Water Allocation and Social Unrest: Evidence from Chilean Water Rights

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Abstract

When water scarcity can be attributed to identifiable actors rather than solely to climatic conditions, affected individuals may be more likely to mobilize in response. I estimate the effects of water rights allocated to commercial uses—primarily agriculture and mining—on water availability and social conflict in Chile. I construct a panel that combines georeferenced surface- and groundwater rights held by more than 50,000 users with streamflow data, complaints filed with the Water Authority, water-theft lawsuits, and protest events, across 80 river basins from 2005 to 2024. To measure competing water allocation, I classify new rights according to whether they are hydrologically connected to each spatial unit, and divide the volume granted by the unit's renewable flow. This measure exploits river-flow direction and distance from intake points, allowing me to estimate spatial spillover effects. A 10-percentage-point increase in competing allocation reduces annual streamflow by 7.3%. While I find no effect on complaints or water-theft lawsuits, protests increase, particularly those targeting firms. The same increase raises the probability of a protest against firms by 8% relative to its baseline rate. The effect is larger where a greater share of renewable flow is already committed, consistent with more rivalry over the resource driving people to the streets. It is also larger where water rights are concentrated among a few large holders, consistent with concentrated ownership creating visible targets which facilitate collective action. The effect is further amplified during severe droughts.

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

JEL codes: Q25, Q54, D74, O13

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1. Introduction

Global freshwater withdrawals have more than tripled since 1950 and continue to rise, driven by agricultural intensification and urbanization. Across much of the world, water extraction now exceeds rates of renewal—a condition that a recent UN assessment called the "era of Global Water Bankruptcy" (Institute for Water, Environment and Health, 2026). A large literature examines the social consequences of climate-induced water scarcity, documenting links between drought and violent conflict, particularly in lower-income countries (Hendrix and Salehyan, 2012; Hsiang et al., 2013; Almer et al., 2017; Harari and Ferrara, 2018; McGuirk and Nunn, 2020; Unfried et al., 2022). Yet water scarcity does not arise from climatic conditions alone. I argue that scarcity is more likely to generate mobilization when it can be traced to identifiable allocation and extraction decisions. When extraction is authorized by law, administered by public institutions, and performed by visible corporate actors, responsibility for the resulting scarcity can be attributed. This creates both a target for collective action and a basis for demanding redress.

Chile offers a useful setting for examining human-driven water scarcity. More than 100 rivers descend from the Andes to the Pacific Ocean, providing substantial hydrological variation within a common national institutional framework. The 1981 Water Code established extraction rights that were perpetual, tradable, and constitutionally protected.[1] Under this framework, the National Water Authority continued granting new rights for free even as renewable supplies declined, causing cumulative allocations to exceed annual renewable flow in many basins. By 2019, 23 river basins were over-appropriated. These allocations, combined with a megadrought during the 2010s (Garreaud et al., 2019), made the consequences of water scarcity increasingly acute throughout the country.

By 2022, 53% of Chile's 346 municipalities were simultaneously under official water-scarcity declarations, and many faced water rationing. Rights to this increasingly scarce

[1]Chilean law grants the right to extract a specified flow from a source, rather than ownership of the water itself. For brevity, I refer to these extraction rights as *water rights* throughout the paper.

resource are highly concentrated: the 1,000 largest corporate holders control 4.7 times as much water as all utilities supplying drinking water to the population combined. This disparity is captured in the protest slogan '*No es sequía, es saqueo*" ('It's not drought; it's looting"), which frames scarcity as the result of extraction by identifiable actors rather than climatic forces alone. In this paper, I estimate the contribution of water allocations to declining streamflow and then examine whether these allocations generate conflict, and through which channels.

First, I estimate the effect of water allocation on water availability using a cell-year panel from 2005 to 2019 that combines georeferenced rights with streamflow measurements. I then examine social consequences in a municipality-year panel from 2005 to 2024, linking the same water rights data to water-theft lawsuits, administrative complaints to the Water Authority, and protest events. My spatial-spillovers design exploits the structure of river networks: a right at an intake point that is hydrologically connected to a unit can reduce the water this unit receives, whereas a disconnected one cannot. I build a time-varying competing-allocation index that normalizes connected surface- and groundwater rights by baseline flow, and use it as a plausibly exogenous treatment variable throughout the analysis. The empirical strategy section details the identifying assumption, fixed effects, and separate tests of the surface-water and groundwater channels.

I provide causal evidence that legally authorized water allocations reduce streamflow. A 10-percentage-point increase in competing allocation reduces annual streamflow by 7.3% ($0.62\,\mathrm{m}^3/\mathrm{s}$, relative to a mean of $8.6\,\mathrm{m}^3/\mathrm{s}$), with a larger response in summer, when demand peaks and natural flow is low. Noncompeting allocations have no discernible effect on annual flow. The results further show the expected spatial patterns: surface-water effects follow river direction, while groundwater effects are concentrated near the focal river segment.

I next examine whether competing water allocation generates social conflict. I distinguish institutional conflict—measured through water-theft lawsuits and administrative complaints—from extra-institutional conflict, measured through protest events. The estimated effects on the two institutional outcomes are not distinguishable from zero. Protests, by contrast, increase: a 10-percentage-point increase in competing allocation raises the probability of any protest by 2.6% and of a firm-targeted protest by 8%, relative to their respective baseline rates. The effect is larger where a greater share of renewable flow is already committed, consistent with heightened rivalry over the resource driving people to the streets.

Rights concentration in a few users is associated with a larger firm-targeted response. The same increase raises firm-targeted protest by 6.9% at the 25th percentile of basin concentration and by 13.5% at the 75th. It does not increase protests against local authorities, which lack authority over water allocation. Finally, the estimated protest response is larger during severe drought, when climatic and human-made scarcity compound one another.

Taken together, the results point to a failure of water governance to adjust to increasing scarcity. Chile grants fixed extraction volumes that do not systematically adjust as hydrological conditions change, while water remains weakly priced and costly to reallocate. The resulting adaptation burden is unequal: larger users can invest in deeper wells, while downstream communities and rural water utilities face greater scarcity. Because these outcomes follow in part from allocation rules, they are not inevitable. Section 6 considers cumulative allocation caps, scarcity pricing, and reforms that lower barriers to reallocation.

The paper makes three contributions. First, it extends the climate–conflict literature beyond exogenous weather shocks by showing that cumulative, legally authorized extraction can generate social conflict in a high-income economy, and by examining how drought compounds this human-made pressure. Second, it connects research on property-rights institutions and common-pool resources (Wade, 1994; Ostrom et al., 1999) with work on the distributional consequences and externalities of water allocation (Rafey, 2023; Ryan and Sudarshan, 2022; Hadachek et al., 2026). I treat contention as a political cost of those externalities, distinguish recorded institutional from extra-institutional responses, and show that more acute basin stress and rights concentration are associated with a larger firm-targeted protest response. Third, I develop a method for measuring water-use externalities from georeferenced rights data. The design combines river-flow direction (Duflo and Pande, 2007; Taylor and Druckenmiller, 2022; Dias et al., 2023) with spatial-spillover methods (Harari and Ferrara, 2018; McGuirk and Nunn, 2020; Unfried et al., 2022), producing a continuous measure of competing allocation portable to other contexts as rights registries and hydrological data become increasingly available.

The remainder of the paper is organized as follows. Section 2 develops the conceptual framework; Section 3 describes Chile's water governance system and the data; Section 4 presents the empirical strategy; and Section 5 reports the main results and heterogeneous effects. Section 6 discusses the findings, policy implications, and external validity, and Section 7 concludes.

2. Conceptual Framework

2.1 Environmental Scarcity and Conflict

A large literature documents that climate shocks increase conflict. Extreme temperatures, drought, and rainfall variability have been linked to civil war, interpersonal violence, and political instability across many settings, with effects that tend to be larger for organized, intergroup conflict than for interpersonal violence (Hsiang et al., 2013; Burke et al., 2015; Harari and Ferrara, 2018). For water specifically, rainfall shocks intensify competition between pastoralists and agriculturalists (McGuirk and Nunn, 2020) and raise political unrest through lost agricultural income (Hendrix and Salehyan, 2012; Almer et al., 2017). Most of this work studies *supply-side* scarcity: exogenous climate events that reduce the physical availability of water. Scarcity, however, is not only a weather phenomenon. Homer-Dixon (1994, 1999) distinguishes three sources: supply-induced (physical depletion of the resource base), demand-induced (rising consumption from population or economic growth), and structural (unequal access to the resource). The demand-induced and structural sources are human, and they are the focus of this paper. While climatic events are affected by human actions on a global scale, these impacts are intermediated by complex weather systems. In this paper I use "human-caused scarcity" to refer to demand-induced and structural water scarcity directly caused by people extracting within the study area.

Human-caused scarcity differs from drought in two relevant ways: there is a responsible party to blame and a possible remedy through policy (AghaKouchak et al., 2021). When a river runs dry from drought, the proximate cause is natural and there is no one to hold accountable. When it runs dry because other users have extracted too much, communities can trace the loss to specific decisions and actors, and can credibly claim a solution (Benford and Snow, 2000). I develop this attribution mechanism in Section 2.3.

Beyond climate shocks and conflict, a parallel literature in resource economics studies how water is allocated, valued, and used. One strand examines water markets and the gains from reallocating scarce water toward higher-valued uses, from Australia's Murray–Darling basin (Rafey, 2023) to California's surface- and groundwater markets (Bruno and Sexton, 2020; Ayres et al., 2021; Bruno and Jessoe, 2021; Ferguson, n.d.). A second documents the externalities of extraction and of climate adaptation: pumping by some users lowers the water table and harms others' access, often regressively (Hadachek et al., 2026), and irrigation adopted to cope with a drying climate stresses shared aquifers (Taylor, 2026). A third traces the long-run consequences of aquifer depletion for agriculture (Hornbeck and Keskin, 2014) and the downstream spillovers of upstream infrastructure across regions and borders (Ando and Lei, 2024; Fan, 2024). This work has mapped the efficiency, distributional, and environmental margins of water allocation.

These literatures have largely stayed apart. The climate-conflict literature treats environmental pressure as an exogenous shock; the water-governance and resource-economics literatures study how water is allocated, priced, and traded—and the externalities allocation entails—without following it through to conflict. Neither offers a framework for how human-driven scarcity turns into social conflict, or for what determines the form that conflict takes. The remainder of this section develops the framework. Section 2.2 relates scarcity to the costs and potential benefits of institutional and extra-institutional contention. Section 2.3 sets out the implications of rights concentration for attribution and target choice. The final subsection addresses the interaction between human-made and climate-driven scarcity.

2.2 Scarcity, Costs, and Routes of Contention

Water replenishes through precipitation, snowmelt, and aquifer recharge, yet in much of the world it is now extracted faster than it renews (Institute for Water, Environment and Health, 2026). Because water is costly to transport, scarcity is local: it reflects the balance between extraction and the endowment of a particular basin, which comprises both the stock held in rivers, lakes, and aquifers and the flow renewed each year. Locality also limits the options of affected users. Land is immobile and communities are tied to place, so when water access deteriorates they tend to contest the loss rather than move away. Whether growing demand harms others, and so provokes conflict, depends on how aggregate extraction compares to this endowment.

Resource economics distinguishes two forms of scarcity (Barnett and Morse, 1963). *Relative* (Ricardian) scarcity arises when the most accessible units of a resource are used, raising the cost of each additional unit, even if it is not fully exhausted. *Absolute* (Malthusian) scarcity arises when demand approaches or exceeds the total stock, so not all claims can be met. Both operate in water, and a basin can sit between them. Below its carrying capacity, more extraction raises costs for others: wells are drilled deeper, flows fall, and storage infrastructure becomes less reliable, but water remains available. Once cumulative rights exceed the flow renewed each year the basin is *over-appropriated*, and each further unit of extraction comes at another user's expense, met by drawing down the stock held in aquifers and reservoirs. This is not yet absolute scarcity, since a stored buffer remains, but it is the state Madani (2026) calls *water bankruptcy*: a society consuming its natural capital rather than living off its returns (see also Gleick and Palaniappan, 2010; Falkenmark, 1989). Sustained, it approaches absolute scarcity as the buffer is drained faster than it recharges.

In principle, property rights could resolve this. With well-defined, tradable rights and low transaction costs, users would bargain to an efficient allocation, regardless of who holds them at the start (Coase, 1960). Common-pool resources rarely allow it (Ostrom, 1990). Aggregate extraction is hard to monitor, and negotiating across many dispersed users is costly. If water rights are fixed in absolute volumes, as in the Chilean case, they are well-defined only while the resource is ample. Once supply falls below the total granted, the claims add up to more water than is available, and the rules for adjusting them leave room for conflict.

An additional allocation affects others only when it reduces water available to them. As the share of renewable flow already committed rises, a further grant is more likely to displace water that another user would otherwise receive. The resulting deficit can be absorbed through private adaptation or become a grievance that prompts action. The same additional allocation is therefore more likely to prompt a larger response where competition over the resource is more acute.

An affected user will not always contest a loss. They may adapt at their own expense, for example by deepening a well or reducing water use, or they may act. The choice depends not only on the severity of the loss but also on the expected benefit of a remedy relative to the costs and risks of pursuing it.

Contention can proceed through institutional or extra-institutional routes. Institutional action uses formal venues to enforce rights, sanction harmful conduct, or change administrative decisions; depending on the setting, these may include litigation, complaints to regulators, and other claims processes. Extra-institutional contention takes place outside such venues, most visibly through protest. The empirical measures in this paper capture lawsuits and administrative complaints in Chile as institutional outcomes and protest as extra-institutional action.

Institutional action can provide a concrete remedy: it can trigger enforcement against an extractor, impose a fine, provide compensation, or revise an administrative decision. Access varies across venues. Some administrative complaint processes are open to any citizen and can be initiated at low cost, whereas litigation may require formal standing, evidence, money, time, and the willingness to confront a firm or authority with greater resources. Collective action can turn shared private losses into a visible political claim and may make broader remedies possible when individual claims are unavailable or inadequate. It too creates costs: participants must coordinate, risk retaliation, and may bear the burden of mobilization while any benefits are shared (Olson, 1965; Granovetter, 1978; Kuran, 1991; Passarelli and Tabellini, 2017). Neither route is inherently easier or more effective. The relevant comparison is between the costs and risks of acting and the remedy each route can plausibly deliver in a given dispute.

Research on environmental conflict has largely focused on extra-institutional outcomes such as protest or violence. However, environmental justice is increasingly pursued through courts and litigation. Examining both institutional and extra-institutional outcomes therefore gives a more complete account of how affected users respond to human-driven scarcity.

H1 (Scarcity and contention). The effect of additional water allocation on contention is stronger where a larger share of basin flow is already committed, because competition over water is more acute.

2.3 Inequality and the Target of Conflict

When water rights are dispersed among many comparable users, responsibility for local scarcity is diffuse. The burden of assigning responsibility and coordinating around a common target is correspondingly greater (Javeline, 2003). By contrast, when rights are concentrated, a dominant firm controls a larger share of the resource, becoming an easy target for collective action. Its economic and political resources can raise the costs of an individual challenge while making it a visible target for a public claim (Javeline, 2003; Esteban and Ray, 2011; Montalvo and Reynal-Querol, 2005).

Targets are chosen not only for their responsibility, but also for their capacity to offer a remedy (Salehyan and Stewart, 2016; Malhotra and Kuo, 2008). A firm may be challenged for extracting water; a public authority may be challenged for the allocation decisions that permitted it or as a demand to intervene.

H2 (Inequality and the target of conflict). When water rights are concentrated in a small number of holders, responsibility for a loss is easier to trace to a visible firm, creating a focal target for collective action. When rights are dispersed among many comparable users, responsibility is diffuse and coordinated action against a common target is harder.

2.4 Human-Made and Climate-Driven Scarcity

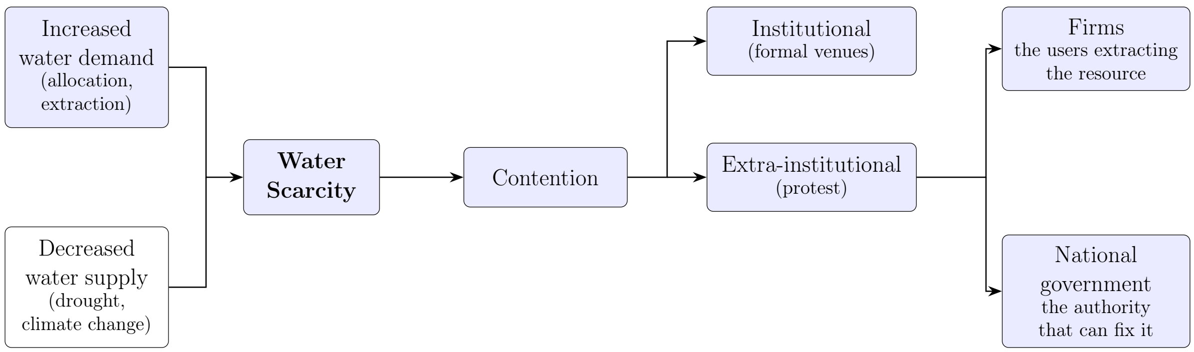
Climate-driven scarcity occurs when precipitation and recharge decrease. Human-made scarcity occurs when claims on the available resource increase. Both reduce water availability, but only the latter supplies a specific actor who can be blamed and a policy decision that can be changed.

When drought and high extraction coincide, their effect on contention is ambiguous. If firms continue extracting from a visibly depleted resource, drought can deepen the loss and make the role of allocation more salient. If the shortage is understood principally as the result of absent rainfall, blame may shift to a natural cause and reduce the incentive to challenge other users or public authorities. The response therefore depends on how affected users attribute the scarcity, which I do not observe directly (Dal Bó and Dal Bó, 2011; McCarthy and Zald, 1977).

H3 (Compound scarcity). When drought and human-made scarcity coincide, their effect on contention depends on whether affected users attribute the shortage to natural conditions or to identifiable actors.

Figure 1 summarizes the framework: the response to additional allocation is stronger as basin stress rises (H1); concentration makes a firm a clearer target for collective action (H2); and the interaction of drought and allocation depends on how affected users attribute scarcity (H3).

Figure 1: Conceptual Framework: Water Scarcity, Contention, and Its Targets



Notes: The figure summarizes the conceptual framework. Increased water demand generates water scarcity, which in turn, provokes contention. Affected users may pursue institutional or extra-institutional contention, depending on the costs, risks, and remedies available. Concentrated rights make a firm a clearer target for collective action. When drought and high extraction coincide, the effect on contention depends on whether scarcity is attributed to natural conditions or identifiable actors.

3. Background and Data

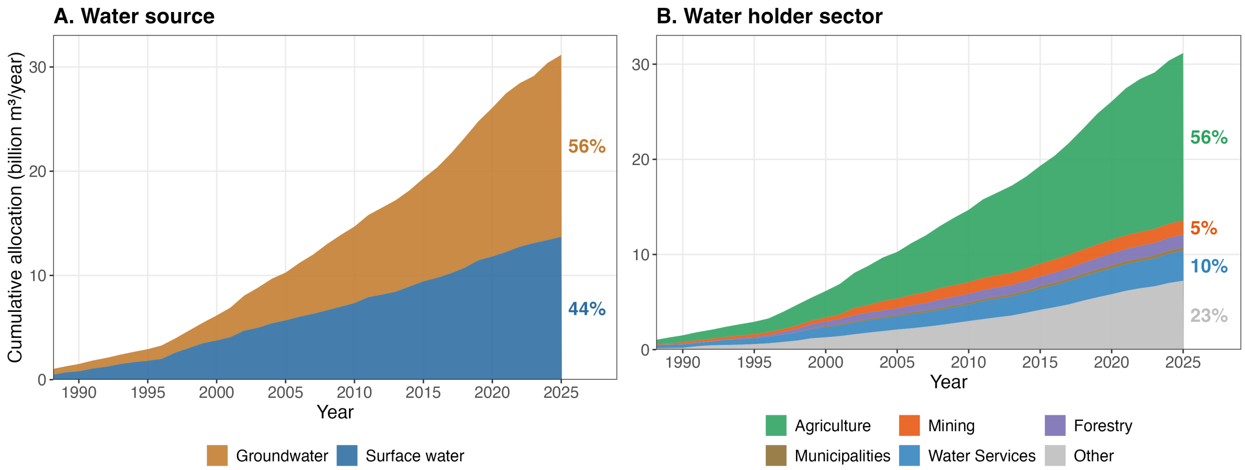
3.1 Water Governance in Chile

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 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).

The 2005 reform established fees for maintaining unused water rights to discourage the accumulation of rights for resale rather than productive use, and allowed the Water Authority (Dirección General de Aguas, 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).

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 Water Authority, 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). Figure 2 shows the rapid evolution of volume of water granted as permanent rights in the past decades.

Figure 2: Cumulative Water Right Volumes Granted, 1990–2025



Notes: Cumulative water right volumes granted from 1990 to 2025, in billion m^3/year. Panel A shows the trend by water source (surface vs. groundwater). Panel B is colored by sector. Labels show percentages for each category in 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).

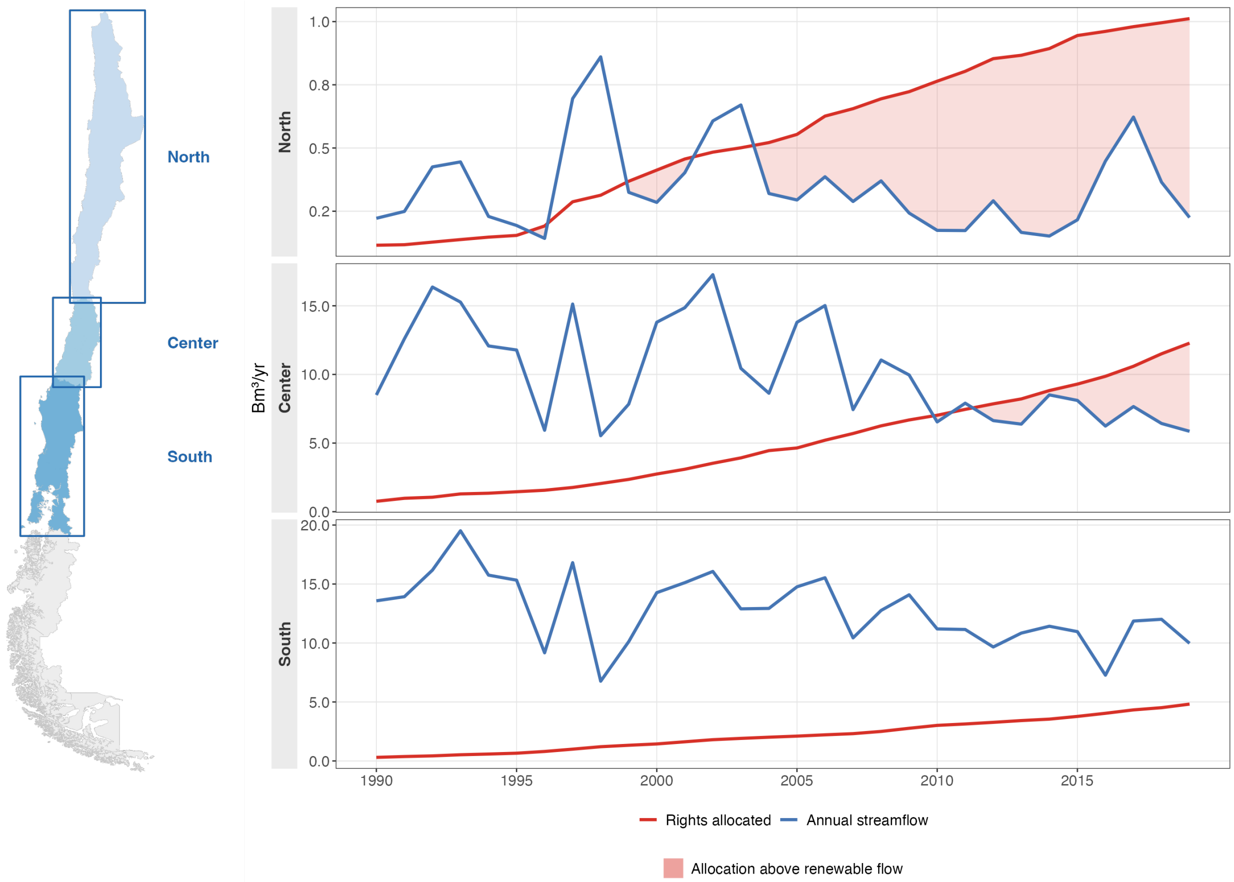
Three characteristics of this design prevent the system from adjusting as scarcity grows: rights are granted at no cost until a source is declared exhausted, holders pay no price for the water they extract, and trading rights once issued is slow and costly. The market lacks formal mechanisms for trading 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 legal framework provides no incentives to account for water's scarcity value. There is no marginal cost for water volume obtained, beyond what users may pay in fees to water user boards for infrastructure maintenance, or the electricity costs for groundwater pumping. Instead, as per the 2005 reform, users are enforced to utilize their full yearly allocation or face non-use tariffs, introduced to discourage speculative accumulation and push unused rights onto the market.

Monitoring and enforcement capabilities are limited and largely delegated to private users. DGA inspectors measure intake infrastructure and confirm pipe diameters cap extraction 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 3 shows that the volume of water allocated surpassed renewable flow in the 1990s in the North, and in the 2010s in the Central Zone. These zones now largely rely on groundwater to satisfy demand.

Figure 3: Rights Allocation vs. Renewable Supply by Zone, 1990–2019



Notes: Each panel shows the zone-level sum of cumulative water rights allocated (red line) and annual streamflow (blue line), in Bm^3/yr, for a balanced panel of basins with at least two gauging stations reporting in 30 or more of the 40 years from 1980 to 2019. The red shade marks the years in which allocated rights exceed renewable streamflow. Because the comparison is against each year's flow, a zone can leave the band in unusually wet years. Rights are restricted to the same set of qualifying basins. The map at left locates the three zones; basins in the Austral zone, where water is abundant, are shown in gray.

3.2 Water Scarcity and Social Conflict in Chile

A deepening water crisis has generated intense social conflict in Chile. The country experienced a prolonged drought during the 2010s—a decade-long sequence of dry years with rainfall deficits of 25–45 percent (Garreaud et al., 2017)—while simultaneously seeing rapid expansion of water-intensive agriculture and industry (Maddocks et al., 2015). Government emergency responses have become chronic rather than temporary, a pattern documented in detail in Appendix A.

The clearest expression of this resistance is *Modatima* (Defense Movement for Access to Water, Land, and Environmental Protection), founded in 2010 in the province of Petorca, in the Valparaíso Region—an emblematic case of the country's water crisis.[2] Over the preceding two decades, the Petorca and La Ligua basins had been reorganized around export avocado orchards, and groundwater fell as new rights were granted even after the drought set in (Duran-Llacer et al., 2020). With surface rights long committed and a few large agribusinesses holding most of the basin's water, residents rationed drinking water while plantations kept irrigating, and public authorities did little to curb extraction (Madariaga et al., 2021). Modatima framed the resulting scarcity as appropriation rather than weather, and attributed it to political choices that enabled over-extraction by powerful economic actors rather than to climate change. Its leaders, among them the agronomist Rodrigo Mundaca, faced repeated threats for pressing that claim. Bolados García et al. (2018) characterize the dispute as an eco-geopolitics of water: a contest over land and territory as much as over the resource itself.

The movement's reach widened beyond Petorca during Chile's 2019–20 social uprising, when access to water was among the most voiced grievances (Panez-Pinto et al., 2017; Macpherson et al., 2023). The constitutional process that followed opened a political opportunity for water activists: in 2021 Mundaca won the first direct election for governor of the Valparaíso Region (La Tercera, 2021), and candidates from water and environmental movements won seats in the Constitutional Convention (López Moreno, 2025). The convention's 2022 draft would have redefined water as a common good not subject to private appropriation and curtailed the private rights established by the 1981 Code, but voters rejected it in September 2022, leaving the Code in place (López Moreno, 2025). Within a decade, a local fight over a drying river became a national constitutional question.

In Appendix A, I provide comprehensive descriptive evidence on how this situation came about in Chile: the rapid expansion of water allocation; the economic transformation that

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

raised water demand, particularly in the agricultural sector; the resulting water stress, visible in government measures and in hydrological data; the stark concentration of water rights in a few firms; and the extent of drought during the study period.

3.3 Data

For the first part of my empirical analysis, I construct a cell-year panel (2005–2024) combining geo-referenced surface and groundwater rights with seasonal streamflow measurements. The spatial unit is a uniform grid of hexagonal cells, each roughly 36 km^2 (about 6 km across), covering mainland Chile.[3] These cells are preferred over administrative or census boundaries for two reasons: their boundaries do not follow rivers, and their finer spatial resolution means that gauging stations located close together within a municipality can contribute independently to identification, rather than being collapsed to a single municipality-level average. For the second part, I build a municipality-year panel (2005–2024) linking the same water rights data with lawsuits 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 B.1 provides descriptive statistics for each panel; data-source details follow. Streamflow is highly right-skewed: annual flow averages 62 m^3/s but has a median of only 11 m^3/s; the gap reflects the wide range of basin volumes across Chile. The average municipality experiences 1.39 lawsuits and 5.55 protests per year. Figure B.1 maps the level and the change in each of the key variables—streamflow, allocated rights, basin stress, protests and lawsuits—across river basins. Figure B.2 plots lawsuits and protests over time.

3.3.1 Water Allocation

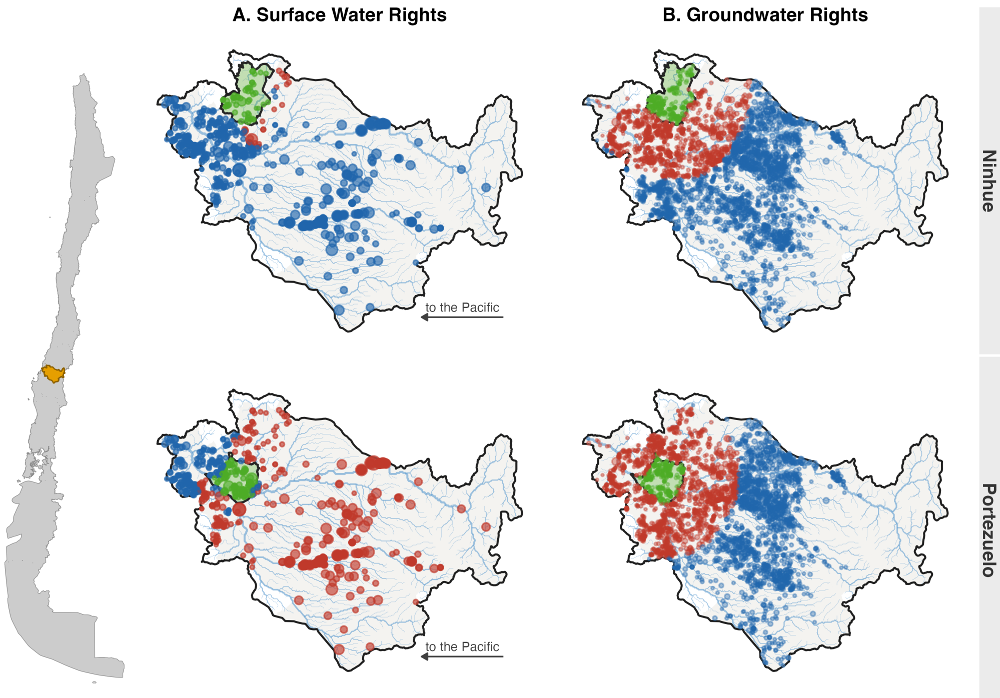
Information on legally approved extraction comes from Public Water Registry maintained by the Water Authority (DGA).[4] Each record lists the water right holder, approval date,

[3] The grid uses Uber's H3 geospatial indexing system at resolution 6.
[4] Available at https://dga.mop.gob.cl.

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 combines surface and groundwater rights into a single competing allocation index. 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. I classify every water right by whether it can affect water availability in each geographic unit. I sum annual water right volumes (L/s) *upstream* of, *downstream* of, and *within* each unit, following the segment-to-segment downstream link of the network; rights with no directed path to or from the unit form a separate *unconnected* category. I further classify groundwater rights by straight-line distance from the unit. The competing pool comprises the productive rights that can draw on the water reaching unit i: surface rights upstream on the channel, and groundwater extraction points within a 25 km radius. Rights within the unit itself are excluded and used as a separate local control. Normalized by baseline flow, this pool forms the unit's *competing allocation*; the non-competing rights—downstream and unconnected—form the placebo. Figure 4 shows the classification of water rights according to their location relative to two distinct municipalities, within one illustrative basin.

Figure 4: Relative Hydrological Distribution of Water Rights



Notes: Illustration of how the water rights variables are constructed, for two municipalities within the Itata River Basin. The map at left locates the basin (amber) within Chile. Black outlines delineate the basin, and the green shaded area is the focal municipality. The river network is HydroRIVERS v1.0; water flows from the Andes in the east to the Pacific in the west, as the arrows indicate. Point area is proportional to the allocated volume of the right. *Panel A* classifies surface water rights by position on the river network relative to the focal municipality: upstream, local (inside it), or placebo (downstream, or in the basin but not hydrologically connected). *Panel B* classifies groundwater rights instead by straight-line distance — within 25 km of the focal municipality, or beyond it. The two rows condition on two different focal municipalities, Ninhue (top) and Portezuelo (bottom), holding the year fixed. Appendix Figure B.3 shows the same construction at the cell level, the unit the streamflow estimates use.

The allocation index is constructed as follows:

$$\tilde{A}_i^c = \frac{\sum\limits_{j \in \mathcal{C}(i)} w_{ij} \cdot r_j}{F_i} \tag{1}$$

where r_j is the cumulative allocation at upstream unit j, w_{ij} is a distance weight,[5] and F_i is the baseline flow in each unit i.[6] Normalizing by baseline flow transforms the treatment

[5]Distance weights $w_{ij} = A_j^{\text{up}}/A_i^{\text{up}}$, are constructed as the ratio of upland catchment area at the intake point unit j to that at i. Upland catchment area is `HydroRIVERS`'s most precise measure of relative position. These weights discount r_j the further the upstream unit is. Results are robust to an unweighted specification.

[6]Baseline flow is the within-unit mean of observed annual gauge flow across the estimation window where

into an allocation-to-flow ratio, i.e. competing rights relative to the water endowment of the receiving area.

For each river basin, I also calculate an overall *water stress ratio* s, defined as the share of renewable flow allocated. Specifically, I divide the cumulative volume of allocated rights (surface plus groundwater) by the average yearly streamflow. Throughout, I use *stressed* as a general term for basins where a large share of renewable flow is already committed, and *over-appropriated* exclusively for the tier in which committed rights exceed flow ($s \geq 1$).

3.3.2 Hydrological Outcomes

Streamflows The CR2 (Center for Climate and Resilience Research) national streamflow database comprises 691 DGA-operated gauging stations with records spanning 1913–2019. I apply two quality filters before aggregation: a station-month is included only if at least 20 daily readings are available, and a station-year is included only if at least 4 qualifying months exist. Monthly averages are then averaged to annual and seasonal means. Each station is assigned to the cell it falls within; when multiple stations share a cell, I take their unweighted mean. These filters yield N = 4,755 cell-year observations, across 371 unique cells over 2005–2019, distributed across all of Chile's sixteen administrative regions (ranging from 9 to 47 cells per region).

3.3.3 Social Conflict Outcomes

The three conflict outcomes seek to map the respective forms of conflict described in the framework in Section 2. Water-theft lawsuits and administrative complaints to the Water Authority measure institutional conflict, while protest events measure extra-institutional conflict.

a station is available, otherwise the macrozone median is imputed. Appendix Table B.2 reports this coverage by region. Results are also robust to fixing baseline flow at a pre-period level.

Lawsuits I extract water-theft lawsuits from publicly available Chilean Judicial Power records for 2015–2024, drawing on the penal-proceedings database and mapping each to the year it was filed. Under Chilean law water theft is a criminal offense: this covers both using water without holding rights to it (Penal Code Art. 459), and a right-holder diverting more than their share (Art. 461). These complaints typically arise between users who share a canal, when one diverts water during another's allotted turn. Canal associations and other water-user organizations help members detect such diversions and pursue the corresponding complaint.[7][8] Cases are aggregated by court jurisdiction and assigned to municipalities; because only 134 of the 340 municipalities in the analysis maintain a local court, the lawsuit analysis is restricted to these units, and municipalities without a court are coded as missing rather than zeros, since their cases may be filed elsewhere.

I treat the filing of a complaint, rather than a conviction, as the measure of conflict: filing signals a dispute over water access, whereas conviction depends on prosecutorial follow-through. Fewer than 3% of water-theft cases end in conviction, the majority being archived or abandoned—often, as the canal associations themselves note, for want of an active complainant to press the case.

Administrative complaints The Water Authority maintains a public register of enforcement cases opened under the Water Code since 2018.[9] Cases may be initiated either through an inspection conducted by the agency or through a complaint submitted by any person. The register identifies the mode of initiation and records the alleged infraction, admission date, site coordinates, resolution, and any resulting fine. I retain the 4,374 cases initiated by

[7]Canal associations and other water-user organizations instruct members on how to identify a diversion, summon the police to verify it, and file the complaint, and they might pursue cases on members' behalf. See, for example, the Pirque Canal dispatch *Qué hacer ante robos de agua* (https://canaldepirque.cl/wp-content/uploads/2019/09/robo-agua_actualizado_v2.pdf), or the monitoring and sanctions page of the Junta de Vigilancia del Río Elqui (https://www.rioelqui.cl/fiscalizaciones-y-sanciones-a-la-usurpacion-de-aguas/).

[8]Anecdotal accounts describe water disputes taking place outside the legal system too, from a fistfight between neighbors at a wedding to a farmer throwing a dead pig into another's well in retaliation for a diversion. I have no systematic data on these informal incidents, but they suggest lawsuits undercount the true extent of bilateral water conflict.

[9]*Planilla de gesti'on de casos sancionatorios*, available at https://dga.mop.gob.cl.

a complaint between 2018 and 2024, 98.7% of which have usable coordinates. The register classifies the alleged infractions into four categories: unauthorized water extraction accounts for 37.6% of complaint-initiated cases; unauthorized works in a water channel, 50.5%; gravel extraction from a riverbed, 4.7%; and other violations of the Water Code, the remainder. Because only the first category directly alleges the taking of water, I use unauthorized-extraction complaints as the outcome. I assign each complaint to a municipality using the coordinates of the alleged offense and aggregate the data by municipality and year.[10]

Protests I draw protest outcomes from the *Observatory of Social Conflict* (OCS) maintained by the Centre for Social Conflict and Cohesion Studies (COES). The OCS systematically codes protest events appearing in national and regional newspapers from 2005 to 2024. Event coordinates are spatially joined to 2017-census municipality polygons and collapsed to annual frequency. About half of municipality-years (51%) record at least one protest, and the average is 5.5 events per municipality-year. The OCS classifies each event by tactic, issue area, and target. The aggregate event count is the main protest outcome; the sub-type coding additionally allows me to analyze the tactics (marches, strikes, blockades, occupations, and property destruction), issue areas (environment and natural resources, human rights, health, education), and targets (private firms, and national or local government).

4. Empirical Strategy

4.1 Identification Strategy

Estimating the effect of water extraction on water availability and social unrest faces a fundamental challenge: new water users generate local impacts beyond extraction itself, from employment, infrastructure, and local spending to migration flows and changes in land

[10]The Water Authority, rather than a court, resolves these cases. Among complaints with a recorded resolution, 31.6% are upheld. Overall, 26.4% of complaints result in a fine. For unauthorized water extraction, the median fine is 140 UTM, approximately US$10,000.

use. Comparing places by how much extraction is permitted would confound the effect of the water lost with the effects of everything else a new user brings.

I use a spatial spillovers design that exploits the direction of hydrological flows (Duflo and Pande, 2007; Taylor and Druckenmiller, 2022; Dias et al., 2023). A right granted upstream of a unit draws down the flow before it arrives; the same right granted downstream does not, because the water passes the unit first. Groundwater attenuates with distance rather than direction: a well affects a unit's water table when its intake is close enough, and not when it is far. Figure B.4 illustrates this idea. The identifying assumption is that a permit's hydrological connection to a unit—upstream or downstream, and how far away—is unrelated to that unit's own characteristics. I aggregate the volume granted each year by its connection to the unit, holding rights inside the unit in a separate term because those may reflect its own characteristics. This isolates the depletion channel.

Identification comes from changes over time in how much allocation competes with a unit's supply, measured against other units in the same basin and year. The basin×year fixed effects absorb basin-wide droughts and regional economic shocks; the unit fixed effects absorb pre-existing differences between upstream and downstream places. This follows established approaches in the spatial spillovers literature (Harari and Ferrara, 2018; McGuirk and Nunn, 2020; Unfried et al., 2022).

4.2 Baseline Specification

Let i index cells or municipalities, b the river basin containing unit i, and t years. I estimate:

$$y_{ibt} = \delta_i + \lambda_{bt} + \beta_1 T^{c}_{it} + \beta_2 T^{nc}_{it} + \beta_3 T^{\text{local}}_{it} + \varepsilon_{ibt}, \tag{2}$$

where y_{ibt} is the outcome of interest, δ_i are unit fixed effects, λ_{bt} are basin×year fixed effects, and each regressor is the log of its allocation-to-flow ratio, $T = \log(1 + \tilde{A})$. Standard errors are clustered at the river basin.

The treatment variable is the competing allocation-to-flow ratio $\tilde{A}^c_{it}$, defined in equation (1): the cumulative volume of surface water rights granted upstream of unit i by year t plus the cumulative volume of groundwater rights granted within 25 km of unit i by year t, all normalized by baseline flow. The non-competing counterpart $\tilde{A}^{nc}_{it}$ comprises the sum of surface water rights granted downstream of unit i or on an unconnected tributary, and the sum of groundwater rights beyond the 25 km radius and on the downstream side of the network. $\tilde{A}^{\text{local}}$ is the sum of water rights granted within unit i's borders. I estimate two additional specifications separating the surface-water and groundwater channels which isolate the upstream–downstream mechanism and the distance gradient respectively.

The coefficient of interest, β_1, measures the effect of competing extraction; β_2 and β_3 control for non-competing and local extraction. β_2 also serves as a placebo: non-competing rights come from the same basin, the same years, and the same allocation process, but they are outside the hydrological channel and cannot reduce the water a unit receives, so β_2 should be zero if competing rights affect the unit through depletion alone. The contrast between the two coefficients, $\beta_1 - \beta_2$, holds the amount of allocation granted nearby fixed, varying only whether it affects the unit. I report both this difference and the individual coefficients.

The results section proceeds in two parts. The first estimates the impact of competing allocation on streamflow, isolating the human contribution to declining flows. The second estimates its effect on social conflict: institutional conflict, measured with water-theft lawsuits; and extra-institutional conflict, measured with protest events. For the conflict outcomes, I then show how the reaction varies with how much of the basin's flow is already committed, with how unequally rights are distributed, and with drought.

Translating coefficients into interpretable magnitudes. To make estimates comparable across outcomes measured on different scales, I translate every regression coefficient reported below into the percentage change in the outcome implied by a 10 percentage point increase in competing allocation $\tilde{A}^c$ evaluated at the sample median.[11] The text quotes the magnitude directly; the regression coefficients and standard errors are in the figures and tables.

5. Results

5.1 Water Availability

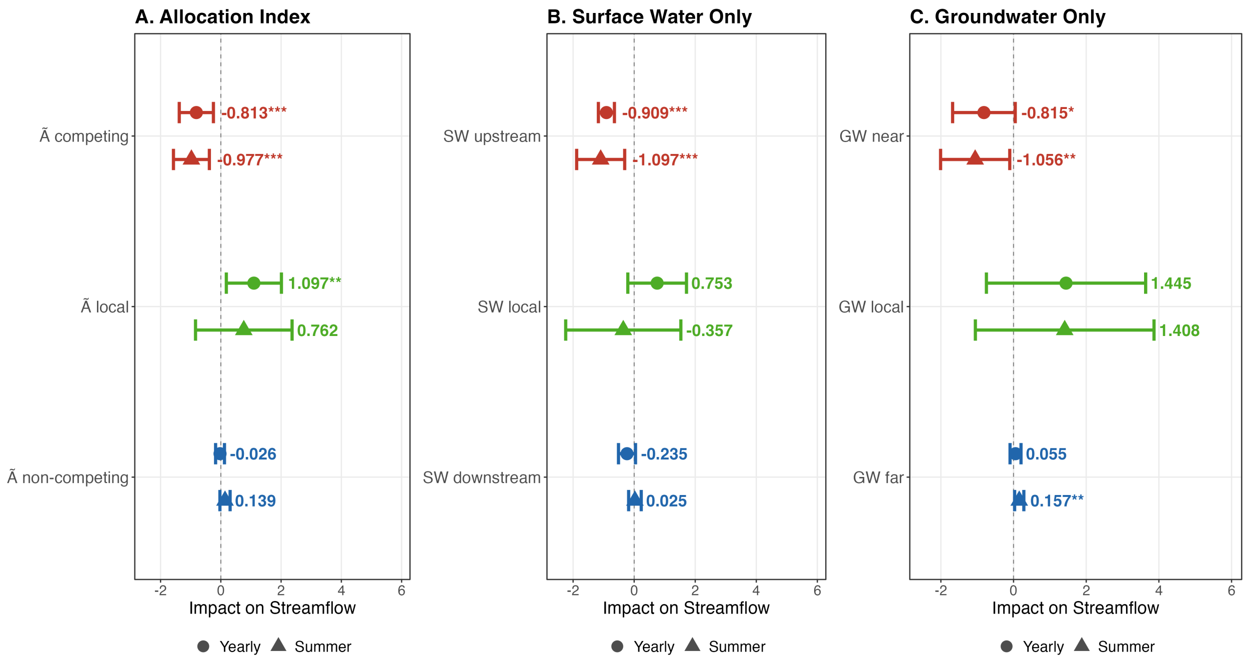
The first main result is that competing water allocation reduces streamflow. Figure 5 reports OLS estimates across the combined, surface water only, and groundwater only specifications (Appendix Table B.4).

Panel A uses the preferred index $\tilde{A}^c$ that combines surface and groundwater rights. A 10 percentage point increase in competing allocation reduces annual streamflow by 7.3%—a loss of 0.62 m^3/s against a typical flow of 8.6 m^3/s. This translates to 0.73 cubic meters per second of annual flow lost for every cubic meter per second of competing rights granted.

Panel B uses surface water rights only: streamflow falls with upstream surface water allocation but not with downstream allocation. Panel C disaggregates groundwater rights by straight-line distance from the cell, into rights within 25 km and rights beyond it. Groundwater within 25 km significantly reduces annual flow; rights beyond that distance do not. This gradient matches the cone-of-depression mechanism, in which pumping depletes the water table around the extraction point and reduces baseflow to the stream, with an effect that falls away as the well moves further from the river segment.

[11] Formally, a 10 percentage point increase in competing allocation implies a change $\Delta = \log(\bar{P} + 0.10 + 1) - \log(\bar{P} + 1)$ in the log-shifted treatment used in the regression, evaluated at the sample median $\bar{P}$. I quote an additive increment rather than a proportional one because $\tilde{A}^c$ is itself a share of baseline flow and is negligible or exactly zero for a quarter of municipality-years, where a proportional rise is not defined. I evaluate at the median rather than the mean because the distribution is strongly right-skewed. For a log-count outcome estimated as $\log(1+Y)$, the implied change in the raw count is $\Delta Y \approx (\bar{Y}+1)\left[\exp(\hat{\beta}\,\Delta)-1\right]$, which I express as a percentage of the sample-mean count $\bar{Y}$. (Reporting $\exp(\hat{\beta}\,\Delta)-1$ alone would understate the response in outcomes with small means, where the $+1$ shift in $\log(1+Y)$ dominates the log.) For a linear-probability outcome the change is $\hat{\beta}\,\Delta$, expressed as a percentage of the sample-mean probability. Count outcomes and the treatment both enter in logs after a $+1$ shift to absorb zeros. Appendix Table B.3 reports the full β–to–magnitude crosswalk, together with the response implied by larger increases.

Figure 5: Competing Water Allocation and Streamflow



Notes: OLS estimates of equation (2) with log(streamflow) as the outcome. *Panel A* uses the competing allocation index $\tilde{A}^c$ (equation 1), showed alongside its non-competing counterpart $\tilde{A}^{nc}$ and the local term. *Panels B and C* apply the same construction to one source at a time: surface water, where the competing pool is upstream rights ("SW upstream") and the non-competing pool is rights downstream or with no channel to the cell ("SW downstream"); and groundwater, where the competing pool is intake points within 25 km ("GW near") and the non-competing pool is wells beyond that radius on the non-affecting side ("GW far"). Circles denote yearly estimates; triangles denote summer estimates. Horizontal bars show 95% confidence intervals. Fixed effects: cell and basin × year. Standard errors clustered at the river basin. Sample: 4,755 cell-years and 371 cells matched to at least one streamflow gauge (yearly), 4,595 and 368 (summer), 2005–2019. Stars: $^{*}\,p < 0.10$, $^{**}\,p < 0.05$, $^{***}\,p < 0.01$.

Appendix Table B.5 tests the effects by season and water user sector. The seasonal pattern is concentrated in summer—the months when irrigation demand is highest and natural flows are lowest. By sector, agriculture and industry show the largest per-unit depletion, though the estimates are noisier for less common users.

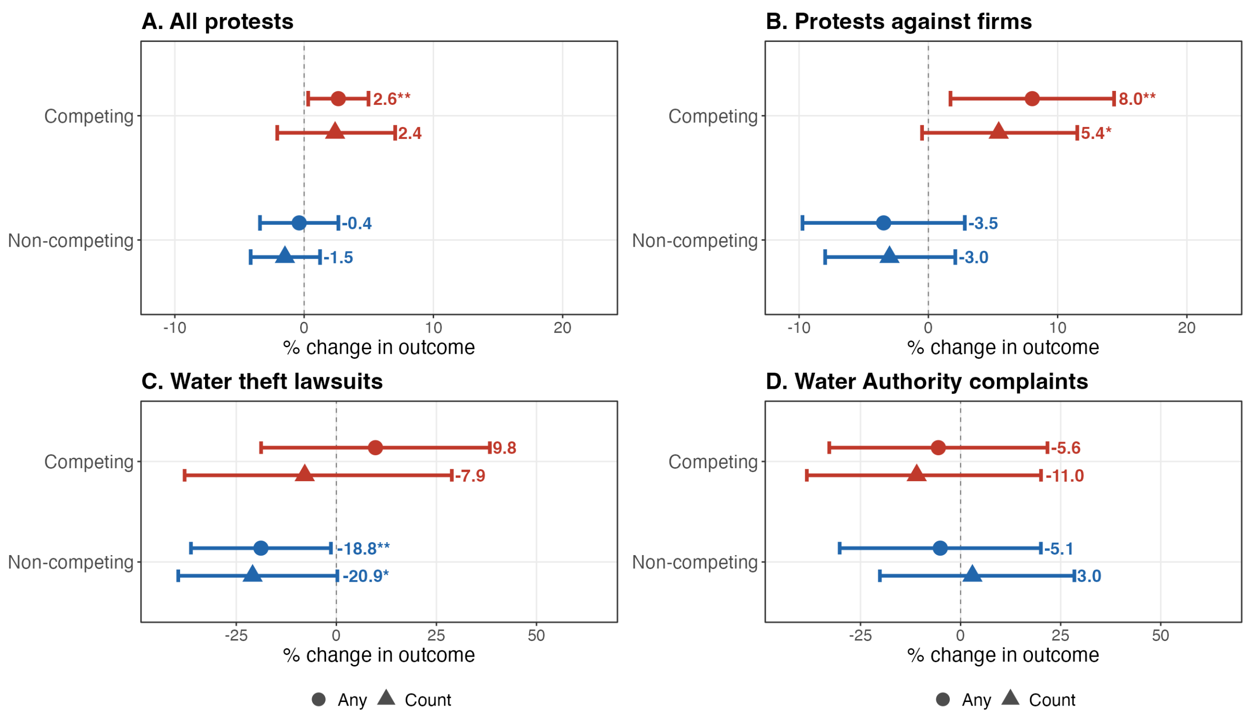
5.2 Social Conflict

I now turn from the hydrological channel to its social consequences. I examine institutional contention through water-theft lawsuits and complaints to the Water Authority, and extra-institutional contention through protest events. I first estimate the relationship between competing allocation and each outcome. The following subsections then examine whether the protest response is stronger where more basin flow is committed (H1), whether rights concentration directs it toward firms (H2), and how it varies with drought.

5.2.1 Institutional and Extra-institutional Contention

Figure 6 reports the effect of the competing allocation index on each of the four outcomes. To ease the interpretation, every estimate is the percentage change in that outcome's own base rate implied by a 10 percentage point increase in competing allocation. Table B.6 reports every regression in this figure, along with the surface water only, and groundwater only specifications.

Figure 6: Competing Allocation and the Form of Contestation



Notes: OLS estimates of equation (2) using different measures of conflict as the outcomes. Panel A shows the effect on all protests, Panel B on protests against firms, Panel C on water-theft lawsuits, and Panel D on Water Authority administrative complaints. The treatment is the competing allocation index $\tilde{A}^c$ (equation (1)), shown alongside its non-competing counterpart $\tilde{A}^{nc}$. The local term is included as a control but omitted from the plot. Circles denote extensive margin estimates (linear probability); triangles denote the log count estimates. Horizontal bars show 95% confidence intervals. Fixed effects: municipality and basin × year. Standard errors clustered at the river basin. Sample: 6,800 municipality-years and 340 municipalities, 2005–2024 (Panels A and B); 1,340 and the 134 municipalities with a local court, 2015–2024 (Panel C); 2,380 and 340 municipalities, 2018–2024 (Panel D). Stars: $^{*}\,p < 0.10$, $^{**}\,p < 0.05$, $^{***}\,p < 0.01$.

A 10 percentage-point (pp) increase in competing allocation raises the probability that a municipality experiences any protest by 2.6% of its base rate, significant at the 5% level. For protests targeting firms, the probability rises by 8.0% on the same margin, also significant at the 5% level. The number of firm-targeted protests rises by 5.4%, significant at the 10% level. These estimates are consistent with the framework's expectation that contention is directed toward firms that are identifiable as responsible for the harm.

Neither water-theft lawsuits nor administrative complaints shows an estimated effect distinguishable from zero. For water-theft lawsuits, the non-competing coefficient is negative and significant, and filings are recorded where courts are located rather than necessarily where disputes occur, making the estimate difficult to interpret. These results do not provide evidence that competing allocation changes either recorded institutional outcome.

Water-theft lawsuits are a demanding measure of local conflict over scarcity. A lawsuit requires an unlawful taking, detection by another user, and recourse to a court. The underlying dispute may arise between users who share a canal or other local source, whereas the court record assigns the case to the municipality in which the court is located. The estimated effect on filings therefore will not capture every conflict generated by lower water availability.

In Appendix Table B.7 I assess this interpretation by varying where filings and complaints are assigned and by comparing the precision of each institutional outcome with protest on the same sample. The lawsuit panel is too small to detect an effect of the size observed for protest. The complaint specifications provide tighter bounds, but do not show a positive response to competing allocation. The evidence therefore does not support a change in these recorded institutional outcomes, while remaining less informative about whether local rivalry itself changes.

The remainder of this section focuses on additional analysis for the protest outcomes to uncover some of the mechanisms behind the effect.

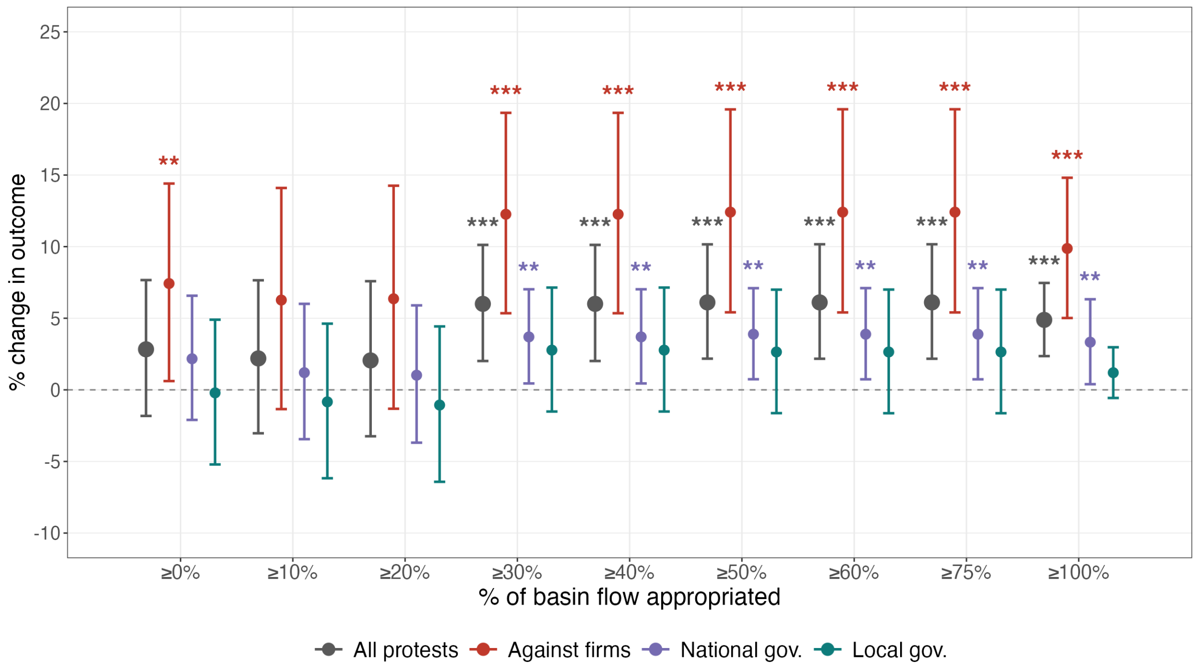
5.2.2 Scarcity and Contention

H1 predicts that the effect of additional competing allocation is stronger where more of a basin's renewable flow is already committed. I measure basin stress as the share of renewable flow allocated, fixed at its value in the last year before the estimation window.

To trace how the relationship varies across the stress distribution, I first interact the competing-allocation index with basin stress. I then re-estimate the baseline model in nested samples, from all basins to those in which progressively larger shares of flow are already allocated. The two approaches provide complementary evidence on whether the response grows as competition over water becomes more acute.

Table B.8, Panel A, reports the interaction between competing allocation and basin stress. The interaction is positive and statistically significant at the 1% level for any protest, the protest count, firm-targeted protest, and protest targeting the national government. It is not distinguishable from zero for protest targeting local government. Chile's national government allocates water rights; municipal governments do not. The contrast is therefore consistent with contention directed toward actors viewed as responsible for the shortage or able to address it.

Figure 7: Basin Water Stress and Protest, by Target



Notes: OLS estimates of equation (2) on four log protest counts — all protests, drawn with the larger marker, and the counts of events targeting firms, the national government and local government. Each point is a separate regression on the municipality-years whose basin stress, the ratio of cumulative water rights to historical streamflow, is at or above the threshold on the horizontal axis, expressed as the percentage change in that outcome's own base rate. Controls: $\tilde{A}^{nc}$, $\tilde{A}^{\text{local}}$. Fixed effects: municipality and basin × year. Standard errors clustered at the river basin; bars show 95% confidence intervals. Sample: every threshold is a different estimation sample, from 5,960 municipality-years in 298 municipalities at no restriction to 2,120 in 106 municipalities in over-appropriated basins, 2005–2024. Stars: $^{*}\,p < 0.10$, $^{**}\,p < 0.05$, $^{***}\,p < 0.01$.

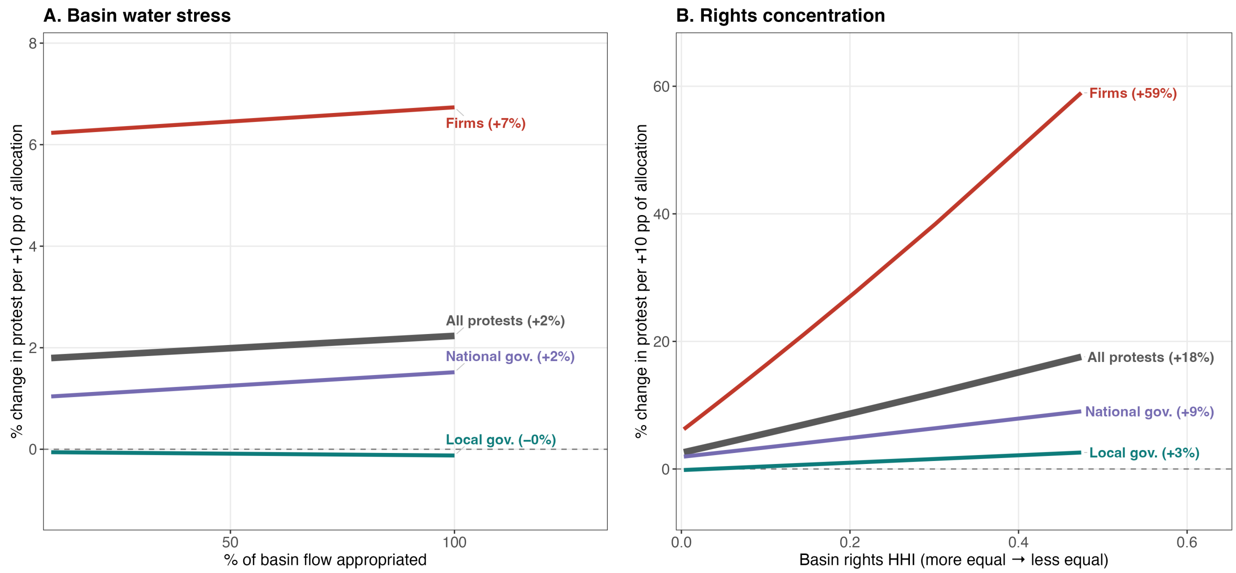
Figure 7 shows how the estimated protest response changes as the analysis is restricted to basins with progressively higher pre-period stress. Below a floor of 30% the estimate for all protest events is not distinguishable from zero. From 30% upward it is significant at the 1% level, and the implied response goes from 2.8% of the base rate with no restriction imposed to 4.9% in over-appropriated basins. The effect on firm-targeted protest is significant even when considering the whole sample of basins, at the 5% level, and it is significant at the 1% level from the 30% floor up. Protest against the national government follows the same trajectory of the pooled protest outcome at about half the magnitude and is significant from the 30% floor up. Protest against local government is not distinguishable from zero at any floor. Confidence intervals narrow rather than widen as the basin stress floor rises, even though each estimate uses fewer observations, because the municipalities dropped are those where water is abundant and allocation is a negligible share of flow: they contribute little information about the effect and still contribute to the standard error (Table B.9). Table B.10 reports the coefficients behind the figure together with the non-competing placebo at every floor, and Table B.11 replicates it for different functional forms of the outcome; as an indicator, a log count and a standardized variable. Results are largely unchanged. Taken together, the interaction and sweep show a progressively stronger protest response as pre-period stress rises.

Additional results distinguish protest by tactic and topic. As basin stress rises, the effect of competing allocation becomes stronger for road blockades and for property destruction, but not for marches and occupations (Table B.12). Higher stress is also associated with a stronger response of environmental protest and protest in rural areas (Table B.13).

5.2.3 Inequality and the Target of Conflict

Having shown that the protest response strengthens as competition for water increases, I turn to whether competing allocation is more likely to generate firm-targeted protest in basins with a clear target. H2 predicts that such a target is more likely where one or a few firms control a large share of a basin's rights.

Figure 8: Basin Water Stress, Rights Concentration and the Target of Conflict



Notes: Each panel plots the estimated effect of a 10 percentage-point increase in competing allocation on four protest outcomes at different values of a basin-level moderator. Panel A uses the share of renewable basin flow already committed; Panel B uses the Herfindahl–Hirschman index of water-rights concentration. Each line is estimated in a separate regression and reports the effect as a percentage of that outcome's base rate. Labels report the estimated effect at the right-hand end of each panel. Panel A spans basins with 10–100% of flow appropriated; Panel B extends to the 95th percentile of concentration. The panels use different vertical scales. Interaction estimates and standard errors are reported in Table B.8; marginal effects at concentration percentiles are in Table B.14. Confidence intervals are omitted from the figure. Controls: $\tilde{A}^{nc}$, $\tilde{A}^{\text{local}}$. Fixed effects: municipality and basin × year. Standard errors clustered at the river basin. Sample: 5,960 municipality-years and 298 municipalities in 50 basins, 2005–2024 (*Panel A*); 6,784 municipality-years and 340 municipalities in 80 basins (*Panel B*).

Figure 8 places the stress and concentration interactions side by side. Panel A reproduces the basin-stress estimates discussed above. Panel B turns to rights concentration.

A 10 percentage-point increase in competing allocation raises firm-targeted protest by 6.9% of its base rate at the 25th percentile of the index and by 13.5% at the 75th percentile. At the 95th percentile, the implied response is 59% and is statistically significant at the 5% level. The interaction between competing allocation and concentration is positive and statistically significant at the 10% level for firm-targeted protest, but not for the other outcomes (Table B.8, Panel B). At the same point in the distribution, the estimated responses are 18% for all protest and 9% for protest targeting the national government, but neither estimate is statistically distinguishable from zero; the local-government response is close to zero.[12]

Panel C of Table B.8 uses an alternative measure of concentration: an indicator for a single holder controlling more than half of a basin's rights. The result is similar. The interaction is positive and statistically significant at the 10% level for firm-targeted protest, but not for the other outcomes. Basins meeting this criterion account for 9% of protest municipality-years and occur in 36 of the 80 basins, so the estimate is identified from a minority of the sample.

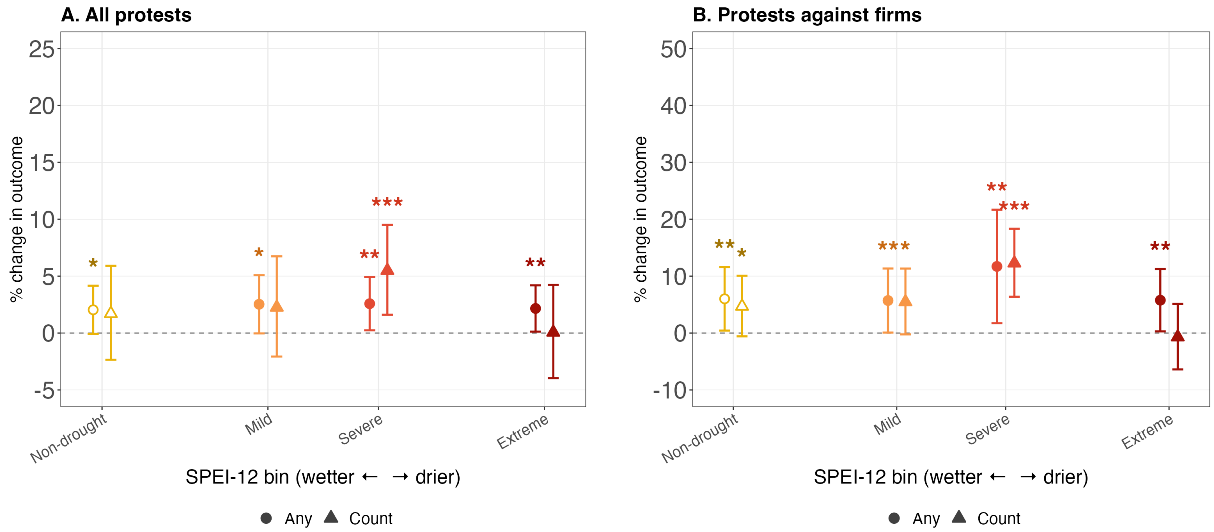
This pattern is consistent with H2. Where rights are concentrated, a firm controls enough of the resource to provide a clear target for collective action, and firm-targeted protest responds to further allocation. Where rights are dispersed, no single actor stands out as responsible for the scarcity.

5.2.4 Human-Made and Climate-Driven Scarcity

Figure 9 reports the estimated effect of competing allocation at each drought severity. The association is strongest under severe drought. A 10 percentage-point increase in competing allocation raises the all-protest count by 1.7% outside drought and by 5.5% under severe drought. For firm-targeted protest, the corresponding estimates are 4.7% and 12.3%. The Extreme bin rests on ten municipality-years, eight in Austral basins, and is therefore shown without interpretation.

[12]Because each series comes from a separate regression, their point estimates cannot be ranked directly. The series share a sample and a regressor, so their estimates are correlated. Stacking the target counts with a target indicator and estimating the difference in one specification gives 0.287 for firm-targeted relative to pooled protest (s.e. 0.487); neither national- nor local-government targeting differs from pooled protest. I therefore report the target slopes as comparable rather than ordered.

Figure 9: Drought and the Allocation–Contention Relationship



Notes: Each panel reports the total effect of competing allocation under each drought level, from a single regression interacting the competing-allocation treatment of equation (2) with SPEI-12 bins. The bins are mutually exclusive: Mild ($-1.5 < \text{SPEI} \leq -1$), Severe ($-2 < \text{SPEI} \leq -1.5$), Extreme ($\text{SPEI} \leq -2$). Non-drought ($\text{SPEI} > -1$) is the reference bin and is drawn hollow. Circles are the indicator for any event, triangles the log count. Each point shows the effect of a 10 percentage point increase in competing allocation on the outcome's own base rate, under that drought severity. Both panels show protest outcomes: all protests in Panel A and firm-targeted protests in Panel B. The comparison shows how the estimated allocation effect varies across drought conditions. The two panels use different vertical scales. The Extreme bin rests on ten municipality-years, eight of them in the Austral macrozone; it is plotted and not interpreted. Controls: $\tilde{A}^{nc}$, $\tilde{A}^{\text{local}}$. Fixed effects: municipality and basin × year. Standard errors clustered at the river basin; bars show 95% confidence intervals. Sample: 6,800 municipality-years and 340 municipalities in 80 basins, 2005–2024. Stars: $^{*}\,p < 0.10$, $^{**}\,p < 0.05$, $^{***}\,p < 0.01$.

Appendix Table B.15 reports regressions that include standardized human extraction and drought as separate covariates. In the levels specification, human extraction is more consistently associated with protest than drought, especially when basin stress is at least 30%. Alternative temporal specifications in Appendix Table B.16 produce different patterns. The figure and tables are therefore best read as evidence on compound scarcity rather than as a decomposition of the separate effects of human extraction and drought.

In May 2025 I conducted thirteen semi-structured interviews in the mining and avocado valleys of north-central Chile and the forestry areas of the south. Participants' own words support some of the mechanisms explored. Interviewees point to a dominant upstream user as a focal target for collective action; to ties that raise the local cost of contention and to scarcity attributed to a visible extractor rather than to drought. Appendix C collects representative passages.

5.3 Robustness

The streamflow estimates hold under two changes to how the allocation index is built. Removing the distance weights leaves the depletion result in place (Table B.18). Rebuilding baseline flow F_i from pre-2005 years only, available for 84% of gauged cells, makes the estimated effect larger (Table B.19). The baseline estimate is therefore not driven by using contemporaneous flow in the denominator.

For the conflict estimates I run four checks. First, the design's own placebo is the non-competing pool: allocations downstream of a municipality, or in an aquifer with no path to it, cannot deplete its water and should not move protest there. They do not at any floor of the sweep for firm-targeted protest, and where the coefficient is not zero it carries the opposite sign to competing allocation (Table B.10).

Second, conflict does not appear to predict where rights are later allocated. Taking the onset of protest in a municipality as an event, competing allocation does not change in the years afterward, and annual allocation growth is unrelated to lagged protest (Table B.20). The lagged terms for firm-targeted protest are significant at the 10% level, but have opposite signs and magnitudes of 0.002 log points or less against a clean non-competing column. This is not a coherent pattern of allocation responding to prior protest.

Third, the protest estimates at the 30% stress floor rest on 24 basins, so I re-estimate them with a wild cluster bootstrap and with Conley spatial-HAC errors (Table B.21). The Conley errors are close to the basin-clustered ones. Under the bootstrap, firm-targeted protest remains significant at the 10% level ($p = 0.065$), whereas the pooled count does not ($p = 0.108$).

Finally, the pattern is robust to the functional form of the outcome (Table B.11). The log and standardized protest counts are not distinguishable from zero below the 30% floor and are significant at the 1% level above it, while the indicator for any protest is significant at the 1% level at every floor. The sample-splitting test does not identify a precise breakpoint: its confidence sets cover most of the stress range (Table B.22). Taken together with the interaction and sweep, these results are consistent with a progressively stronger protest response as basin stress rises.

The allocation measure also has a limitation: water-right volumes measure legal entitlements rather than observed withdrawals. If rights are systematically underused, the estimates understate the effect of actual withdrawals; since 2005, non-use fees have made persistent non-use costly. Unobserved over-extraction raises a different concern: unless it systematically varies with allocated volume, it adds measurement error; if it does vary with allocation, the estimates capture the effect of granting a right rather than of a precisely measured cubic meter withdrawn. The results should therefore be read as effects of water allocation.

Recorded rights growth is also unlikely to be purely an administrative artifact. Real agricultural exports grew by 170% between 1996 and 2024, while estimated water demand from major orchard crops rose by 1,074% between 1999 and 2024 (Appendix A, Figure A.3). The expansion was driven by perennial crops including cherries, avocados, blueberries, and table grapes, whose water demand persists throughout an orchard's productive life. These figures do not establish that every right is exercised, but they show that the expansion of the registry coincided with substantial, durable new demand for extraction rather than only the formalization of pre-existing uses.

6. Discussion and Policy Implications

6.1 Diagnosis

Three characteristics of Chile's governance framework enable the depletion and conflict documented above. First, allocation is granted in fixed volumes that do not automatically adjust when the resource available decreases, and water rights allocated surpass the renewable flow available in more than twenty basins. Second, scarcity is unpriced. Holders pay no marginal price for the water they take, and non-use fees push them to use their full allocation. There is no mechanism rewarding conservation as water tables fall. Large users adapt by drilling deeper wells, while smallholders and rural drinking-water cooperatives cannot and absorb the loss. Third, transaction costs are high: partial rights cannot be sold and relocating an intake point can take years, so the market is rigid, and rights mostly stay where they were first issued. These are policy choices, and the proposed reforms below address each in turn.

6.2 Policy Implications

Four reforms follow from this diagnosis. The first is basin-level water accounting with cumulative caps: no new productive rights in basins that are already over-appropriated. The streamflow results show that grants in stressed basins do not add productive water; they shift scarcity, and the conflict that comes with it, onto downstream users. This requires completing the real-time extraction monitoring mandated by the 2022 reform and assessing cumulative impact at the basin scale in place of the current case-by-case review. The second is lower water-market transaction costs. Relocating an extraction point now takes about three years, which freezes the reallocation the market was meant to deliver. A faster, cheaper transfer process would let water move toward higher-value uses without new grants in stressed basins. The third is pre-negotiated, basin-wide drought protocols in place of reactive declarations. Discretionary emergency measures concentrate scarcity decisions in the state; proportional reduction rules, agreed in advance and triggered by streamflow thresholds, make drought management predictable and less open to dispute. The fourth is public investment in rural water capital: communal wells, on-farm storage, efficient irrigation for small producers, and legal protection for rural drinking-water cooperatives against industrial-scale competitors. Smallholders absorb the cost of scarcity because they cannot afford the adaptations available to larger users, and this asymmetry prompts conflict.

Inaction is already expensive. Chile spends about USD 9 million a year on government tanker-truck delivery, and the bill rises as the share of municipalities under emergency water-scarcity declarations approaches 50%. Seawater desalination of about 1,000 L/s, the size of a single large industrial right, cost hundreds of millions of dollars in capital; conserving the same volume through efficient irrigation, lower transport losses, or leak repair costs a fraction of that. Scarcity pricing that scales with basin stress, together with a shift of emergency-supply spending toward demand-side efficiency, would move the system from buying ever more costly supply toward protecting the water it has.

These recommendations are specific to Chile, but the principles behind them are not. They follow the agenda of the recent UN assessment of global water bankruptcy (Institute for Water, Environment and Health, 2026). The first is accounting: extraction should be measured against the water a basin renews, akin to a budget, so that deficits are caught before the loss becomes irreversible. The second is to get more from existing water, through reuse and greater efficiency, before spending on new supply, which is slower and more costly. The third is to price scarcity properly, so that large users pay the marginal cost of the water they extract rather than receiving it for free until a source is declared exhausted. The fourth is to protect the users who lose access as the system adjusts, since scarcity falls hardest on those least able to adapt. All four apply under permit, concession, or open-access regimes alike, wherever water extraction is surpassing its rates of renewal.

6.3 External Validity

The mechanism does not depend on Chile's particular system. It requires only that human extraction push past what a basin renews, and that the resulting loss be traceable to identifiable users or to the state. Both conditions are now common. Human pumping has driven groundwater and streamflow below replacement across much of the irrigated world, from northwestern India to the Middle East and the western United States (Rodell et al., 2018). The resulting scarcity provokes contention under many institutional arrangements, including ones with no water market at all. In Kerala, communities mobilized against a bottling plant drawing down an open-access aquifer to which no one held a tradable right (Koonan, 2007); in Mexicali, farmers and residents under a state concession system framed scarcity as "saqueo"—looting—and aimed it at a foreign brewery taking local groundwater (Cortez Lara, 2020). Chile's formal, registered rights do not create this conflict; they make it measurable, recording who holds how much water and where. The main data constraint in this literature is measuring how much each user actually extracts from a shared source (Zipper et al., 2022). Chile's rights registry approximates this, allowing me to estimate the consequences of extraction.

The link between the distribution of rights and whom contention is aimed at should travel across settings. Where one large or external user is the visible cause of the deficit, blame concentrates and scarcity drives extra-institutional mobilization against that actor, as in the Kerala and Mexicali cases. Where the loss is instead shared among comparable neighbors and no single party stands out, the conflict turns inward: peers contend with one another, and the cooperation needed to manage a common source begins to erode. I use water-theft lawsuits to measure how this institutional conflict surfaces in Chile, where courts give water users a formal venue. In settings without that infrastructure it can take other forms, from informal disputes to a race to drill ever-deeper wells against one's neighbors in the open aquifers of western India (Shah, 2009). Local conditions will determine the extent of the conflict and the channel through which it manifests—e.g. how tightly extraction is monitored and enforced, and what alternatives those who lose water have. Chile, with secure rights and an imperfect water market, is a conservative case. The conditions that generate the underlying scarcity are spreading as more economies exploit finite groundwater under a drying climate. These pressures are not unique to poor or food-insecure economies; they also arise where intensive, export-oriented development has pushed basins past their limits, as in Chile. Because that scarcity follows from allocation decisions, policy decisions can also address it.

7. Conclusion

This paper combines administrative, hydrological, and socio-political data for Chile with a spatial-spillovers strategy that exploits hydrological connections. It provides causal evidence that competing water allocation reduces streamflow and is associated with increased protest, particularly protest targeting firms. The protest response is stronger where more basin flow is already committed, and rights concentration makes firms clearer targets for collective action. Drought and human-made scarcity can compound one another, although their combined effect depends on how affected users attribute the shortage.

The qualitative evidence provides context for these patterns. Interviewees described a large upstream user as a focal target, economic dependence on firms as a cost of public challenge, and contrasting accounts of scarcity attributed to extraction or to a lack of rain. They also described conflicts between neighboring users over irrigation turns and barriers to participating in formal water governance. These accounts illustrate the mechanisms through which allocation can generate contention and why the response to scarcity may vary (Appendix C).

Several questions follow for future research. Emerging water-intensive industries, including data centers and lithium extraction, may reproduce these patterns as they enter already stressed basins (Lehuedé, 2025). Their political consequences will depend on how cumulative withdrawals are governed and how affected communities understand the resulting loss. Research should also examine effects that precede or extend beyond visible protest, including trust in firms and public authorities, electoral accountability, and cooperation among water users. This question is especially salient in Chile, where consumer confidence in companies has recently declined across water-intensive sectors (PwC Chile et al., 2026). Finally, it should examine whether institutions charged with resolving water disputes enforce rules consistently across users with unequal economic and political resources. These questions matter across settings in which scarcity is shaped not only by climate, but by decisions about whose claims on water are recognized and enforced.

The structure of water governance determines whether depletion produces conflict and what form it takes. Chile's experience is a cautionary tale for the growing number of economies where water extraction is outpacing renewable supply, and where policies designed in an era of abundance now confront the physical limits of the resources they govern.

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Online Appendix

Table of Content

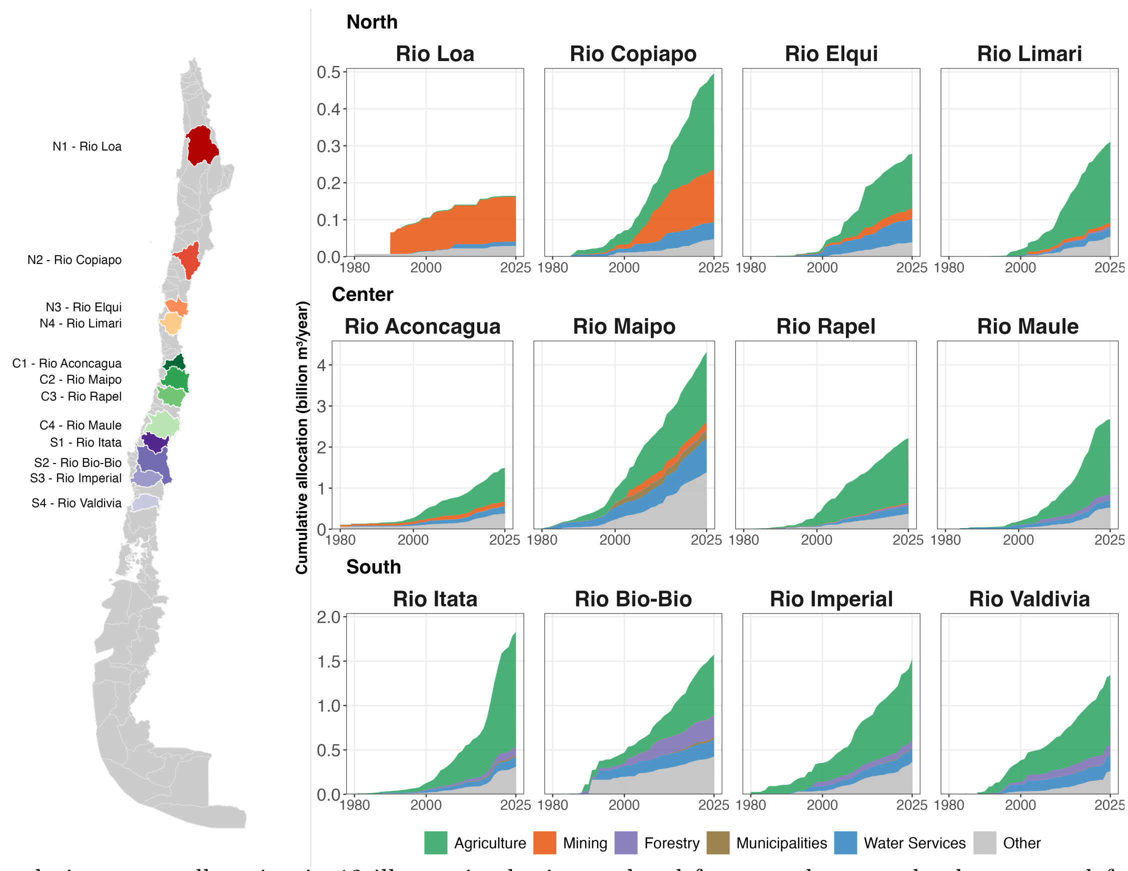
A. Descriptive Evidence: Allocation, Stress, and Concentration

This appendix documents the empirical setting in which the paper's estimates are situated: the expansion of water allocation, the growth of water stress, and the concentration of rights among productive users. The evidence is descriptive, but it establishes why competing allocation is substantively consequential and why the study examines basin stress, corporate targets, and the interaction of human and climatic scarcity.

A.1 The Expansion of Water Allocation

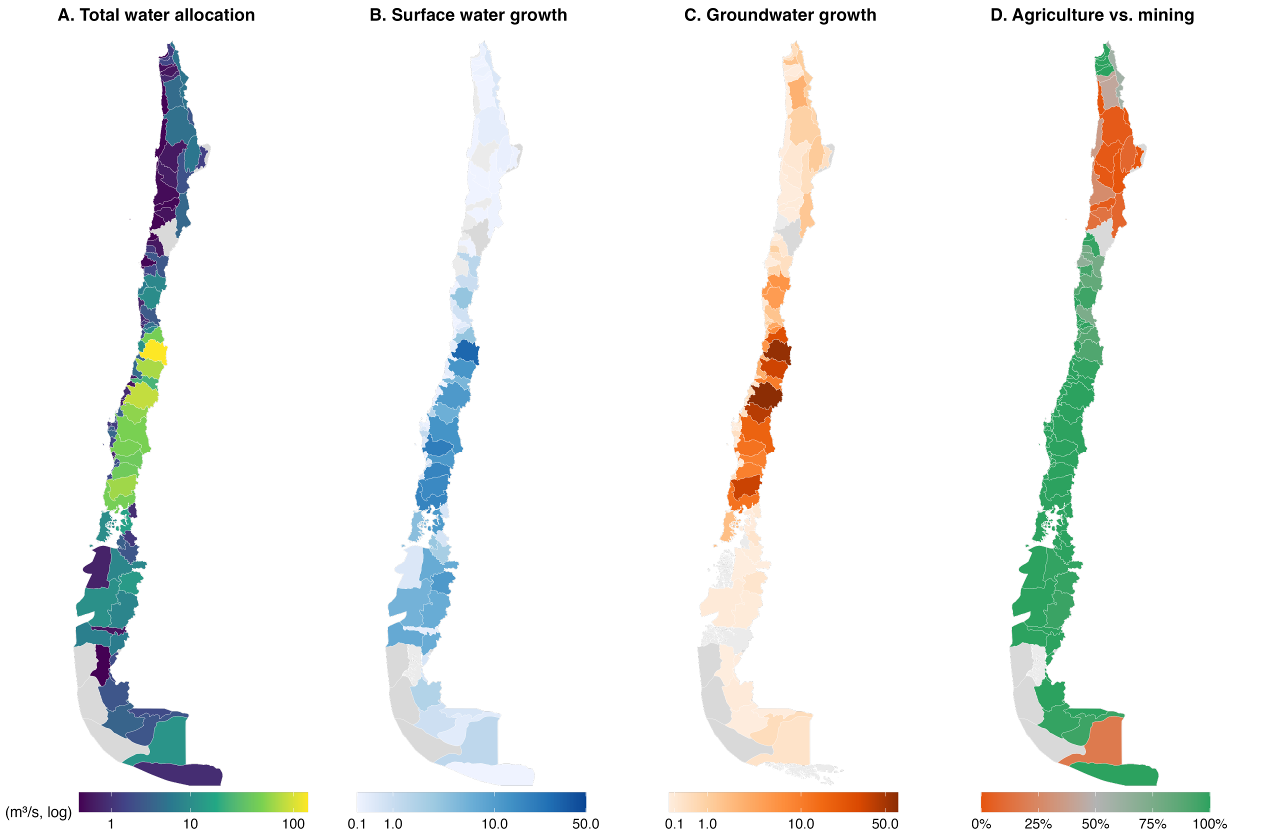
Chile's Public Water Registry records a dramatic expansion of formal water allocation since the 1981 Water Code was promulgated. Cumulative granted volumes reached approximately 30 billion m^3/year by 2025, roughly five times the level in 2000 (a compound annual growth rate of about 7%). As shown in Figure 2, the growth has been especially rapid since 2000. Groundwater rights surpassed surface rights in 2012, and now constitute 56 percent of the total. Agriculture accounts for 56 percent of all allocated volume, likely an under count considering smallholder farmers that may not have formalized their water consumption. A residual "other" category—mainly energy, aquaculture, food and beverages—follows at 23 percent, with water utilities and sanitation at 10 percent and mining at 5 percent. National averages hide important cross-basin heterogeneity. Mining activities are concentrated in the North, where water is scarcer, and their water use accounts for up to 98% of the water granted in those basins. Figure A.1 shows the expansion by basin in a few illustrative examples across zones. Figure A.2 documents the agriculture-versus-mining gradient showing a spatial pattern: northern basins are predominantly mining-oriented, while central and southern basins are agricultural.

Figure A.1: Cumulative Water Right Volumes Granted 1980–2025, by Basin



Notes: Cumulative water allocation in 12 illustrative basins, ordered from north to south; the map at left locates them. Colors indicate the holder's user sector. The vertical extent varies by zone. Data from the Dirección General de Aguas (DGA).

Figure A.2: Water Rights Allocation, Growth, and Sectoral Composition by Basin, 2005–2025



Notes: Basin-level water allocation in Chile. Panel A displays total cumulative water rights (groundwater + surface water) granted as of 2025, in m^3/s on a log scale. Panels B and C show the absolute increase in surface water and groundwater rights, respectively, between 2005 and 2025 (m^3/s, log scale, same scale for comparability). Panel D shows the agriculture-versus-mining gradient: color indicates agriculture's share of the combined agricultural and mining allocation within each basin, ranging from mining-dominated (brown) to agriculture-dominated (green), with grey indicating an equal split. Grey basins have no recorded allocation or no change over the period. Data from the Dirección General de Aguas (DGA).

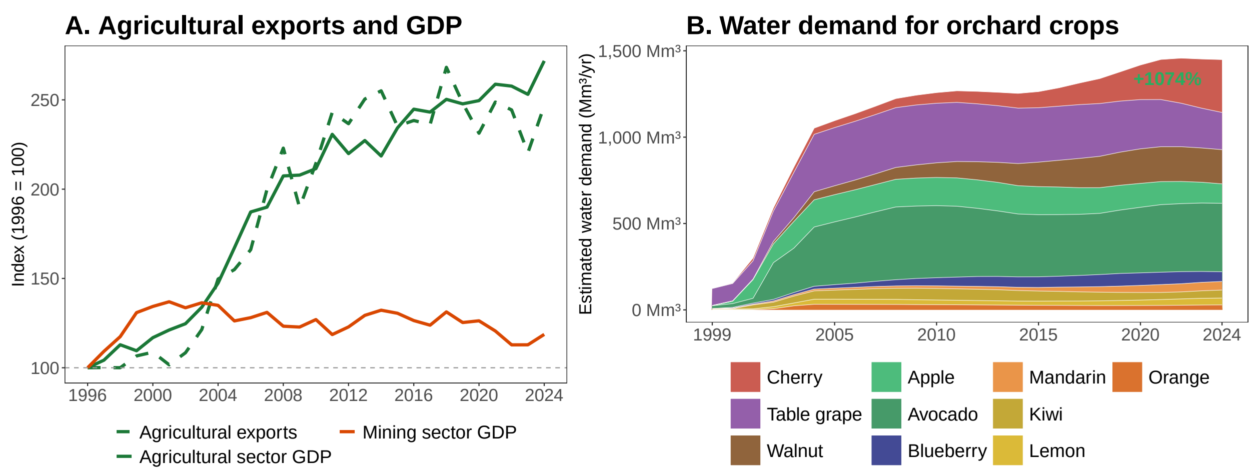
A.2 Demand-Side Transformation: Agriculture and Economic Growth

The expansion of water rights reflects a real transformation of Chile's agricultural economy, beyond administrative formalization of pre-existing uses. Figure A.3 shows that real agricultural exports grew by approximately 170 percent relative to 1996, with agricultural sector GDP following a similar trajectory. Mining GDP, by contrast, has remained relatively flat, though still substantively larger in absolute terms.[13]

[13]Mining represents nearly 13% of GDP, while agriculture and fishing contribute around 3%.

Since the late 1980s, Chile has sought to position itself as a "food power", a marketing concept based on its abundant fruit production. Orchard crops show the clearest evidence of structural demand expansion. Estimated water demand from major orchard crops rose by about 1,074 percent between 1999 and 2024, from roughly 120 to approximately 1,400 million m^3/year, driven by the expansion of cherry, table grape, walnut, avocado, and blueberry cultivation (Figure A.3, Panel B). These are highly water-intensive perennial crops whose planted area and water demand persist over time. This structural expansion is a key driver of the rights growth documented above, and helps explain why allocated volumes have continued rising even as renewable supply has declined.

Figure A.3: Agricultural Transformation and Fruit Sector Water Demand, 1996–2024



Notes: The scale and composition of Chile's agricultural transformation since the mid-1990s. Panel A shows real agricultural exports (deflated to 2021 USD using BLS CPI-U), agricultural sector GDP, and mining sector GDP (both in real 2018 CLP), all indexed to 1996 = 100. Panel B shows estimated total water demand from the major orchard crop sectors, 1999–2024, in million cubic meters per year (Mm^3/yr). Demand is computed as annual planted area from ODEPA regional fruit surveys (interpolated to annual frequency) multiplied by FAO IDP56 crop-specific evapotranspiration coefficients (m^3/ha/yr): avocado 12,000; table grape 6,500; kiwi 6,000; walnut and apple 4,500; cherry, lemon, and orange 4,000; olive 3,500. The percentage label indicates the change from 1999 to 2024. This estimate reflects crop evapotranspiration only – the efficient lower bound on water consumption – and covers major orchard species tracked by ODEPA; annual crops, wine grapes, vegetables, and non-agricultural uses are excluded. Gross water diversions required to achieve the reported evapotranspiration are approximately 2–4× larger depending on irrigation technology. Data sources: ODEPA balanza silvoagropecuaria histórica; Banco Central Cuentas Nacionales 2018 (CCNN2018); FAO Irrigation and Drainage Paper 56.

A.3 Signs of Water Stress and Over-Appropriation

The gap between water demand and available supply—with supply also shrinking due to temperature rise and drought—is visible across multiple indicators of water stress. Emergency tanker-truck government expenditures, used to ensure water availability for domestic use, rose from below 1 million USD in 2007 to approximately 9 million USD in 2023, and the share of municipalities reporting any municipal tanker spending grew from around 10 to nearly 50 percent over the same period (Figure A.4).

Government-issued water scarcity declarations follow a similar trend. Figure A.5 documents their expansion from isolated basin-level decrees in 2008 to a peak in 2022 when 53 percent of municipalities were simultaneously under active declaration. Of the 270 municipalities that experienced at least one declaration year between 2008 and 2025, 44 have been under declaration for 12 years or more, indicating structural deficits rather than one-off shocks.

These alerts are backed by hydrological data. Figure A.6 shows three independent measures declining in parallel since the early 2000s: mean streamflow fell by 5.1 m^3/s per decade in the Center zone and 5.6 m^3/s per decade in the South; water table depth increased by 2.1–2.6 meters per decade across the North and Center zones (progressive groundwater depletion); and GRACE satellite measurements show water storage declining at 2.1–2.8 cm equivalent water height per decade.

Figure 3 plots total cumulative rights against annual renewable streamflow by zone: in the North, rights have exceeded mean annual flow since the late 1990s; in the Center, the gap between the two series has been closing steadily as streamflow declines. Figure A.7 shows that the number of nationally over-appropriated basins—where rights exceed mean flow—grew from none in 1980 to 23 by 2019, with over 75 percent of northern basins over-appropriated by 2000. Figures A.8 and A.9 show this at the basin level: the supply-demand balance for illustrative basins, and the stress tier and year of first crossing of the over-appropriation threshold. Scarcity in these basins reflects both natural variability and a rights regime that has granted paper claims far exceeding the flow renewed each year.

A.4 Concentration and Inequality

The expansion of rights has been highly unequal. Figure A.10 shows that the top 10 percent of water rights holders control 81.6 percent of all allocated volume, while the bottom 50 percent control just 1.8 percent.

Figure A.11 contextualizes this concentration: the top 1,000 companies hold 4.7 times the total allocation of all water utilities that supply drinking water to the population combined (14.7 versus 3.1 billion m^3/year). Panel C of Figure A.9 and Table A.1 document basin-level concentration: in multiple northern and central basins, a single holder or small group of firms controls over half of all allocated volume. Table A.2 lists the largest individual holders by name.

A.5 Natural versus Human Causes

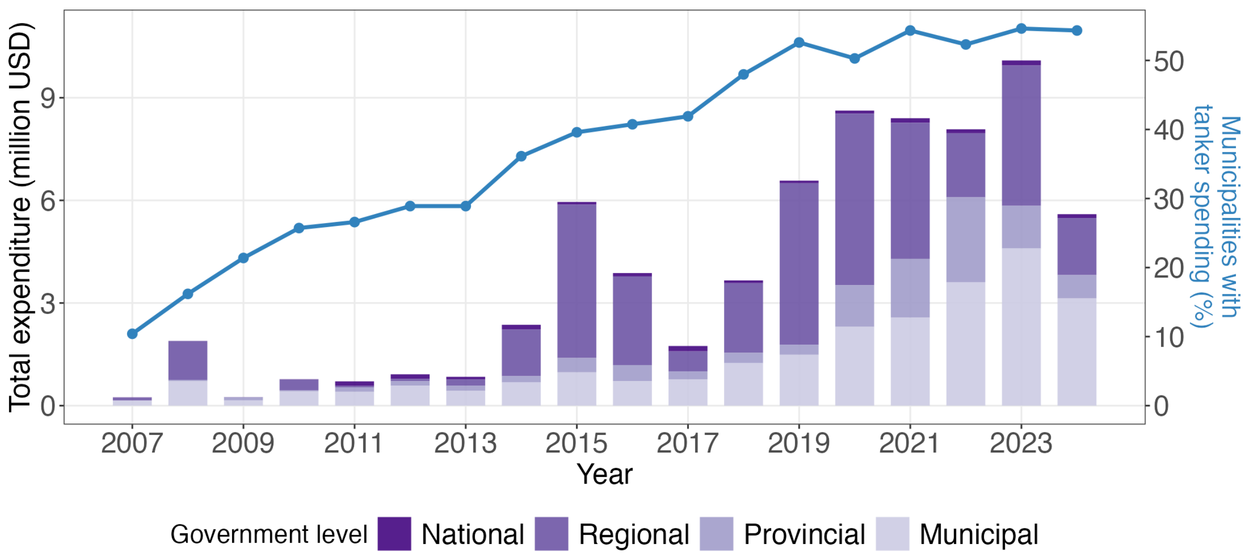
The hydrological declines documented above are partly attributable to drought. Figure A.12 shows SPEI-12 by zone from 2005 to 2024: the Center zone experienced a documented mega-drought from 2010 to 2019, with negative SPEI in nearly every year of the decade, while the South shows persistently negative SPEI throughout the entire study window.[14]

Yet drought alone is unlikely to fully account for the observed patterns. Streamflow declines in the Center zone predate the 2010 mega-drought and continue in years when SPEI recovers. The North zone, which has experienced more moderate precipitation deficits than the South, shows the most severe groundwater depletion, with water table depths deepening faster than anywhere else in Chile. These divergences suggest that rising water demand is compounding natural supply variability, and motivate the empirical strategy in Section 4:

[14]SPEI is the Standardized Precipitation–Evapotranspiration Index; the 12-month version (SPEI-12) compares the accumulated water balance over the prior year to the historical norm. Values below zero indicate drier-than-normal conditions, with SPEI below -1, -1.5, and -2 commonly denoting moderate, severe, and extreme drought.

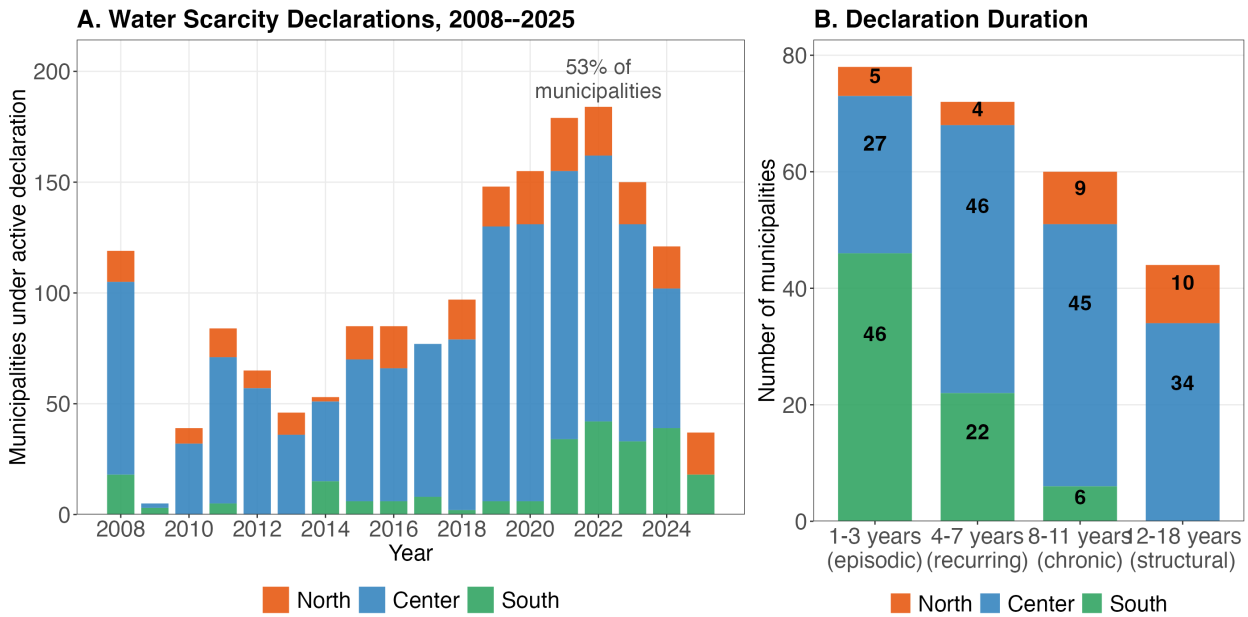
identifying the causal contribution of competing rights accumulation to downstream hydrological outcomes, net of drought-driven variation.

Figure A.4: Government Emergency Water Delivery by Level, 2005–2024



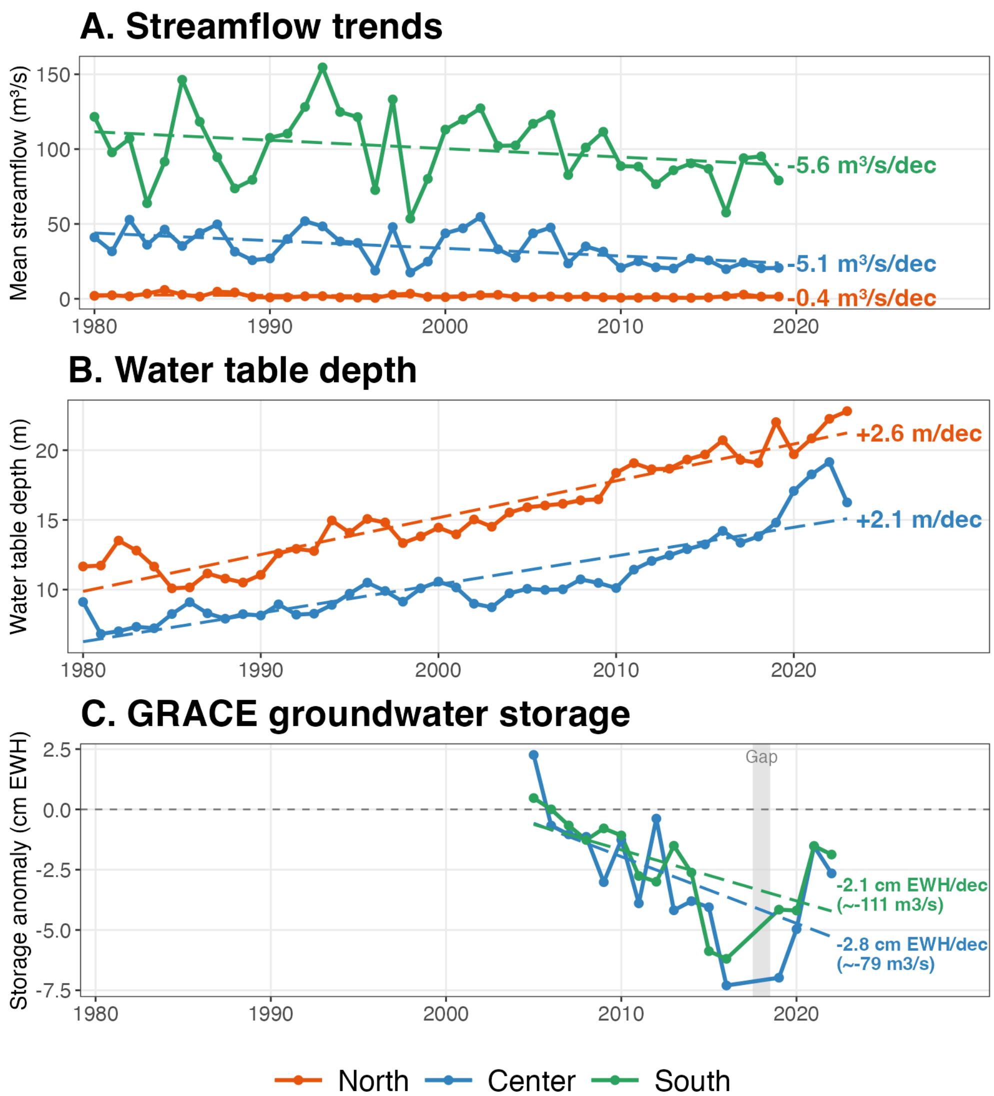
Notes: Stacked bars show annual government expenditure on emergency tanker-truck water delivery (million USD, converted at 950 CLP/USD), disaggregated by the level of government that placed the procurement order: national ministries and agencies (darkest), regional governments (*Gobiernos Regionales* and *Delegaciones Presidenciales Regionales*), provincial delegations, and municipalities (lightest). The blue line and right axis show the share of Chile's 346 municipalities that reported any municipal tanker expenditure in that year. Data source: Mercado Público, the open registry of all Chilean government purchase orders. Tanker-truck spending is identified by filtering orders containing *camión aljibe*, tanker truck. Regional governments primarily cover fixed costs (purchasing trucks), while municipalities cover variable costs (purchasing water from utility companies to fill the trucks).

Figure A.5: Emergency Water Scarcity Declarations in Chile, 2008–2025.



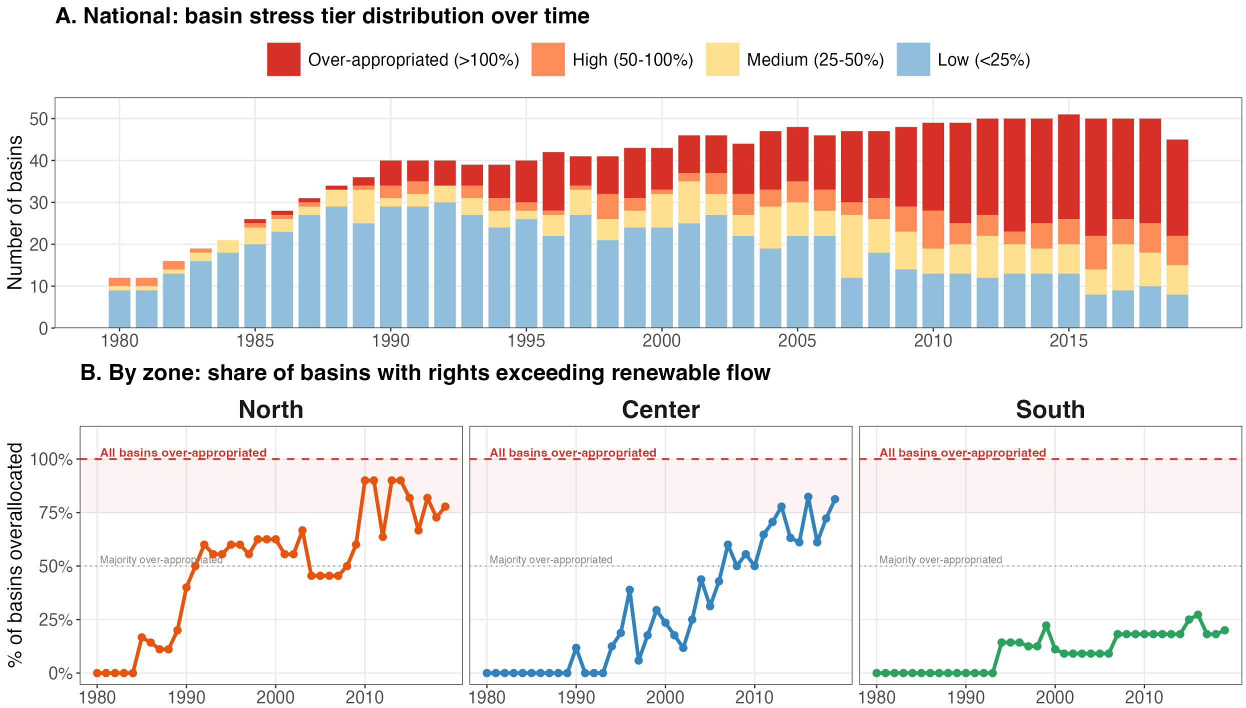
Notes: Panel A: Number of municipalities under active scarcity declaration each year, stacked by macro-zone. The 2008 peak reflects 6 large basin-level decrees that collectively covered 128 municipalities but all expired before January 2009, explaining the sharp 2009 dip. The sustained rise from 2016 onward and the 2022 peak (54% of municipalities) reflect a structural shift toward chronic, renewable declarations. *Panel B*: Cumulative years under active declaration per municipality (2008–2025), grouped by persistence category. A total of 270 municipalities (out of 346) experienced at least one declaration year, representing approximately 13.8 million people (2017 census). Structurally exposed municipalities (12–18 years, $n = 44$) account for approximately 2.0 million people, concentrated in the Center zone. Data: DGA shapefile through May 2021, supplemented with DGA administrative records through 2025.

Figure A.6: Water Availability Trends by Zone, 1980–2023



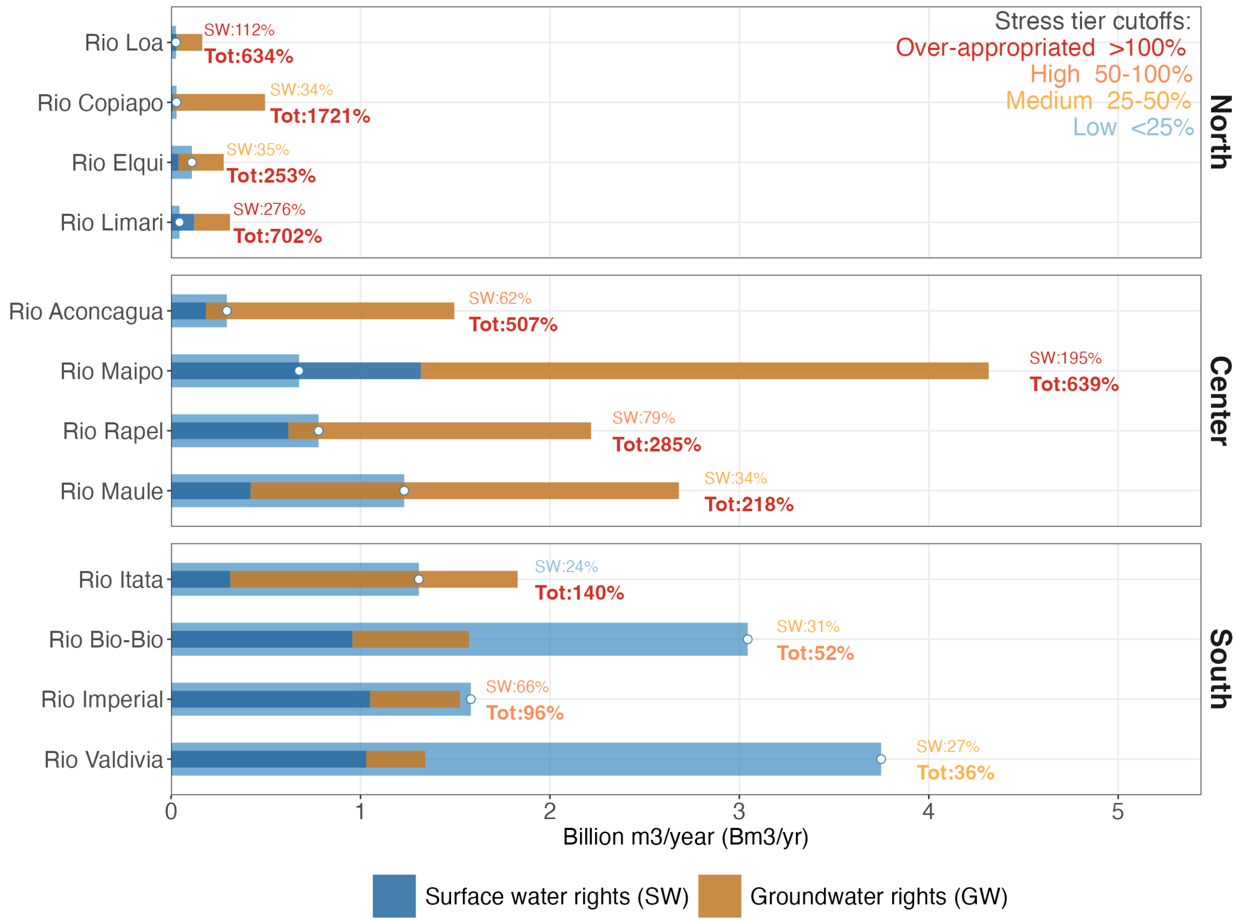
Notes: Panel A: Mean annual streamflow (m^3/s) averaged across basins per zone, from DGA gauging stations (1980–2019). Includes all basins with at least two stations reporting in 30 or more of the 40 sample years; zone-years with fewer than two qualifying basins are dropped. *Panel B*: Mean water table depth (meters below surface) averaged across basins per zone, from DGA well monitoring stations (1980–2023). Includes all basins with at least two wells reporting and data in 20 or more years; basin-years where wells fall below 20% of a basin's median well count are excluded. South zone omitted due to insufficient basin coverage after applying these filters. *Panel C*: GRACE/GRACE-FO terrestrial water storage anomaly (cm equivalent water height) relative to the 2004–2009 baseline (2005–2022); North zone excluded due to sparse satellite pixel coverage. All series aggregate station-level data to basins and then to zones (North, Center, South). Dashed lines show OLS trends; annotations report the estimated slope per decade.

Figure A.7: Growing Over-Appropriation across Chilean River Basins, 1980–2019



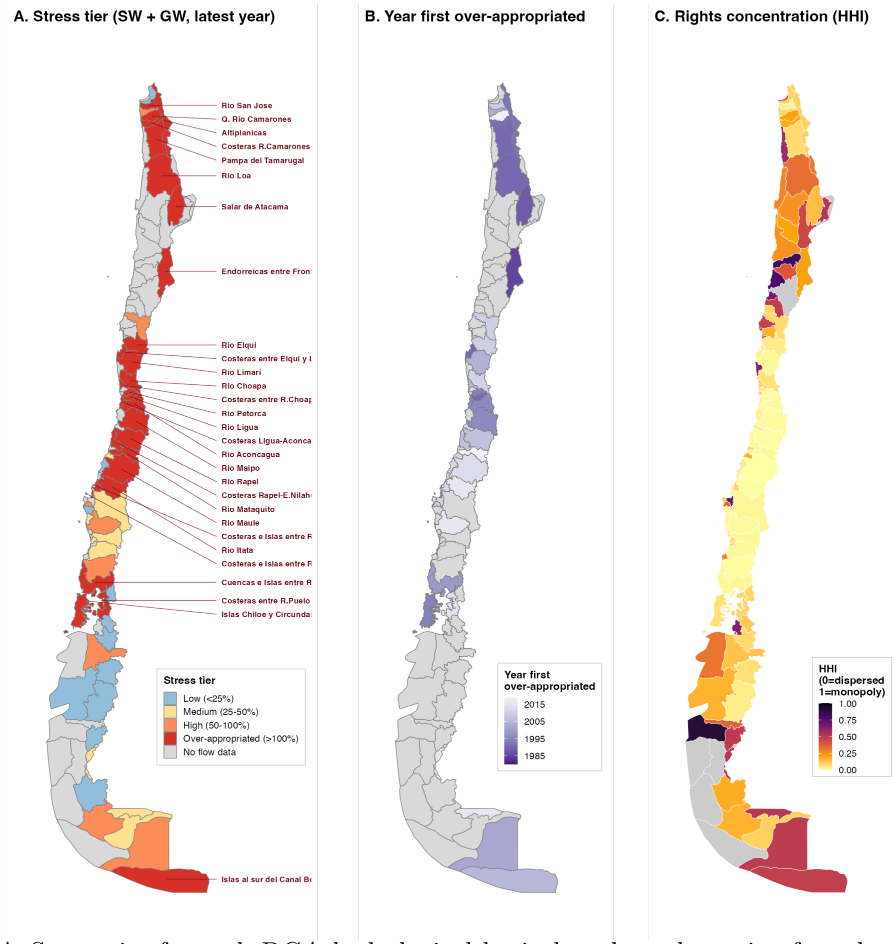
Notes: Panel A shows the number of river basins in each water stress tier nationally, by year. A basin is classified as Over-appropriated (≥100%) if total allocated rights exceed mean annual streamflow; High (50–100%), Medium (25–50%), or Low (<25%) otherwise. *Panel B* shows the share of basins in each zone whose total allocated rights exceed annual streamflow (i.e., classified as over-appropriated), by year. In both panels, the sample is restricted to basins with matched DGA rights records and at least one CR2 gauge station within the basin boundary. Basin coverage grows from 31 basins in 1980 to over 50 basins from 2005 onwards. Stress ratio = total water rights (surface + groundwater) / mean annual streamflow. Rights data from Chile's National Water Registry (DGA). Streamflow from the CR2 daily gauge dataset aggregated to basin-year means (CR2, 1913–2019).

Figure A.8: Water Supply–Demand Balance in Illustrative Basins



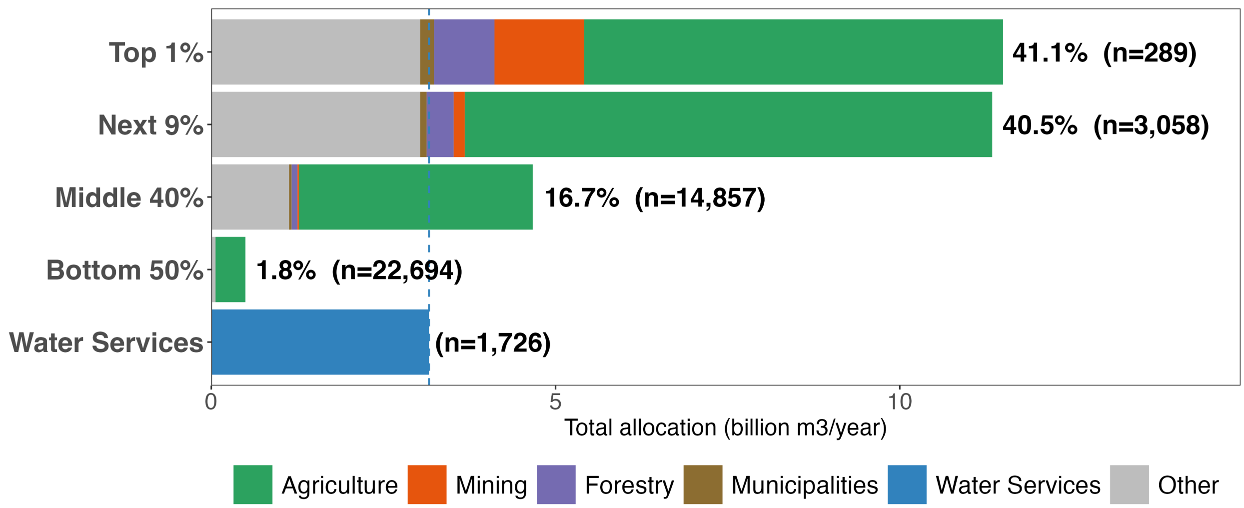
Notes: Each row shows one basin's water budget. The wide blue bar is mean annual renewable streamflow, averaged across all available gauge years. The stacked narrow bars are total water rights registered with the DGA as of 2024 (demand), split by source: surface water (SW, blue) and groundwater (GW, amber). Labels at right give the basin stress ratio — *SW:* = surface water rights / mean flow; *Tot:* = total (SW + GW) rights / mean flow — color-coded by tier: Low (<25%), Medium (25–50%), High (50–100%), Over-appropriated (≥100%). A basin is classified as "over-appropriated" when total allocated rights exceed mean annual renewable supply. Basins ordered north to south within each zone.

Figure A.9: Basin Water Stress, Onset of Over-Appropriation, and Rights Concentration



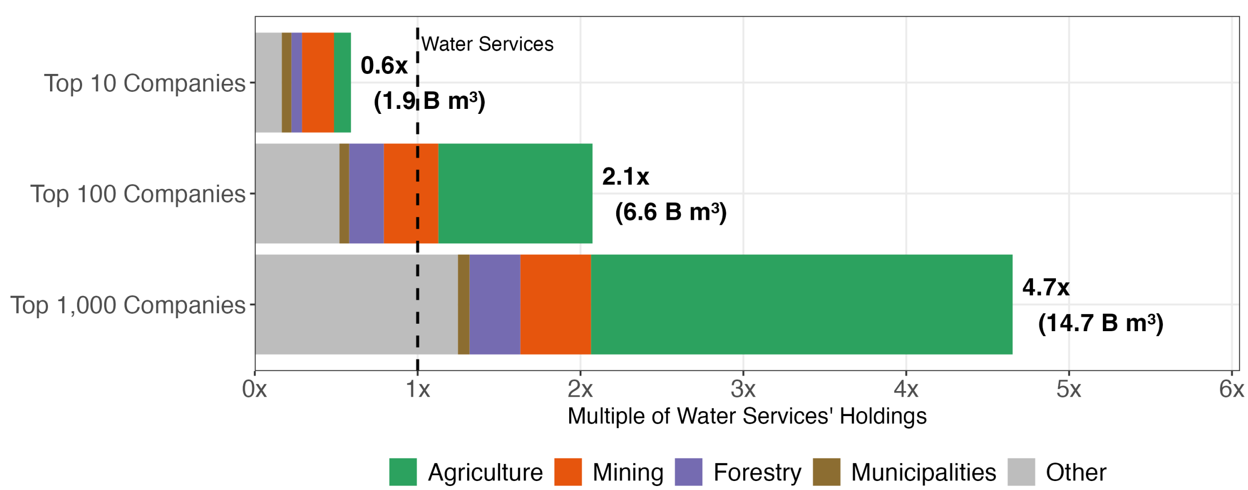
Notes: Panel A: Stress tier for each DGA hydrological basin based on the ratio of total cumulative water rights allocated (surface and groundwater combined) to mean annual streamflow, using the latest year with matched rights and flow data available for each basin. Tiers: *Low* (<25% of flow allocated), *Medium* (25–50%), *High* (50–100%), and *Over-appropriated* (≥100%). Basin names in red label basins currently in the Over-appropriated tier. *Panel B*: First year in which each basin's stress ratio exceeded 100%; darker red indicates earlier onset, yellow indicates more recent onset, and grey indicates basins that have never exceeded the threshold. Flow data are from DGA gauging stations aggregated to the basin level; rights are cumulative active allocations from the DGA water rights registry. *Panel C*: each basin shaded by its Herfindahl–Hirschman index, computed over individual holders' shares of total allocated flow, where 0 is perfectly dispersed and 1 a single holder. Water utilities, sanitation companies and municipalities are excluded. Grey basins have no matched allocation data. The dominant holder and share for the most concentrated basins are in Table A.1.

Figure A.10: Water Rights Volume Concentration



Notes: Concentration of cumulative water right volumes granted by 2025, in billion m^3/year. Bars show total allocation by holder percentile group, colored by sector. The dashed line is the total allocation of all water utilities and sanitation companies ($n = 1{,}726$), a benchmark for domestic supply. Data from the Dirección General de Aguas (DGA).

Figure A.11: Concentration of Water Rights Relative to Water Utilities Holdings



Notes: Water allocation of the top 10, 100 and 1,000 companies relative to the total allocation of water utilities (1× at ∼3.1 billion m^3/year). Colors indicate use type: agriculture, mining, forestry and other. Data from the Dirección General de Aguas (DGA).

Table A.1: Dominant Water Rights Holders by River Basin

Zone	Basin	Holder	Sector	Share (%)	Alloc.	HHI	N
North	Endorreica entre Fronterizas y Salar Atacama	EXPLORACIONES,INVERSIONES Y ASESORI	Mining	67.8	1.5	0.515	5
North	Costeras entrre R. Los Choros y R. Elqui	ANDES IRON SPA	Other	65.8	1.5	0.467	14
North	Endorreicas Salar Atacama-Vertiente Pacifico	MINERA ESCONDIDA LIMITADA	Mining	60.8	2.5	0.450	6
North	Rio Loa	CODELCO CHILE	Mining	56.2	4.9	0.334	49
North	Fronterizas Salar Michincha-R.Loa	CODELCO CHILE	Mining	43.6	2.8	0.317	6
North	Endorreicas entre Frontera y Vertiente del Pacifico	NORTE ABIERTO SPA	Mining	41.2	4.2	0.211	21
North	Rio los Choros	AGRICOLA Y EXPORTADORA TIERRA PURA	Agriculture	39.1	1.8	0.173	112
Center	Rio Carampangue	CELULOSA ARAUCO Y CONSTITUCION SA	Forestry	83.9	1.2	0.706	75
Center	Rio Lebu	BOSQUES CAUTIN SA	Forestry	57.9	2.6	0.350	86
South	Costeras entre R.Valdivia y R.Bueno	BOSQUES SA	Forestry	51.4	1.8	0.279	100
Austral	Costeras entre R. Pascua Limite Region. Archipielago Guayeco	AGRICOLA CONQUIL LIMITADA	Agriculture	94.5	5.0	0.897	3
Austral	Costeras entre R.Yelcho y limite Regional	SOCIEDAD AGRICOLA SANTA CAROLINA LI	Agriculture	75.9	1.3	0.632	5
Austral	Vertiente del Atlantico	PEDRO ANTONIO MIHOVILOVIC KUZMANIC	Agriculture	68.7	2.1	0.512	18
Austral	Rio Pascua	IAN SZYDLOWSKI ALVAREZ	Agriculture	60.1	6.8	0.496	47
Austral	Tierra del Fuego	COMPANIA MINERA TIERRA DEL FUEGO SA	Mining	69.2	11.0	0.490	91
Austral	Costeras entre Seno Andrew y R. Hollemberg e islas al oriente	AQUACHILE MAGALLANES SPA	Other	28.1	2.5	0.183	67
Austral	Costeras e Islas entre R Aisen y R Baker y Canal Gral. Martinez	COMPANIA DE INVERSIONES LA UNIVERSA	Other	32.4	10.8	0.172	64
Austral	Costeras e Islas entre R Hollemberg, Golfo Alte. Laguna Blanca	DUSAN VILICIC KARNINCIC	Agriculture	27.0	3.9	0.171	32

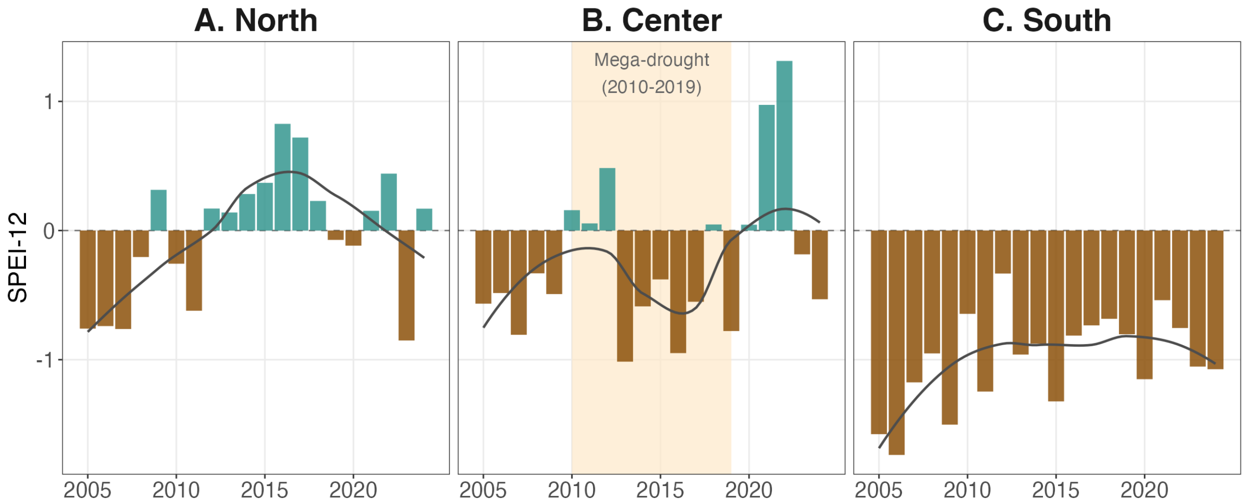
Notes: Basins with HHI > 0.15 and total allocation > 1,000 L/s. One row per basin showing the largest single holder. HHI = Herfindahl–Hirschman Index = $\sum_i s_i^2$ where s_i is holder i's share of total basin allocation. Range: 0 (dispersed) to 1 (monopoly). Share (%) and HHI are computed excluding water utilities, sanitation companies, and municipalities. Alloc. = top holder's allocation in m^3/s. N = total number of rights holders in the basin after exclusions. Source: DGA water rights registry.

Table A.2: Top-50 Productive Water Rights Holders (GW+SW, Excl. Utilities and Municipalities)

Rank	Name	Sector	GW (m^3/s)	SW (m^3/s)	Total (m^3/s)	Share (%)	Pop. equiv. (M)
1	COMPANIA MINERA TIERRA DEL FUEGO SA	Mining	0.00	7.62	7.62	0.87	3.29
2	CODELCO CHILE	Mining	7.06	0.15	7.21	0.82	3.11
3	FISCO DE CHILE	Other	1.07	5.82	6.89	0.79	2.98
4	BOSQUES CAUTIN SA	Forestry	0.01	6.50	6.51	0.74	2.81
5	PATRICIO EDUARDO ESPINA YANEZ	Agriculture	0.00	5.70	5.70	0.65	2.46
6	PETROX SA Y OTROS	Other	0.00	5.00	5.00	0.57	2.16
7	EXPLORACIONES, INVERSIONES Y ASESORIAS MANANT	Mining	0.00	4.89	4.89	0.56	2.11
8	AGRICOLA CONQUIL LIMITADA	Agriculture	0.04	4.72	4.76	0.54	2.06
9	ASESORIAS E INVERSIONES SAFORA LIMITADA	Other	0.00	4.67	4.67	0.53	2.02
10	MANUEL EDUARDO MACHUCA CANALES	Agriculture	0.00	4.47	4.47	0.51	1.93
11	AUBERTO HUENCHULLANCA HERNANDEZ	Agriculture	4.34	0.00	4.34	0.49	1.88
12	IAN SZYDLOWSKI ALVAREZ	Agriculture	0.00	4.14	4.14	0.47	1.79
13	COLBUN SA	Other	1.09	2.70	3.79	0.43	1.64
14	RIJK ZWAAN CHILE LIMITADA	Other	3.53	0.00	3.53	0.40	1.52
15	COMPANIA DE INVERSIONES LA UNIVERSAL SA	Other	0.00	3.49	3.49	0.40	1.51
16	INVERSIONES AQUACHILE SPA	Other	0.00	3.15	3.15	0.36	1.36
17	MINERA ESCONDIDA LIMITADA	Mining	3.06	0.00	3.06	0.35	1.32
18	CELULOSA ARAUCO Y CONSTITUCION SA	Forestry	0.21	2.82	3.03	0.35	1.31
19	MOWI CHILE SA	Other	0.37	2.60	2.98	0.34	1.29
20	RODRIGO RAMIRO REYES ACHURRA	Agriculture	0.00	2.96	2.96	0.34	1.28
21	AGRICOLA SANTA ISABEL SPA	Agriculture	0.03	2.50	2.53	0.29	1.09
22	RAIMUNDO HUMBERTO VARAS GUTIERREZ	Agriculture	0.00	2.44	2.44	0.28	1.05
23	TERRAMATER SA	Agriculture	0.00	2.36	2.36	0.27	1.02
24	ANDRES ALBERTO ROSA KOELICHEN	Agriculture	0.00	2.28	2.28	0.26	0.99
25	AGRICOLA ROBLEDAL LIMITADA	Agriculture	0.00	2.20	2.20	0.25	0.95
26	FRUTICOLA Y EXPORTADORA ATACAMA LIMITADA	Agriculture	2.04	0.00	2.04	0.23	0.88
27	ASOC DE CANAL MAUCO	Other	0.00	2.00	2.00	0.23	0.86
28	FORESTAL PEHUEN LIMITADA	Forestry	0.00	2.00	2.00	0.23	0.86
29	OSCAR RUIZ-TAGLE DOMINGEZ	Agriculture	0.00	2.00	2.00	0.23	0.86
30	SOCIEDAD AGRICOLA Y COMERCIAL LOS LLEUQUES LI	Agriculture	0.00	1.96	1.96	0.22	0.85
31	COMPANIA DE SEGUROS DE VIDA CONSORCIO NACIONA	Other	0.88	1.08	1.95	0.22	0.84
32	CMPC PULP SPA	Forestry	0.00	1.83	1.83	0.21	0.79
33	SOCIEDAD AGRICOLA Y FORESTAL ESTERO TEATINOS	Forestry	0.00	1.81	1.81	0.21	0.78
34	NORTE ABIERTO SPA	Mining	1.75	0.05	1.80	0.21	0.78
35	AGRICOLA ARIZTIA LIMITADA	Agriculture	0.07	1.72	1.78	0.20	0.77
36	GONZALO DONATO QUEZADA PRESSAC	Agriculture	0.00	1.74	1.74	0.20	0.75
37	AGRORESERVAS DE CHILE SPA	Agriculture	1.74	0.00	1.74	0.20	0.75
38	SOCIEDAD AGRICOLA EL PORVENIR SA	Agriculture	1.72	0.00	1.72	0.20	0.74
39	PEDRO ANTONIO MIHOVILOVIC KUZMANIC	Agriculture	0.00	1.72	1.72	0.20	0.74
40	AGRICOLA SUPER LIMITADA	Agriculture	1.70	0.00	1.70	0.19	0.73
41	AGRICOLA E INVERSIONES HW SPA	Agriculture	0.00	1.67	1.67	0.19	0.72
42	ERNESTINA DEL CARMEN CURIQUEO PIUTRIN	Agriculture	0.00	1.67	1.67	0.19	0.72
43	NIBALDO RAUL FERNANDO ARAVENA PALMA Y OTROS	Agriculture	0.00	1.67	1.67	0.19	0.72
44	AGRICOLA SANTA CLOTILDE	Agriculture	0.00	1.66	1.66	0.19	0.72
45	BOSQUES SA	Forestry	0.00	1.65	1.65	0.19	0.71
46	JCE CHILE SA	Forestry	0.00	1.65	1.65	0.19	0.71
47	JORGE SCHMIDT Y CIA LIMITADA	Agriculture	1.63	0.00	1.63	0.19	0.70
48	CLAUDIO ANDRES MELGAREJO VILLARROEL	Agriculture	0.00	1.59	1.59	0.18	0.69
49	EXPORTADORA LOS FIORDOS LIMITADA	Agriculture	0.25	1.33	1.58	0.18	0.68
50	COMERCIALIZADORA AGRICOLA SAN JOSE LIMITADA	Agriculture	0.00	1.58	1.58	0.18	0.68
–	ALL WATER SERVICES (combined)	Water Services	78.62	21.66	100.28	11.43	43.32

Notes: GW and SW report cumulative groundwater and surface water allocations in m^3/s. Share (%) is each holder's allocation as a fraction of total productive allocation, excluding water utilities and municipalities. Population equivalent reports the number of people that could be supplied at 200 L/person/day. Names are truncated to 45 characters. The bottom row ("–") shows all water utilities and sanitation companies combined as a benchmark. Source: Dirección General de Aguas (DGA) water rights registry.

Figure A.12: SPEI-12 by Zone, 2005–2024



Notes: Annual mean SPEI-12 (Standardized Precipitation-Evapotranspiration Index, 12-month scale) aggregated to zone from municipality-level panel data. Teal bars indicate above-normal moisture; brown bars indicate below-normal moisture (drought). The LOESS curve (grey line) shows the low-frequency trend. The shaded band in the Center panel marks the mega-drought period (2010–2019), characterized by persistent precipitation deficits linked to a weakening of the South Pacific Anticyclone. SPEI < 0 in every year since 2010 in the South zone reflects a structural shift toward drier conditions across the entire study period.

B. Empirical Analysis

Figures

Tables

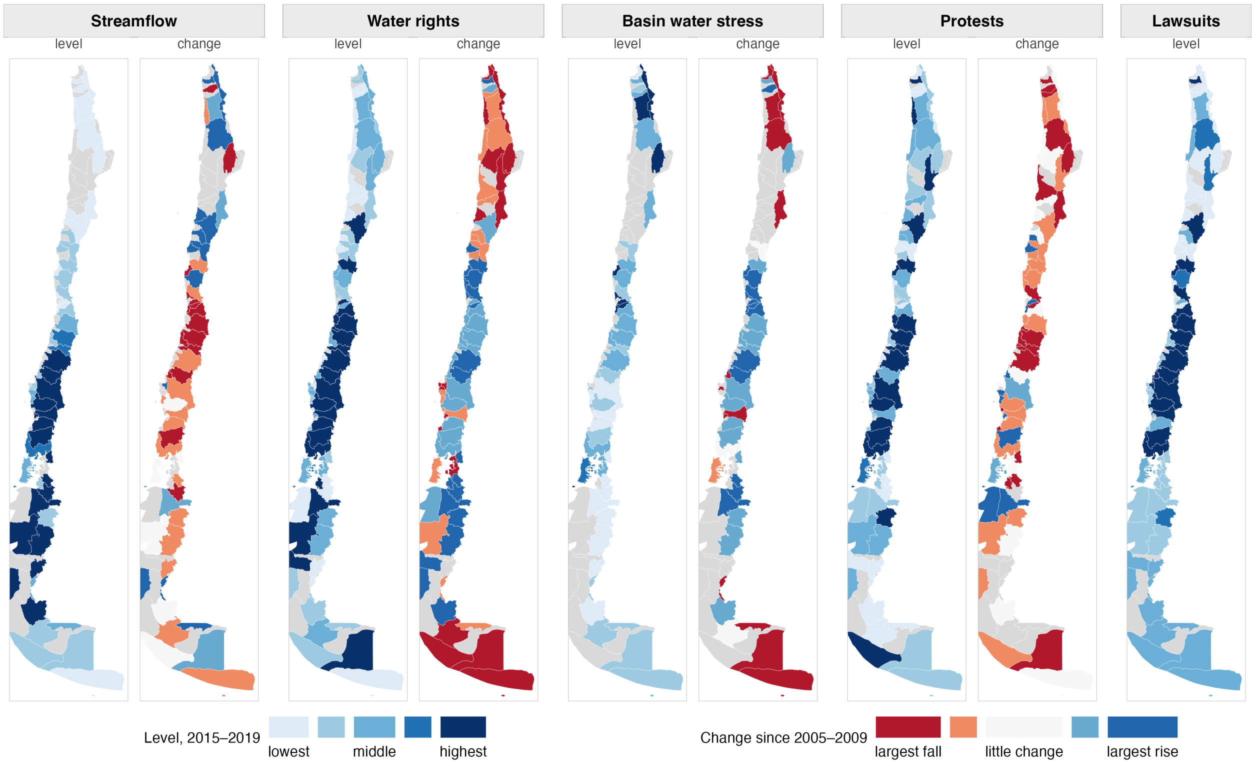
B.1 Data

Table B.1: Summary Statistics

Variable	N	Mean	SD	Min	Median	Max
Panel A: Cell-year (2005–2019)						
Annual streamflow (m^3/s)	4,755	62.10	142.87	0.00	11.10	1163.21
Summer streamflow (m^3/s)	4,363	54.85	153.78	0.00	6.51	1375.33
Upstream SW rights (L/s)	4,755	957.74	2305.13	0.00	74.31	25828.26
GW rights within 25 km (L/s)	4,755	1385.80	2623.65	0.00	233.53	23506.81
GW rights beyond 25 km (L/s)	4,755	8718.79	12267.61	0.00	3829.48	74942.46
Local SW rights (L/s)	4,755	51.29	206.43	0.00	0.00	2260.75
Local GW rights (L/s)	4,755	35.53	106.30	0.00	0.00	1767.61
Panel B: Municipality-year (340 municipalities)						
Any water theft lawsuit (=1)	1,340	0.42	0.49	0.00	0.00	1.00
Water theft lawsuits (count)	1,340	1.39	3.74	0.00	0.00	75.00
Any COES protest (=1)	6,800	0.51	0.50	0.00	1.00	1.00
COES protest events (count)	6,800	5.55	19.51	0.00	1.00	497.00
Marches	6,800	2.48	10.36	0.00	0.00	251.00
Strikes and blockades	6,800	2.25	7.20	0.00	0.00	126.00
Occupations	6,800	0.56	2.53	0.00	0.00	50.00
Property destruction	6,800	0.56	2.53	0.00	0.00	60.00
Environmental	6,800	0.20	1.07	0.00	0.00	27.00
Human rights	6,800	0.43	2.18	0.00	0.00	71.00
Firm-targeted	6,800	0.72	2.34	0.00	0.00	35.00
Government-targeted	6,800	3.10	12.74	0.00	0.00	376.00
Any Water Authority complaint (=1)	2,380	0.30	0.46	0.00	0.00	1.00
Water Authority complaints (count)	2,380	0.68	1.64	0.00	0.00	23.00
Upstream SW rights (L/s)	6,800	2633.72	5175.96	0.00	378.18	52948.50
GW rights within 25 km (L/s)	6,800	3833.32	7001.53	0.00	377.43	38242.09
GW rights beyond 25 km (L/s)	6,800	14684.30	17546.81	0.00	7134.09	90399.10
Local SW rights (L/s)	6,800	871.33	1631.23	0.00	176.31	13344.44
Local GW rights (L/s)	6,800	953.55	1538.29	0.00	316.29	18156.55
Basin over-appropriated (=1)	4,335	0.52	0.50	0.00	1.00	1.00
Scarcity declaration (=1)	6,800	0.25	0.43	0.00	0.00	1.00
SPEI-12 (drought index)	6,800	-0.53	0.76	-2.23	-0.63	2.21

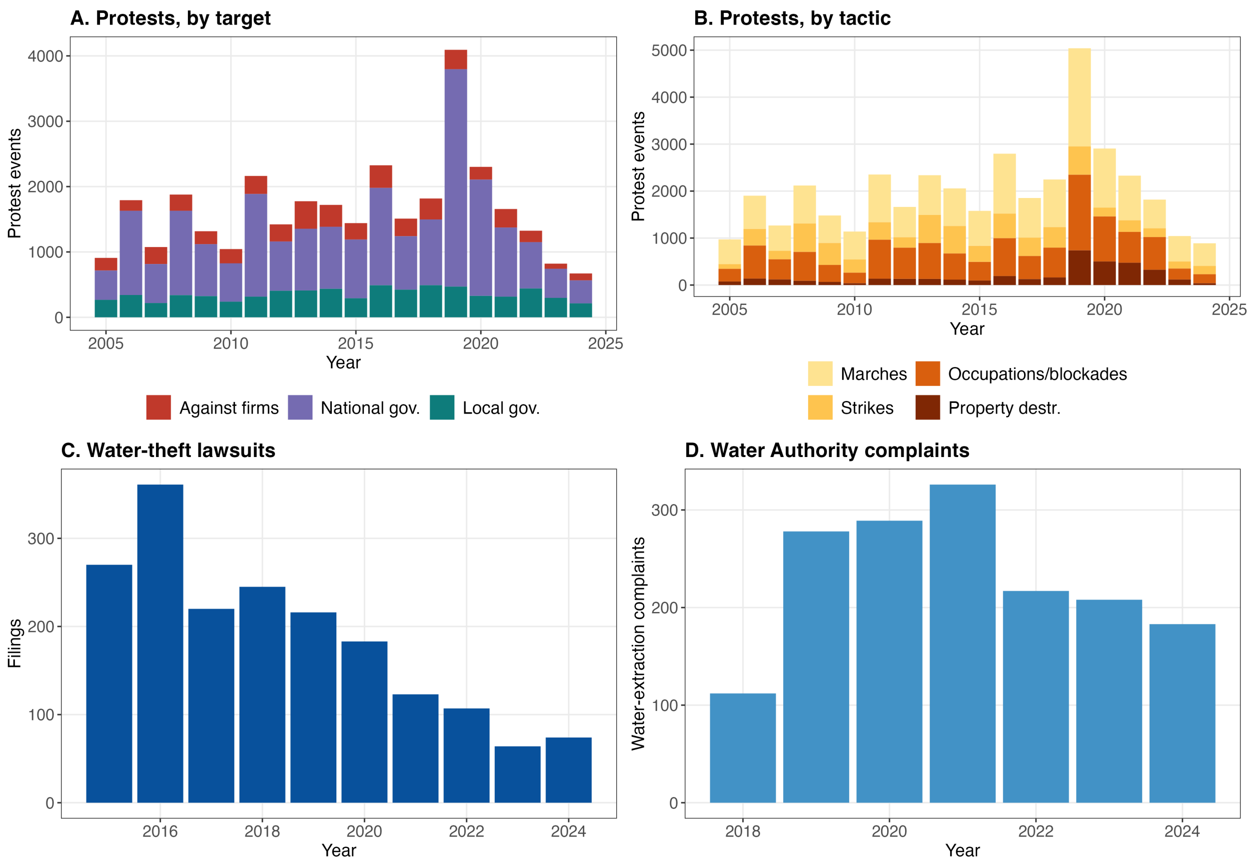
Notes: Panel A: cell-year panel (2005–2019), restricted to cells containing at least one CR2 streamflow gauge with reliable data. *Panel B*: municipality-year panel (340 municipalities) with HydroRIVERS river assignment. Lawsuit rows cover 2015–2024 and Water Authority complaint rows 2018–2024, each register beginning in that year; COES and treatment rows cover 2005–2024. The complaint rows count complaints of unauthorized extraction of water. The indented rows below the COES protest count are event counts by protest sub-type (tactical: marches, strikes and blockades, occupations, property destruction; issue: environmental, human rights; target: firm-targeted, government-targeted). Cumulative water rights are stocks of all active rights as of year t, in litres per second (L/s); SW = surface water, GW = groundwater (same-aquifer upstream only). Basin over-appropriated = 1 when cumulative basin rights exceed estimated baseline flow. SPEI-12 is the 12-month Standardized Precipitation Evapotranspiration Index; negative values indicate drought.

Figure B.1: The Key Sources of Variation, by River Basin



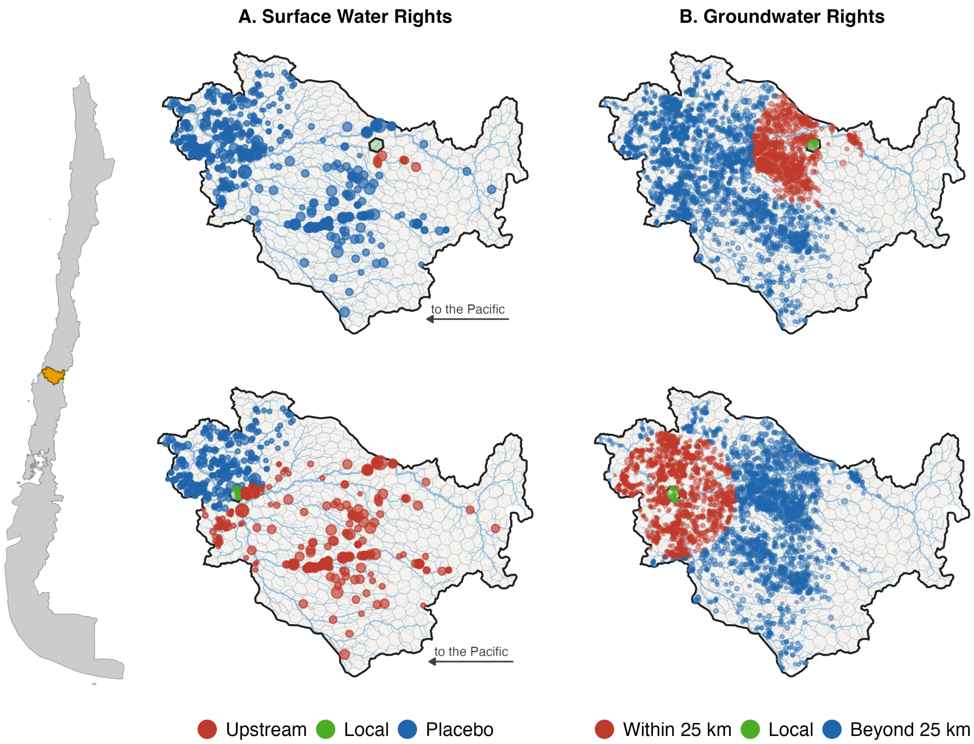
Notes: Each variable is shown as a pair of strips—level (left) and change (right)—for all river basins with data. Levels are averaged over 2015–2019; changes are relative to 2005–2009, in percent of the earlier level. Every strip is classified into its own quintiles, so color shows where a variable is high or rising relative to other basins. Basins in gray lack data for that variable. Streamflow is the municipality mean within the basin, rights are cumulative surface plus groundwater allocations, stress is the rights-to-flow ratio, capped at 100 times flow, and the conflict strips are event counts summed across the basin's municipalities. Lawsuits have no change strip, as filings data is available from 2015.

Figure B.2: The Conflict Outcomes over Time



Notes: Panel A: COES protest events by the target of the protest. The three target counts are independent flags in the register, so an event naming more than one target enters more than one series; 83.2% of firm-targeted events name firms alone. *Panel B*: the same events by tactic, on the COES family grouping, with occupations and blockades in one series and strikes in another. Tactic is a six-slot multi-response field, so one event can carry several tactics and the *Panel B* totals exceed *Panel A*'s. The 2019 peak in both protest panels is the national *estallido social*. *Panel C*: water-theft lawsuits filed each year. *Panel D*: complaints of unauthorized extraction of water filed with the Water Authority. Coverage: 2005–2024 for protest, 2015–2024 for lawsuits and 2018–2024 for complaints, each series beginning with its register. Sources: Centre for Social Conflict and Cohesion Studies (COES) (*Panels A* and *B*), Chilean Judicial Power penal-proceedings records (*Panel C*), and the Water Authority sanction register (*Panel D*).

Figure B.3: Relative Hydrological Distribution of Water Rights, at Cell Resolution



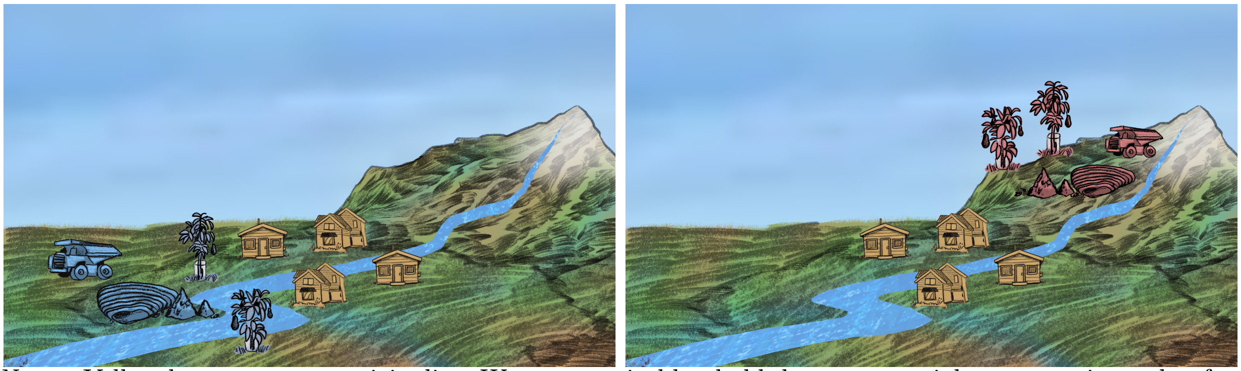
Notes: The construction in Figure 4, replicated at the unit the streamflow estimates use: H3 resolution-6 cells in place of municipalities. Panels, colors and classification rules are otherwise identical to Figure 4.

Table B.2: Baseline-Flow Imputation Coverage, by Region

Region	Gauge	Imputed	Total	% Imputed
North				
Antofagasta	3	6	9	67%
Arica y Parinacota	3	1	4	25%
Atacama	7	2	9	22%
Tarapacá	4	3	7	43%
Central				
Coquimbo	12	3	15	20%
Santiago	9	40	49	82%
Valparaíso	10	26	36	72%
Central South				
Biobío	17	16	33	48%
Maule	17	13	30	43%
O'Higgins	9	24	33	73%
Ñuble	11	10	21	48%
South				
Araucanía	25	7	32	22%
Los Lagos	16	14	30	47%
Los Ríos	10	2	12	17%
Austral				
Aysén	8	2	10	20%
Magallanes	10	0	10	0%
All Chile	171	169	340	50%

Notes: Source of each municipality's estimated baseline flow $\bar{Q}_i$ (equation (1)). "Gauge" is a recorded flow series; "Imputed" is the macrozone median, the fallback described in Section 3.3. Nationally 171 of 340 municipalities rely on a gauge and 169 on the median, with regional gauge coverage ranging from complete in Magallanes to 18% in the Santiago Metropolitan Region. The cell-level streamflow sample of Section 5.1 contains no imputed observations: a cell enters it only with a recorded flow series.

Figure B.4: Upstream versus Downstream Water Rights



Notes: Yellow houses are a municipality. Water users in blue hold downstream rights, extracting only after the municipality has taken its share; water users in red hold upstream rights, which draw on the basin's endowment before it reaches the municipality.

B.2 Water Allocation and Streamflow

Table B.3: Coefficient-to-Magnitude Crosswalk: Implied Response to a Rise in the Allocation-to-Flow Ratio

		Extra competing allocation			
Outcome	$\hat{\beta}$	+10 pp	+20 pp	+50 pp	+100 pp
Panel A — Water availability					
Streamflow (% change)	-0.813***	−7.3	−13.5	−27.6	−42.5
Matched units (m^3/s per m^3/s)		0.73	0.67	0.55	0.43
Panel B — Social conflict (% of the baseline mean)					
Water-theft lawsuits	0.463	+9.8	+18.7	+41.8	+71.7
Protests	0.425***	+4.9	+9.5	+22.3	+40.7

Notes: Each cell converts an estimated coefficient into the percentage change in the outcome implied by allocating the column's additional share of baseline flow to competing rights, evaluated at the median ratio $\bar{A}$ (the conversion defined in footnote 11). The streamflow rows share one median ratio, competing allocation being season-invariant. *Panel A* (water availability): percentage change in streamflow from $\hat{\beta}$ on log(flow); a 10% rise lowers annual flow by 0.62 m^3/s and summer flow by 0.48 m^3/s, against typical flows of 8.6 and 5.6 m^3/s. *Panel B* (social conflict): two points on the basin-stress sweep — the water-theft filing indicator at no stress restriction, as a percentage of the baseline filing rate, and the log protest count in over-appropriated basins ($\geq$ 100% of flow allocated), as a percentage of the mean count scaled by $(\bar{Y}+1)/\bar{Y}$. The filing row converts a coefficient that is not statistically distinguishable from zero. *Panel C* reports the annual and summer streamflow estimates in matched units: cubic meters per second of flow lost per cubic meter per second of competing rights granted. The +10 pp column reproduces the magnitudes quoted in the abstract and the introduction. Source estimates: Table B.4 for streamflow, Table B.10 for protest and Table B.11 for filings; fixed effects, standard errors and samples are those of the source tables. Stars: $^{*}\, p < 0.10$, $^{**}\, p < 0.05$, $^{***}\, p < 0.01$.

Table B.4: Competing Allocation and Streamflow Levels

	log(Streamflow)	
	Yearly	Summer
Panel A — Combined SW+GW Allocation		
$\tilde{A}^c$ competing	-0.813***	-0.977***
	(0.289)	(0.304)
$\tilde{A}^{\text{local}}$ local	1.097**	0.762
	(0.467)	(0.817)
$\tilde{A}^{nc}$ non-competing	-0.026	0.139
	(0.075)	(0.086)
Difference $(c - nc)$	-0.786***	-1.115***
	(0.296)	(0.302)
Panel B — Surface Water Rights Only		
$\tilde{A}^c_{\text{SW}}$ upstream	-0.909***	-1.097***
	(0.134)	(0.401)
$\tilde{A}^{\text{local}}_{\text{SW}}$ local	0.753	-0.357
	(0.490)	(0.962)
$\tilde{A}^{nc}_{\text{SW}}$ downstream	-0.235	0.025
	(0.142)	(0.105)
Difference $(c - nc)$	-0.675***	-1.122***
	(0.166)	(0.377)
Panel C — Groundwater Rights Only		
$\tilde{A}^c_{\text{GW}}$ near (<25 km)	-0.815*	-1.056**
	(0.440)	(0.486)
$\tilde{A}^{\text{local}}_{\text{GW}}$ local	1.445	1.408
	(1.118)	(1.254)
$\tilde{A}^{nc}_{\text{GW}}$ far (>25 km)	0.055	0.157**
	(0.077)	(0.065)
Difference $(c - nc)$	-0.870*	-1.213**
	(0.479)	(0.527)
Cell FE	✓	✓
Basin × Year FE	✓	✓
Controls	✓	✓
Mean dep. var.	2.147	1.718
Observations	4,755	4,595
Cells	371	368

Notes: OLS estimates of equation (2) with log(streamflow) as the outcome. *Panel A* uses the competing allocation index $\tilde{A}^c$ (equation 1). *Panels B and C* apply the same construction to one source at a time: surface water, where the competing pool is upstream rights and the non-competing pool is rights downstream or with no channel to the cell; and groundwater, where it is wells within 25 km against wells beyond that radius on the non-affecting side. Each panel includes its own local and non-competing terms. The final row of each is $\beta_c - \beta_{nc}$, with a standard error from the full variance–covariance matrix. Fixed effects: cell and basin × year; standard errors clustered at the river basin. Sample: 4,755 cell-years (yearly), 4,595 (summer), 2005–2019. Stars: $^{*}\,p < 0.10$, $^{**}\,p < 0.05$, $^{***}\,p < 0.01$.

Table B.5: Competing Allocation and Streamflow: Seasonal and Sector Decomposition

Panel A. Seasonal decomposition

	Impact on log(Streamflow)				
	Annual (ref.)	Summer (DJF)	Autumn (MAM)	Winter (JJA)	Spring (SON)
$\tilde{A}^c$ competing	-0.813***	-0.977***	-0.719	-0.526	-0.736
	(0.289)	(0.304)	(0.490)	(0.397)	(0.442)
Non-competing (placebo)	-0.026	0.139	-0.007	0.223	0.363***
	(0.075)	(0.086)	(0.106)	(0.144)	(0.135)
Difference ($c - nc$)	-0.786***	-1.115***	-0.712	-0.749**	-1.099**
	(0.296)	(0.302)	(0.504)	(0.366)	(0.559)
Cell FE	✓	✓	✓	✓	✓
Basin × Year FE	✓	✓	✓	✓	✓
Controls	✓	✓	✓	✓	✓
Mean dep. var.	2.150	1.720	1.660	2.290	2.230
Observations	4,755	4,595	4,402	4,316	4,239
Cells	371	368	369	367	370
Years	2005–2019	2005–2019	2005–2019	2005–2019	2005–2019

Panel B. By user sector

	All users	Agriculture	Mining	Industry	Forestry	Water Utilities
$\tilde{A}^c$ competing	-0.805***	-1.025***	-0.932	-1.291	0.779	-1.076
	(0.293)	(0.381)	(0.831)	(0.777)	(1.987)	(1.355)
Non-competing (placebo)	-0.033	-0.079	-0.194	-0.263*	-0.393	-0.556*
	(0.085)	(0.078)	(0.708)	(0.137)	(0.341)	(0.281)
Difference ($c - nc$)	-0.773**	-0.947**	-0.738	-1.028	1.173	-0.521
	(0.317)	(0.399)	(1.166)	(0.818)	(1.868)	(1.310)
Cell FE	✓	✓	✓	✓	✓	✓
Basin × Year FE	✓	✓	✓	✓	✓	✓
Controls	✓	✓	✓	✓	✓	✓
Observations	4,755	4,755	4,755	4,755	4,755	4,755

Notes: Panel A. Each column is a separate regression of log(seasonal flow) on $\tilde{A}^c + \tilde{A}^{\text{local}} + \tilde{A}^{nc}$. Seasons follow the Southern Hemisphere calendar: Summer (Dec–Feb), Autumn (Mar–May), Winter (Jun–Aug), Spring (Sep–Nov). The final row is $\beta_c - \beta_{nc}$ from the same regression, with a standard error from the full variance–covariance matrix. Fixed effects: cell and basin × year. Standard errors clustered at the river basin. Sample: cells with at least one streamflow gauge — 4,239 to 4,755 cell-years and 367 to 371 cells depending on the season, 2005–2019. Stars: $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. *Panel B.* Each row is a separate regression of log(yearly flow) on a sector-specific competing allocation variable log(sector $\text{rights}_{\text{up}}/\bar{Q} + 1$) (Competing) and its non-competing counterpart (Non-competing), with $\tilde{A}^{\text{local}}$ as control. Fixed effects: cell and basin × year. Standard errors clustered at the river basin. Sample: 4,755 cell-years and 371 cells, 2005–2019. Stars: $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

B.3 Water Allocation and Social Conflict

Table B.6: Competing Allocation and Social Conflict

	All protests		Protests against firms		Water theft lawsuits		Water Authority complaints	
	Any	Count	Any	Count	Any	Count	Any	Count
Panel A — Combined SW+GW Allocation								
$\tilde{A}^c$ competing	0.145**	0.215	0.195**	0.241*	0.438	-0.502	-0.180	-0.490
	(0.065)	(0.207)	(0.078)	(0.134)	(0.653)	(1.101)	(0.451)	(0.681)
$\tilde{A}^{nc}$ non-competing	-0.021	-0.135	-0.084	-0.135	-0.844**	-1.386*	-0.165	0.128
	(0.085)	(0.126)	(0.078)	(0.117)	(0.400)	(0.715)	(0.416)	(0.535)
$\tilde{A}^{\text{local}}$ local	0.033	0.027	-0.039	-0.059	-0.469**	-0.424	-0.532**	-0.440
	(0.098)	(0.122)	(0.047)	(0.064)	(0.195)	(0.282)	(0.244)	(0.332)
Difference $(c - nc)$	0.166	0.351	0.279***	0.377**	1.282	0.884	-0.015	-0.619
	(0.110)	(0.237)	(0.100)	(0.149)	(0.831)	(1.561)	(0.469)	(0.732)
Panel B — Surface Water Only								
$\tilde{A}^c$ competing	0.221***	0.292	0.253***	0.286**	0.202	-0.210	0.058	0.082
	(0.066)	(0.221)	(0.095)	(0.138)	(0.571)	(0.988)	(0.329)	(0.527)
$\tilde{A}^{nc}$ non-competing	0.109	-0.035	-0.087	-0.160	-1.384**	-2.222*	-0.340	0.054
	(0.122)	(0.160)	(0.095)	(0.163)	(0.580)	(1.173)	(0.586)	(0.719)
$\tilde{A}^{\text{local}}$ local	-0.224	-0.258	-0.276**	-0.421**	-0.106	-0.130	-0.672***	-0.402
	(0.150)	(0.201)	(0.133)	(0.165)	(0.287)	(0.393)	(0.241)	(0.378)
Difference $(c - nc)$	0.112	0.327	0.341***	0.446**	1.586*	2.012	0.398	0.028
	(0.125)	(0.249)	(0.114)	(0.185)	(0.928)	(1.931)	(0.413)	(0.490)
Panel C — Groundwater Only (within 25 km)								
$\tilde{A}^c$ competing	0.178	0.309**	0.192**	0.298**	0.232	-2.163	0.228	-0.686
	(0.107)	(0.144)	(0.081)	(0.125)	(0.652)	(1.523)	(0.392)	(0.434)
$\tilde{A}^{nc}$ non-competing	-0.101	-0.206*	-0.113	-0.158	-0.766**	-0.887	-0.066	0.322
	(0.089)	(0.106)	(0.081)	(0.118)	(0.341)	(0.553)	(0.436)	(0.528)
$\tilde{A}^{\text{local}}$ local	0.081	0.033	0.019	-0.002	-0.754***	-0.666**	-0.667*	-0.578
	(0.118)	(0.125)	(0.041)	(0.069)	(0.210)	(0.281)	(0.377)	(0.466)
Difference $(c - nc)$	0.279*	0.515***	0.305**	0.456**	0.998	-1.276	0.294	-1.009
	(0.149)	(0.179)	(0.150)	(0.208)	(0.842)	(1.708)	(0.574)	(0.625)
Municipality FE	✓	✓	✓	✓	✓	✓	✓	✓
Basin × Year FE	✓	✓	✓	✓	✓	✓	✓	✓
Controls	✓	✓	✓	✓	✓	✓	✓	✓
Mean dep. var.	0.511	0.849	0.226	0.269	0.419	0.504	0.300	0.312
Observations	6,800	6,800	6,800	6,800	1,340	1,340	2,380	2,380
Clusters	80	80	80	80	51	51	80	80

Notes: OLS estimates of equation (2) on the four conflict outcomes, with the allocation pools built from one water source at a time. *Panel A* uses the combined index $\tilde{A}^c$ reported throughout the paper. *Panel B* restricts every pool to surface water: the competing pool is rights upstream on the channel, the non-competing pool rights downstream or with no channel to the municipality. *Panel C* restricts them to groundwater: the competing pool is wells within 25 km, the non-competing pool wells beyond it on the non-affecting side. *Any* is an indicator that at least one event occurred, estimated as a linear probability model; *Count* is $\log(1+N)$. The difference row is $\beta_c - \beta_{nc}$, with a standard error from the full variance–covariance matrix. Water Authority complaints are restricted to complaints of unlawful water extraction. Fixed effects: municipality and basin × year. Standard errors in parentheses, clustered at the river basin. Sample: 6,800 municipality-years and 340 municipalities, 2005–2024 (protest); 1,340 and the 134 municipalities with a local court, 2015–2024 (lawsuits); 2,380 and 340 municipalities, 2018–2024 (complaints). Stars: $^{*}\,p < 0.10$, $^{**}\,p < 0.05$, $^{***}\,p < 0.01$.

Table B.7: Institutional Contention: Alternative Measures and Detectable Effects

Specification	$\hat{\beta}$ (s.e.)	Effect	95% CI	MDE (80%)	$\tilde{A}^{nc}$	Obs. (munic.)
Water-theft lawsuits						
Any filing (baseline)	0.438 (0.653)	9.8%	[-18.8, 38.3]	40.8%	-0.844**	1,340 (134)
Log count of filings	-0.502 (1.101)	-7.9%	[-37.9, 28.8]	57.6%	-1.386*	1,340 (134)
Any filing, court jurisdiction	0.056 (0.296)	0.9%	[-8.9, 10.8]	14.0%	-0.298*	3,270 (327)
Log count, court jurisdiction	-0.042 (0.512)	-0.5%	[-13.1, 13.2]	20.2%	-1.184***	3,270 (327)
Administrative complaints to the Water Authority						
Any water-extraction complaint (baseline)	-0.180 (0.451)	-5.6%	[-32.8, 21.7]	39.0%	-0.165	2,380 (340)
Log count of water-extraction complaints	-0.490 (0.681)	-11.0%	[-38.4, 20.1]	47.7%	0.128	2,380 (340)
Any water-extraction complaint, indexed upstream	-0.242 (0.256)	-4.0%	[-12.2, 4.2]	11.7%	0.355	2,380 (340)
Citizen share of the caseload	-0.081 (0.171)	-1.4%	[-7.2, 4.4]	8.3%	0.042	1,616 (314)
Any complaint, all offence types	0.768** (0.343)	13.4%	[1.7, 25.1]	16.7%	-1.351***	2,380 (340)
Any gravel-extraction complaint	0.539*** (0.169)	79.0%	[30.4, 127.7]	69.5%	-0.100	2,380 (340)
The same design and the same municipality-years, for protest						
Any protest, lawsuit sample	0.403 (0.360)	5.0%	[-3.8, 13.8]	12.5%	-0.216	1,340 (134)
Any protest, complaint sample	0.467** (0.204)	7.9%	[1.1, 14.7]	9.7%	-0.060	2,380 (340)
Any firm-targeted protest, complaint sample	0.733 (0.523)	29.0%	[-11.5, 69.5]	57.9%	0.094	2,380 (340)

Notes: OLS estimates of equation (2) on the institutional conflict outcomes. The first group reports water-theft lawsuits, the second administrative complaints to the Water Authority, and the third protest on the municipality-years of each institutional sample. *Any* is an indicator that at least one event occurred, estimated as a linear probability model; *Log count* is $\log(1 + N)$. *Court jurisdiction* assigns each filing to every municipality the issuing court serves; *indexed upstream* assigns each complaint to the municipalities downstream of the offence; the *citizen share* is complaints divided by complaints plus Water Authority inspections. *Effect* is the change in the outcome's own base rate implied by a 10 percentage point increase in the share of baseline flow held by competing rights, evaluated at the median of each estimating sample, and the 95% confidence interval is on that same scale. *MDE* is the smallest effect a two-sided 5% test detects with 80% probability, 2.80 standard errors, on that same scale. $\tilde{A}^{nc}$ is the coefficient on the non-competing pool. Standard errors in parentheses. Controls: $\tilde{A}^{nc}$, $\tilde{A}^{\text{local}}$. Fixed effects: municipality and basin × year. Standard errors clustered at the river basin. Every row is a different estimation sample, with observations and municipalities in the last column, over 2015–2024 for lawsuits and 2018–2024 for complaints. Stars: $^{*}\,p < 0.10$, $^{**}\,p < 0.05$, $^{***}\,p < 0.01$.

Table B.8: Competing Allocation Interacted with Basin Stress and Rights Concentration

	All protests		Protests by target		
	Any	All	Firms	National gov.	Local gov.
Panel A: % of flow appropriated, pre-period					
Water allocation	0.098*	0.154	0.243*	0.077	-0.002
	(0.052)	(0.219)	(0.145)	(0.184)	(0.125)
Allocation × % flow	0.028***	0.042***	0.022***	0.041***	-0.003
	(0.004)	(0.008)	(0.005)	(0.006)	(0.003)
Observations	5,960	5,960	5,960	5,960	5,960
Clusters	50	50	50	50	50
Panel B: Rights concentration (HHI)					
Water allocation	0.140**	0.228	0.263**	0.153	-0.010
	(0.063)	(0.185)	(0.116)	(0.150)	(0.107)
Allocation × HHI	-1.022	2.657	4.433*	1.173	0.316
	(1.721)	(3.007)	(2.478)	(2.174)	(0.849)
Observations	6,784	6,784	6,784	6,784	6,784
Clusters	80	80	80	80	80
Panel C: Dominant holder (> 50%)					
Water allocation	0.146**	0.216	0.238*	0.148	-0.013
	(0.066)	(0.207)	(0.132)	(0.159)	(0.110)
Allocation × dominant holder	-2.002	-1.096	4.207*	-1.464	2.268
	(2.232)	(2.134)	(2.143)	(1.604)	(1.471)
Observations	6,784	6,784	6,784	6,784	6,784
Clusters	80	80	80	80	80
Mean dep. var.	0.511	0.849	0.269	0.565	0.311
Municipality FE	✓	✓	✓	✓	✓
Basin × Year FE	✓	✓	✓	✓	✓
Controls	✓	✓	✓	✓	✓

Notes: Each column is a separate regression of a protest outcome on competing allocation interacted with a basin-level moderator. *Panel A* uses the share of basin flow appropriated, measured in 2004, before the protest window opens; *Panel B* the basin-level Herfindahl–Hirschman Index of water-rights concentration; *Panel C* an indicator for a single holder controlling more than half of the basin's rights. Each moderator is basin-level and absorbed by the basin × year fixed effects, so only the interaction appears. *Any* is an indicator for at least one protest in the municipality-year and *All* the log count; the last three columns split the protest count by the protesters' target. Controls: $\tilde{A}^{nc}$, $\tilde{A}^{\text{local}}$. Fixed effects: municipality and basin × year. Standard errors in parentheses, clustered at the river basin. Sample: municipality-years, 2005–2024 — the 298 municipalities whose basin stress is observed in *Panel A*, all 340 in *Panels B* and *C*; observations and clusters are reported in each panel. Stars: $^{*}\, p < 0.10$, $^{**}\, p < 0.05$, $^{***}\, p < 0.01$.

Table B.9: Sample Composition across Stress Thresholds

				% of dropped from				
Threshold	Municipalities	Municipality-years	Dropped	North	Central	Central South	South	Austral
≥ 0%	298	5,960						
≥ 10%	274	5,480	24	4%	0%	50%	12%	33%
≥ 20%	245	4,900	53	2%	0%	23%	58%	17%
≥ 30%	152	3,040	146	1%	2%	55%	36%	6%
≥ 40%	152	3,040	146	1%	2%	55%	36%	6%
≥ 50%	145	2,900	153	3%	4%	52%	34%	7%
≥ 60%	144	2,880	154	3%	5%	52%	34%	7%
≥ 75%	144	2,880	154	3%	5%	52%	34%	7%
≥ 100%	106	2,120	192	2%	4%	57%	31%	6%

Notes: Each row is one floor of the basin-stress sweep. *Municipalities* and *Municipality-years* are the sample that survives the floor; *Dropped* is the number of municipalities no longer in it, and the zone columns give their geographic composition, cumulative relative to the unrestricted sample. Sample: protest municipality-years with non-missing basin stress — 5,960 municipality-years and 298 municipalities at no restriction, 2005–2024.

Table B.10: Basin-Stress Sweep by Target of Protest

	All protests		Against firms		National gov.		Local gov.		
Basin stress	Competing	Non-comp.	Competing	Non-comp.	Competing	Non-comp.	Competing	Non-comp.	N
≥ 0%	0.248	-0.134	0.291**	-0.130	0.168	-0.105	-0.010	0.008	5,960
	(0.210)	(0.125)	(0.136)	(0.114)	(0.170)	(0.115)	(0.121)	(0.072)	
≥ 10%	0.193	-0.128	0.246	-0.135	0.093	-0.099	-0.040	0.013	5,480
	(0.237)	(0.128)	(0.153)	(0.116)	(0.187)	(0.115)	(0.130)	(0.074)	
≥ 20%	0.181	-0.110	0.250	-0.133	0.080	-0.101	-0.050	0.023	4,900
	(0.241)	(0.128)	(0.154)	(0.116)	(0.190)	(0.116)	(0.131)	(0.073)	
≥ 30%	0.520***	-0.154	0.477***	-0.103	0.285**	-0.170**	0.130	-0.010	3,040
	(0.175)	(0.098)	(0.136)	(0.101)	(0.128)	(0.077)	(0.103)	(0.097)	
≥ 40%	0.520***	-0.154	0.477***	-0.103	0.285**	-0.170**	0.130	-0.010	3,040
	(0.175)	(0.098)	(0.136)	(0.101)	(0.128)	(0.077)	(0.103)	(0.097)	
≥ 50%	0.529***	-0.187*	0.483***	-0.109	0.299**	-0.205***	0.124	0.005	2,900
	(0.172)	(0.100)	(0.137)	(0.105)	(0.123)	(0.065)	(0.102)	(0.097)	
≥ 60%	0.529***	-0.187*	0.483***	-0.109	0.299**	-0.205***	0.124	0.005	2,880
	(0.172)	(0.100)	(0.138)	(0.105)	(0.123)	(0.065)	(0.102)	(0.098)	
≥ 75%	0.529***	-0.187*	0.483***	-0.109	0.299**	-0.205***	0.124	0.005	2,880
	(0.172)	(0.100)	(0.138)	(0.105)	(0.123)	(0.065)	(0.102)	(0.098)	
≥ 100%	0.425***	-0.132	0.386***	-0.028	0.257**	-0.167**	0.056	0.071	2,120
	(0.111)	(0.114)	(0.096)	(0.093)	(0.115)	(0.075)	(0.042)	(0.089)	
Municipality FE	✓	✓	✓	✓	✓	✓	✓	✓	
Basin × Year FE	✓	✓	✓	✓	✓	✓	✓	✓	
Controls	✓	✓	✓	✓	✓	✓	✓	✓	

Notes: OLS estimates of equation (2): each pair of columns is one regression of the named log protest count on log competing and log non-competing allocation. *Competing* is the coefficient of interest; *Non-comp.* is the placebo, the coefficient on allocations that cannot reach the municipality. Each row restricts the sample to municipality-years at or above the stated basin stress, so every row is a different estimation sample; the four targets share that sample at each row and N is reported once. The three target counts are independent flags in the event register, so an event naming more than one target enters more than one count and the three do not sum to the first. Controls: $\tilde{A}^{\text{local}}$. Fixed effects: municipality and basin × year. Standard errors in parentheses, clustered at the river basin. Sample: protest municipality-years, 2005–2024 — 5,960 in 298 municipalities at no restriction, 2,120 in 106 municipalities in over-appropriated basins. Stars: $^{*}\,p < 0.10$, $^{**}\,p < 0.05$, $^{***}\,p < 0.01$.

Table B.11: Basin-Stress Sweep under Alternative Functional Forms

	Protests			
Basin stress	Linear prob.	Log count	Standardized	N
$\geq$ 0%	0.161***	0.248	0.110	5,960
	(0.060)	(0.210)	(0.093)	
$\geq$ 10%	0.188***	0.193	0.089	5,480
	(0.058)	(0.237)	(0.109)	
$\geq$ 20%	0.193***	0.181	0.086	4,900
	(0.061)	(0.241)	(0.115)	
$\geq$ 30%	0.282***	0.520***	0.274***	3,040
	(0.083)	(0.175)	(0.092)	
$\geq$ 40%	0.282***	0.520***	0.274***	3,040
	(0.083)	(0.175)	(0.092)	
$\geq$ 50%	0.280***	0.529***	0.295***	2,900
	(0.072)	(0.172)	(0.096)	
$\geq$ 60%	0.280***	0.529***	0.294***	2,880
	(0.072)	(0.172)	(0.096)	
$\geq$ 75%	0.280***	0.529***	0.294***	2,880
	(0.072)	(0.172)	(0.096)	
$\geq$ 100%	0.262***	0.425***	0.256***	2,120
	(0.075)	(0.111)	(0.067)	
Municipality FE	✓	✓	✓	
Basin × Year FE	✓	✓	✓	
Controls	✓	✓	✓	

Notes: OLS estimates of equation (2) on all protests under three transformations of the dependent variable, over the basin-stress sweep of Table B.10. *Linear prob.* is an indicator for any protest event in the municipality-year; *Log count* is $\log(1+N)$; *Standardized* divides both the outcome and the treatment by their own standard deviations. Each row restricts the sample to municipality-years at or above the stated share of basin flow appropriated, so every row is a different estimation sample and N is reported beside the coefficients it belongs to; the three forms use the same rows. Controls: $\tilde{A}^{nc}$, $\tilde{A}^{\text{local}}$. Fixed effects: municipality and basin × year. Standard errors in parentheses, clustered at the river basin. Sample: protest municipality-years, 2005–2024, $N = 5{,}960$ with no stress restriction. Stars: $^{*}\,p < 0.10$, $^{**}\,p < 0.05$, $^{***}\,p < 0.01$.

Table B.12: Competing Allocation and Protest Tactics by Basin Stress and Rights Concentration

	Protests			
	Peaceful	Disruptive		Violent
	Marches	Occupations	Blockades	Prop. destruction
Panel A: % of flow appropriated, pre-period				
Water allocation	0.178	0.026	-0.035	-0.228
	(0.176)	(0.118)	(0.160)	(0.193)
Allocation × % flow	0.010	0.003	0.039***	0.013**
	(0.007)	(0.005)	(0.005)	(0.005)
Observations	5,960	5,960	5,960	5,960
Clusters	50	50	50	50
Panel B: Rights concentration (HHI)				
Water allocation	0.239	0.026	0.037	-0.138
	(0.153)	(0.113)	(0.144)	(0.159)
Allocation × HHI	1.198	2.291	2.169	0.758
	(1.452)	(2.241)	(2.240)	(1.596)
Observations	6,784	6,784	6,784	6,784
Clusters	80	80	80	80
Panel C: Dominant holder (> 50%)				
Water allocation	0.232	0.013	0.029	-0.142
	(0.157)	(0.108)	(0.155)	(0.165)
Allocation × dominant holder	1.391	2.038**	-3.474**	-0.218
	(1.231)	(0.968)	(1.327)	(0.184)
Observations	6,784	6,784	6,784	6,784
Clusters	80	80	80	80
Mean dep. var.	0.448	0.189	0.373	0.188
Municipality FE	✓	✓	✓	✓
Basin × Year FE	✓	✓	✓	✓
Controls	✓	✓	✓	✓

Notes: Each column is a separate regression of the log count of protests with the named tactic on competing allocation interacted with a basin-level moderator. Tactical tiers follow the source coding: *peaceful* is marches and static rallies, *disruptive* is occupations and blockades, *violent* is arson and destruction of property. *Panel A* uses the share of basin flow appropriated; *Panel B* the basin-level Herfindahl–Hirschman Index (HHI) of water-rights concentration. Controls: $\tilde{A}^{nc}$, $\tilde{A}^{\text{local}}$. Fixed effects: municipality and basin × year. Standard errors in parentheses, clustered at the river basin. Sample: protest municipality-years, 2005–2024 — the 298 municipalities whose basin stress is observed in *Panel A*, all 340 in *Panel B*. Stars: $^{*}\,p < 0.10$, $^{**}\,p < 0.05$, $^{***}\,p < 0.01$.

Table B.13: Competing Allocation and Protest Topics by Basin Stress and Rights Concentration

	Protests				
	Rural	Environmental	Human rights	Health	Education
Panel A: % of flow appropriated, pre-period					
Water allocation	-0.045	-0.136	-0.064	0.071*	0.061
	(0.202)	(0.093)	(0.083)	(0.040)	(0.042)
Allocation × % flow	0.017***	0.008**	-0.001	-0.003*	-0.005**
	(0.006)	(0.003)	(0.002)	(0.002)	(0.002)
Observations	5,960	5,960	5,960	5,960	5,960
Clusters	50	50	50	50	50
Panel B: Rights concentration (HHI)					
Water allocation	-0.016	-0.124*	-0.030	0.071*	0.102
	(0.169)	(0.074)	(0.072)	(0.039)	(0.068)
Allocation × HHI	2.174*	2.507*	-0.092	-0.917	0.175
	(1.291)	(1.497)	(0.956)	(0.837)	(0.664)
Observations	6,784	6,784	6,784	6,784	6,784
Clusters	80	80	80	80	80
Panel C: Dominant holder (> 50%)					
Water allocation	-0.028	-0.136	-0.029	0.075	0.101
	(0.182)	(0.086)	(0.074)	(0.046)	(0.064)
Allocation × dominant holder	0.560	-0.276	0.384	0.295***	0.129
	(0.595)	(0.167)	(0.234)	(0.096)	(0.112)
Observations	6,784	6,784	6,784	6,784	6,784
Clusters	80	80	80	80	80
Mean dep. var.	0.248	0.092	0.155	0.041	0.115
Municipality FE	✓	✓	✓	✓	✓
Basin × Year FE	✓	✓	✓	✓	✓
Controls	✓	✓	✓	✓	✓

Notes: Each column is a separate regression of the log count of protests with the named topic on competing allocation interacted with a basin-level moderator. *Panel A* uses the share of basin flow appropriated; *Panel B* the basin-level Herfindahl–Hirschman Index (HHI) of water-rights concentration. Controls: $\tilde{A}^{nc}$, $\tilde{A}^{\text{local}}$. Fixed effects: municipality and basin × year. Standard errors in parentheses, clustered at the river basin. Sample: protest municipality-years, 2005–2024 — the 298 municipalities whose basin stress is observed in *Panel A*, all 340 in *Panel B*. Stars: $^{*}\,p < 0.10$, $^{**}\,p < 0.05$, $^{***}\,p < 0.01$.

Table B.14: Marginal Effect of Competing Allocation at Basin-HHI Percentiles, by Target

	All protests	Protests by target		
HHI percentile	All	Firms	National gov.	Local gov.
p10	0.242	0.285**	0.159	-0.008
	(0.178)	(0.114)	(0.147)	(0.105)
	[2.7%]	[6.4%]	[2.0%]	[-0.1%]
p25	0.252	0.303***	0.163	-0.007
	(0.174)	(0.113)	(0.146)	(0.104)
	[2.8%]	[6.8%]	[2.0%]	[-0.1%]
p50	0.281*	0.352***	0.176	-0.003
	(0.165)	(0.116)	(0.144)	(0.102)
	[3.1%]	[8.0%]	[2.2%]	[-0.1%]
p75	0.429**	0.597***	0.241	0.014
	(0.214)	(0.196)	(0.187)	(0.104)
	[4.8%]	[13.7%]	[3.0%]	[0.3%]
p90	1.030	1.600**	0.506	0.086
	(0.835)	(0.730)	(0.628)	(0.242)
	[11.9%]	[38.4%]	[6.4%]	[1.6%]
Municipality FE	✓	✓	✓	✓
Basin × Year FE	✓	✓	✓	✓
Controls	✓	✓	✓	✓
Observations	6,784	6,784	6,784	6,784
Clusters	80	80	80	80

Notes: Each percentile block reports the marginal effect of competing allocation at that value of the basin-level Herfindahl–Hirschman Index, its standard error in parentheses, and in brackets that effect as a percentage of the outcome's own base rate. One percentile grid serves every column, taken from the protest sample: 0.0056 (p10), 0.0092 (p25), 0.0189 (p50), 0.0738 (p75), 0.2855 (p90). Controls: $\tilde{A}^{nc}$, $\tilde{A}^{\text{local}}$. Fixed effects: municipality and basin × year. Standard errors clustered at the river basin. Sample: 6,784 protest municipality-years and 340 municipalities, 2005–2024. Stars: $^{*}\,p < 0.10$, $^{**}\,p < 0.05$, $^{***}\,p < 0.01$.

Table B.15: Human Extraction and Drought: Multivariate Regression of Standardized Components

	All protests		Protests by target		
	Any	All	Firms	National gov.	Local gov.
Panel A: All municipality-years					
Human extraction (z)	0.077**	0.098	0.084	0.078	-0.011
	(0.037)	(0.096)	(0.067)	(0.082)	(0.038)
Drought (z)	0.014	0.025	0.044	-0.024	0.055**
	(0.029)	(0.043)	(0.034)	(0.034)	(0.025)
Observations	6,800	6,800	6,800	6,800	6,800
Panel B: Basin stress at or above 30 percent					
Human extraction (z)	0.193***	0.283**	0.250***	0.158	0.036
	(0.049)	(0.125)	(0.073)	(0.114)	(0.040)
Drought (z)	0.027	0.058	0.083*	-0.007	0.030
	(0.042)	(0.057)	(0.042)	(0.049)	(0.033)
Observations	3,040	3,040	3,040	3,040	3,040
Municipality FE	✓	✓	✓	✓	✓
Basin × Year FE	✓	✓	✓	✓	✓
Controls	—	—	—	—	—

Notes: Each outcome is regressed jointly on the human-extraction component (competing allocation) and the climate component (drought, measured as −SPEI-12), each standardized to mean zero and unit variance within the estimation sample, so coefficients read in standard-deviation units. Outcomes: an indicator for any protest, estimated as a linear probability model, and four log protest counts — all protests and the three targets. *Panel A* is all municipality-years; *Panel B* restricts to municipality-years at or above the 30% basin-stress floor of Section 5.2.2. Fixed effects: municipality and basin × year. Standard errors in parentheses, clustered at the river basin. Sample: 6,800 protest municipality-years and 340 municipalities in 80 basins, 2005–2024 (*Panel A*); 3,040 municipality-years and 152 municipalities in 24 basins (*Panel B*). Stars: $^{*}\,p < 0.10$, $^{**}\,p < 0.05$, $^{***}\,p < 0.01$.

Table B.16: Human Extraction versus Drought: Trend-Robust Decomposition

	All protests		Protests by target		
	Any	All	Firms	National gov.	Local gov.
Panel A: Levels					
Human extraction (z)	0.074**	0.111	0.101	0.079	0.017
	(0.031)	(0.095)	(0.070)	(0.088)	(0.042)
Drought (z)	0.008	0.003	0.001	0.009	-0.017**
	(0.008)	(0.022)	(0.017)	(0.017)	(0.007)
Observations	6,800	6,800	6,800	6,800	6,800
Panel B: First differences (within commune)					
Δ Human extraction (z)	0.030	0.180	0.329	0.021	-0.078
	(0.057)	(0.123)	(0.268)	(0.117)	(0.051)
Δ Drought (z)	0.018*	0.020	0.028**	-0.008	-0.009
	(0.009)	(0.018)	(0.013)	(0.021)	(0.010)
Observations	6,460	6,460	6,460	6,460	6,460
Panel C: Levels + non-competing/local controls					
Human extraction (z)	0.056*	0.075	0.099	0.035	0.009
	(0.029)	(0.096)	(0.063)	(0.087)	(0.053)
Drought (z)	0.008	0.003	0.001	0.009	-0.017**
	(0.008)	(0.022)	(0.017)	(0.017)	(0.007)
Observations	6,800	6,800	6,800	6,800	6,800
Municipality FE	✓	✓	✓	✓	✓
Basin × Year FE	✓	✓	✓	✓	✓

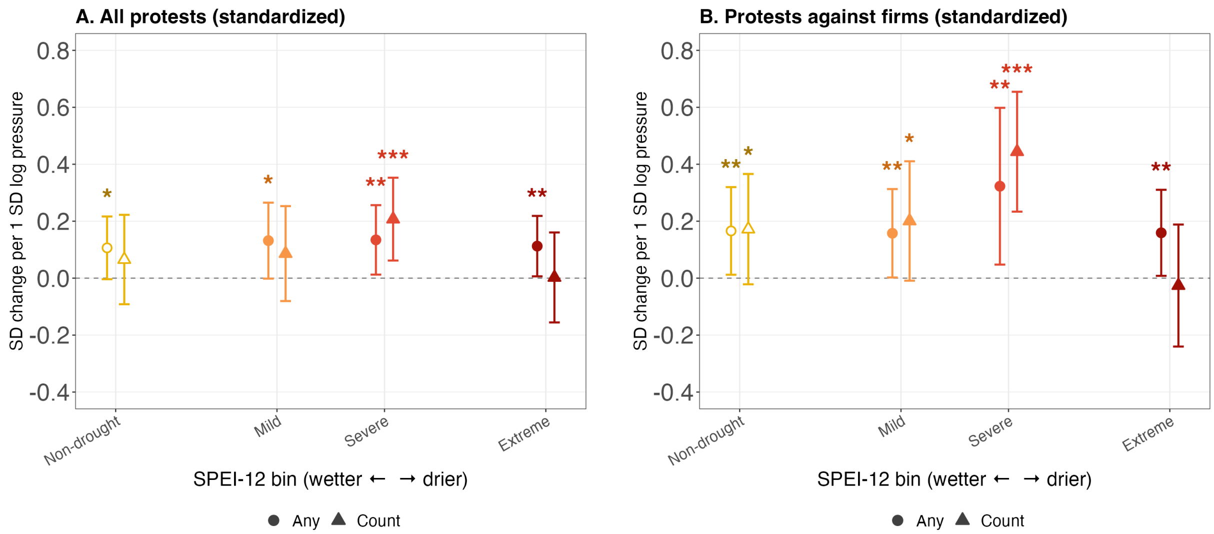
Notes: Each outcome is regressed jointly on the standardized human-extraction component (competing allocation) and the standardized drought component (−SPEI-12). *Panel A* is in levels. *Panel B* is in first differences within municipality, which removes any common time trend shared by extraction and drought and isolates their year-to-year timing. *Panel C* adds the non-competing and local allocation terms in levels. Fixed effects: municipality and basin linear trends (*Panels A* and *C*), year (*Panel B*). Standard errors in parentheses, clustered at the river basin. Sample: 6,800 protest municipality-years and 340 municipalities, 2005–2024; 6,460 in first differences, the first observed year dropping for each municipality. Stars: $^{*}\,p < 0.10$, $^{**}\,p < 0.05$, $^{***}\,p < 0.01$.

Table B.17: Basin-Stress Sweep by Target of Protest, excluding 2019

	All protests		Against firms		National gov.		Local gov.		
Basin stress	Competing	Non-comp.	Competing	Non-comp.	Competing	Non-comp.	Competing	Non-comp.	N
≥ 0%	0.191	-0.094	0.301**	-0.130	0.116	-0.084	-0.028	0.017	5,662
	(0.214)	(0.128)	(0.140)	(0.116)	(0.170)	(0.125)	(0.120)	(0.071)	
≥ 10%	0.147	-0.089	0.253	-0.133	0.056	-0.080	-0.044	0.019	5,206
	(0.243)	(0.130)	(0.156)	(0.118)	(0.188)	(0.124)	(0.130)	(0.072)	
≥ 20%	0.128	-0.073	0.259	-0.131	0.036	-0.084	-0.056	0.030	4,655
	(0.247)	(0.130)	(0.157)	(0.118)	(0.191)	(0.125)	(0.131)	(0.072)	
≥ 30%	0.479**	-0.143	0.481***	-0.108	0.261**	-0.162	0.127	-0.014	2,888
	(0.178)	(0.104)	(0.141)	(0.106)	(0.125)	(0.104)	(0.107)	(0.096)	
≥ 40%	0.479**	-0.143	0.481***	-0.108	0.261**	-0.162	0.127	-0.014	2,888
	(0.178)	(0.104)	(0.141)	(0.106)	(0.125)	(0.104)	(0.107)	(0.096)	
≥ 50%	0.488**	-0.187*	0.486***	-0.110	0.276**	-0.209**	0.120	-0.002	2,755
	(0.175)	(0.099)	(0.144)	(0.109)	(0.121)	(0.088)	(0.106)	(0.097)	
≥ 60%	0.488**	-0.187*	0.486***	-0.110	0.276**	-0.209**	0.120	-0.002	2,736
	(0.175)	(0.099)	(0.144)	(0.109)	(0.121)	(0.088)	(0.106)	(0.097)	
≥ 75%	0.488**	-0.187*	0.486***	-0.110	0.276**	-0.209**	0.120	-0.002	2,736
	(0.175)	(0.099)	(0.144)	(0.109)	(0.121)	(0.088)	(0.106)	(0.097)	
≥ 100%	0.371***	-0.111	0.386***	-0.030	0.211**	-0.145	0.053	0.064	2,014
	(0.098)	(0.098)	(0.107)	(0.106)	(0.096)	(0.091)	(0.052)	(0.090)	
Municipality FE	✓	✓	✓	✓	✓	✓	✓	✓	
Basin × Year FE	✓	✓	✓	✓	✓	✓	✓	✓	
Controls	✓	✓	✓	✓	✓	✓	✓	✓	

Notes: Table B.10 re-estimated with 2019 dropped; October 2019 was a nationwide protest wave, accounting for 13.1% of the protest events in this panel. Every row is a different estimation sample and N is reported once for the four targets. Controls: $\tilde{A}^{\text{local}}$. Fixed effects: municipality and basin × year. Standard errors in parentheses, clustered at the river basin. Sample: protest municipality-years excluding 2019, 2005–2024 — 5,662 at no restriction, 298 fewer than the parent table. Stars: $^{*}\,p < 0.10$, $^{**}\,p < 0.05$, $^{***}\,p < 0.01$.

Figure B.5: SPEI Interaction with Standardized Outcomes



Notes: The competing-allocation treatment interacted with SPEI-12 bins, with each dependent variable and the treatment divided by their own standard deviations within the estimation sample, so every point is a standard-deviation change per one standard deviation of log competing allocation. *Panel A* is all protests and *Panel B* protest against firms. Circles denote the indicator for any event; triangles denote the log count. The bins are mutually exclusive: Mild ($-1.5 < \text{SPEI} \leq -1$), Severe ($-2 < \text{SPEI} \leq -1.5$) and Extreme ($\text{SPEI} \leq -2$), against non-drought ($\text{SPEI} > -1$) as the reference, plotted hollow. The Extreme bin rests on ten municipality-years, eight of them in Austral basins; it is plotted and not interpreted. Controls: $\tilde{A}^{nc}$, $\tilde{A}^{\text{local}}$. Fixed effects: municipality and basin $\times$ year. Standard errors clustered at the river basin; bars show 95% confidence intervals. Sample: 6,800 protest municipality-years and 340 municipalities, 2005–2024. Stars: $^{*}\,p < 0.10$, $^{**}\,p < 0.05$, $^{***}\,p < 0.01$.

B.4 Robustness

Table B.18: Sensitivity to the Distance Weighting of Competing Allocation

	log(Streamflow)	
	Yearly	Summer
$\tilde{A}^c$ competing, unweighted	-0.340**	-0.241
	(0.165)	(0.157)
$\tilde{A}$ local	0.853*	0.324
	(0.456)	(0.732)
Non-competing (placebo)	-0.004	0.140
	(0.087)	(0.084)
Cell FE	✓	✓
Basin × Year FE	✓	✓
Controls	✓	✓
Mean dep. var.	2.147	1.718
Observations	4,755	4,595
Cells	371	368

Notes: The streamflow specification of Table B.4 *Panel C*, re-estimated with the distance weights removed: upstream rights enter as a plain sum, not weighted by upstream catchment-area share, and are normalized by estimated baseline flow as in the weighted index. Fixed effects: cell and basin × year. Standard errors in parentheses, clustered at the river basin. Sample: 4,755 cell-years and 371 cells (yearly), 4,595 and 368 (summer), 2005–2019. Stars: $^{*}\,p < 0.10$, $^{**}\,p < 0.05$, $^{***}\,p < 0.01$.

Table B.19: Baseline Flow Measured before the Estimation Window

	log(Streamflow)	
	Yearly	Summer
Panel A — Baseline flow from the estimation window		
$\tilde{A}^c$ competing	-0.813***	-0.977***
	(0.289)	(0.304)
$\tilde{A}^{\text{local}}$ local	1.097**	0.762
	(0.467)	(0.817)
$\tilde{A}^{nc}$ non-competing	-0.026	0.139
	(0.075)	(0.086)
Panel B — Baseline flow from the pre-2005 period only		
$\tilde{A}^c$ competing	-1.082**	-1.316***
	(0.473)	(0.412)
$\tilde{A}^{\text{local}}$ local	0.673	0.713
	(0.501)	(0.950)
$\tilde{A}^{nc}$ non-competing	0.030	0.156*
	(0.088)	(0.086)
Cell FE	✓	✓
Basin × Year FE	✓	✓
Controls	✓	✓
Mean dep. var.	2.147	1.718
Observations	4,755	4,595
Cells	371	368

Notes: The streamflow specification re-estimated under two measurements of the baseline flow F_i that normalizes cumulative rights, the within-cell mean of gauged annual streamflow. *Panel A* computes that mean over the estimation window itself, so years after allocation had begun enter the denominator. *Panel B* computes it over 1980–2004 only, before the estimation window opens; 319 of 378 gauged cells (84%) have pre-period flow, with a median of 20 years, and the remainder fall back to the macrozone median as in the main specification. Fixed effects: cell and basin × year. Standard errors in parentheses, clustered at the river basin. Sample: 4,755 cell-years and 371 cells (yearly), 4,595 and 368 (summer), 2005–2019. Stars: $^{*}\,p < 0.10$, $^{**}\,p < 0.05$, $^{***}\,p < 0.01$.

Table B.20: Reverse Causality: Lagged Protest and Subsequent Allocation Growth

	Δ Competing alloc.	Δ Non-competing alloc.
Panel A: All protests		
Lagged log protest count	-0.000 (0.001)	-0.001 (0.001)
Lagged any-protest indicator	-0.001 (0.001)	0.000 (0.001)
Panel B: Firm-targeted protests		
Lagged log protest count	-0.002* (0.001)	0.001 (0.001)
Lagged any-protest indicator	0.001* (0.001)	-0.001 (0.001)
Municipality FE	✓	✓
Basin × Year FE	✓	✓
Controls	—	—
Observations	6,460	6,460
Clusters	80	80

Notes: OLS regression of the annual change in log water allocation on lagged protest — the log COES count and an any-protest indicator. *Panel A* uses all protests and *Panel B* protests against firms, each panel a separate regression. The competing column uses distance-weighted competing allocation; the non-competing column is the placebo. Fixed effects: municipality and basin × year. Standard errors in parentheses, clustered at the river basin. Sample: 6,460 municipality-years and 340 municipalities, 2006–2024, the first year dropping to the lag. Stars: $^{*}\,p < 0.10$, $^{**}\,p < 0.05$, $^{***}\,p < 0.01$.

Table B.21: Alternative Inference for the Conflict Estimates

Outcome	Water allocation	Cluster SE	Wild-cluster p	Conley SE	N	Clusters
Panel A: All municipality-years						
Protests, any	0.145**	(0.065)	0.118	(0.083)	6,800	80
Protests, all	0.215	(0.207)	0.325	(0.156)	6,800	80
Protests, against firms	0.241*	(0.134)	0.173	(0.113)	6,800	80
Panel B: Basin stress at or above 30 percent						
Protests, any	0.282***	(0.083)	0.108	(0.096)	3,040	24
Protests, all	0.520***	(0.175)	0.108	(0.172)	3,040	24
Protests, against firms	0.477***	(0.136)	0.065	(0.133)	3,040	24

Notes: The competing-allocation coefficient $\beta_{\tilde{A}^c}$ for each headline outcome under the preferred specification, with alternative inference. Controls: $\tilde{A}^{nc}$, $\tilde{A}^{\text{local}}$. Fixed effects: municipality and basin × year. *Panel A* imposes no restriction; *Panel B* estimates the same rows at a basin-stress floor of 30%, the floor at which the sweep reports them. "Cluster SE" is the river-basin clustered standard error, and the stars on β use it. "Wild-cluster p" is from a wild cluster bootstrap with the null imposed and Rademacher weights drawn over river basins (999 replications). "Conley SE" is a spatial heteroskedasticity- and autocorrelation-consistent standard error with a Bartlett kernel of 100 km in great-circle distance and a 5-year temporal Bartlett kernel. Point estimates are identical across columns; only the standard errors and the p-value differ. A CR2 small-sample correction is not reported: the municipality fixed effects are nested within the basin clusters, which collapses its Satterthwaite degrees of freedom. Sample: 6,800 protest municipality-years in 340 municipalities and 80 basins, 2005–2024 (*Panel A*); 3,040 in 152 municipalities and 24 basins (*Panel B*); N and clusters are reported for each row. Stars: $^{*}\,p < 0.10$, $^{**}\,p < 0.05$, $^{***}\,p < 0.01$.

Table B.22: Formal Threshold Test for the Stress–Conflict Relationship

Outcome	Water allocation (pooled)	$\hat{\gamma}$	95% CI	sup-W p	N	Clusters
Protests, all	0.248 (0.210)	90%	[10%, 100%]	0.527	5,960	50
Protests, against firms	0.291** (0.136)	90%	[30%, 100%]	0.553	5,960	50
Protests, national gov.	0.168 (0.170)	20%	[10%, 100%]	0.350	5,960	50
Protests, local gov.	-0.010 (0.121)	20%	[10%, 100%]	0.407	5,960	50

Notes: Sample-splitting threshold regression (Hansen, 2000) of each conflict outcome on log $\tilde{A}^c$, allowing the slope to differ above and below an unknown basin-stress threshold $\hat{\gamma}$. "Pooled $\beta_{\tilde{A}^c}$" is the single-slope coefficient; $\hat{\gamma}$ minimizes the residual sum of squares; the 95% confidence interval inverts the likelihood-ratio profile; the sup-W p-value tests the absence of any threshold (wild cluster bootstrap over river basins, 299 replications). Controls: $\tilde{A}^{nc}$, $\tilde{A}^{\text{local}}$. Fixed effects: municipality and basin × year. Standard errors clustered at the river basin. Sample: protest municipality-years 2005–2024 and lawsuit municipality-years 2015–2024, with N and clusters reported for each outcome. Stars: $^{*}\,p < 0.10$, $^{**}\,p < 0.05$, $^{***}\,p < 0.01$.

Table B.23: The Protest Estimates on Restricted Samples

	Full panel	Excl. North	Excl. Central	Excl. Central South	Excl. South	Excl. Austral	Excl. coastal
Panel A — All protests, indicator							
$\tilde{A}^c$ competing	0.145**	0.180***	-0.060	0.128	0.117	0.167**	0.108
	(0.065)	(0.059)	(0.128)	(0.087)	(0.093)	(0.067)	(0.069)
$\tilde{A}^{nc}$ non-competing	-0.021	-0.021	-0.107	-0.041	0.085	-0.022	-0.011
	(0.085)	(0.083)	(0.172)	(0.077)	(0.062)	(0.084)	(0.086)
Difference ($c - nc$)	0.166	0.201*	0.047	0.169	0.032	0.189*	0.118
	(0.110)	(0.105)	(0.153)	(0.137)	(0.134)	(0.112)	(0.113)
Panel B — All protests, log count							
$\tilde{A}^c$ competing	0.215	0.277	-0.165	0.156	0.329*	0.166	0.150
	(0.207)	(0.203)	(0.513)	(0.186)	(0.183)	(0.231)	(0.221)
$\tilde{A}^{nc}$ non-competing	-0.135	-0.132	-0.243	-0.283*	-0.061	-0.126	-0.124
	(0.126)	(0.124)	(0.254)	(0.154)	(0.105)	(0.128)	(0.129)
Difference ($c - nc$)	0.351	0.409*	0.078	0.438*	0.390*	0.291	0.274
	(0.237)	(0.233)	(0.526)	(0.229)	(0.232)	(0.264)	(0.250)
Panel C — Protests against firms, log count							
$\tilde{A}^c$ competing	0.241*	0.251*	0.155	0.159	0.326***	0.205	0.229
	(0.134)	(0.133)	(0.350)	(0.140)	(0.113)	(0.150)	(0.143)
$\tilde{A}^{nc}$ non-competing	-0.135	-0.133	-0.247	-0.277*	-0.018	-0.132	-0.135
	(0.117)	(0.116)	(0.216)	(0.150)	(0.076)	(0.117)	(0.117)
Difference ($c - nc$)	0.377**	0.383**	0.403	0.437**	0.344**	0.337**	0.364**
	(0.149)	(0.149)	(0.348)	(0.170)	(0.166)	(0.160)	(0.157)
Municipality FE	✓	✓	✓	✓	✓	✓	✓
Basin × Year FE	✓	✓	✓	✓	✓	✓	✓
Controls	✓	✓	✓	✓	✓	✓	✓
Mean dep. var.	0.511	0.491	0.498	0.591	0.476	0.512	0.503
Observations	6,800	6,220	4,800	4,460	5,320	6,400	5,580
Clusters	80	58	67	66	66	66	47
Treatment variance surviving FE	1.0%	1.2%	2.2%	0.8%	1.0%	0.9%	1.0%

Notes: OLS estimates of equation (2) re-estimated on restricted samples, with the specification held fixed throughout. Each column is one sample: the full panel; the panel with one macrozone dropped, one column per macrozone; and the panel excluding coastal basins. *Panel A* is an indicator for any protest in the municipality-year, estimated as a linear probability model; *Panel B* is the log protest count and *Panel C* the log count of protest against firms. The three outcomes are observed on the same rows, so observations and clusters are common to the panels, and *Mean dep. var.* is the *Panel A* indicator. The difference row is $\beta_c - \beta_{nc}$, with a standard error from the full variance–covariance matrix. *Treatment variance surviving FE* is the share of the competing-allocation variance left after the fixed effects. Controls: $\tilde{A}^{nc}$, $\tilde{A}^{\text{local}}$. Fixed effects: municipality and basin × year. Standard errors in parentheses, clustered at the river basin. Sample: protest municipality-years, 2005–2024, from 6,800 in 80 basins on the full panel to 4,460 in 66 basins with Central South dropped. Stars: $^{*}\, p < 0.10$, $^{**}\, p < 0.05$, $^{***}\, p < 0.01$.

C. Field Evidence on Mechanisms

To probe whether the mechanisms behind the conflict results are visible on the ground, I draw on thirteen semi-structured interviews conducted in May 2025 across the two settings that anchor the empirical analysis: the mining-and-avocado valleys of north-central Chile (the Choapa, Aconcagua, and La Ligua basins) and the forestry frontier of the south.[15]

Concentration and the target of conflict (H2). The clearest field analogue of the inequality result is a contrast between valleys with and without a dominant water user. The technical advisor to one small-river surveillance board described his valley's cooperative management in terms of the *absence* of a large holder:

> *"No tenemos un socio que sea la sanitaria, no tenemos un socio que sea la minera, no tenemos un socio que sean grandes agrícolas que estén dirigiendo y tomando decisiones sobre la distribución del agua. [...] El 99% son pequeños productores agrícolas [...] eso nos permite administrar y distribuir el agua amigablemente."*
>
> ["We don't have a partner that is the water utility, a mining company, or large agribusiness directing and making decisions over how the water is distributed. [...] Ninety-nine percent are smallholders [...] and that lets us manage and distribute the water amicably."]

In the adjacent valley, where a large mine operates, the same informant described environmental groups organizing because they held no water rights and therefore had to seek other channels: *"se han organizado [...] para luchar [...] pero no tienen los derechos de agua, entonces [...] tienes que buscar otras alternativas"* ("have organized [...] to fight [...] but they hold no water rights, so [...] you have to look for other channels"). The account points to formal exclusion as one condition that can lead affected users to seek public alternatives.

[15] Interviewees included long-time residents, leaders of water-user organizations (*juntas de vigilancia*, canal associations, and rural drinking-water committees), municipal officials, and firm representatives. Interviews were conducted under IRB protocol 25-0411 and audio-recorded with consent. Quotes are lightly edited for readability (filler removed; [...] marks omissions) and translated by the author; participants are identified by role rather than name. The evidence is illustrative of mechanism, not a source of identification.

The cost of contention (H1). Interviewees also described how economic dependence on a powerful firm can raise the cost of public challenge. A resident and former activist explained the mechanism plainly:

> *"Yo reclamo mucho contra la minera, entonces vienen ellos y contratan a uno de mis hijos con un buen cargo, entonces yo dejo de reclamar por lealtad a mi hijo. Y eso ellos lo usan mucho, sobre todo con los agricultores que están [. . .] más cerca de ellos."*
>
> ["I complain a lot against the mine, so they come and hire one of my children in a good post, and then I stop complaining out of loyalty to my child. They use that a lot, above all with the farmers closest to them."]

A rural-school director described the same logic on the contracting side: the small contractors who service the mine *"y participan en los paros, no los vuelven a contratar"* ("and who take part in the strikes don't get hired again"). Both accounts suggest that the cost of acting can rise with proximity to a concentrated holder.

Institutional disputes and the lawsuit margin. The water-theft lawsuits that constitute the institutional outcome have a concrete referent in how scarcity plays out between neighbors on the same canal. The same director recalled neighbors who would steal an irrigation turn—*"había gente que nos robaba el turno [. . .] esas personas ponían tacos [. . .] para regar ellos"* ("there were people who stole our irrigation turn [. . .] they put in blockages [. . .] to water their own")—and identified the users *"que están aguas arriba que le roban [. . .] su turno"* ("upstream, who steal your turn") as the source of conflict. This is the everyday form of the *usurpación de aguas* that the lawsuit data capture.

Access to formal water governance. Interviewees also described barriers to participating in formal water governance. The technical advisor explained that regularizing a right can require technical studies, legal filings, and fees that users must finance themselves. He also noted that voting in water-user organizations is tied to rights holdings: *"el que tiene 20 acciones tiene 20 votos"* ("the one who has twenty shares has twenty votes"). These accounts indicate how differences in resources and rights holdings can shape access to formal venues and influence within them.

Attribution: scarcity with a culprit versus scarcity without one (H3). Finally, the fieldwork illustrates the exploratory attribution channel. Where residents trace scarcity to a human agent, the response is grievance and engagement; where they read it as weather, it is resignation. A La Ligua resident framed it as injustice—contrasting a smallholder whose well inspectors shut down over a minor excess with the upstream avocado estates that extract far more—and concluded that *"la gente ahora ya se entregó porque el poder es difícil"* ("people have given up now, because [fighting] that power is hard"). Two service workers in the same region, by contrast, located the cause entirely in nature—*"yo creo que es algo natural [. . .] porque no ha llovido"* and *"es un problema de la naturaleza [. . .] de la falta de lluvia"* ("I think it's something natural [. . .] because it hasn't rained" / "it's a problem of nature [. . .] the lack of rain")—and reported no organizing of any kind. These contrasting accounts illustrate how attribution can shape whether scarcity becomes a grievance directed at an identifiable actor.