Guest Editors' preface

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Origin of this theme issue

About three years ago Cliff Voss, the Executive Editor of *Hydrogeology Journal*, asked the readers of the journal to send him ideas for the theme issue of March 2005. R. Llamas suggested that in that issue (The Future of Hydrogeology), it might be good to highlight the need for a closer relationship between the natural and social sciences, in order to achieve better governance of groundwater or, in other fashionable words, to facilitate a sustainable use of groundwater resources. As a consequence of this suggestion, T. Shah and A. Mukherji were invited to write a paper (appearing as the last one in the March 2005 theme issue (Mukherji and Shah 2005)). A few months later Cliff wrote to us inviting us to be the Guest Editors for the theme issue of 2006, which will be devoted mainly to social, economic, institutional and political issues related to groundwater sustainability. We accepted and have looked for the topics, authors and reviewers of the corresponding manuscripts. The final result of our work are the 12 articles of this issue. This issue deals with a general, current problem: the gap between Society and Science and Technology.

In the preface of the previous theme issue on the Future of Hydrogeology, Cliff Voss comments on the inability of hydrogeologists, or rather hydrogeology as a complete science, to make accurate predictions on the physical and chemical evolution of groundwater systems. We are not challenging such a point of view, but we think that the current capability of hydrogeologists to design plausible future scenarios is significantly more reliable than the capability of social scientists to design similar future scenarios. In a certain way, what is presented in this issue is a facet of the general problem of the gap or lack of connection between Society and Science and Technology. This gap, in the case of groundwater development, is significantly larger than in the case of surface water development. There exist several factors that explain this greater gap. Perhaps the main factor is the newness of the intensive use of groundwater that rarely is older than four or five decades (mentioned by most articles in this issue). Surface water systems for urban water supply or for irrigation, on the other hand, have been developed for millennia.

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During the last half century Hydrogeology has become a solid scientific dominion. However, scholars of social sciences (economics, sociology, general education and others) have only begun to seriously study groundwater management in the last two or three decades. Even today, water decision-makers frequently try to apply to groundwater management the same criteria that applies to surface water management, without taking into account the relevant technical and social differences that usually exist between the two resources and their uses, although both of them are integrated within one hydrological cycle. This topic is mentioned in several articles of this issue.

As a matter of fact, the use of groundwater was generally scarce, at least in comparison to that of surface water, until the technology for drilling water wells and abstracting groundwater became cheap and easily available. This occurred in most countries less than half a century ago. This fact, linked with the general institutional inertia, may explain why most high-level water decision-makers have paid scarce attention to planning, development, operation and control of groundwater resources.

However, mainly in arid and semiarid countries, and in small islands where surface water is not available and water is a precious resource to produce food or for drinking, the current availability of cheap technology to abstract groundwater has facilitated a spectacular increase in groundwater abstraction. This abstraction has been mainly undertaken by millions of private farmers with scarce planning, financing and control by the usual governmental water authorities. This phenomenon has been described as a 'silent revolution' (Fornés et al. 2005; Llamas and Martínez-Santos 2005). It has produced great economic and social benefits but also some problems. In general, these problems are frequently exaggerated and are not serious, yet may become serious if the 'colossal chaos' that exists in groundwater development (DebRoy and Shah 2003) is not appropriately addressed.

Scope and aim of this issue

Our aim in preparing the contents of this issue has been to facilitate the joint analysis of groundwater problems by scholars from natural and social sciences. One important tenet for us is that although the hydrological principles governing groundwater behaviour are universal, their

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application to attain sustainable resource development are mainly driven by social, economic, ecological, cultural and political conditions. In other words, there is no blueprint that can be designed by the best hydrogeologists and applied everywhere. This is a basic assumption that explicitly or implicitly appears in almost every article of this issue.

We have also tried to focus our task on those topics that seemed to us more urgent and relevant. This is why we have not paid much attention to questions related to transboundary aquifers or to chemical groundwater pollution. The first is a medium or a long-term problem, and the second is not the key issue in developing countries, in which more than 50% of the global population live, yet where, probably, 80 or 90% of the current groundwater abstraction occurs. For these people generally, the presence of organic carcinogenic compounds in their drinking water is not a significant problem at least in comparison with bacterial pollution. Therefore, our main interest has been focused on irrigation as the main usage of surface and groundwater in all the arid and semiarid countries.

Trying to dispel some false, simplistic or obsolete pervasive paradigms on groundwater management

As previously mentioned, the intensive use of groundwater is a new phenomenon, less than half a century old in most regions. Therefore, lack of adequate knowledge and institutional inertia may explain why the mindsets of many high-level water decision-makers are still anchored in traditional paradigms and are fraught with difficulties in understanding the new situation. This new situation is due, in part, to the scientific and technological advances in hydrogeology and in other disciplines but also due to rapid social changes.

We are not intending to describe in detail such false or obsolete paradigms. It is not only the different authors that have different points of view on the existence and relevance of them—the Guest Editors of this theme issue may have different points of view too. We leave it to the reader to make his/her choice. However, we would like to emphasize the following three points.

The first point is to avoid a simplified concept of groundwater sustainability, in effect reducing it to only one of the many dimensions associated with this concept (Llamas et al. in press). These dimensions are related not only to hydrology and ecology but also to the economic, social, cultural, political, intergenerational, intragenerational and other aspects which need to be considered. The concept of sustainability is driven by the weight given to these dimensions and this is mainly a political dimension. This confirms that there is no blueprint applicable to every case.

Secondly, in considering the pervasive paradigm of the 'fragility' of groundwater development, many seem to consider that every groundwater development is bound to be a 'tragedy of the commons' (described by Hardin 1968) in that, being a resource in common ownership (or no ownership at all), the groundwater resource will invariably suffer degradation through over-exploitation. The articles here seem to show that this is not usually the case. Possibly, this is due to the fact that, usually, the groundwater storage in aquifers is huge, 100 or 1,000 times greater that the average annual recharge. This means that it takes one or two generations in time before serious adverse effects appear. In the meantime, and frequently, a positive social transition has taken place and facilitated effective methods of irrigation using groundwater. The children of the initially poor (frequently illiterate farmers) have become educated and they have moved from agriculture to other jobs or they are now applying better agricultural technology, making more money and using less water.

The third point is that management of intensive groundwater use requires a greater degree of participation of the stakeholders (mainly the farmers) than in surface water irrigation systems, where a 'lord of the gate' usually exists. In groundwater systems, there exist thousands of independent 'lords of the well'. Without their collaboration, it is almost impossible to succeed in good governance of groundwater. Such collaboration demands an intensive education campaign and a greater transparency in the availability of water rights, and of hydrological and economic data, to everybody.

The order of the articles in this issue

Most articles deal with many social and political aspects of groundwater management. However, we have divided the 12 articles into two groups. The first six articles (Wang et al., Shah et al., Giordano, Feitelson, Villholth and Garrido et al.) are mainly related to the spread, and the social and economic dimensions of intensive use of groundwater in irrigation. The second group (Schlager, Lopez-Gunn and Martinez Cortina, van Steenbergen, Mukherji, Kretsinger Grabert and Narasimhan, and Polak and Yoder) is dealing mainly with institutions of groundwater governance and associated issues. A short description of each article follows.

The analysis of the rise of intensive groundwater irrigation in North China by Wang et al. emphasizes the gradual decline of collective ownership of tubewells and rapid evolution of economic institutions based on private ownership and market exchange. The North China study, based on a large survey encompassing 448 villages spread over six provinces of North China, highlights the significant economic and livelihood gains accompanied by emerging environmental threats in the form of falling groundwater levels. Like in South Asia, North China's groundwater story too, is all of 40 years old and still in the making, with private investments in new tubewells booming during the 1990s. Moreover, here too the official picture provided by government statistics underplays the scale and significance of the groundwater economy on the region's agrarian society. Government figures place the number of private tubewells in China at 3.5 million. Wang et al., based on their survey, project their numbers at more like 7.5 million.

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Wang et al.'s article highlights three major transformations that have occurred in water institutions of North China during the past 50 years. First, while vast surface irrigation capacities were created during the 1950s and 1960s, these have rapidly declined and given way to tubewell irrigation. Second, collective ownership of irrigation assets has given way to private ownership. Third, individual ownership of tubewells is rapidly getting surpassed by 'share-holding tubewells'. Between 1990 and 2004, private tubewells as a whole grew 4 times, but share-holding tubewells grew 14 times! Finally, all these in turn imply one more transformation. Pre-1980, much irrigation infrastructure was financed and controlled by village governance structures; with the rise of private tubewell capital, the ability of these structures to regulate water use in agriculture remains somewhat undermined. The authors conclude that the rise of the private groundwater economy has had positive effects on crop yields and income in rural China between 1990 and 2004. However, they also conclude that while the private groundwater development either increased the sown area or the cropping intensity (and, as such, evapotranspiration), the rise of private tubewells has, at the same time, contributed to the fall in groundwater level.

The kind of groundwater revolution that Shah et al. describe in South Asia and Wang et al. outline in parts of North China is unheard of in Africa. Little is known about water use in agriculture in Africa, much less about groundwater use. *Giordano's* article in this volume provides the first—and much welcome—assessment of the role groundwater plays in supporting rural and agricultural livelihoods in sub-Saharan Africa. Giordano confirms the general impression that groundwater irrigation in the region is marginal—covering 1–2 million ha and touching the lives of 1.5–3% of the rural population. This is to be contrasted with its role in South Asia—where areas irrigated fully or partially by groundwater amount to at least 65–70 million ha, if independent studies are to be believed (see Shah et al. in this volume) and touches the lives of over half of the rural population. Giordano's article, however, shows that groundwater's role in supporting the vital livestock sector is far more critical in sub-Saharan Africa. This, however, changes the overall socio-ecology of groundwater use in rural Africa; herders using groundwater wells to provide drinking water for livestock need to abstract small quantities of groundwater per hectare of grazing areas. Rural groundwater use therefore is unlikely to pose the kind of resource governance challenges that face South Asia and North China. As Giordano himself suggests, 'understanding of the value of groundwater use in support of rural livelihoods in sub-Saharan Africa should be based on different models than have typically been applied in Asia.'

What the contributions to this issue flag as a key water governance issue is the emergence of groundwater as the pivot around which intense political mobilization tends to occur. In South Asia, governing groundwater presents complex regulatory challenges in the absence of a suitable legislative framework. However, even with such a framework, it would be difficult to rein in runaway growth in groundwater use because of the intense political processes that such attempts are bound to unleash. The political interest articulation becomes particularly invidious when aquifers are shared by two states; and it takes much political savvy to evolve mutually agreeable and equitable formula for development and management of such shared aquifers. *Feitelson's* case study of the negotiations between Israel and Palestine that led to the 1995 interim agreement between the two states on the sharing of the Mountain aquifer, highlights the preconditions for a stable arrangement. Citing Putnam, Feitelson suggests that international negotiations—such as around shared aquifers or river basins—take place concurrently on two 'tables': the first, where appointed negotiators work, and the other where domestic pressure groups do. According to Feitelson, the key to arrive at a stable agreement is to understand and manage an 'array of domestic power structures, and particularly the power of small cohesive interest groups'.

In countries of South Asia, a key concern in governance of groundwater is the absence of an administrative apparatus to implement agreed policies on a multitude of dispersed users of groundwater. However, Feitelson's analysis shows that even where an effective apparatus for regulation is in place, as in Israel, the intense politics of small, cohesive interest groups may frustrate efforts to produce order.

Villholth's article is a plea to develop knowledge, awareness and understanding of groundwater resources so that governments can intervene more effectively to cope with imbalances arising out of unplanned and unregulated development of groundwater globally. Villholth draws attention to four critical 'missing links' which need to inform the debate about groundwater management: the link between surface and groundwater; the link between groundwater quantity and quality; the link between urban and rural demand for groundwater; and the link between physical processes and characteristics of groundwater and the socio-economic factors driving human decisions to develop, use and manage the resource. Globalization has helped improve our understanding of these links through several new initiatives; however, impediments in evolving effective groundwater management regimes remain. Villholth identifies four preconditions for an effective groundwater governance strategy to emerge in developing countries: first, there must be significant economic surplus available at the national level to maintain acceptable living standards and also to invest in resource protection; second, there must be requisite knowledge and information available; third, there should exist a political will to confront problems and take corrective action; and finally, a major detrimental event needs to occur that can 'trigger' serious corrective action. The serious problems of seawater intrusion and land subsidence due to groundwater overexploitation acted as a trigger to take such corrective action in Bangkok metropolitan area (Thailand) during the mid-1980s. The 1995 agreement between Israel and Palestine which entitled the latter to a much larger share in the Mountain aquifer than it has enjoyed historically, acted as a trigger for Israel's Water Commissioner to enforce groundwater regulations in a more serious fashion.

There is a general impression—conveyed, for instance, in the article by Villholth in this issue—that the problems

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of keeping groundwater irrigation sustainable are peculiar to developing countries. However, this does not seem to be so. Feitelson's article showed that even with a tight system of groundwater monitoring and regulation, managing groundwater demand has not been a cakewalk for Israel's water commissioners, one of whom had to be dismissed for non-performance. The article by Garrido et al. in this issue shows that the case of Spain, another affluent country experiencing intensive groundwater use in agriculture, is no different. The cost of groundwater irrigation is such a small fraction of its marginal value productivity in Mediterranean Spain's strawberry and citrus economy that the demand pull from growers for groundwater irrigation has proved all but irrepressible. The reasons are not surprising. Groundwater productivity in Spanish farms may go as high as €4/m^3 for pepper and tomato although for field crops like corn and soyabean it may be as low as €0.2/m^3. However, the cost of groundwater irrigation is a small fraction of the gross value of the output; and it may take a price as high as €0.25–0.30/m^3 to have any deterrent effect on groundwater demand.

In the face of growing water scarcity, researchers often argue for discouraging inefficient uses and improving water productivity. Ironically, high productivity of groundwater use in Spanish agriculture is proving enemy number one to groundwater sustainability. In many areas of Spain, agricultural groundwater use is facing tough competition from other uses, especially tourism. In the Canary Islands, tourism has purchased the water rights from growers. Yet, even this high-price competition is not helping ease pressure on groundwater irrigation in mainland Spain. Such is the nature of the intense 'demand pull' that the groundwater resource is facing from irrigators in semi-arid climes.

Like in other parts of the world such as India and Mexico, in Spain too, the demand pull for groundwater irrigation is partly driven by subsidies. In the former countries, it is the energy subsidies that artificially lower the cost of pumping. In Spain, it is the European Union (EU) farm subsidies that make groundwater irrigation far more lucrative than it otherwise would be. The analysis by Garrido et al. suggests that removal of EU subsidies would be one effective means to ease pressure on groundwater: "Resource price signals will be clearer and water saving technology adoption, coupled with more environmentally friendly production technologies will be encouraged". However, even if subsidies are completely removed, farmers' benefits are far more stable with groundwater than without it, so irrigation will likely remain in business. Should the irrigation sector's survival be threatened, the social costs would be significant even in Spain. After all, on the margin, groundwater produces five times more value than surface irrigation and creates three times more jobs.

From modifying laws to self-governance *Schlager's* article deals with the challenges of governing groundwater in the arid western provinces of the United States. Over the last several decades, groundwater use has become increasingly important in meeting both agricultural and urban demands for water, but institutional mechanisms that govern surface water use (such as prior appropriation doctrine) are not entirely suited for groundwater governance. This stems from the intrinsic physical difference between groundwater and surface water on the one hand and the way groundwater and surface water users organize themselves on the other hand. This article provides a succinct review of the historical development of surface water laws in the first place and its later application in the sphere of groundwater regulation and shows how due to the different physical and organizational nature of surface water and groundwater, many of the principles that have worked reasonably well in the surface water regime, have been less successful in governing groundwater. As a result, some scholars have argued for total dissolution of the prior appropriation doctrine, which is seen to be 'inefficient, wasteful and environmentally destructive', in favour of a permitting system in which the focus of control shifts from the individual to the state government. However, given the constitutional sanctity that prior appropriation doctrine enjoys in almost all the western states, and the strong interest group of the senior water appropriators (who would certainly resist any curtailment of their rights), drastic measures such as replacement of prior appropriation doctrine with a new law seems difficult, if not impossible. The author recognizes this and suggests do-able things within the broader framework of the prior appropriation doctrine by modifying it proactively in order to 'accommodate the active management of groundwater basins for long-term sustainability'. At the heart of the do-able things is co-management (also called conjunctive use) of surface water and groundwater resources such that water rights are upheld for both the sources, the proportion of which will vary depending on whether it is a dry or a wet year. This will be complimented by planned recharge of aquifers in relatively wetter years. This is a pragmatic approach that encourages a positive incremental change (as opposed to drastic change) within an existing legal framework.

On the other hand, Spain has, so to say, taken the full leap forward by drastically modifying its water laws. By the Water Act of 1985, groundwater was taken away from the private domain and the ownership rights were bestowed upon the State. Self-regulation by the groundwater users was emphasized by this new Act and all groundwater users were required to organize themselves into groundwater user associations. Through amendments in 1999 and 2001, participation of groundwater users in aquifer management was further emphasized. *Lopez-Gunn and Martinez Cortina's* article looks into the performance of groundwater user associations (GWUAs) in Spain and analyzes the factors (both internal to the organization and those pertaining to the external or higher authorities), that are conducive to successful self-regulation by the groundwater users. Using Elinor Ostrom's framework of attributes of institutional change, this article compares the functioning of eight GWUAs in Spain. In contrast to conventional wisdom, i.e. that internal attributes of the *user* organization (such as homogeneity, trust and reciprocity, autonomy, leadership and prior organizational experience) are the most important determinants in the success of self-governing institutions, this article finds that attributes of the higher level authorities, and their

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relationship with the water users, is more crucial in ensuring smooth functioning of such GWUAs. Thus, those GWUAs that have a good synergy and understanding between themselves and the higher level water authorities outperformed those where no such synergies existed. This article also points to the role of local leadership in creating trust among the users and thereby successful functioning of GWUAs. However, the article throws a caveat against regulatory capture by external organizations by 'ensuring that the regulator and the regulated are not so close in their relationship as to be detrimental to effectiveness'.

While Lopez-Gunn and Martinez Cortina look into GWUAs legally set up according to a new law (though a few of the GWUAs were already in existence before), *van Steenbergen*, in his article, discusses few instances of 'home-grown' local groundwater management norms that have worked reasonably well in either enhancing supply (e.g. through recharge and water harvesting) or controlling the demand for groundwater (through restrictions on withdrawals or crop types). While not numerous, there are indeed few scattered examples of successful self-imposed groundwater regulations by the users themselves. The author, quoting examples of self-regulation by groundwater users in India, Pakistan, Yemen and Egypt, distils common underlying factors that facilitate success of such organizations. Some of the factors that he finds common to all the successful cases are: a non-exclusionary principle that is seen as fair and non-threatening to users; simple and low transaction cost rules; flexibility of using either demand management or supply management strategies or a clever combination of both; reasonably accurate hydrological information; and the supportive role of the local governments. In emphasizing the role of the external agency (in this case the local government) van Steenbergen echoes the findings of Lopez-Gunn and Martina Cortez. The author further goes on to make a case for actively promoting local self-governance by the groundwater users and in support of his optimism about the potential of such venture, cites two examples of state-promoted local institutions in the Indian state Andhra Pradesh. In the first case, the government of Andhra Pradesh has initiated a programme on participatory hydrological monitoring where the groundwater users are taught to develop rudimentary water balance accounts, while in the second case, through micro-level resource planning, villagers are encouraged to calculate irrigation demand estimates based on groundwater availability. The second initiative is also linked with a watershed management programme and, though quite new, both the programmes have had positive response from the local users.

The common thread that binds these last three articles from different parts of the world (developed as well as developing) is that all of them deal with the rather intractable problem of groundwater governance. Few unifying themes emerge from these articles. First, irrespective of the level of economic development of a nation, governing groundwater remains a challenge. Of course, the varying degree of economic prosperity ensures that different sets of policies will work in different places. Thus Schlager's proposal of proactively managing conjunctive use of groundwater and surface water at the basin level will perhaps work better in the context of the US than in countries such as India and Pakistan, where there are no groundwater laws in the first place and the organizations managing surface water and groundwater do not work in tandem. Second, while self-regulation by groundwater users is believed to be a more superior option than top-down management by public agencies, very often forging successful user organizations is a challenging task. While it is important to glean out the factors that ensure successful operation of groundwater user organizations, there is no easy short cut for their replication. Finally, implied in these articles, though not explicitly spelt out as such, is the importance of politics in either resolving or compounding groundwater problems. In the example from US, it is clear that doing away with seemingly inefficient doctrine of prior appropriation is not politically feasible, while in Spain, top management in charge of groundwater authorities are invariably political appointees and often discontinuity at this level poses problem. At the same time, strong political will of these very top level officials bring about positive changes in the few instances when GWUAs work successfully. In the south Asian subcontinent, livelihood issues are very important and any attempt to regulate groundwater use that might have a potentially negative impact on people's livelihoods is opposed vociferously.

The article by *Mukherji* captures the politics of groundwater in India with the help of contrasting examples from two Indian states—water abundant West Bengal and water scarce Gujarat. With the example of successful groundwater regulation in West Bengal and mobilization of farmers in Gujarat to protect their groundwater rights, this article offers the hypothesis that groundwater-related policies in India has very little to do with the scarcity, depletion or quality of groundwater, and more to do with rural politics, manifested, among other things, in terms of the presence or absence of farmer lobby groups. While groundwater users in Gujarat have successfully thwarted the government's attempt to increase electricity tariff, farmers in West Bengal have failed to put up effective resistance against their curtailment of groundwater access through strict groundwater regulation on the one hand and increase in electricity tariff on the other hand. Paradoxically, West Bengal has abundant groundwater resources and does not need much regulation, while the groundwater condition in Gujarat is quite precarious. The answer to this paradox lies in the nature of the peasant organizations in the two states. In Gujarat, the peasant organization is led by holders of large and medium farms actively engaged in agriculture, while in West Bengal, the leadership lies with the rural intelligentsia (mostly school teachers) and membership is open to non-cultivating classes such as agricultural labourers and rural traders. As such, the interests of farmers get diluted in such an organization and they are easily co-opted by the state government. Thus farmer lobbies play an important role in determining groundwater policies in a state.

The article by *Kretsinger Grabert and Narasimhan* on the evolution of water management in California provides

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a perspective significantly different from the one of the previous article. California is one of the most affluent regions in the world. Groundwater-irrigated agriculture has played a relevant role in the development of this state of the USA. Probably, this is the first region of the planet where intensive use of groundwater for irrigation began. This use facilitated the formation of booming agriculture and the formation of powerful farmer lobbies. These groups still play a very significant role in California's policy. Significant problems related to this intensive groundwater use are well known, for example, significant land subsidence in the Central Valley and the degradation of many wetlands. However, up to now the farmers have been able to keep the old regulation that maintains groundwater in private ownership. They were also able to promote the construction of large hydraulic infrastructures, mainly funded with federal money, to transfer surface water from the northern rivers of California and from the Colorado River. On the other hand, in California can be found some of the best world examples of conjunctive use of surface and groundwater, and of master plans to manage some of the 400 or so official groundwater basins. The authors describe the decades-long transition process from intensive and often unmanaged groundwater development towards more effective and sustainable integrated water resources management. A distinctive characteristic of this process is that it has not followed a governmental 'command and control' approach but mainly a 'bottom-up' approach aided with technical help and economic incentives on the part of the different governments. The authors emphasize the relevance of long-term systematic groundwater and surface water monitoring programmes as an integral part of management.

And last, but not least, we would like to call attention to the special features of the *Polak and Yoder* article. These authors address the role that groundwater may play in achieving the UN Millennium Development Goals in relation to drinking water and nourishment for more than 550 million of the current 1.1 billion people earning less than $1 a day and living off agriculture in developing countries. They consider that a revolution in water control is needed to develop and mass-disseminate new, affordable, small-plot irrigation technologies. A revolution in agriculture is required to enable smallholders to produce high-value, marketable, labour-intensive cash crops. A revolution in markets is needed to open access to markets for the crops they produce and the input they need to produce them. Finally, a revolution in design, based on the ruthless pursuit of affordability, is needed to harness shallow groundwater. The authors present their 20-year long experience on the use of treadle pumps, low-cost drip irrigation and water storage systems. The wealth of these technologies generated, coupled with falling prices for small diesel pumps in countries like India and China, created a suitable environment for transition to the classical 'intensive groundwater use silent revolution', based in mechanized (diesel or electric) tubewells. This revolution has already occurred in most arid and semiarid regions as described in the Garrido et al., article.

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