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Why is state-centered groundwater governance largely ineffective? A review

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Abstract

Faced with severe groundwater depletion, many governments have opted to increase the power of the state. Despite calls for more inclusive governance and a role for groundwater users, modes of governance have tended to continue to rely on a diversity of policy tools and state-run strategies in the attempt to control groundwater (over)abstraction. Yet, around the world, the performance of state-centered governance has remained dismal. Beyond common difficulties in terms of data and financial or human resources, this article analyzes in greater depth the limited effectiveness of state groundwater policies that has been observed, emphasizing its political ramifications. The various aspects of weak monitoring and enforcement, as well as of the infamous "lack of political will," are considered from the perspective of the political economy of groundwater economies. Cases of relative success are then used to identify favorable drivers and contexts for effective state-centered groundwater governance.

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groundwater governance, groundwater policy, monitoring, political will

1 | INTRODUCTION

The use of groundwater resources above their "safe yield" for an extended period of time is called overabstraction and leads to the depletion of groundwater stocks (Custodio, 2002). Nearly a third of the world's largest aquifers are being depleted faster than they can be replenished (Richey et al., 2015). Since groundwater contributes 43% of the water requirement for agriculture, the overabstraction of groundwater by a multitude of small farmers constitutes a considerable challenge to the sustainability of agriculture, especially in the face of intersectoral competition and the gradual reallocation of water to urban uses (Siebert et al., 2010).

In the past 15 years or so, several global studies and research projects (e.g., the Groundwater-MATE project supported by the World Bank), and various edited volumes and studies (e.g., Giordano & Villholth, 2007; Jakeman, Barreteau, Hunt, Rinaudo, & Ross, 2016; Margat & van der Gun, 2013; Villholth, Lopez-Gunn, Conti, Garrido, & van der Gun, 2017; Wijnen, Augeard, Hiller, Ward, & Huntjens, 2012) have contributed a wealth of information and analyses on groundwater management. Yet, in the OECD's (2015) assessment, "groundwater is generally under-studied and there is a need for more in-depth assessment of groundwater stocks, use, and management practices." One area that requires deeper investigation is that of

governance, a topic addressed by the Groundwater Governance Project, supported by various multilateral organizations.[1] This foundational project found that "gaps, flaws and lags in governance are pervasive," and proposed an array of improvements in terms of data, actors (capacity, leadership, awareness, resources, etc.), and legal frameworks (FAO, 2016).

While building on existing work, this article begins from an acknowledgement that state-centered groundwater governance is largely ineffective—a statement that is substantiated elsewhere (Molle & Closas, 2017; see also OECD, 2015; FAO, 2016)—and explores the reasons behind this. We start with a brief summary of the conventional toolbox of groundwater state policies. We then include, but also go beyond, observations on the limitations of data, means, and capacity to further unpack (a) the drivers behind weak monitoring and enforcement and (b) several key dimensions of the infamous "lack of political will." This serves to explain the ubiquitous overallocation of groundwater resources. We then identify cases across the literature where policies were enforced to some extent and groundwater abstraction successfully controlled and even reduced. We conclude with a discussion on the limited success of state-centered groundwater governance.

This analysis is drawn from a wider global stock-taking exercise of groundwater governance that considered ~1,200 documents, complemented by communications via email with 40 knowledgeable scientists in various key countries and further insight from field and policy research conducted in the MENA region.[2] The review has two identified biases: it focuses on countries where groundwater overexploitation is a salient issue and its agricultural use is massive. It leaves aside questions of groundwater quality and contamination, as well as transboundary issues, to focus on quantitative issues and overexploitation.

Governance is usually construed as the joint exercise of decision-making by a diversity of actors that goes beyond conventional government by states (Pierre & Peters, 2000). Indeed, we illustrate later that both the elaboration and implementation of policies largely fall beyond the sole remit of the state. Nonetheless, groundwater governance is often dominated by laws and regulations issued by the government and implemented by state administrations. Although groundwater governance can also be community centered (Schlager, 2007) or typified as comanagement between users and the state (for a parallel analysis of this form of governance, see Molle & Closas, 2019), we focus here on the (most commonplace) situation: where the state attempts to recover control of groundwater resources largely on its own initiative and regulation (although this can include a token role for user associations).

2 | STATE-CENTERED REGULATION AND ITS TOOLBOX

State administrations facing severe quantitative deficits in groundwater resources usually have three main policy objectives: (a) preventing the drilling of *new* wells and increased depletion of the aquifer, (b) controlling or reducing the water abstracted by *existing* wells, and (c) increasing supply through water transfer and/or recharge. A panoply of policy tools corresponds to each of these objectives.

Controlling the drilling of wells is generally based on a system of licensing, whereby prospective users apply for a drilling permit and a license that are considered against the local status of water resources, demand, and supply. It is often obligatory to install a meter. Special zones are often designated, where the drilling of wells is restricted or banned, in areas that are under the most pressure. But remedying a condition of overuse usually means dealing with a hefty backlog of illegal wells to be decommissioned or legalized, and/or overallocated rights that must be curtailed or bought back. Control can also be exerted on drilling companies, or indirectly by altering the production factors or the economic environment that makes agricultural use attractive.

Controlling drilling is a prerequisite to the (thornier) task of controlling actual abstraction. Metering allows quotas and volumetric pricing mechanisms that have the potential to elicit reductions in groundwater use. Where this is legally possible, drought and/or dropping water tables may trigger reductions in entitlements or the temporary retirement of land (usually against financial compensation). "Technological fixes" are also often used to reduce use, mainly involving the lining of canals and reservoirs and adopting water-saving technologies. However, any perceived "savings" are often the result of confusion between plot-level water consumption (by evapotranspiration) and applied water. In most cases, shifting to drip irrigation increases water consumption and the reduction in return flows often impacts their appropriators (Grafton et al., 2018). Changing behavior through indirect regulation is often more promising: groundwater abstraction can be influenced, for example, by adjusting energy pricing, tariff structures, and incentive schemes, by restricting, or banning, certain thirsty crops, such as rice, banana, or sugarcane, and by raising awareness of the issues.

Last, states prefer to avoid implementing the measures mentioned above, with their economic and political implications, by finding ways to augment supply, such as storage, interbasin transfers, wastewater treatment, desalination, and groundwater recharge. Such command-and-control tools have all been widely applied, yet with very little success (see a more detailed

analysis in Molle & Closas, 2017 forthcoming). In the next section, we unpack and discuss the key features of state regulation that help explain these tendencies.

3 | KEY FEATURES OF STATE-CENTERED REGULATION

3.1 | Hydrological blindness

One well-identified difficulty for the state in its management of groundwater resources is the uncertainty surrounding the resource itself (Foster, Tuinhoff, Kemper, Garduño, & Nanni, 2006). This firstly has to do with the complexity of hydrological processes, particularly when it comes to its hidden part: groundwater. It is extremely difficult to estimate how much water percolates in different ways into the subsoil, and the heterogeneity of aquifers is often baffling. As a result, the level of aquifer recharge is often a case of "best guess." In the Altar-Pitiquito area of Mexico, for example, recharge (natural and induced) was estimated at around 300 Mm^3 in the 1970s and later at 213 Mm^3, with an annual water extraction at about 308 Mm^3. More recently, recharge was estimated at only 118 Mm^3 (overexploitation is thus much higher than believed), while others estimate it at 70 Mm^3 (Wilder, 2008).

A further difficulty is the fluctuating nature of the hydrological process and occasionally the long-term shifts associated with climate change. For example, the south-west of Australia has been experiencing a significant drying trend over recent decades, with winter rainfall down by 17% since 1970 and an associated dramatic decline in streamflow to reservoirs (more than 50%) and groundwater recharge (Bennett & Gardner, 2014).

Groundwater/surface water interactions are difficult to ascertain and evolve as the hydrologic regime is reshaped, but they must be understood in order to allocate water effectively. In the Murray-Darling Basin, Australia, it took until the early 2000s to fully address the management of hydraulically connected surface and groundwater, so as to avoid "double accounting" of water (Turral & Fullagar, 2007). In 1998, Kansas filed a complaint with the United States Supreme Court to maintain its share of the Republican River, claiming "that Nebraska had violated the compact between the two states by allowing the development of thousands of groundwater wells in hydraulic connection with the Republican River and thereby using more water than its allocation under the Compact" (Zellmer, 2008, p. 400). Only in 2004 did Law 962 provide for the effective management of these two hydrologically connected resources. In Copiapó, Chile, water rights were granted "without knowledge of the capacity of the aquifer; laws, decrees, and resolutions did not have hydrological basis or tried to obscure mistakes without solving them" (RedAgricola, 2016).

Hydrological blindness makes it even more difficult to agree on what the "safe yield" is (and therefore on how much water can be allocated), since its determination involves value-laden judgments on the values of groundwater uses and functions, and on the level of externalities that is deemed "acceptable" (Molle, López-Gunn, & van Steenbergen, 2018).

3.2 | The monitoring and enforcement conundrum

It is all too common to hear officials say, "in our country we have all the best laws and regulations, but the problems are implementation and enforcement." It is often claimed that applying regulations involves too much work and expense (implying that with greater means, funding, and capacity building it could be possible). We briefly review here the main challenges to the enforcement of regulation posed by its own capacity but also users' behaviors on the ground.

3.2.1 | Insufficient means

The primary difficulty public administrations face in enforcing groundwater regulation is what we described elsewhere as the (commonplace) "logistical nightmare" (see Molle & Closas, 2017 forthcoming; Shah, 2014); that is, managers and regulators do not receive the necessary means (in terms of staff, vehicles, budget, incentives, training, etc.) to monitor a situation that sometimes involves (tens or hundreds of) thousands of dispersed points of use.

In Guanajuato, Mexico, the CONAGUA state agency has the logistical capacity to carry out 280–320 inspections annually, while the number of existing wells is estimated at 20,000 (Hoogesteger, 2018). In Morocco, the Souss Massa River Basin Agency has only two agents acting as water police for an area that has tens of thousands of wells (BRLI, Agro Concept, 2012). In Lebanon, the Department of Water Rights and Expropriation has only 10 field staff against an estimated requirement of 100, and the Department of Groundwater and Hydrogeology has 49 positions in its flowchart but currently only nine employees, none of whom is a hydrogeologist (Nassif, 2016). In Spain, the Guadiana Water Authority has a small number of

guards, with only four for the 550,000 ha of the Western Mancha Aquifer (López-Gunn, 2003). In South Africa, the monitoring of licenses barely takes place (it should be done every 5 years), "due to capacity constraints, and the review process is mainly an administrative 'paper' monitoring process" (Movik & de Jong, 2011, p. 72).

3.2.2 | The ineffectiveness of sanctions

States conventionally count on the power of penalties to dissuade against any violation and to elicit compliance. For example, in France, the failure to declare a well can theoretically result in a fine of up to €15,000. In Western Australia, the penalty for taking water without a license or for breaching the conditions of a license is a maximum fine of $10,000 ($50,000 for corporations) plus a daily penalty of up to $1,000 (Bennett & Gardner, 2014). In Karnataka, India, illegal drilling faces a fine of up to US$80, up to 6 months in prison and seizure of the well (Water Governance Facility, 2013). Indeed, many countries consider prison as one of the sanctions.

Faced with widespread violations of groundwater regulations, states often choose to toughen punishments. Yet this is often tantamount to an admission of failure and a misguided adherence to the idea that the fear of increased penalties will discourage people from infringing the law. In Egypt, for example, toughening the provisions of the Irrigation and Drainage Law of 1984 is part of a proposed law with punishments for different violations, entitling the police to take action against the accused in addition to fines of up to EGP 25,000 (US$3,100) (El Arabi, 2012). In Jordan, a 2014 law amendment stated that a failure to follow the standard procedure for obtaining a well license would entail prison (for a period of no less than a year and not more than three) and a fine between US$1,200 and US$5,000.

But excessively increasing penalties can be counterproductive in two ways. First, the sanctions lose credibility since their enforcement would create such social impact and unrest that nobody really believes it would be possible. In the Western Mancha Aquifer, Spain, farmers do not take penalties seriously since they have learned by experience that fines of €30,000 for the drilling of illegal wells are eventually reduced to €1,800 (López-Gunn, 2009). Second, they provide a bigger "stick" to local officials, who can then extract larger bribes from illegal groundwater users (see below).

The lack of credible sanctioning breeds pervasive unauthorized well drilling and groundwater usage in agriculture, even in Europe (Dworak, Schmidt, De Stefano, Palacios, & Berglund, 2010). In a system where noncompliance is the norm social tolerance can create a disincentive to compliance with regulation because breaking the law can seem the most rational course of action (López-Gunn & Martínez-Cortina, 2006).

3.2.3 | Fraud, bribery, and corruption

Water fees or reports of violations depend on the information collected and sent to the upper levels of the administration. This obviously opens space for "arrangements," bribery, and selective application of the law, whether the initiative comes from the farmer or the field/office staff. This stark reality was recognized in 1974 by a Gujarat chief minister who refused to sign a bill into law because he failed to see how it could be effectively enforced against a million small, private well operators scattered across a vast rural area and understood that it would become yet another instrument of rent seeking for the local bureaucracy (Mukherji, Shah, & Giordano, 2012). But such awareness is the exception rather than the rule.

Indeed, in Indian states with set tariffs and meter reading, staff were found to be cogs in a system riddled with endemic corruption (Shah, Mehta, Sankar, & Mondal, 2012). Aguilar (2011) refers to a 2004 study that reported that more than 40% of individuals polled had bribed state water officials in order to alter meter figures and decrease their bills. Bangladesh is known for its corruption problem within state-controlled schemes (Zaman, 2015), where "the farmers can find the appropriate level and get their work done through payment of unofficial fees, or in other words bribery." In Jordan, bribing is believed to be a major reason behind the large under-reporting of actual groundwater use (Al-Naber & Molle, 2017).

Instances of corruption within the regulatory system of water management also concern well drilling and permitting. In Yemen, influential ministers, sheikhs, wealthy farmers, and army and security officials continue to drill wells without permits due to their connections and ability to pay bribes (Zeitoun, Allan, al Aulaqi, Jabarin, & Laamrani, 2012). In West Bengal (India), following the Groundwater Act of 2005, which required permits for wells, 64% of applications were rejected, with evidence of likely rent-seeking behavior on the part of the administration (Buisson, 2015). Other examples include China (WIN, 2011), Algeria, where the granting of loans and well permits in prohibited areas fuelled clientelism and corruption (Amichi, Mayaux, & Bouarfa, 2015), Mexico, where falsified well concession licenses and permits are common (Tetreault & McCulligh, 2018; World Bank, 2009), Lebanon, where Internal Security Forces are reported to accept payment in exchange

for turning a blind eye to infringements (Nassif, 2016), or Syria, where "officials forced farmers to pay bribes for new licenses, which in turn triggered strong resentment in rural areas." (de Châtel, 2014, p. 12).

3.2.4 | Meters and tampering

Water use is generally calculated from meter readings. But meters are costly, users often fail to install them, and when installed they are frequently broken or tampered with (Molle & Closas, 2017). This is partly why, in Tunisia, meters have never been made compulsory in tubewells: it was recognized that they would be tampered with and the administration lacked the capacity to handle them (Hamdane, 2019). In Bangalore, the regulation of groundwater was problematic as board officials lacked enthusiasm, knowing the "various ways in which well owners tend to tamper with irrigation pump meters and refuse to adhere to binding regulations" (Grönwall, 2008, p. 356). Farmers have indeed been creative in finding ways to tamper with meters and skew measurements, as illustrated earlier by the cases of Jordan (Al-Naber & Molle, 2017) and Mexico (Hoogesteger, 2018).

It is understandable that the monitoring and enforcement of well regulation will be limited where meters are costly, often broken or nonexistent, where accessing private property is complicated, and the number of wells causes logistical problems. In such cases, virtually all attempts at volumetric regulation are undermined. In European countries and the United States, meter tampering is less prevalent, but most wells do not have meters and reporting is usually the users' responsibility (OECD, 2015).

3.2.5 | Legal constraints

In a number of cases, legal constraints hamper or even preclude the proper monitoring of groundwater use or the issuing of penalties. The South African Department of Water Affairs and Forestry has no power to act against previously lawful users who exceed their water entitlement until they become licensed users—a process that has proved sluggish (Movik & de Jong, 2011).

In Texas, GCDs (groundwater conservation districts) struggle to enforce regulations as they, "do not have the financial capacity to adequately deal with the legal battles that face them" (GCD staff, personal communication, 2014, 2015, quoted by Closas & Molle, 2018). Despite having regulatory enforcement on "point source" issues, such as improper drilling, drought restrictions, illegal dumping sites, and direct contamination, GCDs have "no teeth." Faced with the threat of litigation, GCDs either run the risk of going bankrupt or "simply concede to the permit request" (Closas & Molle, 2018). The situation is even more extreme in Chile, where the protection of individual property rights enshrined in the 1964 Water Law prohibits anyone from entering a private property to check the status and use of wells.

3.2.6 | Personal relationships, legitimacy

The enforcement and monitoring of regulations on the ground requires interaction between individuals, be they users or the staff of various agencies, leaving the possibility that those involved have personal relationships. Officials who have family or social links with local users are not inclined to enforce tough regulation, especially when they do not sense clear support for it in the higher echelons or, perhaps more significantly, from local state representatives. This has been observed in Jordan (field staff are often recruited from local families) and in Lebanon, where municipalities rarely report infringements to the ministry and consider themselves unable to intervene because of their social proximity to farmers and residents (Nassif, 2016).

An issue pertinent to the gaining of compliance with regulation is that of social capital (Pretty & Ward, 2001). Water users often distrust the authorities, which can lead to decreased legitimacy of official decisions and regulations (López-Gunn & Martínez-Cortina, 2006). The reasons for this lack of trust are diverse and might include a past history of inefficiency or ineffectiveness, political meddling in cooperatives or Water User Associations (e.g., Tunisia), or the perceived unfairness or arbitrary decision-making on the part of the public administration (see Mirnezami, Bagheri, & Maleki, 2018 for the case of Iran).

In Maharashtra, India, individual violations of the Groundwater Act violations are known to take place, but farmers usually consider their reporting by the local Gram Panchayat to be vengeful (Phansalkar & Kher, 2006). Legislation lacks social legitimacy since groundwater abstraction is believed to be a farmer's right, and there is also sympathy for the view that people would want to use groundwater to improve their lives (Phansalkar & Kher, 2006). Such disdain for the law means the Gram Panchayat is reluctant to take the necessary action against offenders.

3.2.7 | Facing raw power

Monitoring and enforcement sometimes face the raw power of high-profile groundwater users. In the Souss, Morocco, the social and relational capital of some well-connected larger abstractors prevents the "water police" from interfering and controlling groundwater abstractions (Del Vecchio, 2013), despite the River Basin Agency officially having the right to close down wells without authorization (BRLI, Agro Concept, 2012). The suggestion that government officials could enter the farms of powerful investors around Marrakech was met with incredulity and laughter by some of these officials (interviews of government officials by the authors in Marrakech 2014). In Abu Dhabi, there is anecdotal evidence of agency staff being prevented from entering the land of irate farmers (Fragaszy & McDonnell, 2016). Turral (personal communication, November 1, 2015) reports problems with monitoring and verification by the authorities during the pumping ban imposed in 2007–2008 in the Werribee Irrigation District (west of Melbourne, Australia) during a seven-to-eight-year drought episode, with users threatening officials with guns on occasion.

In the Ica Valley of Peru, the association of groundwater users' monitoring tasks is hampered by the fact that many properties are guarded and landowners do not allow association representatives access to their farms (Cardenas Panduro, 2012). James' (2015) investigation in the area revealed confrontations between villagers struggling to preserve what they saw as "their" resource and thugs paid by investors. In Jordan, there were several instances of water authority staff being barred from entering the property of a Bedouin farmer, a local commenting that "it is a tribe and the tribe has power; the small government employee cannot say no to the big tribe" (Al Naber & Molle, 2016, p. 501).

In other cases, official action can be thwarted by popular unrest or even rioting, as observed in Morocco, Tunisia, and Gujarat, India, where staff related to the Jyotigram scheme were reluctant to venture into villages for fear of violence from irate mobs (Shah et al., 2012).

3.3 | The infamous "lack of political will"

Aside from the many difficulties described above regarding monitoring and enforcement, the ineffectiveness of groundwater regulation is commonly blamed on a "lack of political will." In other words, the means of control are believed to be sound and generally sufficient but are not implemented because the "government," that is, the bureaucracies responsible for groundwater as well as those in power, are ultimately *unwilling* to make use of the "sticks" at their disposal. Here, we attempt to unpack four major drivers of this ubiquitous "lack of political will."

3.3.1 | Private vested interests

First, it is sometimes the case that the government officials and political leaders responsible for the voting in and application of regulations are major beneficiaries of the groundwater economy. Nowhere is this clearer than in Yemen, where sheikhs and landlords command considerable power in the parliament and the government. It has been reported (Alhamdi, 2012) that on the very day a law was passed to ban wells in the Sana'a Basin, the Minister of the Interior was drilling an illegal well on his property. Al-Zubari (2012) notes the lack of political will in Arab countries "to enforce legal regimes that contradict local institutional regimes as well as the vested interest of political and economic elites."

In Guanajuato state, Mexico, powerful groundwater users, such as large-scale producers and investors producing for export markets, often have close political connections, and politicians themselves are known to invest in such ventures (Hoogesteger, 2017). Reis (2014) has shown how, in Mexico, industrialists knew how to stay "on good terms" with the administration (CONAGUA) in order to secure their leniency in reading meters. In the Ica Valley, Peru, investors quickly obtain permission to link their wells to the power grid, which small farmers often struggle to do (James, 2015). In Abu Dhabi, one agriculture official explained that, "here there is no such thing as 'illegal' for a local who has good connections" (Fragaszy & McDonnell, 2016).

In Azraq Oasis, Jordan, investors include powerful figures, such as former ministers, heads of the public security and intelligence apparatus, senators, members of parliament, and large investors, such as shopping mall owners (Al Naber & Molle, 2016). In Morocco, the investment boom in the groundwater economy is largely associated with the financial interests of large local and foreign investors.

3.3.2 | Conflict with higher-level state priorities

Second, the need to conserve groundwater (as well as surface water) resources often ranks beneath higher national priorities, such as poverty alleviation, economic growth or export promotion.

Pakistan faces the pressure of producing sufficient food to feed the population and reduce poverty in rural areas, where more than 70% of the population lives. This explains why the government has been reluctant to enforce groundwater regulation, when the resource has come to cover more than 50% of the total crop water requirements (Qureshi, McCornick, Sarwar, & Sharma, 2010). In northern Algeria, the state administration has tended to turn a blind eye to the proliferation of wells, in part because farmers were dispossessed of their water resources as these were redirected to cities.

In Tunisia, local and regional authorities pay little attention to the *Code des Eaux*, which provides for the establishment of protection or prohibition areas (Hamdane, 2014). The provincial governor (*wali*) retains the power to apply or filter central regulations from the ministry. Walis commonly approach the central government to militate against the control of groundwater use and request support for industrial and tourist development in their provinces (Interview with CRDA staff 2015). In Morocco, priority is given to productivity and to date no specific area has been declared a groundwater prohibition zone (despite legal provision for it). In the south, the Souss Massa Basin Organization prepared the necessary files and made such a request in 2009, but the central administration has so far failed to take any action. The Tensift River Basin Agency issued a memorandum in 2008 banning the drilling of new wells, but with no willingness to constrain the expansion of tourism in the Marrakech region, its enforcement has remained elusive. In Abu Dhabi, the overriding concern is maintaining stability and security. This has hindered the introduction of metering in rural areas, where the Emirati cultural ties to the land are pronounced.

In Turkey, the monitoring of actual water use by individuals and cooperatives is weak to nonexistent, partly due to the very high number of wells but also because of groundwater's crucial importance in making agriculture competitive—a high-priority policy objective (Apaydin, 2011). In Mexico, the introduction of 50 "zonas de veda" (prohibition areas) between 1948 and 1963 had no effect, since the development of groundwater resources was considered key to the expansion of commercial agriculture at the time, and extraction was not monitored (Wolfe, 2013, p. 17). In Western Australia, policy decisions have deliberately allowed overallocation to continue, "in order to facilitate the ongoing operation of coal mining and coal-fired electricity generation in the area" (Bennett & Gardner, 2014, p. 61). Likewise, in Chile water pumped from an aquifer when extracting mineral from deep open pits is not considered water use.

3.3.3 | Consolidating power and political clienteles

Defining the degree of implementation, or disregard, of groundwater regulation is one aspect of power building and creating or sustaining political clienteles. Implementing heavy-handed "stick" regulations is often tantamount to political suicide (or at least electoral disaster), or in some cases to generating serious social unrest and upheaval.

In India, although the agricultural elite exercises its power, small and medium farmers have increasingly been able to exert pressure on local authorities and governments whether by voting or through agrarian movements (Mukherji, 2006). In Gujarat, in 2013, a bill proposing the licensing of groundwater abstraction beyond a certain depth was deemed "antifarmer" by the opposition and shelved by the governing party before the election "for fear of irking farmers," and as a message of "good governance to the people" (The India Express, 2014). In Jordan, initial groundwater tariff reforms in 1994 were also met with opposition, leading to the occupation of the parliament floor and intervention by the king in the matter (Venot, Molle, & Hassan, 2007). In Morocco, in 2004, the Souss Massa River Basin Agency decided to close two wells drilled without authorization. Agricultural unions staged several protests calling for the governor (*wali*) to suspend the decision. Generally speaking, but most notably in Egypt, Tunisia and Morocco, the Arab Spring has substantially weakened the states' authority and capacity to act.

Obviously, such prospects are not attractive to local or national politicians, who predictably procrastinate and weakly enforce regulations. Sweeping the matter under the carpet is all the easier since the effects of overexploitation do not manifest dramatically within the electoral timeframe, meaning tough decisions can be postponed. In Maharashtra, Phansalkar and Kher (2006) found that nominated leaders who fear not being re-elected as much as they fear for their social standing were reluctant to implement laws restricting the digging or drilling of new wells. As Cullet (2012, p. 65) notes with regard to India, until recently "state governments often preferred opening up their coffers to ensure that sufficient groundwater could be pumped up in a context of falling water tables rather than tackling the issue upfront by starting to allocate, restrict, and take a broader view of groundwater governance." Groundwater is therefore the locus of clientelism. In West Bengal, local village councils control new electricity connections for submersible pumps. The issuing of new permits is co-opted by local elites, such as village council heads, who refuse to forward applications either because the applicant did not support their party or the permit would

harm the interests of party supporters (Mukherji, 2006). In Lebanon, there are reported cases of local political leaders from the Bekaa Valley petitioning the ministry to issue permits to their electors (Nassif, 2016).

More generally, groundwater can be part of state-community relationships, especially in Arab countries. In Yemen, the state sought to strengthen its power and legitimacy by co-opting elites in crucial rural constituencies through preferential access to irrigation, public investment in new wells, and diesel subsidies (Al-Weshali et al., 2015). In many tribal rural areas, tubewells became signs of wealth and prestige, and financing groundwater abstraction became an effective patronage mechanism among tribal leaders. In Jordan, in order to win the support of Bedouin tribes, the Hashemite regime has always engaged in a give-and-take relationship, including access to land and water (wells) (Kark & Frantzman, 2012). More generally, and particularly around the Mediterranean Basin, subsidies for well drilling or up to 100% for microirrigation systems, as well as other personalized favors (accessing loans without land titles, permits for wells in prohibited areas, etc.) fueled clientelism (Molle & Sanchis-Ibor, 2019).

3.3.4 | Bureaucratic competition and intersectoral contradictions

Despite standard calls for the application of IWRM principles, there is ample evidence that decision-making regarding water issues is frequently fragmented (Özerol & Bressers, 2015), which affects states' authority. In the groundwater subsector, this is clearly illustrated by contradictory if not antagonistic actions and policies on the part of different administrations and ministries, such as those in charge of agriculture, water, public works, or the environment. The main contradiction is that between water or environment managers, concerned with achieving a degree of control over groundwater (over)abstraction, and agricultural development administrations concerned with expanding cropping areas and enhancing production.

A clear illustration is provided by Morocco's *Plan Maroc Vert*, which supports subsidies, massive investment in agriculture and provisions for the bypassing of groundwater restrictions to subsidize well drilling and drip irrigation. These are associated with an intensification of agriculture, often resulting in increased consumption of water (Molle & Tanouti, 2017). Private and political interests in the promotion and expansion of agriculture have the upper hand over resource and environmental conservation. Tunisia's Agricultural Ministry still extends substantial subsidies to private investment in water mobilization. The government covers 25% of investment in well drilling and associated irrigation facilities (pump set, on-farm reservoir, filters, pipes, etc.) (Hamdane, 2015). Algeria has also been fully subsidizing the expansion of date palm and other crops in the country's oases and desert areas with scant regard for the availability of the resource. In the early 2000s, the EU extended subsidies to water-intensive crops, such as corn, beetroot, and alfalfa (Martínez-Santos, De Stefano, Llamas, & Martínez-Alfaro, 2008). There are countless examples of agricultural administrations subsidizing and incentivizing groundwater-based irrigation where aquifers are already dropping dramatically (World Bank, 2007).

Other common cases of policy contradictions include a lack of coordination between energy producers/providers and those in charge of water and agriculture. The former's general lack of concern for groundwater sustainability leads to subsidies for groundwater pumping (in most countries), precludes using electricity supply to regulate groundwater abstraction, and encourages adverse policies, such as the production of ethanol/biofuel or, more recently, the development of solar pumping (FAO, 2018).

3.4 | The overallocation syndrome

The laissez-faire attitude that tends to prevail at the beginning of groundwater development invariably results in (over)use, whether legal or illegal, outstripping the available resource. When the pressure to rationalize abstraction increases, management often introduces water rights or entitlements but it is too late and very hard to implement restrictions. The question then also arises as to exactly how much of the resource can be shared. This is an issue that is rarely answered adequately, partly due to the heterogeneity of aquifers and the complexity of groundwater flows but more meaningfully to the "optimism" about availability and the associated tendency to overallocate resources.

This tendency has been well documented for surface water allocation (see illustrations of several river basins in Molle & Wester, 2009) and is also evident with regard to groundwater, as is the apparent dislike for fixing constraining limits. In the Murray Darling Basin, the 1994 cap on surface water abstraction was tellingly not paralleled by similar action on groundwater, the latter having been left as an additional resource for farmers to resort to once surface water was restricted (indeed, they largely shifted to groundwater). In Toluca, Mexico, agricultural users could state any volume they wanted during legalization and acquire the concession. As a result, most aquifers are "overconcessioned" (Reis, 2014). One cause of groundwater overabstraction in the Copiapó Basin, Chile, was the overestimation by 30% of aquifer recharge by taking as baseline data the unusually humid period of 1980–1990 (Bitran, Rivera, & Villena, 2014). Here, as in Australia's Murray Darling Basin,

overallocation partly resulted from water rights defined as the capacity of the well and not fully used that were transferred to more intensive uses (mines), translating into much higher abstraction.

Hydrologic estimates tend to be optimistic, and "safe yields" or recharge are almost invariably too high and reassessed downwards (as illustrated in Molle & Closas, 2017). This suggests that flawed assessments reflect not only uncertainty in hydrologic knowledge but also political interests. The hypothesis that groundwater authorities are slow to set allocation limits and quotas because of their unpalatable consequences, and that when they do it is always on the optimistic rather than conservative side, is consistent with the reasons for the observed "lack of political will" discussed earlier.

4 | SEARCHING FOR SUCCESS STORIES

Having examined the difficulties inherent in state-centered approaches to groundwater governance, it is appropriate at this stage to try to identify a few "success stories." These could serve to determine the particular circumstances that are conducive to effective state regulation (understood as abstraction having stabilized at an acceptable level). The following cases were selected to illustrate situations where public authorities have achieved a degree of success in controlling groundwater use, in order to identify contextual factors and promising policy options. We limit ourselves here to cases where governance can by and large be identified with state's action and decision-making, although the agency of other actors can never fully be discounted.

4.1 | Japan

Japan has successfully stabilized abstraction from some coastal aquifers (and controlled salinity intrusion). The regulation in "designated areas" made it necessary to obtain a permit from the appropriate prefecture, which constrained drilling in terms of well diameter and depth. For example, in Koto Ward (Tokyo), well outlet size was to be between 21 and 46 cm^2 and depth greater than 250 m (Endo, 2015). In 1962, only wells with outlet under 21 cm^2 and deeper than 650 m would be allowed, which made virtually any pumping uneconomical and impossible (Endo, 2015). Such technical constraints, however, were made acceptable/effective because the government delivered subsidized surface water as a substitute, recycling domestic and industrial wastewater, while improving cooling and other industrial processes as well as domestic use efficiency and resorting to artificial recharge (Endo, personal communication, November 1, 2015b). Savings in groundwater resources were also due to substantial wastewater fees, whereby industries had to pay for any water released into the drainage system, prompting efficiency gains and recycling. It is important to note that users are mainly utilities and factories, with agricultural use being negligible to nil.

4.2 | California and Florida

Southern California has been credited with successfully regulating abstraction in coastal aquifers (Blomquist, 1992).[3] The West Coast Basin is an example of an aquifer from which pumping has been controlled and even reduced. As Lipson (1978) wrote, the adjudication of the basin, which involved a cut back in pumping through the agreement of all parties, rested on the availability and possibility of a massive import of surface water (four to five times the amount of groundwater used) and also some recycling of wastewater, as well as desalination and recharge. But even the overall use is declining slightly. Agriculture is minimal and decreasing because the area is largely if not fully urbanized; in addition, per-capita consumption may have gone down thanks to more efficient appliances. Another side to the story is corruption and the interests that were associated with the oversizing of infrastructure and overestimated projections for use (Steed, 2010).

The Orange County Water District (OCWD) has reached a balance between demand and supply. Demand has decreased with the shift from agricultural to urban use and the increased efficiency of domestic appliances and industrial processes. Supply has been increased through water and flood harvesting and infiltration structures (import of Colorado water), and injection of recycled water into the coastal area (to control seawater intrusion) (Endo, 2015). All wells must be registered and fitted with a meter, except those with an outlet diameter of less than 1 in. OCWD promotes mutual checks by publishing the annual pumping volume of the major groundwater users.

In the (small) Raymond Aquifer, the stabilization of groundwater abstraction was achieved by an increasing dependency on imported water from the Colorado River (now 60% of supply), as well as the regulation of wells and the control of pumped volumes. Users are in fact bulk users, which numbered 30 in 1944 and 16 at present (Steed, 2010). The stabilization of groundwater abstraction levels in Los Angeles and other places was ultimately made possible by the tapping of new sources of water from inside and outside the basin, which requires political and financial capacity, a control of abstraction by (a limited number of) users, and state-enforced adjudication or other process that cap overall abstraction.

In Florida, a reduction in the impact of groundwater pumping on the Tampa Bay ecosystem and watershed was largely obtained via the development of alternative surface-water-supply sources. The abstraction of groundwater from 11 well fields was brought down from 158 to 90 million gallons per day by the end of 2008 (Yates, Greening, & Morrisson, 2011). There was an accompanying increase in the reuse of treated effluent for irrigation and industry, together with the implementation of aquifer storage (China).

Minqin County is an example of groundwater overdraft driven by unsustainable economic targets and grain quotas. By the early 2000s, 32,000 people had left Minqin as "ecological refugees" and 20,000 ha of farmland had been abandoned (Mao & Zhang, 2018). In 2007, the prime minister called the preservation of Minqin a "national security issue" and the Shiyang River Basin Management Plan was designed to reduce groundwater abstraction in Minqin from 517 to 89 Mm^3 by 2010. The central government's keen interest in controlling groundwater abstraction and desertification in Minqin County (as shown by a total budget for the plan of US$641 million) arose from the fact that if the oases were to disappear, the two surrounding deserts would join to form the largest source of sandstorm threatening the populated east, including the capital. Until 2007, several measures had been attempted, but to no avail. They included a water transfer from the Yellow River (50 Mm^3 for Minqin), increasingly tough procedures to obtain well-drilling permits, well spacing limits, incentives to turn farmland into forests, and prohibiting the acquisition of wasteland by farmers.

The 2007 plan introduced new measures, including subsidies for drip irrigation and greenhouses, individual crop-and-area-based quotas (adjustable according to the quantity of surface water available), water pricing, cutting electricity to private wells outside the community, using prepaid cards to implement quotas at each well, buying back wells, and establishing groundwater user associations to implement the measures (Aarnoudse, Bluemling, Wester, & Qu, 2012; Mao & Zhang, 2018).

In 2012, 3,000 of the 7,000 existing wells had reportedly been filled in and disconnected from the grid, although it seems some of them were no longer in use. This very rare instance of well closures can be explained by such factors as: the determination of the central government (explained above), the fact that the wells had been drilled with government funding and control (and were, therefore, not individually owned), the fact that the land was also in public ownership, allowing its redistribution between farmers, the village authorities' involvement in the process of selecting the wells to be closed, the compensation (between US$800 and US$5,000) paid to farm groups using the wells, and the aging population with a declining interest in farming. Minqin remains an exceptional case, as elsewhere in China "the implementation of the quota policy is very poor," according to one expert (Wang, personal communication, November 1, 2015).

4.3 | Jordan

Since the first ban on agricultural wells in 1992, Jordan has experimented with a wide range of regulations and policies aimed at controlling groundwater abstraction in the country, most notably in the highlands (Al-Naber & Molle, 2017). The 2002 bylaw was seen as watershed legislation in reinstating the licensing of all existing wells, establishing annual quotas for each well, limiting the number of well licenses to one per plot of land, and introducing a block tariff pricing system (Venot et al., 2007). But its practical implementation has been lax and the drilling of new wells has continued unabated, fueled by the profitability of irrigated agriculture as well as land speculation (Venot et al., 2007). The implementation of the legislation has been bedeviled by the cost of reading meters and monitoring the existence and dimensions of wells, bribery, and the uncertain resolve of higher-level authorities to enforce the law.

However, to deal with lingering problems of illegal well drilling, meter tampering, and unpaid water bills, the Ministry of Water Resources and Irrigation has recently implemented new measures, including cracking down on illegal wells and drilling companies, increasing the water tariff for unlicensed wells, limiting the granting of labor permits, "naming and shaming" violators in newspapers with the sum of their unpaid bills, using satellite imagery to estimate and charge water consumption, and improving interdepartmental coordination to make users pay their bills before embarking on other administrative procedures (passport applications, renewing driver's licenses, purchasing assets, etc.) (Al-Naber & Molle, 2017). It is too early to make a definitive assessment of this move, but the combination of (creative) measures is showing signs of successfully hindering illegal drilling. Effectiveness hinges around the ability of the state to raise and sustain pressure on users amid a volatile political context.

4.4 | Denmark

Groundwater provides 99% of Denmark's water supply, but overall abstraction is limited (400 Mm^3—50% less than 25 years ago). Agriculture accounts for around 25% of abstraction. The reduction in use is partly ascribed to water pricing, although half occurred prior to price increases. Due to pollution by nitrates and pesticides, public awareness of the need to protect

groundwater is fairly high. Municipalities, who are close to users, are responsible for licensing and monitoring. Further, around 2,500 companies carry out the bulk of abstraction for water supply, meaning it is more easily monitored in terms of volume (also since declared abstraction is compared to billed volumes, with companies paying for losses greater than 10%) (Jørgensen, Villholth, & Refsgaard, 2016). Although many aquifers are sustainably exploited, some areas, including the Copenhagen region, still show substantial levels of overdraft.

4.5 | Australia

Perth, Western Australia, illustrates how the need to stabilize groundwater abstraction can result in the constructing of massive desalination plants, in the face of growth in demand and a dramatic decline in surface water. The city's water utility established a "Groundwater Security Strategy" in 2013, which includes the development of groundwater recharge projects with treated wastewater (with the goal of recharging 14 Mm^3 per year), allowing it to continue abstracting groundwater at the same rate for its water supply (Water Corporation, 2013). The plan transferred groundwater abstraction to the deeper aquifers surrounding the city to protect groundwater-dependent ecosystems and secure groundwater supply. Since 2006, desalination has been used to compensate for the lack of surface water and relieve pressure on groundwater resources, with a first plant producing 45 Mm^3 (soon be expanded to 145 Mm^3/year). Although this is an effort in water supply augmentation, it is accompanied by legislative reforms (2004) centered on environmental objectives, the systematizing of well licensing and metering, establishing conditions wherein entitlements can be temporarily curtailed, and introducing trading (Bennett & Gardner, 2014).

In some aquifers of the Murray-Darling basin,[4] mostly those with high connectivity between the aquifer and the river, plans have been set up to restrict abstraction in drought years. In the Lower Murrumbidgee Valley, entitlements for groundwater were reduced from 514 to 270 Mm^3 in 2006. Following the Water Sharing Plan for the valley, at the start of every year, an available groundwater determination (from shallow and deep sources) is made, setting the allocation of groundwater for the different categories of access licenses.

4.6 | Edwards Aquifer, Texas

Early settlers above the Edwards Aquifer drilled artesian wells for domestic and irrigation purposes, eventually drying up the San Antonio Creek. The Edwards Aquifer Authority (EAA) was established when the stress caused by overabstraction culminated in a lawsuit in 1991 by the Sierra Club against the US Fish and Wildlife Service for failing to enforce the Endangered Species Act and protect those species dependent on adequate flows in springs and rivers (Boadu, McCarl, & Gillig, 2007). The Edwards Aquifer Authority Act (the EAA Act) was historic in that it replaced the rule of capture with a permit system administered by the EAA, installed meters on wells, and limited the total amount of groundwater withdrawals to 450,000 acre-feet per year.

Following many legal challenges, a total of 881 groundwater permits were issued, amounting to 549,000 acre-feet (677 Mm^3)—far higher than the cap. This carried considerable environmental risk, particularly if people were to use their rights fully. Texas could have bought back some of the excess water rights but the public funding was not available. Instead, it passed a bill in 2007 that relaxed the cap on total water rights (increasing it by 5% to 572,000 acre-feet), while at the same time shifting from a cap on permanent water rights toward a cap on water allocations during drought periods. The system, which came into effect at the end of 2012 (Debaere et al., 2014), follows a table describing five successive stages, and setting entitlement reductions for each (of between 20 and 44%) (Charbeneau & Kreitler, 2011). Reduction in overall groundwater abstraction was accomplished through investment in improved agricultural irrigation efficiency, conservation measures in the city and in industrial processes, the recycling of wastewater, and the underutilization of water rights (Debaere et al., 2014; www.edwardsaquifer.org).

The law requires that all wells tapping the Edwards Aquifer be registered with the EAA, regardless of their age or purpose. (This can be done by mail and carries a fee of $10.) Water users must report their use annually as standard and monthly when restrictions are in place. The EAA has been promoting the use of remotely sensed meters and meter-tampering detectors. Of the 2,135 licenses, 67% are for domestic use. The EAA maintains a website that is remarkable in terms of transparency, providing in particular a list of all license holders and hydrological data. The EAA is a rare example of a body that has acted more on demand management than supply augmentation (aside from wastewater reuse) and that, notwithstanding little stakeholder involvement, has established a system of volumetric management that appears to work.

5 | DISCUSSION AND CONCLUSION

The examples above pertain to very different physical and political contexts. However, together with the discussion presented in this article and additional specific observations drawn from other documented cases, they can be used to identify an array of factors that appear to be associated with a higher likelihood of success of state-centered groundwater management. We can distinguish (a) facilitating factors, (b) capacity factors, and (c) willingness factors.

Facilitating factors refer to contextual conditions that make state action easier. They include a limited number of institutional bulk users (typically domestic water providers or industries), limited use of groundwater for agriculture, or negligible political influence of that sector. These conditions are typically met in Japan (Endo, personal communication, November 1, 2015b), coastal California, and Denmark. In the Lower Murrumbidgee, Australia, there are only 314 groundwater licenses for the deep aquifer source. The number of bulk users is even lower in some Californian coastal aquifers. State action is obviously facilitated where the legal framework allows for groundwater abstraction to be set or capped (Australia, France, Edwards aquifer, etc.), as opposed to situations where it faces legal impediments (e.g., Chile, parts of California, South Africa).

Capacity factors include the state's financial capacity to fund such (generally capital-intensive) supply-augmentation options (e.g., Australia, California, Japan), its bureaucratic capacity to implement policies (sectoral policy alignment, sufficient trained staff and means on the ground, limited corruption, monitoring and technical capacity, etc.), and its political legitimacy and capacity to impose inter-basin transfers (e.g., China or Morocco vs. Spain), enforce regulation, and penalize violators (a strong state with coercive power, as in China, or sufficient power and legitimacy to rein in the actions of individuals [e.g., USA, Australia, and Denmark]).

Technological innovations, such as swipe cards to activate water pumps and manage an overall quota (China or Bangladesh), tamper-proof and remotely sensed meters, or the use of remote sensing to help monitor well expansion and assess existing abstraction (e.g., Spain, Jordan, and Mexico) allow managers to partly bypass human intervention and improve their management capacity.

But capacity must be paralleled with a *willingness to act*. The latter is enhanced when the political cost of inaction exceeds that of action. In the short term, the political benefits of inaction can include support from farmers and/or investors who directly benefit from the groundwater economy, but they may be counterbalanced by rising unacceptable social costs, such as massive land subsidence in urban areas or coastal aquifer salinization threatening water supply. The greater (yet far from general) mobilization in cities sited on coastal aquifers (e.g., California, Japan, and Bangkok) can be explained by the fact that influential urban elites perceive the threat to domestic water supply and valuable assets (from land subsidence) as particularly serious.

It is a well-recognized fact that crisis situations open windows of opportunity for politicians and law makers to pass more restrictive regulation (Birkmann et al., 2010), as has been seen in Texas (the Edwards Aquifer Authority Act), Nebraska, and California (after the recent drought). In Jordan, where the situation is extremely critical, the government was also motivated to develop a more rigid stance. In the case of illegal drilling/pumping during the drought in south-east Australia, as reported by Turral (personal communication, November 1, 2015), illegal wells were eventually forcibly decommissioned and the users prosecuted. In China, the need to protect the capital from sandstorms prompted strong action against desertification in Minqin.

Crises also tend to make free-riding behavior by some unacceptable to others. They prompt users to report violations to the administration and assist in law enforcement. In Ica, Peru, in 2014, the National Water Agency issued a fine approaching US $130,000 to the company Agricola Miranda for having drilled wells within the banned area and proceeded to close the 10 wells after a representative of the farmers reported them to the agency. In Marrakesh, Morocco, a farmer reported his neighbor's illegal drilling of a well because it was directly affecting his own. Similar cases of farmers readily reporting illegal drilling to the authorities include Algeria, Yemen, Eastern Mancha, Spain, with violations reported to the Groundwater Association, and the Lower Murrumbidgee, Australia, where users can report suspected unauthorized pumping or water theft to a Compliance Unit (by email or telephone; all reports remain confidential). Jordan also has a "unified water emergency number" for reporting abuse, and the Philippines a "hotline" to receive calls from the public on illegal deep wells. In Wadi Qarada in Yemen, user associations lodge complaints to the government if one discovers that another has engaged in unlicensed drilling (Van Steenbergen, Bamaga, & Al-Weshali, 2012). In south-east Australia, if individual users notice any irregular activity on the part of their neighbors, they can report it to the authorities (Turral, personal communication, November 1, 2015).

States' willingness to act is also enhanced by threats to key public interests, for example, when well drilling clearly affects public wells used for urban domestic supply (e.g., India, Jordan, and Oran, Algeria), affects cities (e.g., China and Manila) or railways (e.g., high speed train in Taiwan) due to land subsidence, or when illegal wells are drilled on public land. More

anecdotally, authorities can be prompted to act when particular individuals have fallen out with officials, whether from repeated and outright challenges to the law, a refusal to pay bribes, or any kind of interpersonal conflict.

The willingness to enforce control also depends, *a contrario*, on the (physical, economic, and political) feasibility of supply-augmentation options. Governments typically favor "bringing more water in" over the less politically palatable option of reducing demand. In many cases, supply-side policy options tend to be jointly implemented, since none may be sufficient on its own, while demand-side options appear to be both limited in scope and more difficult to implement. As emphasized elsewhere (Molle & Closas, 2017), many regions in various countries are currently hopeful that their salvation lies in surface water transfers. This allows governments to buy time but results in increasingly costly investments and tends to build/shift pressure onto other basins. Enhancing aquifer recharge by impounding treated wastewater is easier in the proximity of cities, as desalination is nearer the sea (e.g., Gulf countries, Western Australia, southern Morocco, Algeria, etc.). The ease with which groundwater can be substituted by transfers of surface water from other basins also varies widely.

The pervasiveness of state-centered groundwater governance, and its associated toolbox of zoning, licensing, metering, pricing, and so on, associated with the conventional "best practices" of IWRM, clearly echoes the "instrumental myth [which] assumes that the intended changes in water management can be made only by formulating and legislating official rules" (Boelens, Dourojeanni, Duran, & Hoogendam, 2002, p. 1997). The persistence of the command-and-control paradigm can also be explained by the fact that it befits the engineering ethos of technical departments (see Nabavi, 2018 on Iran); it flatters politicians' sense of "taking charge"; and it speaks to the illusion that power can be exerted through clean paperwork, without "muddying boots on the ground." The paradigm remains highly attractive, even in weak states such as India, in a political economy that has introduced free electricity in rural areas rather than strict regulation. The latest (2011) Groundwater Model Bill proposed by the federal government extends the requirement for permits for all uses. Half India's states have passed laws more or less inspired by the 2005 Model Bill, with common features such as the prohibition of drilling in "notified" areas, licensing, regulation of the depth and spacing of wells, and the blanket regularization of existing wells/uses (Water Governance Facility, 2013).

It is arguable that in many settings such regulations are *necessary* (although never *sufficient*), but attention must be given to contextual prerequisites. It is important to acknowledge that the power of the state to control and reorder the use of groundwater is overstated, which speaks both to its *capacity* to deploy regulatory power on the ground and its *willingness* to do so, as discussed earlier. Adherence to formal "best practices" and to the hope that they will "do the job" by their own virtue is generally proved to be illusory and failure damages the state's credibility, echoing Ostrom (2000) warning that, "the worst of all worlds may be one where external authorities impose rules but are only able to achieve weak monitoring and sanctioning." Weak implementation and sanctioning, or inaction, can also eventually be seen as favoring the *status quo*, showing a political reluctance to alter the stream of benefits generated by the groundwater economy.

We have indeed emphasized that the dealings of the state with situations of groundwater overabstraction is not a purely rational endeavor to apply "best practices" and restore sustainability. Rather, it operates at the intersection of stakes and interests that include the social (e.g., small vs. big farms), economic (e.g., commercial vs. subsistence farming), bureaucratic (e.g., ministerial rivalry), sectoral (e.g., agriculture vs. urban uses), and political (e.g., clientelism or state capture). How groundwater policies and state action/inaction, purposefully or not, redistribute costs and benefits and reshape social relationships must be ascertained in each situation. Yet, it is apparent that what is generally held as a failure to mobilize enough data, staff, and resources to enforce sound regulation is, in fact, the manifestation and confrontation of the (relative) power displayed by a diversity of actors, such as rural communities, local leaders, non-governmental organizations, decentralized administrations, bureaucrats, investors, politicians, and experts, with frequent overlap of interests and even identities. It is apparent that groundwater governance is "thick with politics," particularly since groundwater is increasingly important for domestic water supply, sustaining agriculture and rural stability, and providing opportunities for capital accumulation to well-connected investors—all highly political stakes.

We are also cognizant of the fact that governance processes frequently "jump scale" and that consideration should be given to global processes (e.g., environmental change, resource grabbing, migrations, hegemonic policy concepts, etc.) that frequently have a bearing on local groundwater governance, but this is better understood on a case by case basis.

The minimal success of state-centered governance has been mostly limited to capital-endowed urban and coastal areas in the North, while poorer—particularly agriculture-based groundwater economies in the South show little sign of sustainable groundwater use under state custodianship; even "in many regions of OECD countries, there is neither effective monitoring of groundwater use in agriculture nor a way to credibly enforce restrictions of groundwater use," according to the OECD (2015). State action is constrained by human and financial means (the pervasive lack of political recognition that managing water resources does require substantial funding), but perhaps more importantly by a lack of legitimacy, a tendency to adopt stick-only measures and to overestimate state power, the logistical nightmare associated with the control of numerous and diffuse users, and a host of political and economic private interests that are inconsistent with the longer term common good.

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AUTHOR CONTRIBUTIONS

Francois Molle: Conceptualization; data curation; formal analysis; funding acquisition; investigation; methodology; project administration; supervision; validation; writing-original draft, review, and editing. **Alvar Closas**: conceptualization; data curation; formal analysis; investigation; methodology; project administration; supervision; validation; writing-original draft, review, and editing.

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ENDNOTES

[1] www.groundwatergovernance.org. This project was developed between 2011 and 2015.

[2] See http://gw-mena.iwmi.org/outputs/. In many instances we indicate relevant countries or cases without providing a full reference due to space limitations. Readers can refer to Molle and Closas (2017) for greater detail.

[3] California arguably does not qualify as an example of state-centered governance but we refer here to the 27 aquifers (out of 512) that have been adjudicated by court and where allocation is supervised by the state, mobilizing public authority (Langridge & Ansell, 2018).

[4] It is debatable whether Australia's experience qualifies as state-centered since definition of the successive plans involved a number of participatory processes. However, these processes were often unsatisfactory and frustrating and although mediated by various sectoral and political interests, policies were largely imposed by the federal government.

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REFERENCES

Aarnoudse, E., Bluemling, B., Wester, P., & Qu, W. (2012). The role of collective groundwater institutions in the implementation of direct groundwater regulation measures in Minqin County, China. *Hydrogeology Journal*, *20*, 1213–1221.

Aguilar, D. (2011). Groundwater reform in India: An equity and sustainability dilemma. *Texas International Law Journal*, *46*, 623–653.

Al Naber, M., & Molle, F. (2016). The politics of accessing desert land in Jordan. *Land Use Policy*, *59*, 492–503.

Alhamdi, M. (2012). Water scarcity and the need for policy redirection in Yemen. In *Yemen in transition: Challenges and opportunities, October 19–20, 2012*. Harvard University, Video recording. Retrieved from http://vimeo.com/52884952

Al-Naber, M., & Molle, F. (2017). Controlling groundwater overabstraction: Policies vs. local practices in Jordan Highlands. *Water Policy*, *19*, 692–708. https://doi.org/10.2166/wp.2017.127

Al-Weshali, A., Bamaga, O., Borgia, C., van Steenbergen, F., Al-Aulaqi, N., & Babaqi, A. (2015). Diesel subsidies and Yemen politics: Post-2011 crises and their impact on groundwater use and agriculture. *Water Alternatives*, *8*(2), 215–236.

Al-Zubari, W. K. (2012). *Synthesis report on groundwater governance regional diagnosis in the Arab region. Groundwater governance—A global framework for action*. Rome: GEF and FAO.

Amichi, H., Mayaux, P.-L., & Bouarfa, S. (2015). Encourager la subversion: Recomposition de l'État et décollectivisation des terres publiques dans le Bas-Chéliff, Algérie. *Politique Africaine*, *137*, 71–93.

Apaydin, A. (2011). Groundwater legislation in Turkey: Problems of conception and application. *Water International*, *36*(3), 314–327.

Bennett, M., & Gardner, A. (2014). *Groundwater regulation in a drying South West*. Adelaide, Australia: National Centre for Groundwater Research and Training.

Birkmann, J., Buckle, P., Jaeger, J., Pelling, M., Setiadi, N., Garschagen, K., … Kropp, J. (2010). Extreme events and disasters: A window of opportunity for change? Analysis of organizational, institutional and political changes, formal and informal responses after mega-disasters. *Natural Hazards* (2010, *55*, 637–655.

Bitran, E., Rivera, P., & Villena, M. J. (2014). Water management problems in the Copiapó Basin, Chile: Markets, severe scarcity and the regulator. *Water Policy*, *16*, 844–863.

Blomquist, W. (1992). *Governing groundwater in Southern California, Center for Self-Governance*. San Francisco, CA: ICS Press.

Boadu, F. O., McCarl, B. M., & Gillig, D. (2007). An empirical investigation of institutional change in groundwater management in Texas: The Edwards aquifer case. *Natural Resources Journal*, *47*, 117–163.

Boelens, R., Dourojeanni, A., Duran, A., & Hoogendam, P. (2002). Water rights and watersheds: Managing multiple water uses and strengthening stakeholder platforms. In R. Boelens & P. Hoogendam (Eds.), *Water rights and empowerment* (pp. 101–143). Assen, the Netherlands: Van Gorcum.

BRLI, Agro Concept. (2012). *Gestion de la demande en eau dans les pays méditerranéens: gestion de la demande en eau—étude de cas du Maroc, Décembre 2012*. Nimes, France: BRLi.

Buisson, M. C. (2015). What does pump sets electrification change? Impacts on cropping patterns, productivity and incomes in West Bengal. In *26th European regional conference, international commission on irrigation and drainage ICID*, 12–15 October 2015, Montpellier, France.

Cardenas Panduro, A. I. (2012). *La carrera hacia el fondo. Acumulación de agua subterránea por empresas agro-exportadoras en el Valle del Ica, Peru*. (Msc thesis). Wageningen University, The Netherlands.

Charbeneau, R. J., & Kreitler, C. W. (2011). Management issues for the Edwards aquifer, Texas (USA). In A. N. Findikakis & K. Sato (Eds.), *Groundwater management practices* (pp. 149–156). Boca Raton, FL: CRC Press.

Closas, A., & Molle, F. (2018). Chronicle of a demise foretold: State vs. local groundwater regulation in Texas and the high plain aquifer system. *Water Alternatives*, *11*(3), 511–532.

Cullet, P. (2012). Groundwater—Towards a new legal and institutional framework. In P. Cullet, S. Paranjape, H. Thakkar, M. S. Vani, K. J. Joy, & M. K. Ramesh (Eds.), *Water conflicts in India—Towards a new legal and institutional framework* (pp. 58–71). Pune, India: Forum for Policy Dialogue on Water Conflicts in India.

Custodio, E. (2002). Aquifer overexploitation: What does it mean? *Hydrogeology Journal*, *10*, 254–277.

de Châtel, F. (2014). The role of drought and climate change in the Syrian uprising: Untangling the triggers of the revolution. *Middle Eastern Studies*, *50*(4), 521–535.

Debaere, P., Richter, B. D., Davis, K. F., Duvall, M. S., Gephart, J. A., O'Bannon, C. E., … Smith, T. W. (2014). Water markets as a response to scarcity. *Water Policy*, *16*, 625–649.

Del Vecchio, K. (2013). *Une politique contractuelle sans contrôle ? La régulation des ressources en eau souterraine dans la plaine du Saiss au Maroc* (Mémoire de Master 2). Université Lumière Lyon 2, Sciences Po Lyon.

Dworak, T., Schmidt, G., De Stefano, L., Palacios, E. & Berglund, M. 2010. *Background paper to the conference: Application of EU water-related policies at farm level*. 28–29 September 2010, Louvain-la-Neuve (Belgium).

El Arabi, N.E. (2012). *The legal and institutional framework for coastal aquifers in Egypt, management of coastal aquifers and groundwater, assessment of the legal, institutional and policy aspects of coastal aquifer management in Egypt*. Paris: UNESCO.

Endo, T. (2015). Groundwater management: A search for better policy combinations. *Water Policy*, *17*(2015), 332–348.

FAO. (2016). *Global diagnostic on groundwater governance*. Rome, Italy: Author.

FAO. (2018). *The benefits and risks of solar powered irrigation—A global overview*. Rome, Italy: Author.

Foster, S., Tuinhoff, A., Kemper, K., Garduño, H., & Nanni, M. (2006). *Characterization of groundwater systems—Key concepts and frequent misconceptions, sustainable groundwater management—Concepts and tools, GWMATE*. Washington, DC: The World Bank.

Fragaszy, S., & McDonnell, R. (2016). *Oasis at a crossroads: Agriculture and groundwater in Liwa, United Arab Emirates*. IWMI/USAID Project Report No.15.

Giordano, M., & Villholth, K. G. (Eds.). (2007). *In the agricultural groundwater revolution: opportunities and threats to development*. Wallingford, England: CAB International.

Grafton, R. Q., Williams, J., Perry, C. J., Molle, F., Ringler, C., Steduto, P., … Allen, R. (2018). Paradox of irrigation efficiency and the global water crisis. *Science*, *361*(6404), 748–750.

Grönwall, J. T. (2008). *Access to water—Rights, obligations and the Bangalore situation*, (PhD Thesis). Linköping, Sweden: Department of Water and Environmental Studies, Linköping University.

Hamdane, A. (2014). *La gestion des ressources en eau souterraines (nappes et aquifères) comme biens communs: Cas de la Tunisie*. SCET-Tunisie, Tunisia: Synthèse régionale sur l'approche économique de la gestion de la demande en eau en Méditerranée.

Hamdane, A. (2015). *Le contrôle de l'utilisation des eaux souterraines et la gestion participative des nappes*. Report to FAO. Tunis, Tunisia: DGGREE.

Hamdane, A. (2019). Tunisia. In F., Molle, C. Sanchis-Ibor, & L. Avella. (Eds.), *Irrigation in the Mediterranean: Technologies, Institutions and policies. Global issues in water policy series* (pp. 15–50). Switzerland: Springer.

Hoogesteger, J. (2017). An elite technology? Drip irrigation, agro-export and agricultural policies in Guanajuato, Mexico. In Venot, J.-P., Kuper, M., & Zwarteveen, M. (Eds.), *Drip Irrigation for Agriculture: Untold Stories of Efficiency, Innovation and development* (pp. 151–166). Oxon, UK: Routledge.

Hoogesteger, J. (2018). The ostrich politics of groundwater development and neoliberal regulation in Mexico. *Water Alternatives*, *11*(3), 552–571.

Jakeman, A. J., Barreteau, O., Hunt, R. J., Rinaudo, J.-D., & Ross, A. (Eds.). (2016). *Integrated groundwater management. Concepts, approaches and challenges*. Switzerland: Springer.

James, I. (2015, December 10). The costs of Peru's farming boom. *The Desert Sun*. Retrieved from http://www.desertsun.com/story/news/environment/2015/12/10/costs-perus-farming-boom/76605530/

Jørgensen, L. F., Villholth, K. G., & Refsgaard, J. C. (2016). Groundwater management and protection in Denmark: A review of pre-conditions, advances and challenges. *International Journal of Water Resources Development*, *33*(6), 868–889.

Kark, R., & Frantzman, S. (2012). Empire, state and the Bedouin of the Middle East, past and present: A comparative study of land and settlement policies. *Middle Eastern Studies*, *48*(4), 487–510.

Langridge, R., & Ansell, C. (2018). Comparative analysis of institutions to govern the groundwater commons in California. *Water Alternatives*, *11*(3), 481–510.

Lipson, A. J. (1978). *Efficient water use in California: the evolution of groundwater management in Southern California, R-2387/2-CSA/RF*. Santa Monica, CA: Rand.

López-Gunn, E. (2003). The role of collective action in water governance: A comparative study of groundwater user associations in La Mancha aquifers in Spain. *Water International*, *28*(3), 367–378.

López-Gunn, E. (2009). Agua Para todos: A new regionalist hydraulic paradigm in Spain. *Water Alternatives*, *2*(3), 370–394.

López-Gunn, E., & Martínez-Cortina, L. (2006). Is self-regulation a myth? Case study on Spanish groundwater user associations and the role of higher-level authorities. *Hydrogeology Journal*, *14*(3), 361–375.

Mao, K., & Zhang, Q. (2018). Dilemmas of state-led environmental conservation in China: Environmental target enforcement and public participation in Minqin County. *Society & Natural Resources*, *31*(5), 615–631.

Margat, J., & van der Gun, J. (2013). *Groundwater around the world. A geographic synopsis*. Leiden: CRC Press, Taylor & Francis Group.

Martínez-Santos, P., De Stefano, L., Llamas, M. R., & Martínez-Alfaro, P. E. (2008). Wetland restoration in the Mancha occidental aquifer, Spain: A critical perspective on water, agricultural and environmental policies. *Restoration Ecology*, *16*(3), 511–521.

Mirnezami, S. J., Bagheri, A., & Maleki, A. (2018). Inaction of society on the drawdown of groundwater resources: A case study of Rafsanjan plain in Iran. *Water Alternatives*, *11*(3), 725–748.

Molle, F., & Closas, A. (2017). *Groundwater governance: A synthesis. IWMI project report no.6, groundwater governance in the Arab world*. Cairo, Egypt: USAID, IWMI. Retrieved from http://gw-mena.iwmi.org/outputs/

Molle, F., & Closas, A. (2019). Co-management of groundwater: A review. *WIREs: Water* (forthcoming).

Molle, F., López-Gunn, E., & van Steenbergen, F. (2018). Local and national politics of groundwater overexploitation. *Water Alternatives*, *11*(3), 445–457.

Molle, F., & Sanchis-Ibor, C. (2019). Irrigation policies in the Mediterranean: Trends and challenges. In F. Molle, C. Ibor Sanchez, & L. Avella (Eds.), *Irrigation in the Mediterranean: Technologies Institutions and policies. Global issues in Water Policy Series* (pp. 279–314). Switzerland: Springer.

Molle, F., & Tanouti, O. (2017). *Analyse des pratiques et stratégies des usagers de l'eau dans la Plaine du Haouz, bassin du Tensift*. Rapport 2.6 Projet ANR Amethyst. Unpublished report.

Molle, F., & Wester, P. (2009). River basin trajectories: An inquiry into changing waterscapes. In F. Molle & P. Wester (Eds.), *River basins trajectories: Societies, environments and development* (pp. 1–19). Wallingford, England and Cambridge, MA: CABI.

Movik, S., & de Jong, F. (2011). License to control: Implications of introducing administrative water use rights in South Africa. *Law, Environment and Development Journal*, *7*(2), 68–78.

Mukherji, A. (2006). Political ecology of groundwater: The contrasting case of water-abundant West Bengal and water-scarce Gujarat, India. *Hydrogeology Journal*, *14*(3), 392–406.

Mukherji, A., Shah, T., & Giordano, M. (2012). *Managing energy-irrigation Nexus in India: A typology of state interventions. Water Policy Research Highlight No. 36*. Colombo, Sri lanka: IWMI-Tata.

Nabavi, E. (2018). Failed policies, falling aquifers: Unpacking groundwater overabstraction in Iran. *Water Alternatives*, *11*(3), 699–724.

Nassif, M.H. (2016). Groundwater governance in central Bekaa, Lebanon. IWMI project report, groundwater governance in the Arab World—Taking stock and addressing challenges. Report No.9. IWMI.

OECD. (2015). *Drying wells, rising stakes. Towards sustainable agricultural groundwater use OECD Studies on Water* (). Paris, France: Author.

Ostrom, E. (2000). Decentralization and development: The new panacea. In K. Dowding, J. Hughes, & H. Margetts (Eds.), *Challenges to democracy: Ideas, involvement and institutions* (pp. 237–256). New York, NY: Palgrave.

Özerol, G., & Bressers, H. (2015). Scalar alignment and sustainable water governance: The case of irrigated agriculture in Turkey. *Environmental Science & Policy*, *45*, 1–10.

Phansalkar, S., & Kher, V. (2006). A decade of the Maharashtra groundwater legislation: Analysis of the implementation process. *Law, Environment and Development Journal*, *2*(1), 67–83.

Pierre, J. B., & Peters, G. (Eds.). (2000). *Governance, politics, and the state*. Basingstoke, England: Macmillan.

Pretty, J., & Ward, H. (2001). Social capital and the environment. *World Development*, *29*(2), 209–227.

Qureshi, A. S., McCornick, P. G., Sarwar, A., & Sharma, B. S. (2010). Challenges and prospects of sustainable groundwater management in the Indus Basin, Pakistan. *Water Resources Management*, *24*, 1551–1569.

RedAgricola (2016). *Desde aguas abajo: La batalla del agua de Copiapó*. Retrieved from www.redagricola.com/reportajes/agua/la-batalla-del-agua-de-copiapo

Reis, N. (2014). Coyotes, concessions and construction companies. Illegal water markets and legally constructed water scarcity in Central Mexico. *Water Alternatives*, *7*(3), 542–560.

Richey, A. S., Thomas, B. F., Lo, M. H., Reager, J. T., Famigletti, J. S., Voss, K., … Rodell, M. (2015). Quantifying renewable groundwater stress with GRACE. *Water Resources Research*, *51*(7), 5217–5238.

Schlager, E. (2007). Community management of groundwater. In M. Giordano & K. G. Villholth (Eds.), *The agricultural groundwater revolution. Opportunities and threats to development* (pp. 131–152). Wallingford, England: CABI.

Shah, T. (2014). *Groundwater governance and irrigated agriculture*. Stockholm: GWP.

Shah, T., Mehta, M., Sankar, G., & Mondal, S. (2012). *Organizational reform in Gujarat's electricity utility: Lessons for revitalizing a bureaucratic service delivery agency* (Vol. 6). Colombo, Sri Lanka: IWMI-TATA.

Siebert, S., Burke, J., Faures, J. M., Frenken, K., Hoogeveen, J., Doll, P., & Portmann, F. T. (2010). Groundwater use for irrigation—A global inventory. *Hydrology and Earth Systems Science*, *14*, 1863–1880.

Steed, B. C. (2010). *Natural forces, human choices: An over time study of responses to biophysical and human induced disturbance in Los Angeles California groundwater governance*. (PhD thesis). Indiana University.

Tetreault, D., & McCulligh, C. (2018). Water grabbing via institutionalised corruption in Zacatecas, Mexico. *Water Alternatives*, *11*(3), 572–591.

The India Express (2014), February 5. "Non-populist" irrigation bill shelved for fear of irking farmers. *The India Express*.

Turral, H., & Fullagar, I. (2007). Institutional directions in groundwater management in Australia. In M. Giordano & K. Villholth (Eds.), *The agricultural groundwater revolution: Opportunities and threats to development* (pp. 320–361). Wallingford, England: CABI.

Van Steenbergen, F., Bamaga, O. A., & Al-Weshali, A. M. (2012). *Groundwater security in Yemen: Role and responsibilities of local communities in conserving groundwater*. Sanaa, Yemen: Embassy of the Kingdom of the Netherlands, Water and Environment Centre, MetaMeta Research.

Venot, J. P., Molle, F., & Hassan, Y. (2007). Irrigated agriculture, water pricing and water savings in the lower Jordan River basin (in Jordan). In *Research report 18, comprehensive assessment of water Management in Agriculture, Colombo, Sri Lanka*. Colombo, Sri Lanka: International Water Management Institute (IWMI).

Villholth, K., Lopez-Gunn, E., Conti, K., Garrido, A., & van der Gun, J. (Eds.). (2017). *Advances in groundwater governance*. Leiden, The Netherlands: Balkema.

Water Corporation. (2013). *Groundwater replenishment scheme—Communications strategy 2013–2016 as at august 2013*. Perth, Australia: Author.

Water Governance Facility. (2013). *Groundwater governance in India: Stumbling blocks for law and compliance*. WGF Report No. 3, Stockholm, Sweden: SIWI.

Wijnen, M., Augeard, B., Hiller, B., Ward, C., & Huntjens, P. (2012). *Managing the invisible: Understanding and improving groundwater governance, water papers*. Washington, DC: The World Bank.

Wilder, M. (2008). *Promises under construction: The evolving paradigm for water governance and the case of Northern Mexico*. Presentation at the Rosenberg Forum on International Water Policy, Zaragoza, Spain, June 24–27, 2008.

WIN. (2011). *Corruption risks and governance challenges in the irrigation sector: What are priorities for water integrity*. WIN Thematic Paper. Berlin, Germany: Author.

Wolfe, M. (2013). The historical dynamics of Mexico's groundwater crisis in La Laguna: Knowledge, resources, and profit, 1930s-1960s. *Mexican Studies/Estudios Mexicanos*, *29*(1), 3–35.

World Bank. (2007). *Making the most of scarcity: Accountability for better water management in the Middle East and North Africa*. Washington DC: Author.

World Bank. (2009). *Poverty and Social Impact Analysis of Groundwater over-exploitation in Mexico, Latin America and Caribbean region*. Washington DC: Author.

Yates, K., Greening, H., & Morrisson, G. (Eds.) (2011). Integrating science and resource management in Tampa Bay, Florida, *US Geological Survey Circular 1384*.

Zaman, A. (2015). *The Barind multipurpose development authority—A model for financial sustainability*. PPT presentation, 7th world water forum, April 12–17, Doegu, Korea.

Zeitoun, M., Allan, T., al Aulaqi, N., Jabarin, A., & Laamrani, H. (2012). Water demand management in Yemen and Jordan: Addressing power and interests. *The Geographical Journal*, *178*(1), 54–66.

Zellmer, S. (2008). Boom and bust on the Great Plains: déjà vu all over again. *Creighton Law Review*, *41*, 385–422.

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