the regression tables report log-point coefficients, I convert these to percentage changes to facilitate interpretation of the results, and focus on a 10% increase in upstream water allocations (calculated as coefficient $\times$ 0.1). At the sample mean, this increase represents approximately 0.7 additional cubic meters per second (700 liters per second)—roughly equivalent to the annual entitlement of the 50th-largest right-holder in the sample, or the water allocation granted to a large agricultural operation or mining company (see Figure A.6 for a ranking showing the top 200 users). Figures A.9 to A.12 show the equivalent coefficients for varying hypothetical percentage increases.

5.1 Water availability

Table 2 and Figure 3 document large and precisely estimated hydrological responses to upstream groundwater extraction. A 10% increase in upstream allocations reduces winter streamflow by 1.0 m^3/s but increases summer streamflow by 0.7 m^3/s. This seasonal pattern likely reflects the timing of groundwater extraction and irrigation practices: pumping occurs primarily during the growing season, directly reducing winter baseflows as aquifers that normally feed streams are depleted, while summer irrigation eventually returns water to the river system through runoff and percolation. Despite this partial recovery, the net annual effect remains a loss of 0.3 m^3/s.

Water table effects provide evidence of persistent aquifer depletion. The same 10% allocation increase deepens water tables by 0.09 meters annually and 0.12 meters during summer months. Unlike streamflow, water table effects show no seasonal recovery, indicating that extraction creates lasting impacts on aquifer levels that do not fully recover between pumping seasons. This pattern suggests aquifer mining, where extraction rates exceed natural recharge rates, creating progressive groundwater storage depletion particularly concerning for rural communities and smallholder farmers who rely on shallow wells and lack resources to adapt.

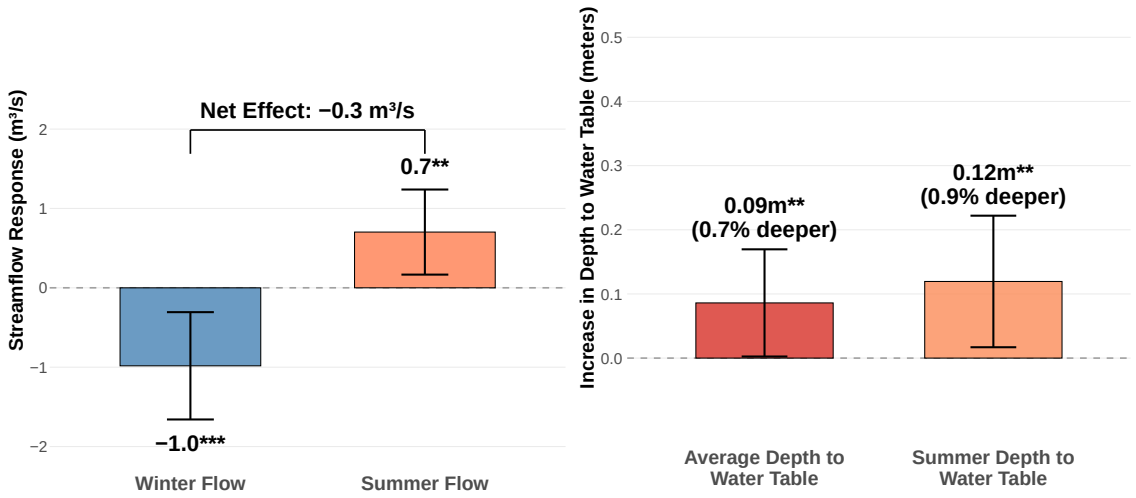
The spatial pattern of effects supports a causal interpretation and validates the theoretical framework. For groundwater allocations, neither downstream nor local allocations significantly affect streamflow, suggesting the upstream impact operates through hydrological connectivity rather than spurious correlation. Remarkably, this clean upstream-downstream distinction does not hold for surface water allocations, which show significant effects from both upstream and downstream grants (see Appendix Figure A.8). This contrast confirms that surface water systems with coordinated management internalize spatial externalities, while individualistic groundwater extraction allows upstream users to impose uncompensated costs downstream.

Table 2: The Impact of Groundwater Allocation on Streamflow and Water Table Depth

	Streamflow		Water Table Depth	
	Winter	Summer	Average	Summer
	(1)	(2)	(3)	(4)
Log Upstream GWA	−10.31***	7.37**	0.90**	1.25**
	(3.62)	(2.87)	(0.45)	(0.55)
Log Downstream GWA	−0.78	−1.63	−0.48	−0.61
	(4.26)	(1.90)	(0.45)	(0.46)
Log Local GWA	−5.22	1.61*	−0.68**	−1.00***
	(3.90)	(0.92)	(0.33)	(0.33)
Fixed Effects		Census Tract, Basin × Year		
Dep. Var. Mean	75.10	38.77	12.71	12.61
Observations	4073	4128	3616	3188
Stations	367	367	228	228
Years	2005 – 2017	2005 – 2017	2005 – 2024	2005 – 2024

Notes: Standard errors clustered at the municipality level are reported in parentheses. All specifications include census tract and basin-by-year fixed effects. Streamflow is measured in m^3/s; water table depth is measured in meters below static level. GWA denotes Groundwater Allocation. $\log \text{GWA}^{\text{up (down)}}$ sums the authorized annual flow upstream (downstream) from the station; $\log \text{GWA}^{\text{local}}$ refers to allocations whose intake points fall within the rural area of the station. Coefficients represent the effect of a one-log-point increase. For easier interpretation, I report effects for a 10% increase (0.1 log points) in the text, calculated as coefficient × 0.1. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$.

Figure 3: 10% Increase in Upstream Groundwater Allocation and Water Availability



Notes: The figure shows the impact of a 10% increase in upstream groundwater allocations on water availability measures. Coefficient estimates and 95% confidence intervals are from regressions with census tract and basin-by-year fixed effects. Winter Flow and Summer Flow measure streamflow in cubic meters per second during June-August and January-March, respectively. Average and Summer Depth to Water Table measure static groundwater levels in meters below ground surface. Effects are expressed as absolute changes, with percentage changes relative to baseline means shown in parentheses where indicated. The net streamflow effect combines winter losses with summer gains. Standard errors are clustered at the municipality level. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$.

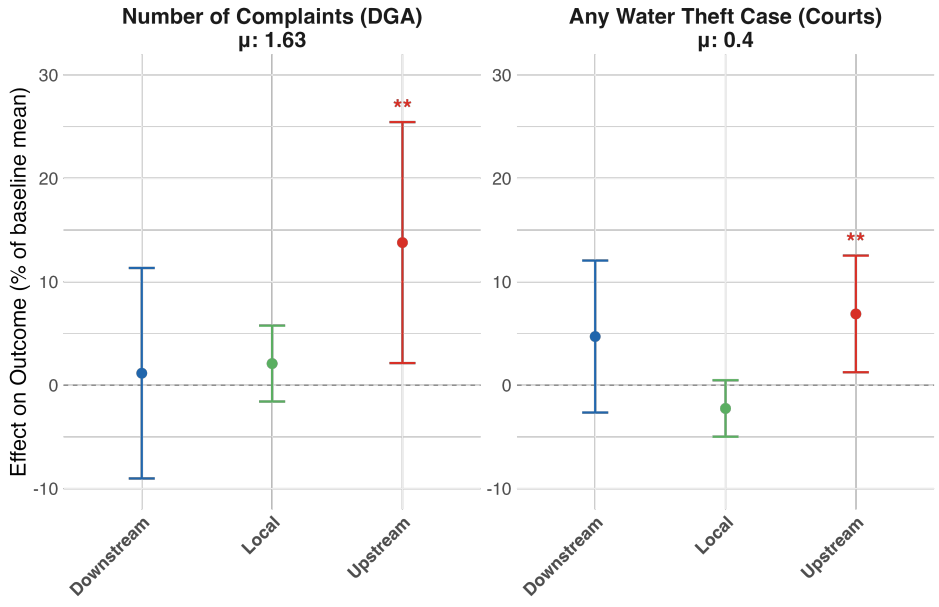
5.2 Social Conflict

5.2.1 Water-related complaints and disputes

Figure 4 and corresponding Appendix Table A.1 show that reduced water availability translates into increased disputes over water resources. A 10% increase in upstream groundwater allocations raises administrative complaints to the DGA by 0.25 incidents per municipality-year—a 15% increase given the sample mean of 1.63 complaints. Similarly, upstream allocations increase the probability of water theft court cases by 2.9 percentage points, representing a 7% increase relative to the baseline rate of 0.40.

The spatial distribution of effects again supports the causal interpretation. Neither local allocations nor downstream allocations significantly affect administrative complaints —which are georeferenced— consistent with upstream extraction driving water stress that manifests in disputes among downstream users. For court cases, the pattern is similar, though downstream allocations show a marginally positive (though statistically non-significant) coefficient. This may reflect jurisdictional constraints, as courts are not available in every municipality and some conflicts originating downstream may be adjudicated in upstream jurisdictions where the nearest court is located.

Figure 4: The Impact of Groundwater Allocation on Water-Related Disputes

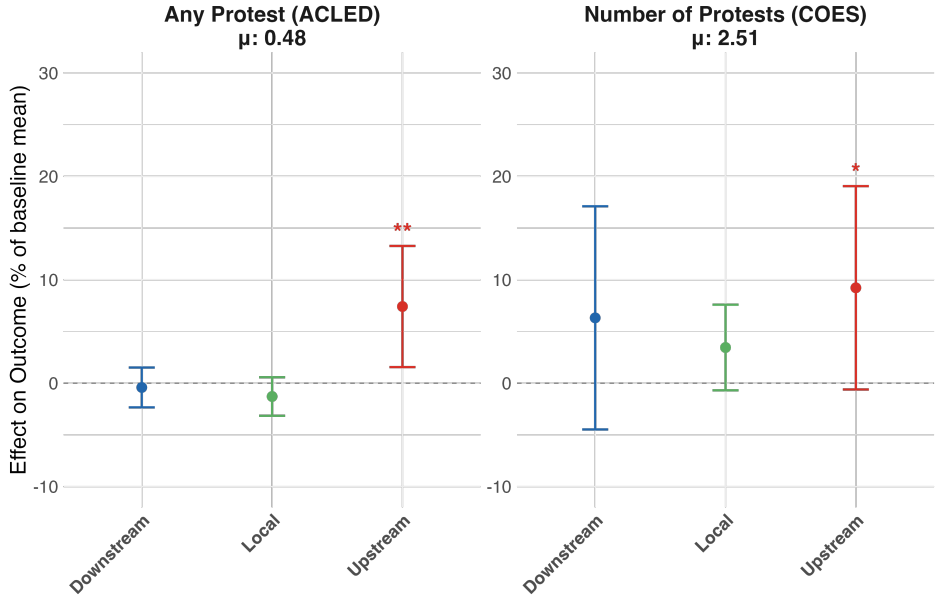


Notes: The figure shows the impact of a 10% increase in groundwater allocations on water-related dispute measures, with effects expressed as percentage changes relative to baseline means. Coefficient estimates and 95% confidence intervals are from regressions with municipality and basin-by-year fixed effects. The left panel shows effects on the number of administrative complaints filed with the General Water Directorate (DGA) for suspected Water Code violations. The right panel shows effects on a binary indicator for any water theft criminal court case filed in a municipality-year. Downstream, Local, and Upstream refer to the hydrological location of groundwater allocations relative to each municipality. Sample means (μ) are reported for each outcome. Standard errors are clustered at the municipality level. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$.

5.2.2 Protests

Figure 5 (Table A.2) demonstrates that water stress from increased allocations extends beyond direct water disputes to broader social conflict. A 10% increase in upstream groundwater allocations raises the probability that a downstream municipality experiences any protest by 3.7 percentage points—a 6% increase relative to the baseline incidence of 48%. Using the COES protest count data, the same increase generates an additional 0.25 protest events per year, representing 9% of the mean count. Consistent with the previous results, neither downstream nor local allocations significantly affect protest occurrence, reinforcing the causal interpretation that upstream extraction drives downstream social tensions.

Figure 5: The Impact of Groundwater Allocation on Protests

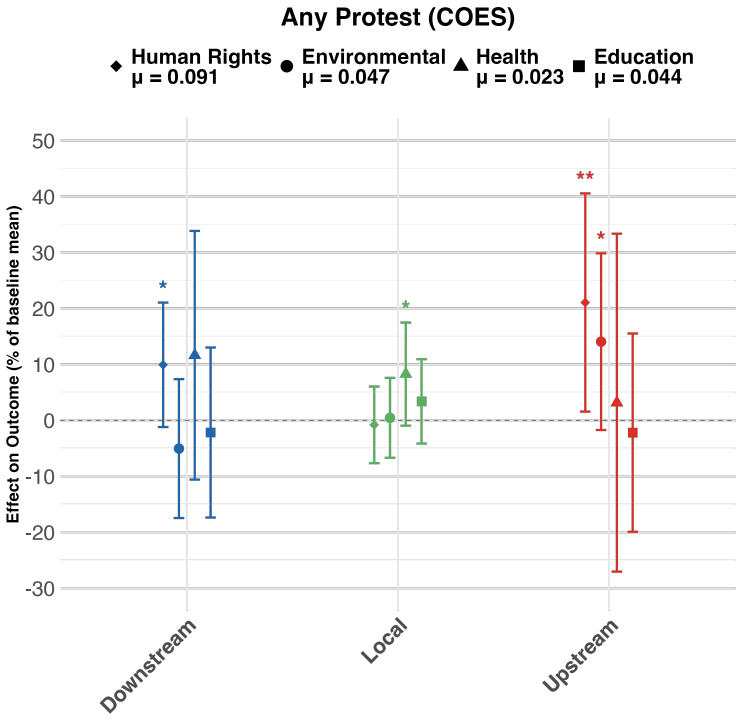


Notes: The figure shows the impact of a 10% increase in groundwater allocations on water-related dispute measures, with effects expressed as percentage changes relative to baseline means. Coefficient estimates and 95% confidence intervals are from regressions with municipality and basin-by-year fixed effects. The left panel shows effects on a binary indicator for any protest occurring in a municipality-year. The right panel shows effects on the protest count in a municipality-year. Downstream, Local, and Upstream refer to the hydrological location of groundwater allocations relative to each municipality. Sample means (μ) are reported for each outcome. Standard errors are clustered at the municipality level. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$.

The nature of these protests provides insight into the mechanisms linking water stress to social unrest. Figure 6 (Table A.3) shows that human rights and environmental protests account for the largest response to upstream water allocations, suggesting that communities mobilize around concerns about resource degradation and ecosystem impacts. The protest targets also reveal institutional grievances: Appendix Table A.4 indicates that national government becomes the primary target of increased protest activity, rather than private companies or local authorities. This pattern suggests that communities view water allocation decisions

as failures of national water policy rather than isolated private actions.

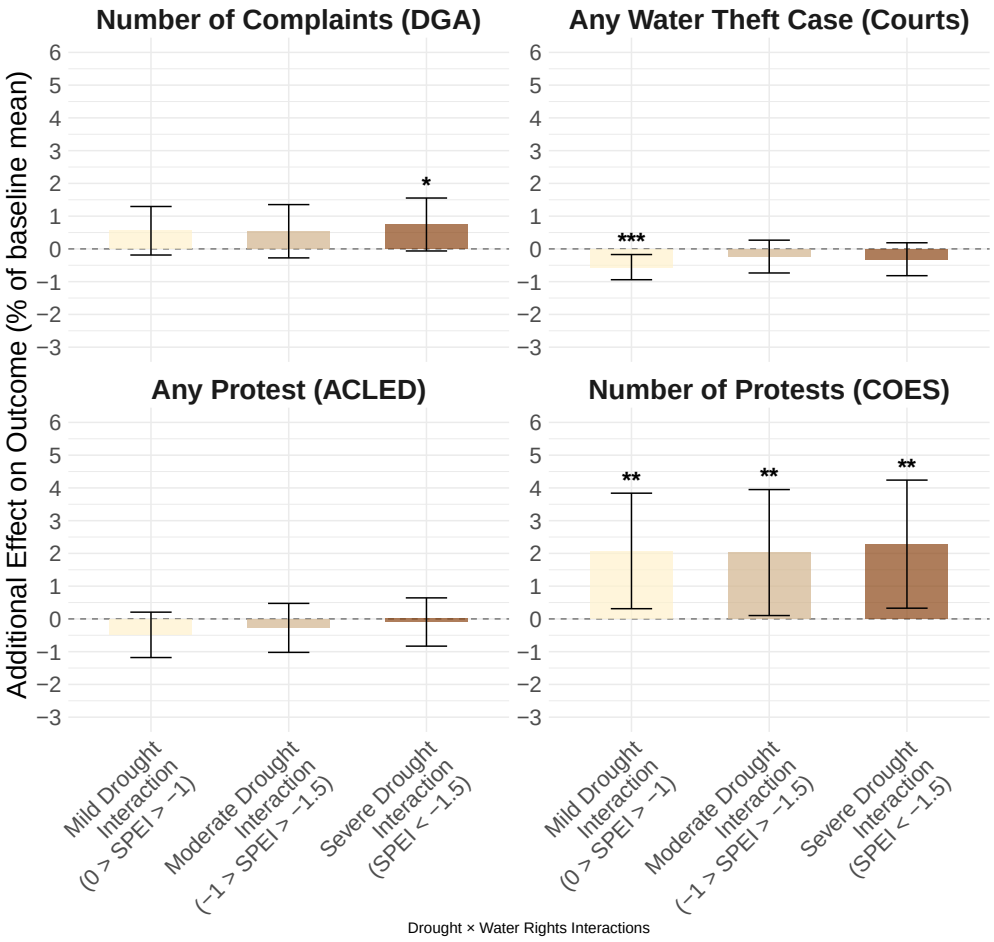
Figure 6: The Impact of Groundwater Allocation on Protests, by Issue



Notes: The figure shows the impact of a 10% increase in groundwater allocations on protest occurrence by issue type, with effects expressed as percentage changes relative to baseline means. Coefficient estimates and 95% confidence intervals are from regressions with municipality and basin-by-year fixed effects using COES protest data (2016-2021). Each panel shows effects on a binary indicator for any protest related to the specified issue occurring in a municipality-year. Downstream, Local, and Upstream refer to the hydrological location of groundwater allocations relative to each municipality. Sample means (μ) show the baseline probability of protests by issue type. Standard errors are clustered at the municipality level. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$.

5.3 Heterogeneous effects by drought conditions

Figure 7: Interaction Effects: Groundwater Allocation × Drought



Notes: The figure shows interaction effects between upstream groundwater allocations and drought conditions on social conflict outcomes. Each panel displays the additional effect of a 10% increase in upstream allocations under different drought severity levels, measured by the Standardized Precipitation Evapotranspiration Index (SPEI). Mild Drought corresponds to SPEI values between 0 and -1, Moderate Drought to SPEI between -1 and -1.5, and Severe Drought to SPEI below -1.5. Effects are expressed as percentage changes relative to baseline means and represent the interaction coefficient from regressions including municipality and basin-by-year fixed effects, plus main effects for both groundwater allocations and drought conditions. Standard errors are clustered at the municipality level. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$.

To assess how increased demand for water interacts with decreased supply due to reduced precipitation, I conduct an additional analysis interacting upstream groundwater extraction with time-varying drought conditions, measured by the Standardized Precipitation Evapotranspiration Index (SPEI). Figure 7 shows that drought conditions can amplify the conflict effects of upstream groundwater allocations, though the patterns vary across outcome types. For water-related disputes, the interaction effects are generally modest: administrative complaints show a small positive interaction during severe drought conditions, while water theft court

cases exhibit a negative interaction during mild drought, suggesting that formal legal proceedings may be less common when water problems are attributed to natural precipitation shortages. The most pronounced interaction effects appear in the broader protest measures. COES protest data shows a clear escalation pattern, with the additional effect of groundwater allocations rising from approximately 2 percentage points during mild drought to over 4 percentage points during severe drought conditions—adding substantially to the baseline effect of 9%. This suggests that while human-induced water scarcity generates conflict even under normal precipitation conditions, the social response intensifies when communities face scarcity from both anthropogenic extraction and climatic water shortages—a dynamic that becomes increasingly relevant under climate change.

6. Conclusion

This paper demonstrates that water institutions themselves can allow scarcity that generates social conflict. Using comprehensive data on Chilean groundwater rights and a novel spatial spillovers identification strategy exploiting the directional flow of water, I provide direct causal evidence linking water allocation permits to hydrological impacts and social tensions, moving beyond the inference-based approaches that have dominated this literature. A 10% increase in upstream groundwater allocations—equivalent to 0.7 cubic meters per second at the sample mean, or the water rights of the 50th largest user—reduces downstream streamflow by a net 0.3 cubic meters per second while deepening monitoring wells by 0.09-0.12 meters.

This human-induced water stress translates into measurable social consequences: a 15% increase in administrative complaints about water violations, a 7% increase in the probability of a water theft court case, and a 9% increase in protest occurrence. The findings reveal important mechanisms through which water governance affects social stability. Communities mobilize primarily around human rights and environmental issues and target the national government rather than private actors, indicating that water allocation decisions are viewed as failures of the centralized water management system rather than isolated private actions. Moreover, drought conditions amplify these effects substantially—the protest response to groundwater allocations increases during severe drought periods, suggesting that governance failures become particularly destabilizing when natural water availability is constrained.

These results have important implications for water governance in an era of increasing scarcity. The Chilean experience demonstrates that market-based allocation systems, while theoretically efficient, can generate significant negative externalities when institutional frameworks fail to account for hydrological connectivity and cumulative impacts. The contrast between surface and groundwater governance reveals that institutional design matters crucially: systems that foster collective management can internalize spatial

externalities, while individualistic extraction regimes allow upstream users to impose uncompensated costs on downstream communities. Basin-wide coordination mechanisms, adaptive allocation limits that respond to hydrological conditions, and stronger monitoring of cumulative impacts may help mitigate these externalities while preserving the benefits of secure water rights.

More broadly, this study underscores the need to consider anthropogenic resource depletion alongside climate-driven scarcity in understanding environmental conflict. The interaction between human-induced and natural water stress suggests that governance failures in resource allocation may be particularly destabilizing during periods when natural availability is already constrained. As human pressure on natural resources intensifies globally, the institutional arrangements governing access and allocation become increasingly consequential for social stability. Future work examining similar dynamics in other resource sectors and institutional contexts could provide valuable insights for sustainable development in resource-constrained environments.

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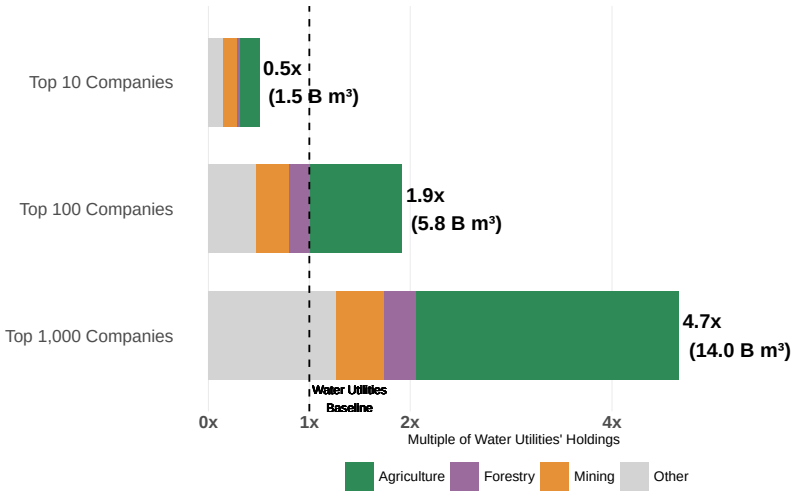
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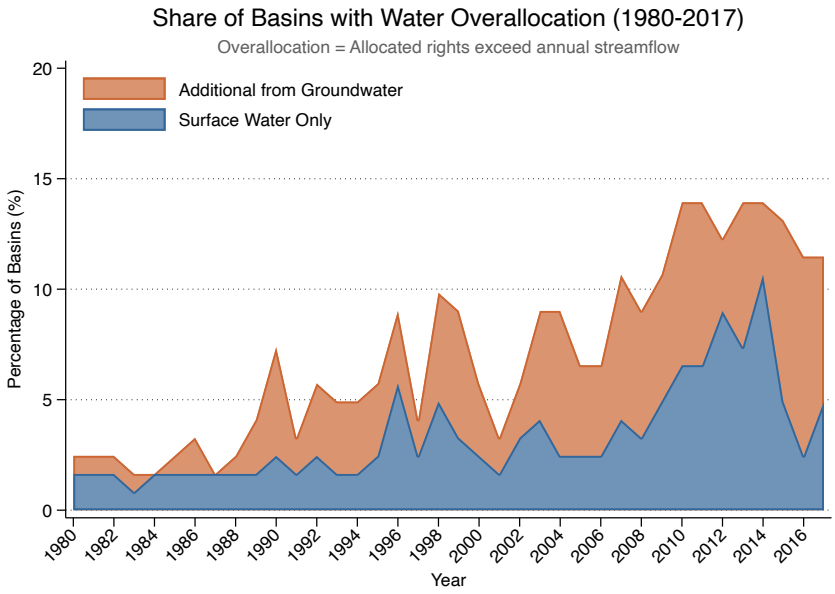
A. Appendix

Figure A.1: Concentration of water rights relative to water utilities holdings



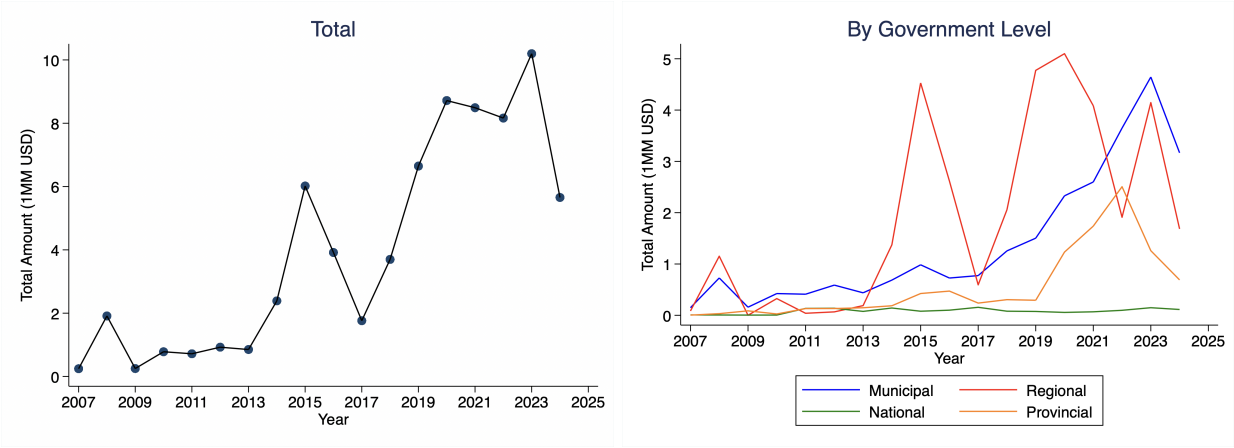
Notes: Figure A.1 shows water allocation of the top 10, 100, and 1000 companies, relative to the total allocation of water utilities (1X at 3 Billion $m^3/year$). Colors indicate use type.

Figure A.2: Share of basins with water overallocation



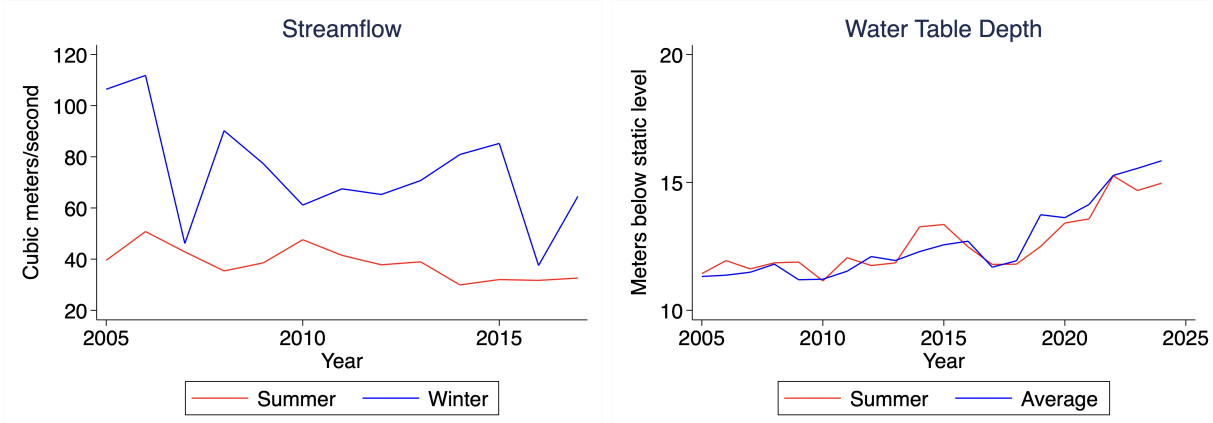
Notes: The figure shows the percentage of river basins in Chile experiencing water overallocation from 1980 to 2017, where overallocation is defined as total allocated water rights exceeding average annual streamflow. The blue area represents basins overallocated from surface water rights alone, while the orange area shows additional overallocation contributed by groundwater rights. The data demonstrate the growing role of groundwater in creating basin-level overallocation, particularly from the early 2000s onward. By 2017, approximately 12% of basins experienced overallocation, with groundwater rights contributing substantially to this overallocation in most affected basins. Source: Author's calculations based on DGA water rights registry and streamflow data.

Figure A.3: Government expenditure on tanker trucks 2007-2024



Notes: Figure A.3 shows total government expenditure on tanker trucks from 2007 to 2024, in millions of USD. The left panel presents total spending across all government levels (national, regional, provincial, and municipal), while the right panel breaks down expenditure by government level. Data comes from Mercado Público, an open dataset of all government purchase orders. Spending is identified by filtering for "*aljibe*"—the specific Spanish term for tanker trucks (*camión aljibe*). Regional governments primarily handle fixed costs (purchasing trucks), while municipalities cover variable costs (purchasing water to fill trucks from utility companies).

Figure A.4: Evolution of streamflow and water table depth

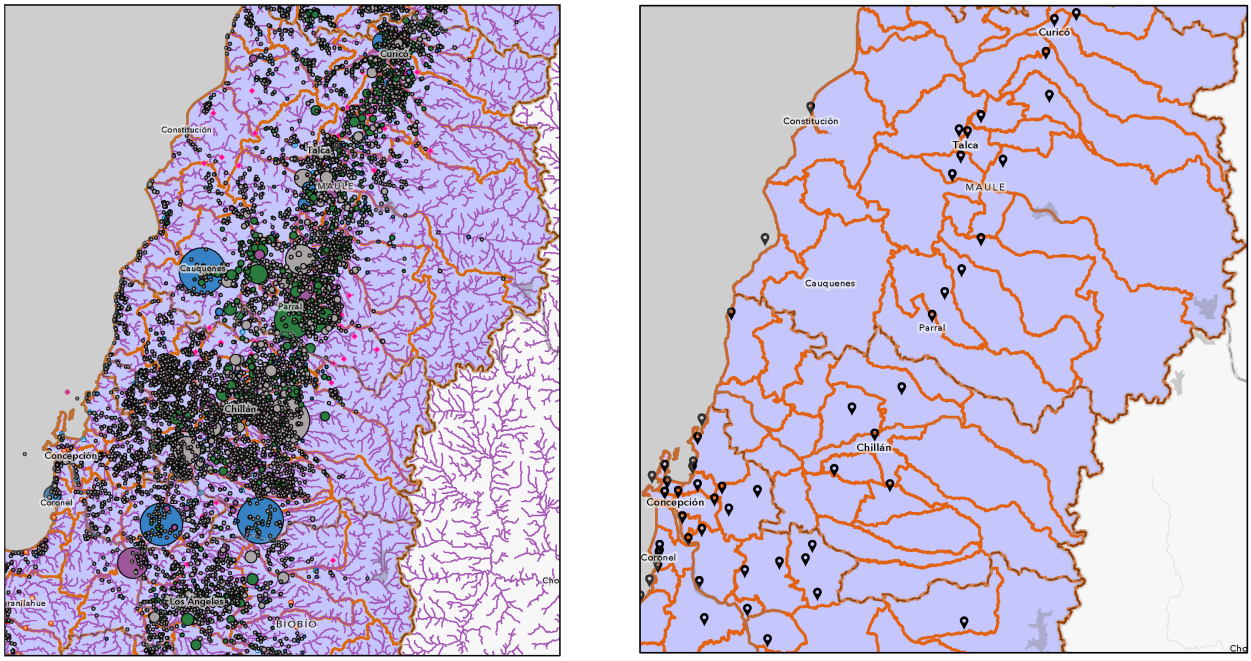


Notes: Each line shows the seasonal average over all monitoring stations. Left panel: summer (January-March) and winter (June–August) average streamflow, expressed in cubic meters per second. Right panel: summer (January–March) and average (January-December) mean static water table depth, expressed in meters below ground surface. Both series are constructed from monthly records maintained by the General Water Directorate and processed by the Centro de Ciencia del Clima y la Resiliencia (CR2).

Figure A.5: Spatial distribution of groundwater rights and protest events in Chile's central–southern zone

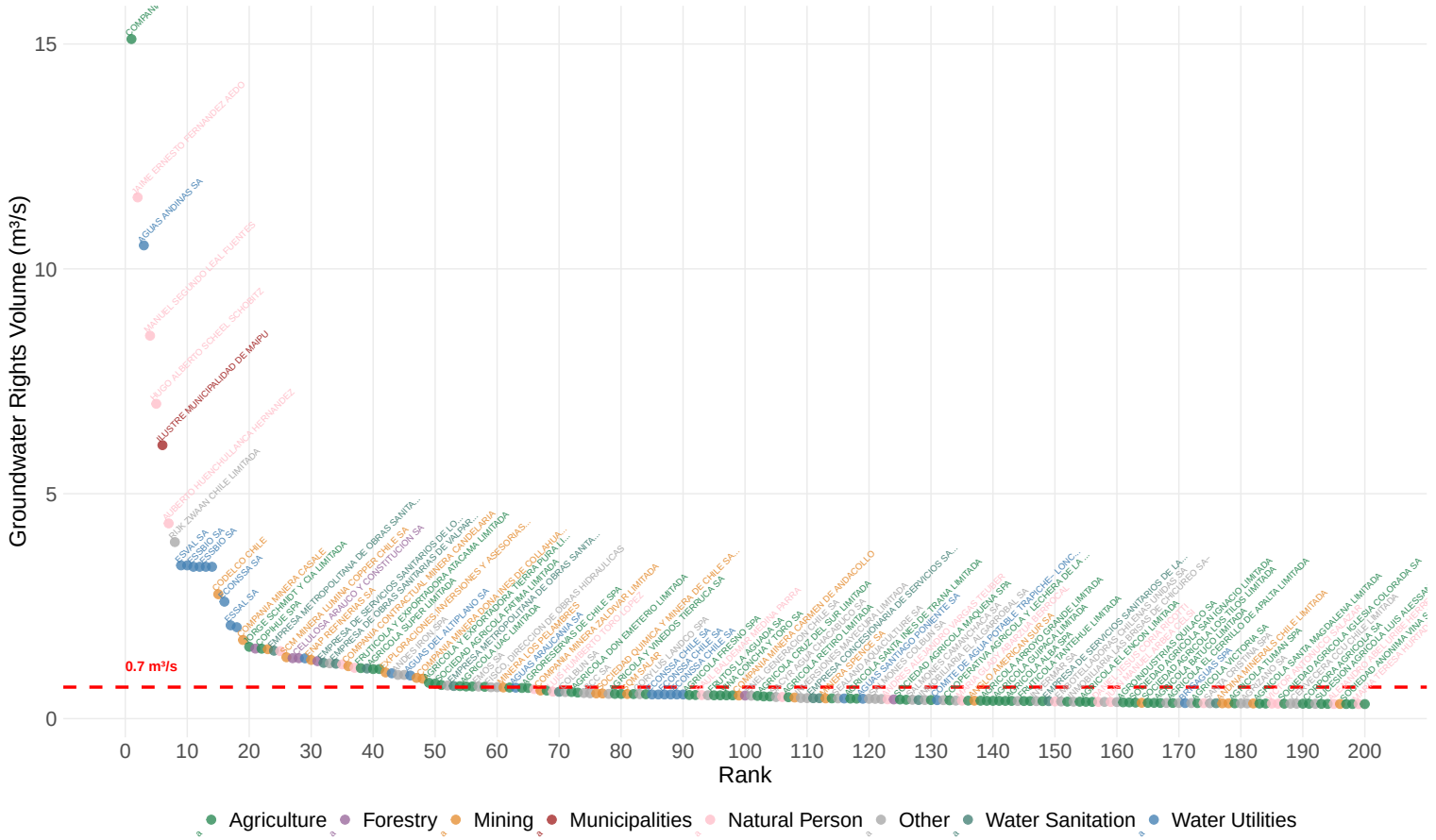
(a) Groundwater rights by sector

(b) Protest events (ACLED, 2018–2024)



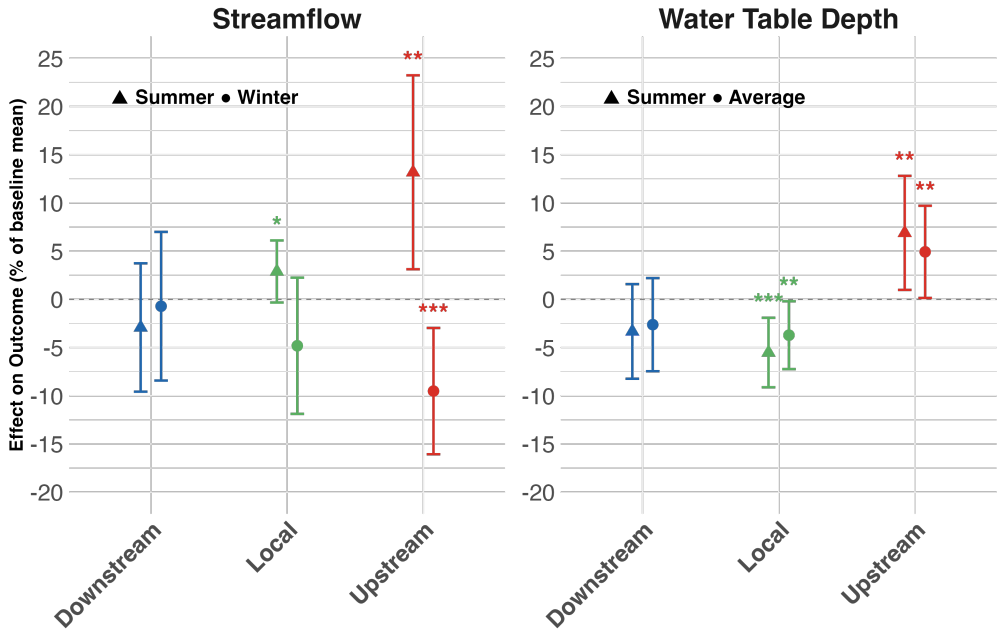
Notes: Panel (a) plots all registered groundwater-right intake points by holder. Point size is proportional to the authorized flow; colors denote the sector of use—agriculture (green), water utilities and sanitation (blue), forestry (purple), and other productive activities (gray). The river network is HydroRIVERS v1.0 (lilac). Panel (b) shows the location of protest events recorded by ACLED for 2018–2024 (black markers). In both panels, orange lines delineate 2017-census municipality boundaries.

Figure A.6: Top 200 Groundwater Right Holders in Chile



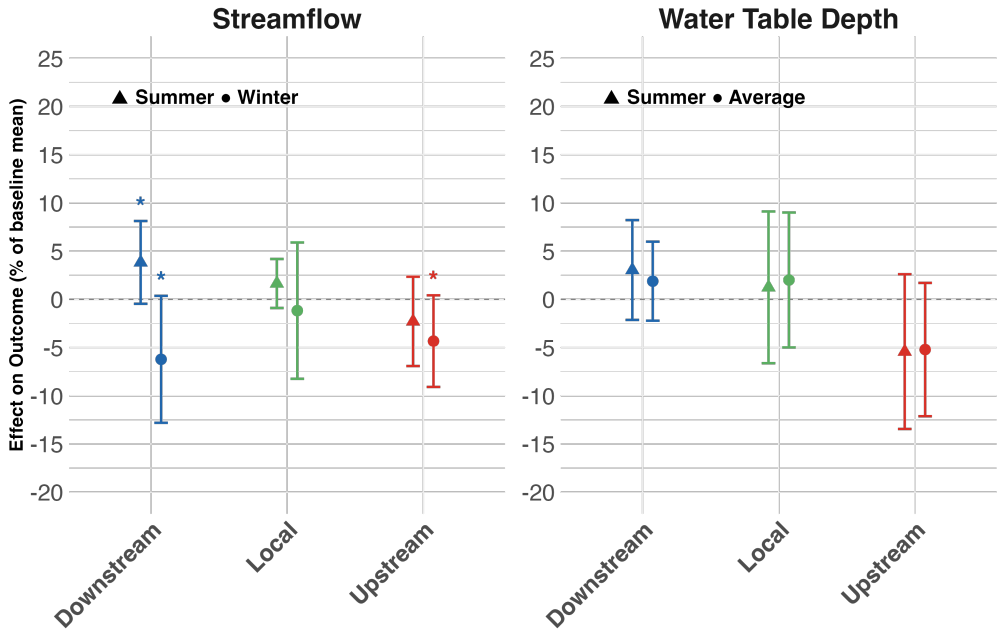
Notes: Figure A.6 shows the top 200 groundwater right holders in Chile as of 2025, color coded according to water use or sector. A dashed red line marks 0.7 cubic meters per second — the allocation equivalent to a 10% increase in upstream groundwater rights at the sample mean for 2005-2024.

Figure A.7: The Impact of Groundwater Allocation on Water Availability



Notes: The figure shows the impact of a 100% increase in groundwater allocations on water availability measures, with effects expressed as percentage changes relative to baseline means. Coefficient estimates and 95% confidence intervals are from regressions with census tract and basin-by-year fixed effects. Winter and Summer Streamflow measure discharge during June-August and December-February, respectively. Average and Summer Water Table Depth measure static groundwater levels below ground surface. Downstream, Local, and Upstream refer to the hydrological location of groundwater allocations relative to each monitoring station. The clear upstream-downstream distinction for groundwater validates the spatial spillovers identification strategy. Standard errors are clustered at the municipality level. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$.

Figure A.8: The Impact of Surface Water Allocation on Water Availability



Notes: The figure shows the impact of a 10% increase in surface water allocations on water availability measures, with effects expressed as percentage changes relative to baseline means. Coefficient estimates and 95% confidence intervals are from regressions with census tract and basin-by-year fixed effects. Winter and Summer Streamflow measure discharge during June-August and December-February, respectively. Average and Summer Water Table Depth measure static groundwater levels below ground surface. Downstream, Local, and Upstream refer to the hydrological location of surface water allocations relative to each monitoring station. Note the absence of clear spatial patterns compared to groundwater (Figure A.7), reflecting institutional differences in water management between surface and groundwater systems. Standard errors are clustered at the municipality level. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$.

Table A.1: The Impact of Groundwater Allocation on Water-Related Disputes

	Administrative Complaints (DGA)		Water Theft Court Cases	
	(1)	(2)	(3)	(4)
Log Upstream GWA	2.33**	1.61	0.29**	0.26**
	(1.01)	(1.22)	(0.12)	(0.11)
Log Downstream GWA	0.21	0.03	0.20	0.17
	(0.89)	(0.82)	(0.16)	(0.16)
Log Local GWA	0.36	0.27	−0.09	−0.10*
	(0.32)	(0.33)	(0.06)	(0.06)
SPEI		−0.36***		−0.05**
		(0.12)		(0.02)
Fixed Effects	Muni, Basin × Year	Muni, Basin × Year	Muni, Basin × Year	Muni, Basin × Year
Dep. Var. Mean	1.63	1.63	0.40	0.40
Observations	2046	2028	1337	1337
Municipalities	341	338	135	135
Years	2018 – 2023	2018 – 2023	2015 – 2024	2015 – 2024

Notes: Standard errors clustered at the municipality level are in parentheses. All columns control for municipality and basin-by-year fixed effects. Administrative complaints include violations related to unauthorized water extraction and unauthorized works in waterways, filed with the General Water Directorate (DGA). Water theft court cases refer to criminal prosecutions for water usurpation filed in tribunals. Columns (1) and (2) use counts of administrative complaints filed with the DGA. Columns (3) and (4) use Water Theft Court Cases data and equals one if at least one criminal case was filed in a municipality-year. Columns (2) and (4) show specifications that include SPEI as an additional control. Lower values of SPEI represent more severe drought conditions. Coefficients represent the effect of a one-log-point increase. For easier interpretation, I report effects for a 10% increase (0.1 log points) in the text, calculated as coefficient × 0.1. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$.

Table A.2: The Impact of Groundwater Allocation on Protests

	Any Protest (ACLED)		Number of Protests (COES)	
	(1)	(2)	(3)	(4)
Log Upstream GWA	0.37**	0.43***	2.45*	2.68*
	(0.15)	(0.16)	(1.34)	(1.45)
Log Downstream GWA	−0.02	−0.05	1.66	1.87
	(0.05)	(0.05)	(1.42)	(1.51)
Log Local GWA	−0.06	−0.10**	0.93*	1.06*
	(0.05)	(0.05)	(0.56)	(0.62)
SPEI		−0.04*		−1.49**
		(0.02)		(0.75)
Fixed Effects	Muni, Basin × Year	Muni, Basin × Year	Muni, Basin × Year	Muni, Basin × Year
Dep. Var. Mean	0.48	0.48	2.51	2.53
Observations	2387	2366	2046	2028
Municipalities	341	338	341	338
Years	2018 – 2024	2018 – 2024	2016 – 2021	2016 – 2021

Notes: Standard errors clustered at the municipality level are in parentheses. All columns control for municipality and basin-by-year fixed effects. The estimations in Columns (1) and (2) use ACLED data and the outcome equals one if at least one protest occurred in a municipality–year. Those in Columns (3) and (4) use a protest events count coded by the COES Observatory. Coefficients represent the effect of a one-log-point increase. Columns (2) and (4) show specifications that include SPEI as an additional control. Lower values of SPEI represent more severe drought conditions. For easier interpretation, I report effects for a 10% increase (0.1 log points) in the text, calculated as coefficient × 0.1. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$.

Table A.3: The Impact of Groundwater Allocation on Protests by Issue

	Any Protests by Issue			
	Environment	Health	Education	Human Rights
	(1)	(2)	(3)	(4)
Log Upstream GWA	0.07*	0.01	−0.01	0.20**
	(0.04)	(0.04)	(0.04)	(0.10)
Log Downstream GWA	−0.02	0.03	−0.01	0.10*
	(0.03)	(0.03)	(0.04)	(0.05)
Log Local GWA	0.00	0.02*	0.02	−0.01
	(0.02)	(0.01)	(0.02)	(0.03)
SPEI	−0.05***	−0.01	−0.01	−0.04**
	(0.02)	(0.01)	(0.01)	(0.02)
Fixed Effects	Muni, Basin × Year	Muni, Basin × Year	Muni, Basin × Year	Muni, Basin × Year
Dep. Var. Mean	0.05	0.02	0.04	0.09
Observations	2028	2028	2028	2028
Municipalities	338	338	338	338

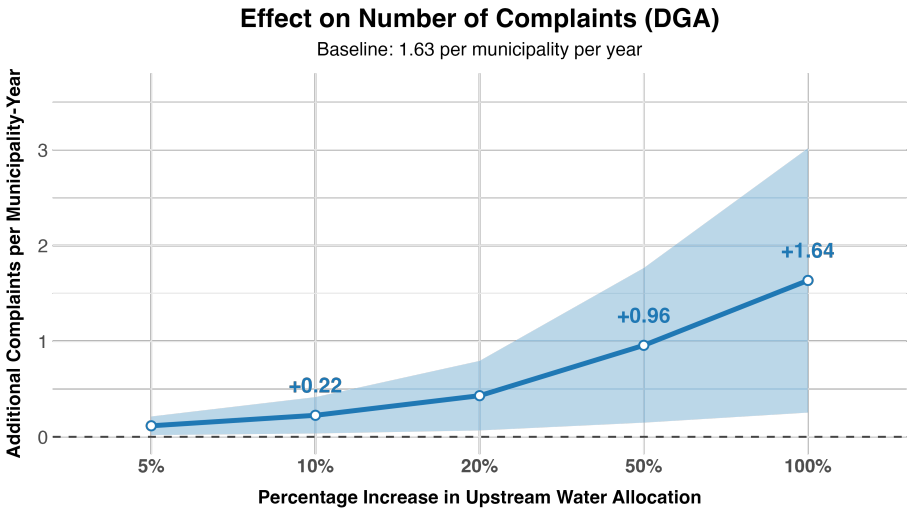
Notes: Standard errors clustered at the municipality level are in parentheses. Both columns control for municipality and basin-by-year fixed effects. Columns (1)-(4) count protest events coded by the COES Observatory that are related to the (1) Environment, (2) Health, (3) Education, and (4) Human Rights. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$.

Table A.4: The Impact of Groundwater Allocation on Protests by Target

	Protests by Target		
	Private Companies	Local Government	National Government
	(1)	(2)	(3)
Log Upstream GWA	0.09	0.37	2.05*
	(0.19)	(0.25)	(1.20)
Log Downstream GWA	0.12	0.08	1.72
	(0.15)	(0.22)	(1.27)
Log Local GWA	0.12	0.13	0.68
	(0.10)	(0.08)	(0.46)
Fixed Effects	Muni, Basin × Year	Muni, Basin × Year	Muni, Basin × Year
Dep. Var. Mean	0.34	0.30	1.75
Observations	2028	2028	2028
Municipalities	338	338	338

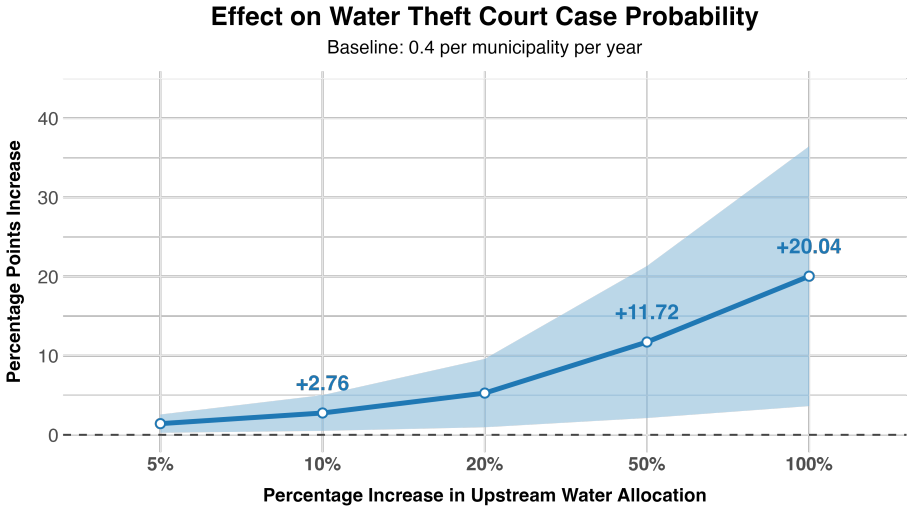
Notes: Standard errors clustered at the municipality level are in parentheses. Both columns control for municipality and basin-by-year fixed effects. Columns (1)-(3) count protest events coded by the COES Observatory, that target (1) Private Companies, (2) the Local Government, or (3) the National Government. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$.

Figure A.9: Effect of Upstream Groundwater Allocation on Administrative Complaints: Varying Percentage Increases



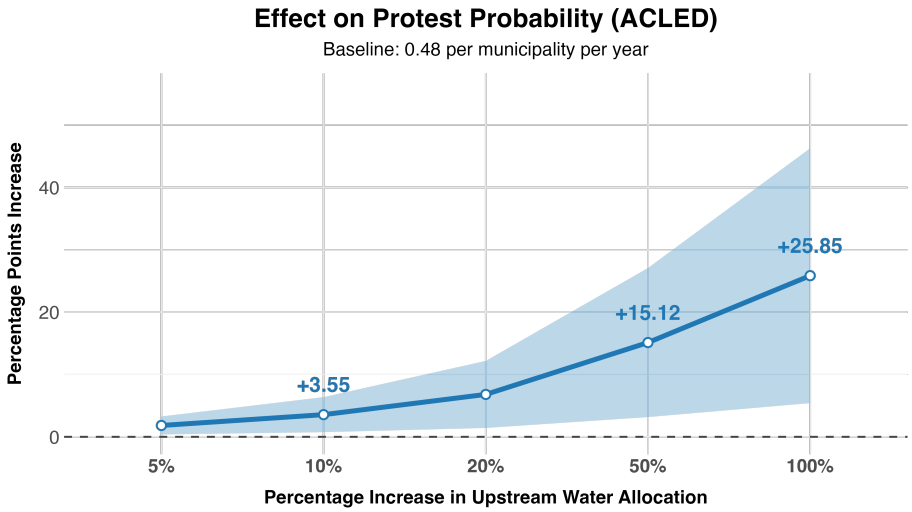
Notes: The figure shows the estimated impact of varying percentage increases in upstream groundwater allocations on the number of administrative complaints filed with the General Water Directorate (DGA). Effects are calculated by multiplying log-point coefficients by the corresponding percentage increase (e.g., coefficient × log(5) for a 5% increase). The regression includes municipality and basin-by-year fixed effects with standard errors clustered at the municipality level. The baseline mean for administrative complaints is 1.63 per municipality-year.

Figure A.10: Effect of Upstream Groundwater Allocation on Water Theft Court Cases: Varying Percentage Increases



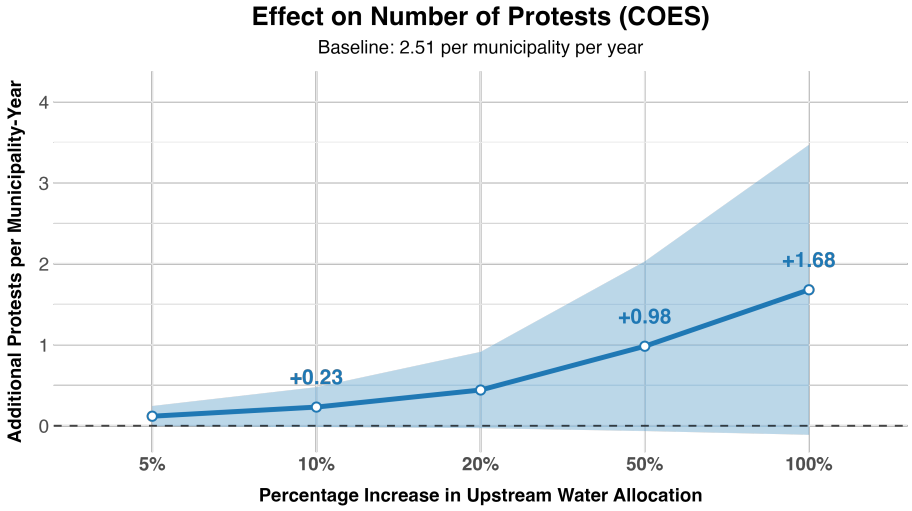
Notes: The figure shows the estimated impact of varying percentage increases in upstream groundwater allocations on the probability of a prosecution for water theft being filed at a local court. Effects are calculated by multiplying log-point coefficients by the corresponding percentage increase (e.g., coefficient × log(5) for a 5% increase). The regression includes municipality and basin-by-year fixed effects with standard errors clustered at the municipality level. The baseline mean for water theft court case probability is 0.4 per municipality-year.

Figure A.11: Effect of Upstream Groundwater Allocation on Protest Probability (ACLED): Varying Percentage Increases



Notes: The figure shows the estimated impact of varying percentage increases in upstream groundwater allocations on the percentage point increases in protest probability (ACLED). Effects are calculated by multiplying log-point coefficients by the corresponding percentage increase (e.g., coefficient $\times$ log(5) for a 5% increase). The regression includes municipality and basin-by-year fixed effects with standard errors clustered at the municipality level. The baseline mean for protest probability is 0.48 per municipality-year.

Figure A.12: Effect of Upstream Groundwater Allocation on Protest Events (COES): Varying Percentage Increases



Notes: The figure shows the estimated impact of varying percentage increases in upstream groundwater allocations on the number of Protest Events as recorded by COES. Effects are calculated by multiplying log-point coefficients by the corresponding percentage increase (e.g., coefficient $\times$ log(5) for a 5% increase). The regression includes municipality and basin-by-year fixed effects with standard errors clustered at the municipality level. The baseline mean for protest count is 2.51 per municipality-year.