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Caring for Groundwater: How Care Can Expand and Transform Groundwater Governance

RESEARCH ARTICLE

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ABSTRACT

Efforts to measure and regulate groundwaters and irrigators are notoriously ineffective. The starting point of this article, therefore, is to question the continued faith in techno-managerial solutions to groundwater depletion. We discuss the potential of the conceptual vocabulary of 'care' to complement, refresh and expand ways of talking about and doing groundwater governance. Mobilizing a diverse range of examples from places where pressures on aquifers are particularly acute, we do this by exploring what care entails in everyday practices of groundwater use and management. We show that foregrounding care nuances and sometimes challenges stories of users unavoidably depleting aquifers when given the chance and means to do so. Irrigators may display concern about the longer-term sustainability of the aquifers on which their livelihoods depend, even when their own pumping practices are unsustainable. In spite of pressures to intensify and individualize, farmers sometimes do hold on to or creatively develop collective rules to fairly share groundwater and use it sustainably, complementing strategies to make do with what is available with investments in conservation and recharge. Attention to care, moreover, highlights the ongoing processes of tinkering that governing groundwater always entails. The ability to tinker hinges on intimate and often embodied knowledge of a watery place. Accepting the care involved in governing groundwater, our analysis therefore concludes, prompts a re-consideration of what is and who has water expertise, with important implications for the role of 'outside' experts. More than a new theory, we propose embracing care as an analytical sensibility, with the study of practices of care serving as one promising way to widen the conceptual and political space for understanding and doing human-groundwater relations.

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INTRODUCTION

Groundwater overexploitation is a worldwide phenomenon with worrying consequences for social justice and the environment (Giordano, 2009; United Nations, 2022). While there are many definitions, in agriculture, which is the focus of this paper, over-exploitation usually refers to (some) farmers using so much water for irrigating their crops that other users, including future ones, become compromised (cf. Molle, López-Gunn, van Steenbergen, 2018). In addition to identifying often technologically advanced ways to increase supply (including forms of artificial recharge, (transbasin) transfers of surface water, re-use of treated wastewater or desalinization), planned efforts to halt depletion mostly focus on improving the governance of groundwater. Research in support of this goal mostly focuses on the identification, dissemination, or testing of instruments (or tools) to measure, account for and regulate the use and distribution of groundwater. As the editorial introduction to this Special Issue so nicely summarizes, governance actors' (mostly public agencies) mobilize (a combination of) prohibitions, licenses, bans, sanctions, subsidies, or water prices to control groundwater behaviors (Bruns and Meinzen-Dick, 2024). Such attempts to make groundwater amenable to institutional, technical, and economic forms of control[1] tend to be couched in a rather techno-managerial language. A 'tragedy of the commons' kind of reasoning pervades the literature: the dominant storyline is that individual irrigators will use more water than is sustainable unless stopped from doing so by outside measures (Zwarteveen et al., 2021).

Partly informed by recent reviews that conclude that, to date, most government efforts to govern groundwater are ineffective (Molle and Closas, 2020; Closas and Villholth, 2020), this paper's starting proposition is that governing groundwater is about more than techno-managerial forms of controlling capricious waters and greedy irrigators. Importantly, or so is our argument, it is also about care. After all, without attentive forms of care, that is: without actively investing in preservation, sustenance, conservation, or upkeep, aquifers will get depleted. Similarly, to prevent water infrastructures from crumbling and breaking down they require regular maintenance, occasional repair, and cautious handling and use. Also, the fair sharing of available waters across people and places requires something akin to care: care for each other, for relations, and for community. This paper sets out to contribute to identifying and recognizing what care in groundwater entails by complementing and refreshing currently dominant techno-managerial languages of control with a more care-full and practice-based vocabulary.

We do this by discussing diverse forms of caring for groundwater that we have collected through an extensive collaborative action-research project that documented grassroots initiatives of people who organize around groundwater in parts of the world – Algeria, Morocco, Peru, Zimbabwe, and India – where pressures on aquifers are particularly acute.[2] More in-depth details of the initiatives discussed here can be found in previously published articles (Chitata et al., 2021 and 2022; Mayaux et al., 2022; Saidani et al., 2022; Bhat et al, 2023; Bossenbroek et al., 2023; Cleaver et al., 2023; Kuper et al., 2023; Leonardelli et al., 2023; Saidani et al., 2023). These articles document diverse experiences of individuals or communities consciously holding on to principles of frugality, solidarity or sharing, enacting those through wisely crafted institutions or infrastructures. Our analysis of these experiences shows that exploring groundwater governance as care not only expands the range of actors, behaviors, skills, and knowledges involved in using and sharing groundwater but also prompts a re-thinking of what good groundwater governance is or should be, and how it can be supported by outside experts.

The rest of the paper is divided as follows. First, we trace the legacy of scholarship on care, situating our intervention within a feminist transformational agenda. Second, we explore the possible meanings of collective care, frugality, and sharing in groundwater that the different case studies present. Finally, we show how foregrounding care draws attention to the importance of processes of tinkering and bricolage when solving groundwater problems. We and with a short conclusion, among others highlighting how care transforms the relations and collaborations between outside experts and communities of groundwater users and managers.

CARE-CARING

A SHORT GENEALOGY OF SCHOLARSHIP ON CARE

Foregrounding and thematizing care when understanding realities, relations, and behaviors is part of a long tradition of scholarship that is seeing a revival in the last decades (see Mol, 2008; Mol et al., 2010a; de la Bellacasa, 2011; Van Dooren, 2014; de la Bellacasa 2017; Harcourt, 2023). The term care can have different meanings and is used for a wide array of societal and theoretical objectives. Here, we present a brief overview (see also Lindén and Lydahl, 2021; Mol and Hardon, 2021; Harcourt, 2023).

Attention to care was inspired by feminist concern about the lack of recognition of care work, much of which is done by, associated with or attributed to women (Martin, Myers,

and Viseu, 2015). Feminist scholars' efforts to remedy this not only consisted in highlighting the importance of relations of reproduction and indeed care in making families, societies and economies function, but also showed that economics and politics happen in the private, domestic sphere as well. This prompted a re-thinking and nuancing of hitherto dominant understandings of social behaviour. It for instance suggested that politics need not just consist of clashing interests and disputes, as people can and do also relate to each other in more affectionate and caring ways. It also led to the development of care ethics, as an alternative to rule ethics (Tronto 2013; Mol and Hardon, 2021). As Mol and Hardon explain: "Care ethics does not operate through weighing the relative value of general principles but by negotiating specific, situated concerns" (Mol and Hardon, 2021, p. 187).

The verb 'to care' draws together the emotional engagement of being concerned and the practical engagement of contributing to restoring, sustaining, or improving something (Mol and Hardon, 2021, p. 185). Even though the term is associated with something positive and good, what 'good' means in a particular situation is never self-evident, nor is it automatically agreed upon by those concerned (Mol and Hardon, 2021). It is therefore important to remain alert to how abilities and resources needed to either care or be cared for are unevenly distributed, and also to how not all have the same power to define what proper or good care is or should be (cf. Martin, Myers, and Viseu, 2015, p. 636).

Many early studies on care and the ethics of care were done in places where care is more or less professionalized, such as in hospitals and (nursing) homes. In more recent years, also scholars interested in studying the ethics and politics of environmental problems have embraced languages of care. De la Bellacasa for instance proposed using the term 'care' in relation to soil ecologies (de la Bellacasa 2011, 2017), while Ureta mobilized care to shed light on how people manage the waste generated by a copper mine (Ureta, 2016). Scholars studying farming have long recognized that farmers also use 'care' terms to make sense of their behaviors (see for instance van der Ploeg, 2023). More in-depth explorations of what it means to understand farming in terms of care have seen the light (Mol et al, 2010a; Singleton, 2010). Water governance scholars have likewise started experimenting with languages of care. They noted how indigenous people foreground relations of mutuality and reciprocity when engaging with water, considering water bodies (aquifers, lakes, or rivers) as living entities that demand respectful consideration (Weir, 2009; Wilson and Inkster, 2018; Verzijl, 2020; Martuwarra RiverOfLife, 2021). This resonates with studies that show how people mobilize notions of justice and reciprocity when claiming water (Beresford et al. 2023). In our own recent work, we have mobilized 'care' both to help decentre the term 'control' in water policies and scholarship, and to emphasize that water infrastructures and institutions are often rather fragile and temporary. We suggested that 'care' helps recognize the adaptive and contingent character of much that goes on in water management and governance, and showed how foregrounding care creates appreciation for the hard and persistent work needed to maintain infrastructures and institutions (Kemerink-Seyoum et al., 2019; Domínguez-Guzmán et al, 2022; Archidiacono et al., 2024).

Beyond drawing attention to hitherto neglected or undervalued activities, emotions, or relations, scholarly work on care has been important in critically re-thinking the pervasive oppositional dichotomies – between nature and culture; men and women; private and public; modernity and tradition – that structure popular as well as scientific ways of making sense of the world. By not automatically opposing care to either control, rationality, or technology, this scholarship helps acknowledge that care can also be rational or cold, while 'cold' technologies can help provide 'warm' forms of care (Mol, et al., 2010; Mol and Hardon, 2021). Care can be part of, but also often eludes or overflows control; it tends to involve more than what can be codified or pinned down in generalizable principles or rules (Pols, 2006; Mol, 2008; Mol, et al., 2010; de la Bellacasa, 2015; Mol and Hardon, 2021).

OUR APPROACH TO STUDYING GROUNDWATER CARE

Inspired by Actor-Network Theory (ANT), in this paper, we are interested in tentatively exploring what care/caring may mean in a range of places where groundwater is used and shared (cf. Mol et al, 2010a). We do not use care as a new container term to denote a range of activities or moral beliefs around groundwater, nor do we propose care as a new grand explanatory concept to explain social groundwater dynamics. Neither are we interested in prescribing what good care is, as a way of normatively distinguishing care from not-care (or good from bad care) in groundwater. Instead, we note and follow those activities or behaviours that fit the broad characterisation of caring that we gave above (caring "draws together the emotional engagement of being concerned and the practical engagement of contributing to restoring, sustaining, or improving something", Mol and Hardon, 2021, p. 185) to explore and discuss the possible meanings care can have in relation to groundwater (cf. Mol et al., 2010a). We mobilize care, in other words, as an analytical sensibility; a combination of alertness to how people's dealings with

groundwater can be interpreted as forms of care, with curiosity about what such an interpretation can help make visible or imagine.

We do this by documenting *practices* of water care, always situating these in the terms and contexts from which they emerge. Through our focus on *practices*, we shift attention from how realities are represented to how they are done (Domínguez-Guzmán et al., 2023). In (groundwater) practices, the social, the material (or natural), and the semiotic are intertwined (Law and Mol, 2020). This also means that hydrogeological information about aquifers or groundwater dynamics cannot be taken as the 'natural' foundation upon which differences emerge as cultural or social. Taking inspiration from Haraway's idea of many naturecultures (Haraway, 2008), we therefore consider the relation between knowing, using, and governing groundwater as an entangled and recursive process, with the behavior of groundwater itself co-shaping how it is used and governed. This comes with an explicit acknowledgment that researchers are situated in, attached and connected to what is studied. (Haraway, 2008; Stengers, 2018; Law, 2021). This more explicit navigation of the entanglements between science, society, and politics makes the answer to the question of what is, or how to do, good groundwater governance more pragmatic, political, and modest.

CARE-FUL(L) GROUNDWATER GOVERNANCE: BEYOND NARROW SELF-INTEREST

The tools for governing groundwater that scholarly and policy texts identify mainly consist of ways to reduce the quantities of water that farmers extract from the aquifer, (Bruns and Meinzen-Dick, this SI). Perhaps inadvertently, this focus on the need to control extraction makes farmers appear (or indeed enacts them) as self-interested individuals who will inevitably pump more water than is allowed or sustainable if given the opportunity or means to do so. Foregrounding care when studying groundwater helps appreciate that groundwater users are not always, or not just, motivated by self-interest. In this section we present examples from our case studies, to illustrate: (a) That farmers can be worried or concerned about the depletion of the aquifers that they depend on, even when they themselves contribute to that depletion; (b) That there are farmers – sometimes helped by others – who voluntarily restrict their use of groundwater, either to share available quantities with others or to save some of it for future use; (c) That caring for groundwater inevitably entails (the crafting of rules for) sharing it, sometimes turning into processes of commoning (Gibson-Graham, 2016; Bollier, 2020; Bossenbroek et al., 2023).

CARE AS CONCERN

At first sight, the cases that we studied appear to support the widespread assumption of farmers' groundwater greed. In almost all our study areas, the depletion of aquifers can be linked to farmers digging ever more and ever deeper wells. Often going against formal regulations, farmers mine groundwater reserves or pump more water than is recharged or sustainable. Yet, is this because farmers are greedy, or primarily motivated by individual self-interest as many scholarly and policy texts on groundwater imply?

Our case studies suggest other possible ways of explaining what is happening. Very few of the smallholder farmers with whom we engaged in the different countries were indifferent to the gradual decline of groundwater availability and quality. Even those who over-extracted expressed awareness and concern about it. For instance, in one village in Maharashtra (Ravangaon), those irrigators present at a workshop to discuss our study findings were quick to acknowledge that their current irrigation practices are unsustainable. Many agreed to the need to transition away from the monocropping of sugarcane, the most water-demanding crop. They accepted that a diversification of cropping baskets would be wise. They also displayed much interest in better understanding their aquifers and in finding ways to better align their irrigation and cropping patterns with the longer-term sustainability of soils and waters. Yet, farmers' political and financial dependence on sugar factory owners, makes it almost impossible for them to grow anything else than sugarcane (Tozzi et al., 2022; Bhat et al, 2023).

Likewise, in the deserts of Peru, Algeria, and Morocco, farmers were deeply worried about dwindling water availability (Domínguez-Guzmán et al., 2017; Saidani et al., 2023; Bossenbroek et al., 2023), even when their own pumping practices were partly to blame. Many of them continue over-extracting not because of ignorance or greed, but because they operate in a political-economic environment that pushes them to intensify their production or shift to higher-value export crops, often prompting them to use more groundwater than is ecologically wise or just. Their stories suggest that in an economic context that externalizes the value of groundwater, over-extraction is the almost inevitable effect of planned policy efforts to intensify and modernize agriculture.

Recognizing this expands the search for ways to govern groundwater beyond efforts to control farmers' groundwater greed to include critical engagement with models and policies of agricultural development that rely for their realization on quantities of groundwater that may not be available.[3] The experiences and stories that we gathered in our case study areas suggest that there are farmers who are eager to support such engagements.

CARE AS FRUGALITY AND RE-PLENISHMENT

The fact that markets – together with taxes, pricing regimes, and subsidy schemes – actively pressure farmers to pump ever more water makes it all the more remarkable that there are irrigators who circumvent or resist such pressures by translating their concern for the sustainability of aquifers into practical conservation and protection efforts. Rather than rejecting or resisting 'modernity' altogether or withdrawing from the market, these are farmers who creatively combine new market and technological opportunities with logics of care, for each other and the watery environment.

Hence, in the oases in the M'Zab valley in Algeria, farmers insist on making do with the water that is available. They adhere to a system that can be called circular: it consists of collecting and then diverting the water from rare flash floods as well as runoff to the ancient oases through channels. Part of the derived water is used to irrigate the date palm gardens on the basis of proportional water rights, replenishing the rootzone but also (partly) the aquifer. The other part of the water is routed to recharge wells or recharge reservoirs. Some of these wells have a dual function: during flood periods, they allow to recharge the water table, while during the dry period, the water stored in the underground aquifer can be pumped for irrigation. Wells are not just used for irrigation, but also for watering livestock and domestic water uses. In the Beni Isguen oasis, for instance, 61 of the 300 wells in the community are specifically designed to be also suitable for recharge purposes. Storing floodwater in underground aquifers potentially ensures the availability of groundwater for about three years. Even when under pressure to intensify their farming enterprises, there are groups of farmers who invest considerable effort in preserving and holding on to this circular logic. They value it precisely because it is more equitable and sustainable. The hard work involved in storing limited quantities of water, in turn, encourages frugal use of this water (Saidani et al., 2023).

Also, on the desert coast of Peru, smallholders hold on to an ancient logic of groundwater care. They dismiss the advice of the government to use pumps and drip irrigation for watering their mango trees – trees that produce the mangos that can be found in Dutch or USA supermarkets – and instead prefer using pozas, a traditional irrigation method consisting of small ponds that store both canal and rainwater. Poza basins – either diked or excavated – capture water in times of abundance to prolong soil moisture availability and maintain groundwater levels after seasonal rains. Pozas are an age-old technology; early 16th-century chronicles already make mention of them. Smallholder farmers stay with these pozas because they consider them a more sustainable and reliable, or indeed care-full, way of making use of available waters. They use their pozas not just to grow mangos, but also for subsistence crops (Domínguez-Guzmán et al., 2017).

Groundwater care in Algeria and Peru is part of sometimes ritualized forms of respect for water and nature more widely and is embedded in cosmologies that emphasize mutuality and conviviality. Caring happens through sophisticated institutions and infrastructural designs, that irrigators continuously adapt to suit new circumstances. In some of the other cases we studied (Saidani et al., 2023; Bossenbroek et al., 2023), farmers (sometimes helped by outside experts or local authorities) only started inventing and developing forms of groundwater care after they became worried about the decline of groundwater tables. While inspired by existing moral-ecological rationalities, this entailed the crafting of new institutions and infrastructures in processes of commoning (Bollier, 2020).

In Randullabad, a community (of around 2000 people) in Maharashtra for instance, village members engaged in prolonged discussions and collective efforts to protect the aquifers on which their livelihoods depend. In the 1990s, they noted how the over-extraction of groundwater by deep borewells led to a gradual decline in the volume of water contained in shallow aquifers, the same aquifers on which they depend for drinking water. Perennial village wells turned seasonal and started running dry in drought years, threatening the community's drinking water security. In addition, villagers noticed how, in surrounding communities, a sharp increase in borewells caused problems of equity and sustainability. The village council therefore called in BAIF, a Development Research Foundation, and ACWADAM, an NGO dedicated to promoting participatory forms of groundwater management, to help in protecting their groundwater. With ACWADAM's guidance, community members mapped their groundwater sources as a starting point for managing these more sustainably. In 2000, the governing council of Randullabad village decided to put a ban on bore wells in the village. Instead of continuously trying to increase supply to meet growing demand, community members started jointly planning their agricultural activities according to the water available in the aquifer – which is a shallow unconfined aquifer system with annual recharge cycles. With the help of ACWADAM, the village also intensified and improved groundwater recharge (Saidani et al., 2023). Groundwater care in Randullabad did not happen automatically or spontaneously; it had to be nurtured and crafted and relied on outside support.

Another version of groundwater care happened in Zimbabwe, and was done by prospectors (diviners). These local groundwater experts consider their water-divining job not just as a means to earn a living, but also as

providing an important societal service: they want to use their intimate knowledge of the aquifer to help safeguard its sustainable and equitable use. They do this among others by actively monitoring the drilling of boreholes by commercial companies, making sure that these do not drill deeper than the recommended depth. Prospectors even go as far as not disclosing the depth of different boreholes, to avoid those drilling new wells digging deeper than their neighbors. As one of the prospectors explained: "We do not tell this information to private borehole owners, lest it will be used for ill intent – to disadvantage others – as some will think of deepening their boreholes unnecessarily. If they drill deeper, it's like building ten houses when you can only stay in one house; that is, wasting a resource and creating artificial shortage." (Cleaver et al., 2023: 180).

These are stories that suggest that people's engagements with groundwater can be inspired by logics of frugality and indeed care, with strategies to make do with what is available complemented by measures to avoid over-exploitation as well as conscious investments in conservation and recharge. In many of the cases we studied, forms of groundwater care emerged because of people's strong sense of territorial belonging. Caring is indeed connecting, to places, waters, and to other people. Investments in infrastructures – for capturing, accessing, recharging, or distributing water – or in sustenance of the aquifer not just express a pre-existing sense of belonging and connection, but are also important in helping materialize or perform it. Through their financial and labor contributions to maintaining and governing shared water systems, irrigators together with their allies almost literally construct and keep alive their attachments to one another as well as to the aquifers on which they depend.

CARING AND SHARING

It is relatively well documented how new drilling and pumping technologies used to access and extract groundwater often drastically change existing patterns of water use and distribution. Also in our case study areas, many farmers embraced new and easier methods of pumping water. These offer a significant level of individual autonomy and water security to irrigators: as compared to surface irrigation systems, they reduce the need to coordinate with others for the sharing of water. The flip side of this, as some scholars predict, maybe the destruction of existing mechanisms of sharing and caring for water and each other. Shah for instance refers to the gradual replacement of the "irrigation community" by a "scavenging irrigation economy" (Shah, 2011, p. 80).

Yet, the already discussed cases of Randullabad, in Maharashtra, and the studies in the M'Zab Valley in Algeria suggest that the disappearance of irrigation communities is not inevitable. In both cases, collective investments of labor and sometimes of funds in the construction and maintenance of infrastructures to capture and store 'difficult waters' (Saidani et al., 2023) or in the protection and recharge of aquifers help create and cement relations between irrigators, as well as between irrigators and the watery environment. How much people contribute (in terms of labor, or in other forms) often co-determines how much water they are allowed to access and use. Hence, there is often a relation between 'caring' contributions to capturing, storing, and restoring groundwater (e.g., actions to improve water quality, recharge of aquifers) and maintaining infrastructures and technologies on the one hand and 'sharing' on the other. Coward famously called this 'hydraulic property' (Coward, 1986).

Sharing hinges on agreements and rules. In addition to the ban on borewells and adapting crop choices and calendars to water availabilities, the Village Watershed Committee in Randullabad developed a set of protocols for water sharing in a process of negotiation between community members, represented both by the village council and the Village Watershed Committee, and between community members and outside experts. In Beni Isguen in Algeria, rules about how the work of maintenance and recharge as well as irrigation waters are to be shared stem from traditions that are upheld by the Umana Essayl, the customary water stewards who operate as a collective. They work in close collaboration with religious as well as secular authorities. The sharing of responsibilities and waters is also partly anchored in infrastructural designs. The width of the field intakes (kua) for instance expresses water rights in proportion to the number of palm trees in the garden to be irrigated (Saidani et al, 2023). Here, just as in Randullabad, the relation between investment (care) and benefit (share) is nevertheless not strictly calculated. This can be partly explained by how the caring for and sharing of groundwater is embedded in wider social webs of collaboration and exchange within and between households but is also linked to how sharing groundwater always hinges on forms of dealing with contingencies (see below).

Just as in Randullabad, also in the Drâa Valley in Morocco, smallholder farmers only started developing rules for sharing water when realizing that the intensification of farming – here: the growing of watermelons – demanded ever larger quantities of groundwater. They noticed a gradual decline in groundwater levels, something that also started threatening their drinking water security. Some local farmers, as a result, became increasingly critical of outside investors using 'their' aquifer to irrigate new commercial watermelon farms. They started engaging in a process of crafting rules to limit watermelon cultivation, mainly aimed at limiting the pumping by 'outsiders' from

their aquifer. This process of rule-making entailed long and difficult discussions about how to distinguish outsiders from insiders (Bossenbroek et al., 2023).

Where contributing to investments in maintenance or recharge provided a basis for rule-making in Randullabad and the M'Zab Valley, (tribal) identity and territorial belonging were important criteria to determine who can and who cannot access water in the Drâa Valley. These criteria are far from easy, straightforward, or politically innocent. They are also not necessarily just or equitable. In the Drâa Valley, women were for instance not at all involved in the process of rule-making, even though they also have clear interests and needs concerning the use of groundwater (Bossenbroek et al., 2023).

MORE THAN CONTROL: GROUNDWATER GOVERNANCE AS TINKERING CARE

Groundwater governance is often understood in terms of precise measurements and clearly defined and implemented rules the execution of which are properly monitored and accounted for. Yet, the fact that systematic attempts to regulate (the use of) groundwater often fail (Closas and Molle, 2020) suggests that groundwater governance is about more than control. Grappling with the complexities of dynamic real-world groundwater conditions also requires improvisation and experimentation and may involve negotiation, diplomacy, and compromises (Pols, 2006; Mol, 2008; Mol, et al., 2010; de la Bellacasa, 2015; Mol and Hardon, 2021). The wider care literature has proposed the terms tinkering and bricolage to capture this.[4] These are terms that are often used interchangeably. Even though they have slightly different scholarly legacies, both help re-think the classical distinction between non-modern skills and modern forms of (scientific) expertise, by showing that also supposedly modern technologies and institutions rely on in-situ adjustments and hands-on forms of experimentation – those that may involve embodied and experiential forms of knowledge –, while supposedly local wisdom often evolve by creatively borrowing elements from other knowledges, including scientific ones (Cleaver 2012; Benouniche et al., 2014; Verzijl et al., 2023). In water scholarship, the term tinkering is mostly mobilized to emphasize how technologies or institutions change or evolve in time, while bricolage tends to be used to refer to the new improvisational use of existing ideas and tools, something that may also happen when technologies or institutional models travel from one place to another (Benouniche et al., 2014; Cleaver 2012; Kemerink-Seyoum et al., 2019; Leonardelli et al., 2023).

Attention to tinkering and bricolage helps recognize that, in practice, governing groundwater always requires the flexibility to deal with changes – in availabilities, qualities, needs, contexts – that are often difficult to precisely predict and anticipate. The fact that people tinker does not in itself mean that they care, but effective groundwater care always hinges on the ability of those involved to tinker. In the Algerian Sahara, young farmers for instance had to engage in a continuous process of social and technical tinkering to adjust to contingently changing social relations of owning water and infrastructure. They took over, first informally, the management of state-implemented boreholes of a small-scale irrigation scheme. In a long process of learning to use and share these boreholes, the farmers devised a range of creative institutional and technological adaptations. In the process, they also re-negotiated their relationship with the state, eventually making the strategic decision to continue operating under its umbrella as this allowed them to secure further public investments. They eventually expanded the group to over 180 users, leading to the creation of a second irrigation scheme. These two irrigation associations put in place numerous rules to avoid over-irrigation and make sure that all users are equitably serviced with (just) sufficient quantities (Mayaux et al., 2022).

The need to tinker when caring for groundwater may be prompted by water itself. After all, water is capricious and seldom neatly follows techno-managerial directives. In Pravah, a relatively recent irrigation system (the Purandar system) brings untreated wastewater from the city of Pune to the village. This water makes the intensification of agriculture possible, something that has allowed many women to assume new farming roles. Yet, because of how the Purandar water mixes with groundwater in the shallow aquifer of the village – the source of water for drinking and other domestic uses –, it also forces women to assume new water quality management tasks at household and community levels. After the irrigation system became operational, women farmers started noticing how their animals got ill if they drank directly from the ponds that store the Purandar water. They also experienced how contact with groundwater triggered rashes and sores on their skin. Through their intimate relationship with water, but also by interacting with others (including field officers, doctors, NGO practitioners, and researchers) over water, women gradually learned to look at the color, smell, and taste of water at different water sources, thus developing an understanding of how qualities of groundwater differ depending on source or location. They need this understanding to decide on each specific moment – hence in a mode of tinkering care – which water to use for which purpose, and how to treat it (Leonardelli et al., 2023).

Also engineers or scientists may engage in tinkering forms of care to make water systems work (Domínguez-Guzmán et al., 2022) or to accurately assess aquifer dynamics. A good example of this comes from the Kaveri Delta in Tamil Nadu. Here, the lack of trustworthy groundwater data complicates the task of assessing and predicting groundwater availabilities (Verzijl et al., 2023). Modelers are devising a range of creative ways to deal with this. They, for instance, engage in reverse engineering or trace geological maps based on older documents. They may also launch citizen science campaigns to record characteristics of wells – such as GPS locations, groundwater levels, salinity, soil types, and borehole depths – to help solve the granularity problem and allow the calibration of their models. Interestingly, this means that their models come to rely on locations and often borehole depths that were initially determined by water diviners, who use tools such as lemons, neem sticks, coconuts, rods, and pendulums to predict where to find groundwater. In this way, in the "prediction of what is underneath the earth" – a phrase from early Tamil to indicate what diviners do but also describing the work of modelers – scientific modelling and divining go together, with the first relying on the second (Verzijl et al., 2023).

Appreciating the importance of tinkering care means appreciating that being alert, supple, and versatile – or attuned attentiveness (Mol et al., 2010a) – may be as important as rigorously setting and enforcing pre-defined extraction targets when governing groundwater. The examples suggest that frequent intimate and embodied encounters with aquifers, wells, and pumps help breed such attentiveness (Leonardelli, et al., 2023; Cleaver et al., 2023; Verzijl et al., 2023). Acknowledging that this is so means that other than scientific forms of expertise and skills gain in importance. It also means that the search for generalizable codes, rules, models, tools, or technologies to do groundwater governance needs to be complemented with attentiveness to the processes that are always needed to translate and adapt these to diverse and changing contexts or circumstances. As care scholars have suggested, the flexibility to experiment, improvise, and adapt may indeed form the heart of care – constituting not just its kindness, but also its effectiveness, tenacity, and strength (Mol et al., 2010a).

CONCLUSIONS

In scholarly writings, the overarching focus of efforts to halt or curb groundwater depletion is on methods (or tools) to control the pumping behaviors of individuals. This continued focus on measurement and regulation is surprising, given the overwhelming evidence of groundwater's tendency to escape control. Indeed, it is well established that it is difficult, cumbersome and often expensive to determine and monitor availabilities (Zwarteveen and al, 2021) and that most government efforts to measure and regulate groundwater are not very effective (Molle and Closas, 2020). This paper started, therefore, by questioning the continued faith in techno-managerial interventions that rely on the possibility to measure and regulate both waters and irrigators. We used the rest of the paper to explore the usefulness of the conceptual vocabulary of 'care' to complement, refresh and expand ways of talking about and doing groundwater governance. To do this, we mobilised empirical studies of communities who care for and share their aquifers in India, Algeria, Morocco, Peru and Zimbabwe.

Our exploration first of all nuanced, and sometimes challenged, by now familiar stories of users unavoidably depleting aquifers and managers needing to control their greed. Our studies suggest that farmers' uses and management of groundwater can also be inspired by logics of frugality and solidarity, with strategies to make do with what is available complemented by investments in conservation and recharge. Feeling connected to their waters is an important reason for irrigators to get involved in practical actions to sustain them. The reverse is also true: by jointly engaging in efforts to conserve waters or maintain and repair water infrastructures, irrigators build and strengthen relations between one another. This, in turn, may provide the basis for crafting effective rules for sharing waters.

Political-economic contexts that force farmers to intensify their agricultural production can compromise such efforts, especially when combined with cheap pumping technologies that individualize the access and use of groundwater. Our stories reveal how communities may engage in delicate strategies to side-step capitalist pressures to individualize, intensify and deplete. Rather than straightforward protest or withdrawal, these can take the form of the joint crafting of collective agreements and rules to share waters fairly and sustainably. By providing glimpses into alternative, non-exploitative, realities, these stories fuel inspiration for ways of doing groundwater otherwise. Yet, these experiences of caring and sharing are seldom unequivocally good or innocent: they always entail difficult compromises, and involve sometimes painful decisions about who can, but also about who cannot, make use of waters and infrastructures.

Foregrounding care helps recognize that groundwater governance is not just about measurement and optimization, but also about attuning to always changing circumstances in often meandering processes of tinkering. The ability to tinker hinges on being attentive to dynamic specificities, something that relies on intimate and often embodied knowledge of a watery place. 'Outside' experts interested in improving

how groundwater is used and managed need to appreciate the importance of such knowledge. Doing this comes with suspicion of forms of theorizing or generalizing that place the researcher outside of that what is studied, to instead nurture situated forms of relation-making and carefully crafted attachments when doing research (Haraway, 2008; Stengers, 2018; Law, 2021). Rather than teaching others what to do, 'outside' experts then engage in a process of joint learning about possible ways to understand and deal with groundwater dilemmas. 'Tools' for doing groundwater governance, then, become loose and playful devices to start conversations or processes of joint learning, rather than generic one-size-fits-all solutions to bring about good groundwater governance in a range of places.

Care-ful(l) groundwater research and recommendation importantly implies accepting that 'caring' for groundwater (or indeed good groundwater governance) may mean something else in each case. The different forms and versions of caring we presented here, therefore, must be understood in their own contexts and even in their own terms. How members of Randullabad in Maharashtra express and enact their concern for the longer-term sustainability of the aquifer cannot be straightforwardly transported to Algeria, Peru, or Morocco. This also means that making lessons about good groundwater governance travel from one place to another relies less on commensuration and generalization and more on a modest, situated, and always collaborative search for the translations (Callon, 1984), re-scriptions (Pols, 2015) or coordinations (Mol, 2002) needed to partially connect diverse contextual practices (see Domínguez-Guzmán et al 2017; Domínguez-Guzmán 2019; also see Zwarteveen et al., 2021).

Investigating a broad variety of cases in detail, trying to learn from all of them on their own terms, while juxtaposing them comparatively, does not provide firm facts or normative conclusions (cf. Mol et al., 2010b). In this sense, care/caring is not a theory in itself, nor does it replace existing theories about society-groundwater interactions or groundwater governance. Yet, the vocabulary of care clearly has more affinity with some theories of (groundwater) governance than with others. Care positively resonates, for instance, with theories of 'commoning' (Bollier, 2020), critical institutionalism (Cleaver, 2012) and sociotechnical tinkering (Kemerink-Seyoum, 2019) while it also can build on the idea of hydraulic property (Coward, 1986). Our plea is to use care as an analytical sensibility, with the study of practices of care serving as one promising way to widen the conceptual and political space for understanding and doing human-groundwater relations (Domínguez-Guzmán et al, 2022; Archidiacono et al., 2024). The hope is that doing this will contribute to strengthening and improving groundwater care.

NOTES

1 Some scholars suggest that modern groundwater science's success in making groundwater visible may even have contributed to accelerating extraction (See Kulkarni and Shankar, 2014).

2 See Zwarteveen et al., 2021 for more information about this project, as well as the project website.

3 Examples of doing this from our project are Underhill et al., 2023; Kuper et al., 2023. Others who have critically engaged with models of development that generate groundwater over-exploitation for instance include Bossenbroek et al., 2017; Damonte and Boelens, 2019; Kuper et al, 2017.

4 Other scholars have mobilized other terms – patchworks (e.g. De Coss-Corzo, 2021), calibration (e.g. Chahim, 2022), pressure (e.g. Anand, 2011) – to refer to similar observations of everyday engagements with and in-situ, often improvised, adjustments of (water) infrastructures and institutions.

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The authors have no competing interests to declare.

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