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Proposals to Prevent the Deterioration and Overexploitation of Groundwater

Policy Paper

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Abstract: Pressure on groundwater, particularly by agriculture, is increasing throughout the world. This leads to pumping races from which the poorest farmers are rapidly excluded. This paper presents the solutions proposed, in particular by public authorities, to regulate access to and use of this resource to limit its overexploitation, and analyses their limits. On this basis it draws up a set of strategic recommendations for managers, policy-makers and donors, to overcome the long-term deadlocks faced by policies to increase capacity, and to develop a shared vision of groundwater that preserves the multifunctional character of this resource.

Key words: groundwater, governance, irrigation, agriculture, common patrimony

Research programme: governance, common-pool resource and territories

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Highlights

- Whether quantitatively (overabstraction) or qualitatively (pollution, salinisation), pressure on groundwater is increasing throughout the world. Agriculture accounts for approximately 70% of groundwater abstraction on a global scale, and a growing proportion (currently around 40%) of the world's irrigated areas use this resource.
- Even when they are aware of the risk of resource depletion, farmers find themselves in a pumping race that excludes the poorest of them, and thus deepens economic and social inequalities. It is therefore necessary to take into account the political, economic and social stakes, just as much as the environmental issues, to engage in the search for sustainable management.
- Limiting groundwater use is a necessity. The solutions proposed at the institutional level are generally a combination of: (i) control by the authorities involving regulatory instruments (permits, bans, quotas, zoning, well closures), economic instruments (taxation, subsidies), or indirect measures linking water to other issues (energy, food security), and (ii) mechanisms based on the participation of all users, involving right holders through community-based management schemes.

- These hybrid solutions come up against several stumbling blocks. The first relates to the invisibility of aquifers and to hydrogeological surveys that are insufficient and that are not widely shared or available, when they exist. They also face operational, financial, social, cultural and often political barriers.
- This Policy Paper is based on the work of a number of contributors who met under the auspices of AFD and COSTEA. Their work has led to a series of strategic recommendations for the use of policy-makers (from local to national level) and donors who support these processes or are involved in developing the resource where potential exists, but also for civil society or even users themselves. These recommendations aim to share knowledge and to achieve a collective formulation of the measures to be implemented to stem the overexploitation of groundwater and thus limit the associated consequences.
- Recommendations: 1) build shared knowledge and representations; 2) promote the expression of all actors to bring about solutions; 3) build on user communities to share responsibilities; 4) strengthen the understanding of groundwater as a common patrimony and develop a territorial project.

Introduction

The characteristics of groundwater, such as its temporal and spatial availability or its quality, make it a fundamental resource. The use of groundwater for agriculture, which soared in the second half of the twentieth century, often competes with other uses. From an environmental point of view, groundwater feeds watercourse flows and enables the preservation of wetlands, which are reservoirs of biodiversity. Furthermore, it is increasingly used to supply cities and industries with drinking water. Greater consideration needs to be given to issues related to the management of groundwater in order to protect it and identify factors for its sustainable use.

This Policy Paper aims to contribute to this debate, focusing on agricultural use as a growing proportion of the world's irrigated land area (currently approximately 40%) uses this resource (FAO, 2016). Furthermore, agriculture accounts for about 70% of groundwater abstraction on a global scale (Siebert et al., 2010), making it a strategic sector. In this text, we will focus on the quantitative aspects related to this abstraction; qualitative aspects will only be discussed in conjunction with these quantitative phenomena. Finally, although agricultural use is predominant for many cross-border aquifers, these latter are not directly addressed in this paper: discussions on cross-border aquifers, which are more related to international relations, have little to do with the topics of sectoral allocation of the resource.

We will firstly present an overview of the agricultural use of groundwater throughout the world and underline the related management issues. We will then analyse the solutions that have been proposed, particularly by public authorities, to regulate the access to and use of this resource, while highlighting their limitations and implementation difficulties. On this basis, we will draw up a set of strategic recommendations designed for managers, policy-makers and donors to overcome the long-term deadlocks faced by policies to increase capacities, and to develop a vision of groundwater with all actors that preserves the multifunctional character of this resource.

1. Global Overview and Dynamics of Groundwater Use in Agriculture

1.1 – Increasing Pressure on Groundwater Worldwide

Whether quantitatively (overabstraction) or qualitatively (pollution, salinisation), pressure on groundwater is growing constantly. Its abstraction for agricultural purposes significantly increased from the second half of the twentieth century (Siebert et al., 2010). There is a risk that these pressures will rise due to climate change, especially in semi-arid and arid areas.

In many parts of the world, both North and South, mobilising groundwater has allowed farmers to secure and increase their income. Territories have been developed by harnessing groundwater. The "green revolution" in India, for example, was enabled by the intensive use of groundwater combined with fertilisers, which made it possible to limit situations of famine. On a worldwide scale, global food security depends on international trade in agricultural products, a significant proportion of which is irrigated using groundwater, including crops that are also widely cultivated under rain-fed agriculture, such as cereals (Dalin et al., 2017).

While some regions already use groundwater intensively, its development potential has not been exhausted in many other regions (in particular, a large part of Sub-Saharan Africa), which have not yet been able to invest in it for economic, political or institutional reasons (Cobbing and Hiller, 2019).

The intensive use of groundwater leads to a set of consequences that are more or less perceived and documented. The most perceived are the lowering of water tables, the deterioration of the resource (induced pollution or marine intrusion in coastal aquifers) and land subsidence problems. This abstraction also has impacts at other levels. It can significantly alter the water cycle: water that would naturally have flowed into rivers or wetlands is instead captured and water exchanges between the surface and underground are redistributed. The consequences are particularly problematic in periods of drought, when groundwater naturally has a regulating effect by supporting rivers at low flow or wetlands connected to water tables.

Aquifers can also be the hosts and vectors of various water quality problems. The natural quality of groundwater may therefore be unsuitable for its various uses. Sometimes exploiting groundwater of adequate quality can mobilise contaminants naturally present in a geological layer in contact with the aquifer. Inadequate management of boreholes (in terms of their design or maintenance) linking water tables of different qualities has also been widely documented. Furthermore, qualitative aspects are paramount when active aquifer management techniques are being considered, such as artificial recharge using treated wastewater or surface water. Finally, groundwater pollution should also be considered, whether diffuse (nitrates, pesticides), accidental or due to spatially localised activities. As for soil salinisation, this can be linked to irrigation using low quality water or with poor drainage, which can raise the level of the water table and thus its salt content.

All of these quantitative and qualitative phenomena generate chains of consequences for which there is no known short-term remedy, even if, for example, the source of pollution is eliminated. They occur at several levels, with impacts on users beyond the affected aquifer, such as downstream surface water users or the environment.

The environmental consequences are generally insufficiently taken into account in processes for allocating water resources. De Graaf et al. (2019) estimate that by 2050, in 42% to 79% of basins worldwide, groundwater abstraction will affect ecological flows, defined as the quantity, seasonality and quality of watercourse flows required to sustain freshwater and estuarine ecosystems as well as the needs and well-being of the people who depend on them. They point out that the impacts related to the alteration of surface flows may prove to be far more problematic than the consequences related to the loss of aquifer reserves and increased pumping costs.

The multiple consequences of intensive abstraction also have economic and social impacts, particularly in terms of growing inequalities. Irrigators who cannot afford to invest in deeper wells, or simply to pay the higher cost of water due to lower groundwater levels, can find themselves excluded from access to the resource.

1.2 – Incentives and Motivations: from Local Actors to National Policies

The use of groundwater for agriculture is motivated by multiple factors acting at different levels, the combination of which conditions the intensity of abstraction. Here we will discuss individual dynamics (in relation with networks of local actors), national agricultural and energy policies, and, more broadly, macroeconomic factors (such as agricultural markets). These factors can explain the situation of overexploitation observed in many semi-arid countries, but also the under-utilisation of the resource observed, for example, in much of Sub-Saharan Africa (Cobbing and Hiller, 2019).

For farmers, groundwater abstraction provides a solution to impossible or insufficient access to surface water. From an economic, social, and even political point of view, it can extricate them from the constraints linked to the collective management (community-based or State-governed) of surface water, such as water turns, for example. It can involve purely individual initiatives or collective efforts for the development of new territories. Promoted by States, they are at the origin of agricultural intensification and expansion in certain arid or even desert areas, such as the Biskra region in Algeria (Amichi et al., 2015).

The level of abstraction is closely tied to drilling techniques. In line with technical progress and depending on their capacities and investment methods (individual or collective), farmers are gradually abandoning traditional wells that draw water from alluvial or shallow water tables to tap deeper aquifers. In the case of the Saïss aquifer system (Morocco), access to a deep aquifer by drilling accelerated in the 2000s. This led to the gradual abandonment of traditional wells, which restricted access to the resource due to the geological characteristics of the aquifer and interactions between neighbouring wells (Fofack et al., 2018). In the Niayes region (Senegal), we can still observe exploitation via traditional wells (using pulley systems) concomitantly with motor pumps.

Farmers can also access deep aquifers using advanced drilling techniques. For instance, several hundred-metre-deep boreholes enable the irrigation of the olive groves of the Loma de Úbeda aquifer (Spain). Their high cost means that several families need to join to develop them, with access to water for each in proportion to their investment, recalling the “tubewell companies” of the state of Gujarat (India). Hydrogeological knowledge plays a key role: deep systems are less well known with greater risks of “dry drilling”. This can sway the decision of irrigators due to the high investment (Fofack et al., 2018).

The intensification of groundwater exploitation is often facilitated by certain public policies. This is the case, for example, with access to energy. Many farmers use engines powered by fossil fuels (petrol, diesel or gas). They can also be connected to the power grid or use solar energy which is developing rapidly. When the State subsidises access to energy, farmers have an indirect incentive to increase their abstraction. The consequences are worrying in some already vulnerable aquifers, as illustrated by a recent study carried out by Gupta (2019) in several areas of the state of Rajasthan (India).

In addition to energy subsidies, agricultural subsidies for certain crops can impact on groundwater abstraction. In Spain, European subsidies for the production of olive oil from La Loma (mentioned above) or wine from the La Mancha Occidental aquifer (on which the Tablas de Daimiel National Park directly depends), have greatly increased pressure on groundwater.

The intensive exploitation of groundwater is often linked to the production of export crops. These could be cereals from the Great Plains of the United States, fruits and vegetables from the Mediterranean region, or crops from South America (asparagus from Peru, grapes and wine from Chile), California (pistachios, almonds, etc.) or Australia (grapes and wine, mangoes and other tropical fruits). The liberalisation of international trade and access to new markets (access to the European market for Spain in the 1980s, then for Morocco in the 2000s) play a decisive role in increasing abstraction. While these phenomena involving the exportation of "virtual groundwater" (Dalin et al., 2017) generate local development, they are often accompanied by a monopolisation of resources by agribusiness and exacerbate water crises at the local level.

1.3 – Over-Allocation of Rights and Widespread Illegal Use

Even when farmers are aware of the risk of the depletion of the resources on which their activities depend, they often remain in a pumping race comparable to the "tragedy of open access": according to Garrett Hardin, the pursuit of individual interests in the exploitation of a common resource inevitably leads to its overexploitation if no mechanisms are put in place to control the situation.

States throughout the world now regulate abstraction through legal frameworks that integrate groundwater, even if the phenomenon of overexploitation and its consequences have been taken on board belatedly. This situation has led to excessive allocations of rights to the resource by public authorities. This can be partly explained by insufficient knowledge of the links with the environmental issues described above as well as by a lack of political will to take the long-term issues into account. It is also a result of the recognition of existing uses based on land ownership alone (Box 1).

Box 1 – Overallocation of Groundwater in Northern Chile

In the Copiapo Valley of Northern Chile, the total capacity of water rights that have been allocated is four times higher than the available renewable resource. Several factors can explain this situation. From a technical point of view, the available resource was evaluated following a relatively wet period, which resulted in its overestimation. The State was also under political pressure which led to the continued allocation of temporary water rights (subsequently regularised) after the situation of overexploitation had been diagnosed. The existence of water markets exacerbated the phenomenon by allowing users whose wells were dry to sell their water rights to other users in better locations and by facilitating the transfer of water rights from users with less intensive practices (farmers using water for only a few months per year) to users with a more regular consumption (drinking water and mines, which use water twelve months per year). [Source: Rinaudo and Donoso, 2019]

This over-allocation of rights is almost systematically compounded by the problem of illegal abstraction. This can involve unauthorised well drilling, unauthorised irrigation of agricultural land, or abstraction exceeding the allocated rights. This phenomenon has been described in Spain, where the Ministry of the Environment counted 510 000 illegal boreholes in the early 2000s, each of which was extracting more than 7 000 m3/year. These "illegal" abstractions are motivated by the profitability of irrigated crops. They are also encouraged by the public subsidies described above as well as crops that generate income and employment for the local economy (Novo et al., 2015), or even as a means to preserve social order. Issues related to regulating illegal use and reforming rights in cases of over-allocation are therefore crucial in many situations around the world.

1.4 – Lack of Knowledge and Status Quo Policy

The invisibility of aquifers makes it difficult for individuals to grasp the scarcity of the resource, which is a crucial aspect of overexploitation. Furthermore, insufficient hydrogeological surveys and a lack of sharing and availability thereof, limit the awareness of the various actors at several levels. The interconnections of aquifers with ecosystems and surface waters are also insufficiently taken on board, as mentioned above.

The lack of knowledge or uncertainty surrounding hydrogeological modelling is sometimes used as a pretext for inaction. For too long, the need for exhaustive knowledge has been put forward to justify a status quo situation, which has considerably delayed the adoption of measures to limit abstraction, or has extended the time for consultation, as has been observed in the case of the Beauce aquifer in France.

2. Some Typical Solutions with Constraints and Implementation Difficulties

When the sustainability of groundwater use is threatened, different solutions are usually proposed, alone or in combination: (i) schemes to increase capacity or save water, (ii) regulatory instruments implemented by the authorities, (iii) community initiatives.

2.1 – Ill-Adapted and Counter-Productive Water Saving or Capacity Expansion Schemes

In many situations, a drop in groundwater levels becomes a driving force for the mobilisation of additional resources: water transfers (sometimes over long distances) or the development of non-conventional resources such as desalination or the re-use of treated wastewater. The relevance of this type of strategy, when used alone, is questionable on two counts: (i) it puts pressure on surface water which is often already in high demand, and therefore on other users and uses, especially environmental ones; (ii) the financial and institutional barriers to these solutions postpone, or even render uncertain, the construction of the necessary infrastructures, maintaining situations of overexploitation in the long term.

In the case of Morocco's "aquifer contracts", such as that of the Souss plain of 2007, the substitution of groundwater by surface water is explicitly advocated for urban supply (Del Vecchio, 2020). This move towards excluding non-agricultural users from groundwater resources can also be observed in the case of Campo de Dalias in Southern Spain, where seawater desalination is a new source of supply, whose increased costs are borne by urban users (Dumont, 2015).

These solutions aiming to mobilise additional resources are often accompanied by efforts to modernise agriculture based on technical innovations such as drip irrigation. Nevertheless, it has been demonstrated that these techniques, presented as ways to save water, often contribute to agricultural intensification (introduction of crops with high added value, increase in irrigated areas), and by extension, to increased water consumption. In Morocco, for example, the arrival of drip irrigation on the Saïss plain was accompanied by a 50% increase in irrigated areas between 2005 and 2014 and a doubling of groundwater abstraction (Kuper et al., 2017).

Moreover, when areas irrigated by surface water undergo a change in irrigation technique it can lead to a drastic decrease in recharge caused by irrigation "losses". This jeopardises the "available resource/abstraction" balance in areas irrigated by both surface- and groundwater, a situation that can be observed in several states of India.

Among the technical solutions, groundwater recharge, by reinforcing the natural capacities of aquifers, is in a category of its own. However, the associated risks with this type of solution must also be recognised, particularly when regular maintenance is involved, as with the re-infiltration of treated wastewater or the use of infiltration wells (Box 2).

Box 2 – Groundwater Recharge in India

In India, groundwater accounts for more than half of the water used for irrigation and most domestic water. In the Union Territory of Puducherry and the state of Tamil Nadu, the water tables are over-exploited and subject to coastal salt intrusion and pollution from economic activities. Artificial recharge systems have been implemented or are planned under national programmes with support from international donors. Long-term monitoring appears to be necessary in both quantitative and qualitative terms (risk of pollution). There is a lack of local ownership of these structures and of user participation in their design and implementation. Their maintenance is most often inadequate and in some cases they are not used for their intended purpose: from recharge to abstraction. Artificial recharge systems are seen as ways to increase water supply without questioning the demand. The implementation methods and techniques are scrutinised without challenging the objective of the recharge. For example, farmers actively defend traditional water retention systems that contribute to recharge as opposed to the creation of recharge wells, which they consider to be too expensive. [Source: Richard-Ferroudji et al., 2018.]

2.2 – The Regulatory Action of Public Authorities Faced with the Complexity of the Resource

Public authorities have a pivotal role in groundwater management. This is firstly due to state prerogatives on the management of land, the environment and natural resources. It is particularly the case of water that is often defined as being in the public domain. The State is also the guarantor of the general interest and of equal access to the resource for the various types of users.

Faced with situations of overexploitation, or simply due to their prerogatives on the use of the resource, public authorities (whether central government, federal states, local authorities or even basin agencies) implement various types of regulation. These can include permits, bans, well closures, quotas, zoning related to irrigated areas or land use, etc. Public authorities may introduce economic tools such as direct or indirect taxes and subsidies. These tools aim to send a price signal to encourage farmers to limit their abstraction but their low amount generally does not have a direct impact on the level of abstraction. Some tools can even encourage abstraction directly (agricultural subsidies) or indirectly (subsidies for water-saving techniques).

Furthermore, the spatial extent of aquifers and the invisibility of the resource make monitoring and control activities difficult and costly: abstraction can be carried out from any location, without its effects being directly perceived. The distribution of volumes of water among the various users is complex if it is not supported by the actors and if the means of control are restricted. Even if significant means are allocated, the action of public authorities is generally limited faced with the extent of the development of groundwater abstraction and the number of boreholes. This results in ill-adapted sanction systems, complicated and costly regularisation procedures for farmers, or legal constraints narrowing the possibilities of control. The inapplicability of this framework is ultimately counter-productive and conducive to false declarations, deteriorations and even corruption. However, some initiatives have aimed at countering the individualistic nature of groundwater exploitation, such as in the Izmir region of Turkey (Box 3).

Box 3 – The Role of Irrigation Cooperatives in the Izmir Region (Turkey)

In Turkey, the area irrigated using groundwater increased from 100 000 ha in 1978 to more than 700 000 ha in 2014. The water administration has tried to remain involved in monitoring this irrigation, particularly through the creation of irrigation cooperatives. These cooperatives, which are responsible for the management of collective boreholes at village level, irrigated nearly 480 000 ha in 2014. Public authorities thus (partially) supervise groundwater abstraction through collective boreholes authorised by the administration and equipped under its technical oversight. The cooperatives play a key role in local agricultural development by facilitating access to groundwater without the farmers having to invest individually in private boreholes. However, this model should not be idealised. Many cooperatives are also in difficulty (depth of the water table, poorly drilled boreholes, incomplete or late collection of fees depending on fluctuations in agricultural income, high energy costs, etc.). [Source: Le Visage and Kuper, 2019]

The obstacles to the effective public management of groundwater resources are also of a political nature. The political costs linked to restricting access to resources can encourage public authorities to favour short-term economic development to the detriment of sustainable resource management. A certain "social tolerance" is thus often observed towards illegal uses. Attempts to restrict access to the resource generate reactions from those whose livelihoods depend on it (Loch et al., 2020). These political costs are closely connected to the economic costs, both for irrigators and at territorial level (Novo et al., 2015). In addition, the State is not a homogenous entity but rather the vehicle of several visions that are expressed through different sectoral policies at various levels, which sometimes prove to be contradictory. A national agricultural strategy favouring food independence or production for export will result, as mentioned above, in an increase in abstraction.

Box 4 – When the State Supports the Development of Groundwater Exploitation: the Example of the Saïss Plain (Morocco)

Since the 1980s, the Saïss plain in the north-west of Morocco has been strongly impacted by the dynamics of groundwater irrigation. Having "one's well, borehole and water" had become a question of dignity and of liberation from state control. On the Saïss plain, the "pumping race" turned into an identity race. Yet the Green Morocco Plan has supported access to and the exploitation of "individual water". Its state subsidies for digging wells and boreholes as well as drip irrigation equipment, have favoured large farms to the detriment of local farmers. Groundwater has thus been monopolised by a minority of major operators with financial capacities and significant networks, allowing them to use the resource in an intensive (and uncontrolled) manner. In this context, the absence of effective state control and regulation is a deliberate policy aimed at stifling growing political and social tensions in rural areas and ensuring the coexistence of a mosaic of farms. [Source: Messaoudi, 2020]

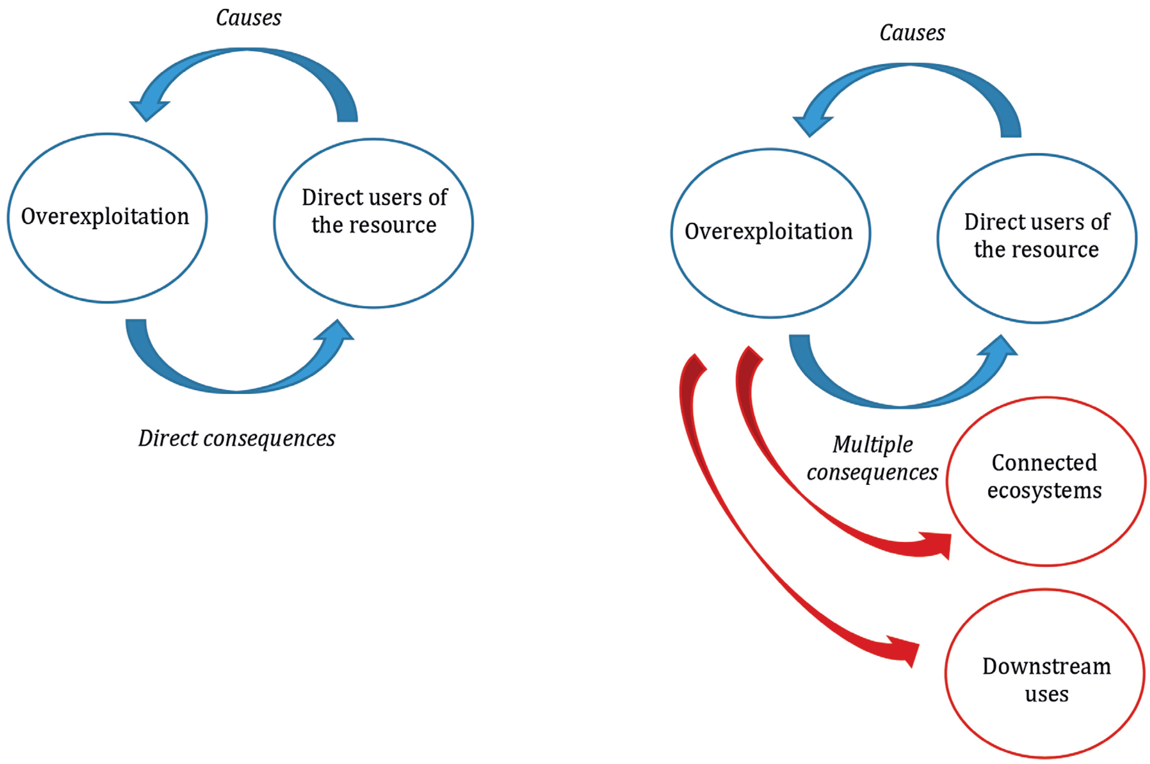
State attempts to reduce water rights have been documented throughout the world, revealing common difficulties. To address the short-term cost to the local economy and the loss of farmers' income caused by restrictions on water rights, "gradual restrictions" are sometimes proposed, either to act as a buffer between dry and wet years, as in Beauce (France), or to reduce abstraction in the long term, as in California. In other cases, public finances may buy back water rights, either temporarily or permanently. For example, through the Plan Especial del Alto Guadiana, the Spanish government, in addition to allocating rights to vine irrigators who had not received them for historical reasons, intended to re-establish natural outflows from the aquifer to the wetlands of the Tablas de Daimiel National Park, justifying the cost of the measure to public finances. However, detailed accounting reveals that the expected results were overly optimistic, particularly because the water rights for vines (irrigated in summer) are fully used each year, unlike for cereals whose level of irrigation depends on rainfall in spring: a right is not equivalent to actual use.

2.3 – From Community to Co-Management: Actors, Legitimacy, Limitations

While the role of public authorities seems fundamental, their action alone is not sufficient. The enforcement difficulties and mixed results of regulatory and economic tools can be linked to a lack of user consultation and involvement in their development, and even in their implementation. Users can be seen as responsible for the deterioration of the resource and as direct beneficiaries of its preservation. As observed through institutional economics (Ostrom, 1990) in many cases of common-pool resources (CPR), this dual position should encourage users to collectively define a level of abstraction that is desirable as much for themselves as it is for "society".

However, it should be borne in mind that Ostrom (1990) limits her approach to systems in which the deterioration of the resource due to the activities of its direct users has consequences only on those same users, with the aim of preserving the resource for its long-term exploitation by them. As illustrated in Figure 1, this configuration is questionable in the case of groundwater since the consequences of overexploitation can extend to uses "for society" and which are outside the system under consideration (environment and downstream users, surface water, etc.).

Diagram 1. Limitations of the CPR approach in the case of groundwater



Source: diagram adapted from Dumont (2015) by the authors.

Situations are reported, or even promoted, in which aquifer users play a leading role without this being a case of "self-regulation". In many cases the State remains a fundamental actor in regulating the use of water resources. It is often the State that initiates consultation with users by establishing rules or taking action. This point can be illustrated by: (i) the confiscation of drills used for illegal wells in Morocco, (ii) the Tunisian State's clampdown at the end of the 1990s which laid the foundations for a discussion leading to the creation of an Agricultural Development Group (ADG) for groundwater management (Molle and Closas, 2020), or (iii) the official "declaration of overexploitation" in Spain making the creation of a user association compulsory. Collective dynamics to ensure that users adhere to allocation schemes or to create or strengthen joint practices are therefore generally co-management solutions in which the State remains fully involved. The question is more about the scope of this co-management.

Groundwater overexploitation problems are relatively recent. Local agricultural organisations may nonetheless have existed for a long time, with some focusing on water management or dedicated to groundwater, such as the *qanats*[1] of North Africa and the Near and Middle East. In some cases, institutions for surface water management can inspire the set-up of specific institutions for groundwater, like the *Huerta de Valencia* in Spain. These structures are generally very rare or, where they do exist, are not adapted to the scale of the problem caused by the intensive abstraction enabled by boreholes. It is therefore uncommon to be able to rely on these organisations to generate collective action for groundwater management.

The establishment of user groups and their legitimacy involves many constraints: no or little tradition of consultation, a desire to prioritise individual interests or to maintain a social status linked to access to water resources, perception of the resource as a private object excluding any collective action or intervention by the public authorities, etc. The cohesion of these groups is hampered by the diversity of profiles (from small farmers to agribusiness representatives) and legitimacy of their leaders (sometimes self-appointed). A user group may not have the support of all of its members or several user groups might coexist.

The very scope of these groups raises questions. The “co-management” model, whether observed or promoted, sometimes turns into a negotiation behind closed doors between the public authorities and direct users of the aquifer. Real spaces for debate and decision-making are often not put in place: they should involve all stakeholders and take into account the diversity of the issues, including environmental challenges and future generations, which are difficult to represent in the debate.

1 Systems dating back to ancient Persia that draw water from aquifer sources above valleys and channel it by gravity along underground tunnels to cultivated fields.

3. Recommendations

While the experiences detailed above reveal a number of difficulties, they also suggest avenues for action, mobilising all stakeholders. This set of strategic recommendations can be useful for public authorities (from local to national level) and for donors supporting these processes, but also for civil society and even users themselves. They are aimed at sharing knowledge and collectively defining the measures to be implemented to curb the overexploitation of groundwater and thus limit the consequences thereof. In addition, ways of financing the actions and building the various actors' capacities over the long term must be found on a case-by-case basis and considered as soon as the processes proposed below have been developed.

3.1 – Build Shared Knowledge and Representations

Establishing shared knowledge of how aquifers function is crucial. The alteration of the natural interactions of aquifers with surface waters and ecosystems due to abstraction needs to be characterised in order to take into account all of the variables and quantify the available resources. It is then necessary to have an estimate of actual abstraction, which is socially and politically accepted. In this context, a clear distinction must be made between allocated water rights, actual abstraction and net consumption (taking into account the possible infiltration of drainage water). Finally, the resource-abstraction dynamic must be known and shared. The temporal inertia of aquifer systems in relation to qualitative and quantitative pressures and to their possible reductions must also be clearly characterised. Measures that are implemented may take several decades to bear fruit, which can jeopardise the efforts made if this dynamic is not sufficiently defined. This is particularly the case for marine intrusion in coastal aquifers. Intermediate indicators can be formulated to reveal possible improvements.

Models on how water tables function and estimates of abstraction established by the public authorities or by technicians attached thereto, are often questioned by users who compare them to their daily experience of the resource and of its scarcity. Scientific knowledge needs to be juxtaposed with empirical knowledge. From a scientific point of view, the knowledge-sharing mechanisms within networks of experts and organisations from the local to the international level should be mentioned. In this respect, the sharing of knowledge and good practices over transboundary aquifers is noteworthy, with the example of the North Western Sahara Aquifer System (SASS - Algeria, Tunisia and Libya) and the work of the Sahara and Sahel Observatory (OSS).

Having an institutionalised space for dialogue (as illustrated by the observatories in Box 5) is crucial to establish shared knowledge and representations based on tools and indicators that can be easily understood. This space must be able to integrate new knowledge and adapt to changing conditions (climate issues). Discussing a common representation helps to create and strengthen a collective approach. Tools developed thanks to citizen science, the setting up of local observatories by managers, and education, awareness and training actions, can all be explored. This shared representation will also facilitate compliance with collectively established rules.

Box 5 – Observatories: Important Forums for Dialogue

Observatories are extremely diverse systems. Their missions are adapted to long-term monitoring requirements and are of scopes deemed important for the actors concerned. In the case of groundwater, they must enable wells and boreholes to be located, monitor water levels and the main qualitative variables, have test sites, facilitate aquifer modelling work, and so forth. The Indo-French Centre for Groundwater Research based in Hyderabad, India, is well in line with this perspective (Marechal et al., 2018). These systems go beyond strictly hydrological aspects, providing detailed information on the various types of ecosystem that exist on the territory and their relations with groundwater, as well as on use and user profiles (particularly from a socio-economic point of view), etc. They mobilise a range of tools including indicators, mapped information as well as socio-anthropological and economic analyses. Finally, to make these mechanisms dynamic, observatories should stimulate ongoing reflection by users and support information exchange and consultation systems.

3.2 – Promote the Expression of All Actors to Bring About Solutions

The concerted decision-making process should contextualise solutions rather than propose solutions that could seem universal. The histories of the different user profiles and uses of the resource should be taken into account, particularly to identify those who have been deprived of access due to a drop in water table levels and who are thus marginalised. The development of different baseline scenarios that are shared among actors helps to inform decision-making. In particular, it is important to understand the dynamics of entrepreneurial agriculture compared to those of traditional groundwater uses by developing alternative scenarios.

Shared diagnoses should be able to focus on the notions of “risk” and “crisis”. The deficit of some over-exploited aquifers is such that even if pumping were to stop immediately, a return to the previous water levels seems improbable in the medium term. It is therefore advisable to intervene as soon as early warning signs of a future crisis are detected.

Demonstrating the environmental and social impacts of groundwater exploitation to the actors concerned can help to define a negotiated pathway to reduce abstraction. Conversely, the will alone of public authorities to preserve a common resource often does not produce the desired effects.

Broadening the debate beyond the establishment of the abstraction limit can generate change based on a set of socio-economic factors. Indeed, focusing only on preserving groundwater resources does not bring about change. Diverging interests come into conflict calling for negotiation processes that integrate all actors, including right holder communities (see the example of Niayes in Box 6). The search for sustainable management is therefore motivated by political, economic or social stakes as much as environmental issues.

Box 6 – Setting up Local Plans for Integrated Water Resource Management: the Case of Niayes in Senegal[2]

In the Niayes area of Senegal, which forms a coastal strip between Dakar and Saint-Louis, the State, with support from the NGO Gret, is setting up local water platforms in municipalities to address the deterioration of groundwater. After two years of consultation, local actors now share a diagnosis and vision for sustainable and equitable water resource management. They have also chosen their mode of governance and drawn up local plans for integrated water resource management. Memoranda of understanding for these latter have been signed by the platforms, the ministerial directorate and the mayors of the municipalities concerned, and approved by the sub-prefects. This territorial and democratic approach stems from a political will to test local integrated water resource management through a process that connects the different levels rather than being top-down. However, the prerogatives of these platforms still need to be guaranteed through a reform of the legislative framework, which is currently underway, to assign them the roles that are currently only set out in their articles of association. Furthermore, the representativeness of the local actors and balance of power within the platforms continue to warrant examination.

2 https://www.gret.org/projet/recherche-action-sur-la-gestion-integree-des-ressources-en-eau-dans-les-niayes/

3.3 – Build on User Communities to Share Responsibilities

The creation of user communities (self-organisation of irrigators or external impetus) is a prerequisite to manage the resource. However, it is insufficient in itself and many issues related to groundwater are debated in discussion forums at other levels. Integrating citizens as well as users who are excluded from the resource into these spaces is also a point that should be given due attention. The State should therefore reform its approach and regulatory tools to integrate these negotiation platforms. It is thus crucial to strengthen human resources (staff and skills) with, for example, the intervention of legitimate mediators with recognised skills.

Depending on how mature the user communities are, they may be given certain responsibilities in exchange for commitments (see the example of La Mancha Oriental, Spain, Box 7). If it is to function well, this concerted management requires a leader who is seen to be legitimate. It should also make it possible to put in place specific arrangements and economic incentives. Finally, it should take full advantage of the entire range of regulatory instruments and render them effective on the ground.

One responsibility may be to define the method for allocating the resource once the overall level of abstraction is established. It may also be the case that any request for a new abstraction right must receive the user group's approval before being submitted to the public authorities. This autonomy can strengthen adherence and compliance with the level of abstraction. More "flexible" water distribution instruments such as water markets or the allocation of a collective right to a community of irrigators can result in a higher rate of water right use: irrigators who would not have used their individual water right for a variety of reasons may transfer it to others. In addition, control may no longer be solely the responsibility of the public authorities and could thus involve users, or at least create a common sense of responsibility.

Finally, the inclusion of users in the sphere of decision-making and compromise-building can be based on an integrated set of solutions combining measures concerning groundwater management and the mobilisation of additional resources (surface water, re-use or desalination), but also actions that support agricultural development. This comprehensive approach can both restore the water balance in the short-term and ensure that management mechanisms are in place for the long term.

Box 7 – Organisation and "Self-Governance" of the Irrigators of La Mancha Oriental (Spain)

The aquifer of La Mancha Oriental is used to irrigate approximately 100 000 hectares of cereals, vegetables and vines. Contributing naturally to the flow of the River Júcar which crosses it, these extracted volumes have an impact on the aquatic ecosystems and the sustainability of traditional irrigation downstream (area surrounding Valencia). The organisation of the irrigators in a user association, which has reduced abstraction by approximately 25% to address this situation, is noteworthy. This has been achieved, in particular, through mutual control among the irrigators and sanction mechanisms established in collaboration with the authorities. As the authorities have a recognised counterpart, they can also more easily establish restrictive measures during droughts, such as financial compensation in exchange for reduced abstraction. This relative success (the environmental impacts are still significant) can be explained by the bottom-up approach of the irrigators and the local "social capital", or by a change in certain agricultural practices. It is also due to a number of "external" factors that could call into question the "spontaneous" side of this organisation. These include the dissuasive effect of the official declaration on the overexploitation of the neighbouring aquifer of La Mancha Occidental by the authorities, and the additional supply of surface water. [Source: partially from Molle and Closas, 2020]

3.4 – Strengthen the Understanding of Groundwater as a Common Patrimony and Develop a Territorial Project

It is crucial to move away from a dominant vision of groundwater as a natural capital to be exploited for the sole purposes of economic development driven by agricultural intensification. In contrast, defining what constitutes a common patrimony among heterogeneous actors whose interests may sometimes clash helps in negotiating how to share and manage groundwater. The technical and economic solutions discussed together must derive from the agreements reached by the social collective at different levels.

Considering groundwater as a heritage (for example by prioritising the preservation of wetlands to take account of long-term issues) enables problems to be discussed collectively to find solutions that veer away from the conception of water as a commodity. This also means being aware of the crucial aspect of access to groundwater for certain vulnerable groups as a means of livelihood and a way out of poverty. However, the development of agribusiness, often supported by States, excludes some groups from access to groundwater and neglects the environmental consequences of its intensive exploitation.

The instruments and rules resulting from the consultation process must be legitimised and politically backed at local level in order to increase the guarantee of sustainable groundwater management. This means that local public actors and "indirect" users should be involved in decision-making on the management of this resource. In this respect, analysing the implications of this management for the territory and the local economy is an effective way to achieve the adherence of local representatives and users. This thus also widens the debate beyond the hydrogeological unit to address the multifunctional character of groundwater. Awareness-raising and communication should be geared towards the general public, especially when local representatives' decisions could be misunderstood. Initiatives to this effect have been carried out, for example, in the Crau aquifer in France (see Box 8).

Box 8 – Questioning Scales: the Example of the Crau Aquifer in France[3]

The Crau aquifer is located in the south of France, in the department of Bouches-du-Rhône. Covering the Crau plain, whose surface area is 550 km², the water table is located at highly variable depths (from 6 to 60 m, depending on the area). This has contributed to sculpting the landscape. It supplies a vast agricultural and market gardening area (the Crau wetlands), where "Crau hay" (protected designation of origin) is produced. On another part, Coussoul (the dry Crau), the plain hosts a rich biodiversity with a nature reserve as well as a Natura 2000 site in a more arid area made up of steppes. Diverse economic activities use the resource in addition to agriculture and groundwater supplies drinking water not only to the inhabitants living within its perimeter (approximately 100 000), but also to a great many users (170 000) who live nearby. This explains why considering the perimeter of the aquifer alone is insufficient to identify all relevant actors concerned by its management. The problems of the different areas within the hydrogeological perimeter of the aquifer (dry Crau and Crau wetlands), as well as those concerning areas located beyond it, differ significantly. All of the challenges, from the preservation of the environment to support for a quality agricultural sector and drinking water supply, are interlinked in different ways depending on the scales concerned. They should nevertheless be approached together with a view to preserving the common patrimony of the groundwater of the Crau region.

3 Source: *Syndicat mixte de gestion de la nappe phréatique de la Crau* [Joint Association for the Management of the Crau aquifer] (https://www.symcrau.com/).

Initiatives to promote groundwater should also help to ensure that its management is fully integrated into discussions on territorial development and basin management so that all local actors value it and consider it in decision-making. It is therefore important to renew development models on a territorial scale building on existing stakeholder groups. It is a matter of determining which territorial project “makes sense”, particularly where there is potential to develop groundwater exploitation, as in Sub-Saharan Africa.

Conclusion

The use of groundwater for agriculture is motivated by different factors. It also reflects visions of a resource imagined to be abundant and available at a low cost. This perception leads to situations of overexploitation. This trend cannot be reversed by traditional solutions such as the enforcement of regulatory tools by the State, itself often poorly equipped and with little legitimacy at local level, or such as increasing capacities.

Ways to improve the situation of over-exploited aquifers or to prevent them from becoming so can be developed. Although they only indirectly address qualitative issues, they are based on strategic directions that could also be applied to this topic, which is causing growing concern. They relate, for example, to the development of shared knowledge and representations, which are often lacking among the users themselves but which would enable them to do more "together" or to establish a better understanding and trust with the public authorities. At another level, it is a matter of ensuring that all actors are integrated in the decision-making process, including those who are affected by issues related to impacts outside the aquifer, particularly those concerning the environment. It is also a question of ensuring that groundwater is recognised as a common patrimony and of acknowledging its role from a general development perspective. The use of groundwater for irrigation should therefore be included in a territorial project and awareness-raising should reach beyond the direct users of the aquifer.

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List of Acronyms and Abbreviations

AFD	*Agence française de développement* (French Development Agency)
BRGM	*Bureau de recherches géologiques et minières* (Geological and Mining Research Bureau)
CACG	*Compagnie d'aménagement des coteaux de Gascogne* (Gascony Hills Development Agency)
CAREP PARIS	*Centre arabe de recherche et d'études politiques de Paris* (Arabic Center for Political Research – Paris)
CIRAD	*Centre de coopération internationale en recherche agronomique pour le Développement* (French Agricultural Research Centre for International Development)
CLERSÉ	*Centre lillois d'études et de recherches sociologiques et économiques* (Lille Centre for Sociologic and Economic Research)
CNRS	*Centre national de la recherche scientifique* (French National Centre for Scientific Research)
COSTEA	*Comité scientifique et technique eau agricole* (Scientific and Technical Committee for Agricultural Water
CPR	Common Pool Resources
FAO	Food and Agriculture Organization
GRET	*Groupe de recherche et d'échange technologique* (Group For Research and Technology Exchanges)
INRAE	*Institut national de recherche pour l'agriculture, l'alimentation et l'environnement* (French National Research Institute for Agriculture, Food and Environment)
IRD	*Institut de recherche pour le développement* (French National Institute Research Institute for Sustainable Development)
NGO	Non-governmental organisation
OFOR	*Office des forages ruraux* (Senegalese Office of Rural Drilling)
OSS	*Observatoire du Sahara et du Sahel* (Sahara and Sahel Observatory)
SASS	*Système aquifère du Sahara septentrional* (North Western Sahara Aquifer System)
SYMCRAU	*Syndicat mixte de gestion de la nappe phréatique de la Crau* (La Crau Groundwater Joint Management Authority)

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