Trends in local groundwater management institutions

Groundwater Governance
A Global Framework for Action

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Groundwater Governance - A Global Framework for Action

Groundwater Governance - A Global Framework for Action (2011-2014) is a joint project supported by the Global Environment Facility (GEF) and implemented by the Food and Agriculture Organisation of the United Nations (FAO), jointly with UNESCO's International Hydrological Programme (UNESCO-IHP), the International Association of Hydrologists (IAH) and the World Bank.

The project is designed to raise awareness of the importance of groundwater resources for many regions of the world, and identify and promote best practices in groundwater governance as a way to achieve the sustainable management of groundwater resources.

The first phase of the project consists of a review of the global situation of groundwater governance and aims to develop of a Global Groundwater Diagnostic that integrates regional and country experiences with prospects for the future. This first phase builds on a series of case studies, thematic papers and five regional consultations.

Twelve thematic papers have thus been prepared to synthesize the current knowledge and experience concerning key economic, policy, institutional, environmental and technical aspects of groundwater management, and address emerging issues and innovative approaches. The 12 thematic papers are listed below and are available on the project website along with a Synthesis Report on Groundwater Governance that compiles the results of the case studies and the thematic papers.

The second phase of the project will develop the main project outcome, a Global Framework for Action consisting of a set of policy and institutional guidelines, recommendations and best practices designed to improve groundwater management at country/local level, and groundwater governance at local, national and transboundary levels.

Thematic Papers

- **No.1 -** Trends in groundwater pollution; trends in loss of groundwater quality and related aquifers services
- **No.2 -** Conjunctive use and management of groundwater and surface water
- **No.3 -** Urban-rural tensions; opportunities for co-management
- **No.4 -** Management of recharge / discharge processes and aquifer equilibrium states
- **No.5 -** Groundwater policy and governance
- **No.6 -** Legal framework for sustainable groundwater governance
- **No.7 -** Trends in local groundwater management institutions / user partnerships
- **No.8 -** Social adoption of groundwater pumping technology and the development of groundwater cultures: governance at the point of abstraction
- **No.9 -** Macro-economic trends that influence demand for groundwater and related aquifer services
- **No. 10 -** Governance of the subsurface and groundwater frontier
- **No.11 -** Political economy of groundwater governance
- **No.12 -** Groundwater and climate change adaptation

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GROUNDWATER GOVERNANCE: A Global Framework for Country Action
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THEMATIC PAPER 7:
Trends in local groundwater management institutions.

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Table of Contents

LIST OF BOXES, FIGURES AND TABLES

Key messages:

1. Private use has been strong driver of demand for groundwater and aquifer services despite the common property nature of the resources. While there have been successes in managing groundwater at local levels, these are scattered and appear to depend heavily on location specific institutional, technical and economic settings.

2. Even if a system of governance is in place, many groundwater management responses are difficult to take to scale given the 'granularity' of aquifer settings.

3. There are few unequivocal ' best practices' for groundwater management. Instead it is more effective to focus on strategies that fit the local aquifer context and patterns of use. To move up a level will necessarily involve entry into the governance arena invoking legislation and institutions (rules of the game), not just organizations.

4. Rather than managing the groundwater resource base *per se,* it may often be more effective and viable to address or mitigate the impacts of changes in groundwater conditions through courses of action that fall outside the arena of direct water management.

1. Introduction

The formation of local institutions around groundwater sources has a long legacy, rooted in common groundwater development around shared springs, hand-dug wells, *adits* and *falaj* systems. Today, many of the local institutions and related customary habits are still active and relevant where groundwater use is relatively 'light' and still conditioned by traditional or non-energized groundwater abstraction. But as indicated in Thematic Paper 8, the advent of the mechanized pump has changed many of these presumptions. Whether natural resource policy and administration, water law and specific groundwater legislation (the institutional environment) has caught up is one question, as discussed in Thematic Papers 5 and 6, but a more important question to ask is whether customary practices amongst groundwater users (i.e. the specific institutional arrangements) have also caught up (Shah, 2007).

This brief account of groundwater institutions attempts to point to the discernible trends in the evolution of local groundwater management institutions and their effectiveness in sustaining the practice of groundwater use. It looks at the scope for securing benefits through improved governance within institutional arrangements and examines the prospects for implementing such improvement.

For reference, the concept of groundwater governance is discussed in Box 1 below and a final version that has been adopted by the project is given.

Box 1: A working definition of groundwater governance

Groundwater governance has been defined as: the process by which groundwater resources are managed through the application of responsibility, participation, information availability, transparency, custom, and rule of law. It is the art of coordinating administrative actions and decision making between and among different jurisdictional levels – one of which may be global. (Adapted after Saunier and Meganck, 2007).

This working definition is, however, quite limited and does not capture the wider context of political and power relations or social drivers that determine outcomes – whether those outcomes are achieved through proactive "management" of the resource or emerge as a direct or indirect consequence of power dynamics and social, political and economic relations. Good governance can be understood as a context in which the mechanisms through which power is exercised and decisions taken are equitable and enable input from diverse sections of society *and* that it is effective – i.e. that decision making processes are as efficient as possible and enable the fundamental goals of society to be met. It is, as a result, both about processes and outcomes. Proactive management of groundwater may be one element of this but other, less management focused, approaches are also central components of the governance equation.

Given the above, the wider definition of groundwater governance adopted by the project is: The process through which groundwater related decisions are taken (whether on the basis of formal management decisions, action within markets, or through informal social relations) and power over groundwater is exercised. A "good" groundwater governance environment is one where governance processes equitably reflect the voices and interests of stakeholders (including regional and global stakeholders with interests in resource sustainability) and where broadly supported courses of action can be implemented in an effective and equitable manner.

The Technical Paper is organized in three parts: Part 1 (Baseline) presents a broad overview of the types of local groundwater institutions and identifies a set of key drivers for such local organization around groundwater; Part 2 (Diagnostic) provides a review of the most relevant constraints to and opportunities for improving governance at local scales and addresses a few specific issues; Part 3 (Prospects) attempts to identify where positive responses are likely to be deployed with most effect.

Part 1 Baseline

2. The Legacy of Early Organization around Groundwater

With few exceptions, groundwater abstraction around the world remained at relatively shallow depth until the end of the 19^{th}century, or even much later in some countries. Apart from diverting water from springs, groundwater mostly used to be tapped by dug wells – rarely deeper than 50-100 m, where water was lifted by human or animal traction – or by infiltration galleries (e.g. *qanats* – tens of meters below surface). Technology for deeper abstraction was not yet available and knowledge on the presence of any aquifers beyond the near surface was in most cases non-existent.

From the start, man relied on open access to springs, river baseflow and shallow groundwater stored in sandy dry riverbeds for their main dry-season water sources. It is, therefore, reasonable to assume early man established strategies to ensure safe access to these water supplies. There is evidence of their limited means for collecting and transporting water. Until recently, the Australian Aboriginal cultures, with no ceramic technology, used animal skins, delicately folded and stitched leaves, tree bark containers, wooded bowls and sea, egg and coconut shells as containers.

Society's systematic exploitation of groundwater for domestic and cattle watering coincided with the transition from forager to sedentary farmer. This followed the domestication of livestock and food plants between 9 000 and 11 000 years BP. Water availability was central in determining man's settlement pattern. The group of 5-m-deep water wells of this age uncovered in Cyprus, and elsewhere in the Near East, reflects a certain understanding of shallow groundwater occurrences. This was likely linked to experience gained when mining of flints and later, metallic minerals for tool making. The establishment of settled farming inherently engendered the concepts of individual or communal ownership of land and water points that required protection by physical force or a system of customary law. Incidentally, it also strengthened the facets of *augmentation and protection* often through implicit systems. Such systems that looked at a larger arena of resource augmentation and protection perhaps saw the first strains of 'governance'.

Archaeological evidence shows the rapid diffusion of all forms of technological advances across North Africa, the Middle East, Arabia, Western Asia, and the Indus Valley and beyond between 10 000 to 4 000 years BP. Parallel technological developments occurred independently across Eastern Asia and South America. By 4 000 BP, wood-lined, hand-dug water wells were in routine uses for community water supplies.

Under differing regional climatic regimes, three main forms of land use evolved:

1) dry land (rain-fed) arable farming developed in the tropical and temperate humid zones;
2) surface water irrigation spread along the major river valleys around 8 000 years BP and more localised pockets of groundwater spring based irrigation developed in the more arid parts of Southern Arabia and along the Persian Gulf;
3) in the sub-humid and semi-arid zones, nomadic pastoralists relied on seasonal vegetation cover and surface and groundwater sources.

Ample surface and groundwater sources are found in rain-fed farming areas and potentially supported the high population densities as seen in the African Lakes Region. In the tropical arid and semi-arid zones from North Africa to Central Asia, a weakening of the southwest monsoon around 5 700 BP caused a regional decline in precipitation. The climate shifted from sub-humid to semi-arid and arid and the woodlands and savannah grasslands across a broad swath of the northern Sahara Desert retreated. The pastoralist and dry land farming population move east to the Nile Valley where they merged with a fast developing surface water irrigation farming culture that mirrored the cultures in the Tigris-Euphrates Valley and the Indus Basin (Bazza, 2007).

2.1 Social cohesion in arid zones – The imperative of scarcity

The evidence of traditional social cohesion around groundwater continues and has been most marked in the rural arid and semi-arid zones where forms of water administration have had to address physical scarcity (FAO, 1978) and shown broad scale cultural responses. Accounts from Yemen where mechanized technologies and the ready availability of diesel (Taher *et al*., 2012) illustrate the importance of tradition but also the capacity to draw up new rules to meet new challenges. Experience from arid developed countries are perhaps less documented (for instance, the south-western USA, and Mediterranean) where intensity of use and rural dependency may have been less pronounced, but systems of abstraction can still be basic (hand-pumps or windlass arrangements).

These modes have not transitioned to urban areas where the need to source groundwater from dedicated well-fields have had to rely on utility models and, in many cases, on the supplementary input of desalinated water. But this scale and concentration of use has also brought about the accumulation of wastewater streams and additional percolation of landscaping water. Shallow groundwater rise and pollution from untreated sewage disposal or leakage from sewers are common groundwater problems inmany arid-zone cities.

2.2 The impact of low-lift technology and social collaboration

The degree to which the progressive introduction of low-lift (non-mechanized) technologies encouraged social collaboration and rule-setting for commonly-owned and -operated groundwater infrastructure is difficult to track in detail. The account given in Thematic Paper 8 indicates evidence of many collaborative initiatives related mainly to both water supply and agricultural use.

With the availability of cheap hand-pumps and shallow groundwater, even poor village communities will opt for individualized on-the-doorstep boreholes and hand-pumps. Taken with the evidence of a trend in private self-supply in urban areas which appears to be global (Foster *et al.*, 2010, Foster et al 2012 – FAO paper), the preference for private access to readily available groundwater seems overwhelming, when no alternative sources are available or when access to a polluted source is considered preferable to higher quality water from water vendors.

The experience of groundwater-based rural water supply in sub-Saharan Africa has been instructive as various solutions for reliable but low-cost manual-lift pumps have been attempted together with attempts to reduce drilling costs. Low-cost and low maintenance technology will continue to be important in mobilizing the low transmissivity aquifers associated with the weathered horizons in basement complex.

2.3 Transitions to mechanized pumping with access to modern technologies

It has been argued that, irrespective of the legal status of groundwater, private interests have shaped the patterns of demand for groundwater (Burke and Moench, 2000). The evolution of these intensely local interests has resulted in a set of identifiable stages. Table 1 outlines the stages of development of the rural non-farm economy (RNFE).

In this sequence, groundwater development would play a particularly critical role, enabling the transition from traditional to locally-linked, but agriculturally-led, non-farm economic development. By enabling farmers to increase production, income and income security, groundwater development would serve as the core engine for rural populations to acquire the wealth necessary for the non-farm economy to grow. Once this has occurred, much depends on the interaction between the groundwater development sequence and the non-farm economic development sequence.

For example, if the availability of groundwater declines when urban areas have a competitive advantage (during the third stage of development), high levels of push migration by farmers to urban areas might be expected. This would also occur if wells went dry, when droughts occurred in regions where water levels had been declining. In contrast, if groundwater remains available throughout all stages of development of the rural non-farm economy, then agricultural economic activities displaced by depletion or degradation of the groundwater resource base may be smoothly absorbed by new non-farm opportunities, and there may be fewer push factors creating an incentive for migration into urban livelihoods.

However, push factors are only one component in the transition now occurring in many regions. Globally, trends towards urbanization are driven by a variety of factors that include the “pull” of urban jobs, urban facilities (e.g. education and health care) and urban lifestyles. In many rural areas, groundwater development may be contributing to the urbanization process, by allowing rural residents to accumulate the capital necessary to successfully migrate and obtain access to the real and perceived benefits available in urban areas. One of the first investments that rural residents often make when they obtain sufficient income is in education. As interviews in drought-affected areas suggest, this is often part of a generational strategy at the household level to ensure that at least one family member has access to non-agricultural employment (Moench and Dixit, 2004). In many regions of India, this trend is seen, even on a day-to-day basis, when many rural people travel to cities for various non-agricultural occupations including labour, services and even small enterprises such as running taxis and auto-rickshaws.

Stage of RNFE	Stage of agricultural development	Level of rural remoteness	Level of urbanization	Main locus of non farm production	Level of non-farm technology, capitalization and returns
One – Traditional	Pre-modern & subsistence	High	Low	Rural (RNFE limited by low purchasing power)	Low: traditional subsistence products
Two – Locally linked	Modernizing and expanding: Initial technology-led agricultural growth	High	Low	Rural (RNFE expands through agricultural-led growth)	Low to medium: Some technology and capital improvements
Three – Leakages to urban area	Modernizing and expanding: Improved urban marketing	Low (new roads open urban markets)	Low	Urban (RNFE competed away by urban goods and services)	Medium to high: as urban location allows investment and economies of scale, RNFE must modernize to survive
Four – New urban linkages	Modernizing and expanding: Increasing urban demand	Low	High (congestion and costs rise)	Shift to rural: Flexible specialization able to exploit to rural advantage	Low to high: From cottage industry outworkers to modern "clustered" and subcontracted units

Source: Start (2001).

Table 1. Development of the rural non-farm economy

Notwithstanding the difficulty in separating the push *versus* pull factors that take people away from ancestral rural homes to towns and cities, groundwater-related problems are significant in making rural people take these decisions. Similar patterns alsoemerge with respect to the development of urban-based businesses and access to urban labour opportunities. As families enable more of their members to move into in urban livelihoods (whether *via* education or other routes),social networks are established that reinforce the transition. Early migrants facilitate the shift for other members of their extended kinship or caste groups. These shifts are probably financed by a combination of income from new urban-based activities and intensive groundwater-based agriculture in rural areas. Again, the core role of groundwater in this transition hinges on its lead role in decreasing the variability in agriculture, enabling agricultural intensification and allowing rural populations to accumulate the capital necessary to diversify into urban-based activities. At the same time, it becomes important to understand how this impinges on the urban water demand and the nature of groundwater use as a consequence of rapid changes in such demand. Much of such rural-to-urban shifts, in large parts of India, for instance, may simply have moved the foci of groundwater abstraction from rural areas at least to peri-urban zones; such zones have now clearly become zones of various 'informal' groundwater transactions and even complex markets.

2.4 Public *versus* private interests

The declaration of public and private interests in groundwater has been pivotal in determining not only the pace and intensity of groundwater development (see Thematic Report 6); it has also conditioned a set of private and community responses. The basic 'rule of capture' for private landowners has dominated and entrenched habits of individual use and expectation. Only in Muslim traditions has the 'right to thirst' systematically protected the third party use of groundwater (FAO, 1978). While this dominance of private interests has persisted into the 21st century, the declarations of public interest in groundwater and aquifer protection find their origin in the protection of public water supply and related public health legislation. Agricultural use has generally remained immune for much of the 20th century.

3. Institutional Models in the 20th Century and their Socio-economic Impact

3.1 Informal models

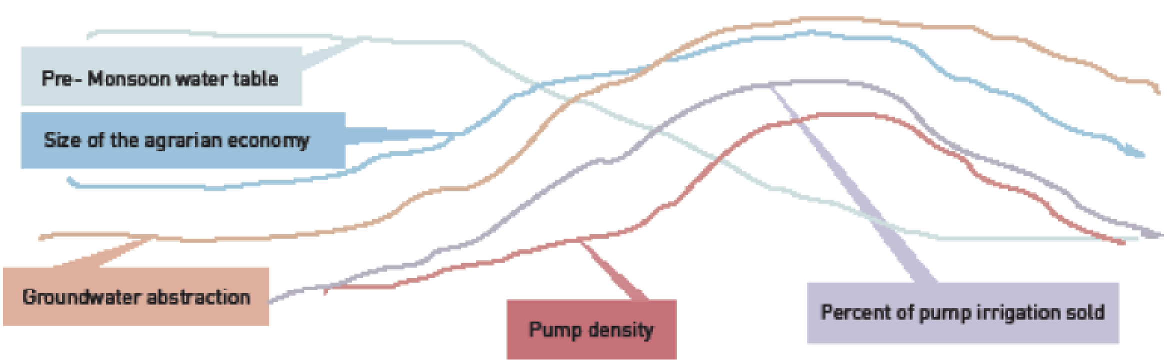
Accounts of contemporary Informal representative organization around groundwater resources, as mechanization and demographic pressure built, are given by van Steenbergen and Shah (2003) and Shah (2007), with more recent examples for Yemen given by Taher *et al.* (2012) and for Andhra Pradesh (Mani *et al.*, 2012) and China (Aarnoudse *et al.*, 2012). In most cases, the driver has been water scarcity. The impulse to fall into some mode of collective management has generally come late with little or no prospect of reversing trends or stabilizing aquifers. Only in the case of recharging shallow and discontinuous aquifers (e.g. Peninsular India), which experience periodic recharge to the point where they can completely fill and discharge, has this form of self-regulation offered a measure of stability from year to year, reversing trends of complete exhaustion by the end of dry years.

The scale and effect of such informal models is difficult to evaluate. There are samples of such local initiatives in many groundwater-scarce localities, and perhaps the most vivid example of the overall shape of groundwater trajectories has been given by Shah *et al.* (2003), as reported in Figure 1.

In many developing countries, governmental organizations for mitigating or otherwise addressing the impact of water scarcity have limited capacities. As a result, populations depend primarily on the resources available within communities and wider social networks. A variety of extended family and patron–client relationships exist that help individuals and families cope with the impact of water scarcity. These networks entitle members to key resources for coping, including:

- *Buffer stocks of food, water and cash.* Networks often enable people to draw on the resources accumulated by others for buffering shortfalls. This can be highly localized (e.g. sharing of resources within a joint family located within a single village) or global (e.g. diasporas – people working outside their country of origin– often supply basic resources to their home areas in times of drought or long-term water scarcity).
- *Credit*. Individuals can, at least in the short term, draw on wealthier family members, patrons or private lenders for cash, food or other forms of support when water scarcity affects agricultural production. In many cases, access to support takes the form of a loan that can be repaid in cash or kind. The terms of such loans vary considerably – from interest-free to usurious – and are often influenced by factors such as kinship and power relations within the community.
- *Alternative livelihoods*. When water scarcity affects the viability of agricultural livelihoods, individuals often rely on social networks to seek alternative livelihoods. This can involve drawing on relatives, friends or social group members who are established in other locations and livelihoods in order to obtain work. As discussed further below, migration tends to follow network affiliations – one particularly outgoing member of a group goes first and "opens the door" for others from his or her home area. It can also involve attempts by wealthy community members to initiate new forms of non-water-intensive livelihoods in their home areas. This has been a common pattern in Kutch (Gujarat) and Rajasthan, where wealthy city-based individuals start craft-development programmes in their rural home areas in order to provide income during drought periods and to develop new long-term livelihoods for rural inhabitants.
- *Risk spreading.* In agriculture, for example, sharecropping often splits the risk of crop loss between the cultivator and the land- or water-owner.
- *Diversification of income sources*. This involves families, or other communities, diversifying livelihood strategies as a group and pooling risk. Often, for example, one brother or sister will have a relatively secure job or business, while others practice agriculture and animal husbandry. Remittance income plays a critical role for many rural communities in buffering the impact of water scarcity. In addition, diversification often occurs between genders, with women staying in the villages to manage agricultural activities while men travel to cities in search of work.

	Stage 01	Stage 02	Stage 03	Stage 04
Stage	The rise of green revolution and tubewell technologies	Groundwater based Agrarian Boom	Early symptoms groundwater overdraft/ degradation	Decline of the groundwater socio-ecology with immiserizing impacts



	Stage 01	Stage 02	Stage 03	Stage 04
Examples	North Bengal and North Bihar, Nepal Terai, Orissa	Eastern Uttar Pradesh, western Godavari, central and south Gujarat	Haryana, Punjab, Western Uttar Pradesh, Centra Tamilnadu	North Gujarat, Coastal Tamilnadu, Coastal Saurashtra, Southern Rajasthan
Characteristics	Subsistence agriculture; protective irrigation traditional crops; concentrated rural poverty; traditional watering devices using human and animal power	Skewed ownership of tubewells; access to pumping irrigation prized; rise of primitive pumping irrigation 'exchange' institutions Decline of traditional and technologies; rapid growth agrarian income and employment	Crop diversification; permanent decline in water tables. The groundwater based 'bubble economy' continues booming; water intensions between economy and ecology surface as pumping costs soar and water market become oppressive, Private and social costs of groundwater use part ways	The "bubble" bursts; agricultural growth declines; pauperization of the poor is accompanied by depopulation of entire clusters of water quality problems assume serious proportions; the "smart" begin moving out long before the crisis deepens; the poor get hit the hardest.
Interventions	Targeted subsidy on pump capital; public tubewell programmes; electricity subsidies and flat tariff	Subsidies continue. Institutional credit for wells and pumps. Donors augmented resources for pump capital; NGOs promote small farmer irrigation as a livelihood programme	Subsidies, credit, donor and NGOs support continue apace; licensing, siting norms and zoning system are created but are weakly enforced. Groundwater irrigators emerge as a huge, powerful vote bank that political leaders can not ignore.	Subsidies, credit and donor support reluctantly go; NGOs, donors assume conservationist posture zoning restrictions begin to get enforced with frequent pre-election relaxations; water imports begin for domestic needs; variety of public and NGO sponsored ameliorative action status

Source: Shah, (2003)

Figure 1. Rise and fall of groundwater socio-ecologies in India (after Shah et al. 2003)

While access to social networks enables implementation of the above coping strategies, such networks often impose constraints on individuals. Access and the ability to use social networks are often influenced considerably by power relations. In many traditional societies, land, labour, credit and water markets are interlocking. As a result, access to resources when they are needed in order to cope with water scarcity is often conditional on other agreements, such as willingness to supply labour or sell products at terms benefiting the creditor (Janakarajan and Moench, 2002). Furthermore, access to networks often depends on the social position of individuals. For example, gender can be a key factor influencing the ability of individuals to obtain credit or engage in risk-spreading activities, such as sharecropping (Chen, 1991). Overall, power relations within social networks are key factors determining both the relative equity with which such networks function and the *quid pro quo* position people are in when they need resources to cope with scarcity. Furthermore, as Chen (1991) comments, the ability of social networks to supply sufficient resources to cope with scarcity problems is influenced considerably by the length and severity of such problems. When problems occur over an extended period or when needs are intense, social networks enabling provision to local resources are often overwhelmed or break down (Chen, 1991). However, networks remain important in relation to migration.

3.2 Formal models

The examples of more formal arrangements driven by national or federal initiative sare not comprehensive, with the United States of America (USA), Mexico and Spain providing the bulk of the evidence. The USA experience is drawn primarily from the mid-west (Ogallala Aquifer), the southwest and the detailed examination, offered by Blomquist (1992), of small basins in southern California. Smith (2003) gives an overview of such collective approaches and assesses their performance in the light of a generally liberal approach to groundwater development. However, despite the long experience of groundwater districts in the western USA, with the exception of Blomquist, little social analysis is published and reliance on administrative/legal approaches tends to occur (Peck, 2007; Schlager 2006).The most notable experience is that gained in Mexico under the COTAS (*ComitésTécnicos de AguasSubterráneas*), provided under the 1992 Mexican National Water Law (Wester *et al.*, 2011).The COTAS experience in the State of Guanajuato, Mexico, may not have produced the anticipated reductions in groundwater abstraction, but does illustrate how participatory mechanisms of this scale (upward of 17 000 well owners across 14 aquifers) are unlikely to advance natural resource conservation without "credible incentives for self-regulation" (Wester *et al.*, 2011). In the same vein, Lopez-Gunn (2006) questions the viability of voluntary self-regulated user associations in Spain without some form or respected or legal thrust.

An overview of available examples is given by Schalger (2007), primarily in relation to agricultural use. However, the degree to which certain forms of groundwater self-regulation are growing urban areas remains 'hidden' for the reasons set out by Foster *et al.*(2012), even if examples of 'condominium' approaches to resolve local temporal-spatial water scarcity are striking (Barraqué *et al.*, 2012).

Several trends stand out. First, the interest of public utilities – strategic reserves and aquifer protection primarily for urban water supply, which can lead to pure groundwater-based institutions and markets. Clearly articulated definitions of conventional approaches to groundwater management are rare, and attempts to compile and evaluate approaches are limited (Sagala and Smith, 2008). Most approaches focus on direct interventions that influence either the supply of or demand for groundwater in order to create desired aquifer conditions – typically, the maintenance of specific water-level or water-quality parameters. Generally, these approaches aim at water allocation across river basins and, in doing so, generally assume the following:

a) *The presence of an organization*. An entity, whether governmental, private sector or community-based should have the capacity to affect the supply and demand for groundwater and to change groundwater quality through a combination of:

    - physical works (e.g. recharge structures, wells, surface storage, water supply and delivery technologies);
    - regulation (e.g. well spacing, licensing and use restrictions); and
    - incentives (e.g. subsidies, pricing, education, development and dissemination of technologies).

b) *Monitoring and scientific capabilities*. The presence of groundwater-level and water quality monitoring networks, along with the hydrological and other scientific capabilities, is necessary to understand and predict the impact of management actions on aquifer conditions (flow directions, water levels, and quality changes). Essential monitoring and scientific capacities for management include many of the technical factors identified in Chapter 4, such as:

    - the ability to document and monitor water use, including accurate data on well numbers, extraction rates, well locations, well ownership, etc.;
    - basic hydrogeological information on aquifers, including key boundary conditions and links with surface systems (recharge areas, locations with potential for interaction with surface streams and wetlands, water available for recharge, information on deep groundwater flows, etc.);

- the ability to monitor conditions in aquifers through a network of monitoring wells and associated analytical capacities for water quality testing;
- the ability to interpret groundwater monitoring data, preferably using standardized modelling tools; and
- the ability to predict, within reason, the likely impact of management actions or use changes on groundwater conditions.

c) *An enabling legal system capable of enforcing management decisions*. Because groundwater use generally occurs through private wells located on privately owned lands and because it affects livelihoods directly, attempts to manage it generally require some form of legally sanctioned enforcement authority and the establishment of a legally-recognized basis for management organizations. Unless the authority of an organization to intervene is "recognized in law", its ability to intervene in ways that affect groundwater use will be undermined by the non-cooperation of some individuals, even if the majority of people in a region support it. As a result, the legal system required for conventional approaches must incorporate:

- a legally-recognized basis for the establishment of a management organization;
- a formal and legally-recognized regulatory authority;
- a clear definition of groundwater rights (whether held privately or by the State); and
- appropriate mechanisms for dispute resolution that are viewed as legitimate by users.

d) *The presence of social – and, by extension, political – incentives to take management action at geographical and temporal scales that can affect groundwater conditions*. Most groundwater experts implicitly presume that the groundwater pollution or depletion problems should create a strong incentive for society in general, and local populations in particular, to take action. However, the research for this study suggests that this presumption is often unfounded. People do not 'care' about groundwater conditions – they 'care' about livelihoods, their economic future and many other values, often including wider environmental conditions. In many cases, the values in which people have such interests are only indirectly related to maintenance of the groundwater resource base. Even where communities or individuals are deeply concerned about groundwater problems, they face major difficulties in developing organizations that function at the scale of an aquifer or over the extended period required for management to be effective. Given the rapid changes affecting society in many parts of the world, long-term sustainability is often of far less importance to people than immediate benefits and the hope that allows for transition to better livelihoods. As a result, populations – and, by extension, their political representatives – may have strong incentives not to manage groundwater resources. At the same time, policy rarely provides the disincentives necessary to counter popular modes and mechanisms of groundwater use in order to achieve better management of the resource.

e) *The awareness and capacity at State or national levels to address cross-sectoral policy issues – such as power pricing or agricultural subsidies – that have a major impact on groundwater conditions*. In many cases, the ability of local organizations to influence groundwater use depends on State-level or national-level policies. For example, this is the case in India, where some states provide electricity free of charge for agricultural users and, as a result, reduce economic incentives to conserve water. Although this scenario is gradually changing with electricity boards opting for single-phasing (domestic supply) *versus* regulated three-phasing supply for agriculture, the actual implementation is proving difficult. However some now argue that regulation of electricity through State-level reforms has had significant impacts in Gujarat and West Bengal (Mukherji *at al.*, 2009). Therefore, conventional approaches to management require at least some ability to tailor national and State policies for other sectors in ways that influence groundwater use.

Finally, the imperatives to organize over conjunctive use in irrigation has come late in the day, even when the trends in conjunctive use had been apparent for several decades or more (e.g. South Asia). Overall, there are very few examples of institutionalization and socialization in order play with groundwater ahead of the game – that is, the establishment of institutions for managing depletion and recharge.

3.3 A reliance on groundwater regulation

Thematic Paper 6 documents the range of regulatory approaches to groundwater management. There have been few specific summaries of the status of groundwater within national water legislation. Burchi (1999) offers a perspective based on some of the explicit mentions of groundwater made in such legislation – but this largely reflects the post-industrial concern with pollution of groundwater and aquifers. A more elaborate overview is offered in FAO (2004) in the discussion of the interface between land and water rights, while the relationship between customary and statutory rights is further explored in FAO (2005). The interest here is one of local governance and regulation of groundwater.

Observed trends in water and groundwater legislation confirm an overall preference to put groundwater in the public domain – to the extent that public registration of groundwater use is required – but as Box 2 illustrates, even when a prima facie case for conserving strategic aquifers exists and regulatory provision is made, actual management can be confounded by persistent 'non-compliance'.

Box 2: The Malta case

The difficulties in applying groundwater regulation do not always appear to be conditioned by the scale of the issue or the lack of knowledge. Even when the imperatives for engaging groundwater users in regulated approaches to resource management would appear straightforward and the level of aquifer understanding is high, resistance to regulation can still arise.

A recent review of the status of groundwater resources and the prospects for its regulation (FAO, 2006a) reveals public ignorance of, and indifference and resistance towards, public policy that would change the *status quo* for Malta's farming community. This is in spite of Malta's need to comply with the European Water Framework Directive and achieve 'good status' with respect to its groundwater resources.

Despite the declaration of groundwater protected zones in the Maltese Islands, public water supply wells are consistently compromised by "illegal" drilling, disposal of waste to groundwater, and over-abstraction from private boreholes. Intense levels of use occur across very open carbonate aquifers, most of which are in direct hydraulic connection with the Mediterranean Sea. Fresh water is available in a marginal lens floating on saline water. Freshwater is skimmed or pumped from this lens for public supply and has to be scrubbed and blended with desalinated water before it can be used as potable water.

The Maltese Resources Authority (MRA) charged with the implementation of the European Water Framework Directive has not been able to advance progressive groundwater regulation.

Source: FAO, 2006b

4. Drivers of Institutional Change and the Governance Outcomes

4.1 Coping with scarcity

Groundwater scarcity appears to be the main driver of institutional response – for both formal and informal approaches. Most cases involve giving up a measure of private interest in groundwater access in order to resolve a common property problem – primarily that of water quantity and, to a lesser extent, that of water quality. What has given the impulse for social organization around aquifer management? An obvious cause might be simple demographic pressure raising the overall level of demand for water. But the actual impulse to organize in relation to specific aquifers has generally derived from a perception of scarcity: the intensive use of groundwater, as identified in Llamas and Custodio (2003), triggers a concern that the same level of service from a specific aquifer cannot be expected in the future, and hence private users become interested in different forms of community response. Without some level of private interest in a common solution, initiatives to set 'rules of the game' for a specific aquifer will not occur – even if the public interest in doing so is high. A wide range of coping responses is reviewed in Section 6.2 below.

Changes in land tenure *per se* do not appear to drive, but land tenure is fundamental if only to grant permits for drilling or digging a borehole or well. The linkage between land (held in title as as a ' perfect' property right) and access to groundwater has always provided a starting point. Within agriculture there are few examples of collective linking of boreholes and transformation into a utility operation (e.g. Nile Rivereast west delta, Egypt). For public utilities and public rural supply, in most cases, public land is implicated although competition with agricultural users on village boundaries and beyond (Chennai, India) is an issue. It is likely that private ownership will force fragmentation until the problem becomes too big to ignore.

4.2 Food security

That groundwater depletion and quality problems have serious implications for food and livelihood security in rural areas is all too apparent. However, these links are not related primarily to overall food production, but more to the income stability and reductions in agricultural risk that groundwater can provide within agricultural livelihood systems. At a macro level, current data availability and analyses are insufficient to demonstrate any direct link between emerging groundwater problems and food production at a global level (FAO, 2001). While not focused on groundwater, analyses by FAO (2000) indicate that: "the overall lesson of the historical experience, which is probably also valid for the future, seems to be that the production system has so far had the capability of responding flexibly to meet increases in demand within reasonable limits." However, this does not imply that groundwater conditions are unimportant in relation to food security. At a national level, countries such as the Syrian Arab Republic have defined domestic production as a national security issue.

More fundamentally, reliable groundwater access can provide a foundation for productive livelihood systems that enable rural populations to obtain access to education and other resources that, in turn, reduce their dependence on groundwater, the initial foundation of their wealth. The argument here is similar to that advanced by Sen and others (Dreze, Amartya and Hussain, 1995; Sen, 1999) when they posit famine as a failure of entitlements – that is access to the market, governance, communication and other socio-political systems that determine the ability to purchase food when localized sources fail.

The link between groundwater and food security depends considerably on the nature of the household economy. Where households depend heavily on agriculture, groundwater provides the secure foundation for forms of production that either generate food or the income necessary to purchase food from the market. Groundwater depletion and degradation threaten this foundation and, thereby, threaten food security, primarily where populations have few options other than to retain their dependence on agriculture. From this perspective, doing nothing toaddress emerging groundwater problems could have major implications for food security at national or global levels as the prime buffers against variable rainfall become progressively depleted and degraded.

4.3 Social stability

Groundwater-based agriculture can provide a foundation for locally-based economies that alleviate poverty and help to root populations in areas where core educational and other services can be developed. This appears to have been a consideration in Saudi Arabia when groundwater development was used to catalyse wheat production. To limit urban migration and stabilize rural populations, Saudi Arabia drilled more than 100 000 wells, provided a 40-percent subsidy for farm equipment, and put in place a price-support policy for wheat between 1980 and 2000 that ranged from USD 0,57 to USD 0,97/kg. Abderrahman (2001) concluded: "This agricultural development was an essential tool for social balance between urban and rural areas. The intensive agricultural developments resulted in the creation of stable farming communities in rural areas…. These prosperous communities helped in supplying the country with educated healthy generations of young men…They also helped in filling the deserted areas and in giving the support to security and defense authorities in remote areas…Other benefits were gained also such as minimization of movement of inhabitants from rural to urban areas."

The use of water as a tool for stabilizing populations is not unique to Saudi Arabia. In many countries, agricultural intensification based on groundwater development has been a leading element in agricultural development and poverty alleviation strategies. This was the case in India and, as recently as 1995, it was proposed as a lead strategy for Nepal (Agricultural Projects Services Centre and John Mellor Associates, 1995).Groundwater overdraft, combined with drought, undermines agricultural production and is a factor catalysing outmigration. For example, this has been well documented in field research on drought in Rajasthan and Gujarat, India (Moench and Dixit, 2004). Effective groundwater management can, at least to some extent, reverse this. For example, in Andhra Pradesh, India, out-migration has halted, and populations are migrating into regions where aquifer management has proved viable. Prior to this, outmigration in years of poor monsoon had become pronounced (APFAMGS, 2007).

4.4 Technology

As detailed in Thematic Paper 8, access to technology and energy will continue to dominate and entrench self-supply under 'liberal' conditions that do, in fact, prevail in most countries with respect to groundwater. The adoption of improved technology and the distribution of energy can be expected to permit the progressive extension of capture of groundwater. This may reflect an overall inability to regulate thousands of individual users or a deliberate policy of rural subsidy. The degree to which local groundwater institutions organize around specific types of technology is revealing. For instance, van Steenbergen *et al.* (2003) point to the role of common ownership of step-down transformers in Andhra Pradesh, India, and the evolution of groundwater 'utilities' with shared pump and distribution technologies in Egypt.

4.5 Groundwater markets

4.5.1 Informal markets

Informal groundwater markets have conferred a distinct level of local organization and a measure of self-regulation, as the demand for groundwater to service both agriculture and potable water supply has grown in Asia (Shah*et al.*, 2003). By their nature, markets are flexible institutions that enable reallocation of water as demand and availability change. Informal water markets, in urban areas, have evolved as a way of coping with poor quality by averting impacts on domestic consumers. Informal groundwater markets are also common in regions, such as in India, where groundwater plays a major role in agricultural production. In many ways, the evolution of such markets can be seen as a mechanism for coping with scarcity and the cost of obtaining supplies. Where groundwater is readily available close to the surface and the cost of wells is, as a result, low, there is little incentive for landowners to buy or sell water. Where water is scarce, in either an absolute sense or because the costs of wells and pumping are significant in relation to farm incomes, then strong incentives often exist for the evolution of local, informal groundwater markets.

Evidence on the role informal water markets play as an institution for coping with water scarcity is mixed. The situation that was discussed above, in locations such as Yemen and Chennai and Ahmedabad in India, indicates the major role that informal water markets can play in reallocating available supplies from agriculture to uses where domestic or industrial consumers have more ability to pay. In such situations, water sales can represent a major source of livelihood for well owners while also meeting the basic needs of domestic consumers.

Box 3 The implicit water markets of the Kolwan Valley

In the Kolwan Valley of the Mulshi Block of western Maharashtra, India, there is little evidence of water trade between farmers. It has 16 villages, forming part of the landscape of the Western Ghat. Paddy is grown in the monsoon as the rainfall is high (1 600 mm), and crops such as wheat and vegetables are cultivated in winter. Some farmers also grown sugar cane. In the dry season, irrigation is through some 100 lifts from the main channel of the river, fed mainly by releases from three upstream reservoirs. Groundwater is used mainly for drinking-water supply but also as a supplementary source of irrigation to the lift schemes. During the course of the AGRAR Project (Kulkarni *et al*., 2005; Gale *et al*., 2006), formal questionnaires revealed that there was no water sharing or trading between farmers. However, subsequent surveys revealed that there was a gap of more than 50 percent between the amount of irrigated land and the quantity of water supplied through the lift irrigation system. Groundwater use was also estimated, and the gap came down to about 40 percent. More probing investigations and field studies revealed that a significant part of the irrigation in the valley was on farms that had no "formal" access to any irrigation source. Farmers in most villages subsequently conceded that there was a trade between farmers with access to surface water and those without. This was essential in order to make sure that they would be able to grow at least the minimum share of the crop that contributed to a major share of their agricultural livelihood. It seems that water markets can exist, even in areas where they do not appear to.

Source: Kulkarni et al., 2005; Gale et al., 2006.

However, water sales appear to be less common in situations where well yields are low and groundwater access is unreliable, than in situations where water availability is higher. For example, research in Tamil Nadu, India, indicates that farmers only sell supplies that are in excess of amounts they need to irrigate their own crops (Janakarajan, 1994 and 1999; Janakarajan and Moench, 2002). Water markets in Gujarat, India, have developed in deep aquifer areas. There, although water levels in the deep alluvial areas are declining at rates of 1-3 m/year, well yields are high, and the amount that can be pumped is more than sufficient to irrigate the land held by most individual farmers. Because water levels have declined substantially, the fixed costs of drilling a well are high. Pumping costs are also substantial, and they are also fixed, because electricity is charged as a flat annual fee based on pump horsepower rather than on consumption. In this situation, the high fixed costs associated with groundwater irrigation, combined with the productive nature of the wells, create a strong incentive for farmers to sell excess supplies. The marginal cost of pumping is zero, and the average cost declines with the amount pumped (Moench, 1993 and 1994; Shah, 1993).

Research in recent decades suggests that the evolution of informal water markets, as a mechanism for allocating available supplies and coping with scarcity, appears to depend on a variety of factors:(i) Hydrology, particularly as it affects well yields, is important. Informal water markets within agriculture are unlikely to evolve if the supplies available from individual wells are insufficient for irrigating the average landholding: (ii) Transport is also a critical factor. In Ta'iz (Yemen), Kathmandu (Nepal), Chennai and Delhi (India), proximity to roads and demand centres is critical to the economic viability of tanker markets;(iii) Cultural characteristics, in particular traditions of cooperation, may also be important. For example, in Gujarat, the Patel community has strong cooperative traditions that enable farmers to easily lay pipelines under one another's fields and to form cooperative groups for managing wells – activities that can be socially complex in other cultural environments. Such cooperative arrangements also appear to provide a foundation for relatively equitable water markets;(iv) Trust is generally high, and exchange agreements are honoured. In other situations, cultural traditions of cooperation are not as widespread, and the social basis for water markets to function may be weaker. Further, as discussed above, informal water markets are often interlinked with credit, labour and produce markets, and are influenced considerably by social power relations at a local level (Janakarajan, 1994; Dubash, 2000). Consequently, while they may help sections of the population cope with water scarcity, other sections may be affected adversely by their operation.

4.5.2 Formal markets

Beyond informal water markets, much has been written on the role that more formalized water markets based on clearly defined rights systems can play in enabling water reallocation in times of scarcity. In the west of the USA, such rights systems have introduced substantial flexibility into existing water allocation patterns. This has played a significant role in the ability of regional agricultural economies and municipal areas to cope with fluctuations in water availability between years. As a result, water markets along the lines of those developed in western USA are often proposed as mechanisms for increasing the efficiency of water use and flexibility of water allocation in other areas. At the same time, the evolution of water markets in these areas was supported not only by the rights system, but also by good scientific data and a continuously evolving water law framework.

While attempts have been made to develop water rights systems and market mechanisms in other areas, e.g. Chile, the results have been mixed (Bauer, 1997). Furthermore, particularly in the case of groundwater where data for the establishment of rights systems are often unavailable, how water rights systems could be established is an open question. Debates over the establishment of water rights systems have been widespread in India but have led to little real movement (Moench, 1994 and 1995). The *Pani Panchayats* in Maharashtra set forth delinking land and water rights for equitable distribution of water, both in small surface water reservoirs as well as in the basalt aquifers from low-rainfall, drought prone regions. Progressively though, many of these were impacted by free-riding resulting from large-scale well-programmes, rural electrification and other such factors (COMMAN, 2005; Kulkarni et al, 2009). In the absence of a right-based legal framework, that India is now attempting to revisit (Cullet, 2012), many efforts at linking rights and allocations through informal, socially-driven efforts seem to be running into many different types of hurdles. In Mexico, the process of registering all wells as a precursor to the establishment of rights has, as previously discussed, been problematic. Finally, in the west of the USA, where volumetric right systems have been established, it has proved difficult to limit groundwater extraction to sustainable levels, and substantial debate exists over the impacts of water markets on third-party and environmental interests. As a result, major questions remain over the role that water markets could play as an adaptive mechanism for coping with changes in water availability and demand.

4.5.3 Synthesis: Issues in the Role of Water Markets

Water markets represent another form of institution for allocating available supplies. Key issues in the role that markets play as part of coping strategies include:

f) *Short-term* versus *long-term impacts.* In locations such as Gujarat and other states in India, informal water markets enable access to “secure” water supplies in drought periods, but they also contribute to overdraft because rights systems bear no relation to the volume available on a sustainable basis. As a result, while they are effective for coping with short-term fluctuations in water availability, they undermine the resource base available for coping in the long term.

g) *Social differentiation.* Groundwater access is influenced considerably by landownership and well-ownership patterns. While water markets enable reallocation of available supplies, they do not reflect third-party interests – such as the interests of agricultural labourers. The trade-offs inherent in existing informal water markets need to be understood more fully. In order to evaluate the role of water markets as a coping mechanism it is, for example, important to know how many livelihoods are being created *versus* how many lost in situations such as those in Tamil Nadu, India, and Ta’iz, Yemen.

h) *Transition from informal to formal.* Informal groundwater markets are common in many areas, but relying on these as a major mechanism for reallocating available supplies in the absence of clearly accepted rights systems has major equity implications. Establishment of such formal rights systems is, however, culturally complex and often requires data that are unavailable.

Overall, while the evolution of markets as a mechanism for coping with water scarcity is common, the operation of water markets has complex implications within local societies. In many cases, informal markets can help populations to cope with short-term fluctuations in water availability. However, because they do little to address (and may exacerbate) overall resource-use imbalances, they may exacerbate long-term water scarcity problems. In theory, markets based on quantified and transferable water rights systems could serve as a highly flexible mechanism for coping with both long-term and short-term fluctuations in water availability – but the establishment of rights systems is complex. Questions of transition between the development of markets as an informal coping response to scarcity and as a formal "institutionalized" response are particularly important.

4.6 Environmental compliance

Finally, environmental compliance and aquifer protection appears weak as a driver of collective management. The impact of groundwater depletion and quality problems on streams and wetlands has been extensively documented in many parts of the world (Sophocleous, 2002a). In India, concerns over the impact of falling water levels on stream flows began to emerge more than two decades ago (Bandara, 1977; Kahnert and Levine,1989). Groundwater and surface water systems are often closely interconnected. Wetlands and base flows in rivers generally depend on groundwater contributions. As abresult, even relatively minor changes in water levels can have a major impact on key environmental values (Burke and Moench, 2000). However, the issue is not related only to water availability. Changes in groundwater quality can also have a major impact on surface ecosystems. In many developing countries, including India, the significance of groundwater in maintaining base flows and wetlands is something that has begun to be understood and accepted only in the last decade or so.

Concerning the question of how widespread the impact of groundwater development is on wetlands and streamflows, the National River Authority in the United Kingdom (UK) "has drawn up a priority list of 40 locations where unacceptably low river flows are considered to be caused by excessive authorised abstractions, rather than drought" (UK Groundwater Forum, 1995). Between the 1960s and 1990s, perennial streams in Kansas, USA, decreased in length in the western third of the state, altering the composition of riverine communities considerably (Sophocleous, 2002a and 2002b). Stream and groundwater quality has also declined with saline migration and the introduction of nutrients from agricultural activities into aquifers that feed surface systems. In the USA, more than 48 per cent of the original wetland areas have been lost on average in all of the States (Gleick, 1993). Some States have seen larger declines. For example, in California, wetland areas have declined from historical levels of 1,2-2,0 million ha to perhaps 182 000 ha, a drop of 85-90 per cent (DWR, 1994). The loss of inland freshwater wetlands is also severe in Europe with losses of 60-70 per cent in several countries (Sophocleous, 2002b). While some of these losses have been caused by changes in land use and intentional drainage programmes, intensive extraction of groundwater for multiple uses is increasingly well documented as a major causal factor. Overall, the impacts of intensive groundwater use on key environmental values have been estimated as significant and the costs of doing nothing assubstantial.

Integrated approaches to groundwater management are conceptually logical but, as suggested above, extremely difficult to implement in practice. This is particularly true under developing-country conditions, where many issues of direct and fundamental importance to survival and livelihoods place large demands on limited financial and technical capital. This could depend on a combination of fundamental factors in the way people organize along with challenges, such as the scale of management needs, data availability and variability that are more groundwater-specific.

5. Constraints

If an environment of good conduct is to be extended to fill the apparent groundwater governance gaps, the need for this to apply at the point of abstraction or the point of pollution will always implicate local institutions who have an interest in maintaining public goods (e.g. water supply or specific common property resources such as pasture and aquifers). Three constraints stand out: First, the local and private nature of many groundwater economies in rural and urban settings stands out as a main constraint – and sometimes as an absolute barrier. The preference for assured private supply from groundwater sources are intense in rural and agricultural settings – but has a relatively recent legacy as cheap hand-pumps and energized pumps have become available. This essentially private nature of informal groundwater economies appears to have confounded attempts at direct regulation of groundwater use – whether to prevent use of polluted groundwater, protect local sources or curb what are regarded as excessive drawdowns.

Second, the rigidity of water management institutions with respect to groundwater and hydrocratic visions is notable and persistent. In the case of groundwater, the ability to implement integrated management concepts is further limited by a combination of factors including:

- *Data, information and technical understanding*. In most cases, data and technical understanding are rarely sufficient for effective management of groundwater systems, let alone integrated management.
- *Scale.numbers, geography and time.* Larger aquifer systems often extend under hundreds of villages containing thousands of users, and the geography of groundwater rarely matches the geography of human administrative systems.
- *Variability*. Aquifer conditions vary considerably even at a micro-level, as do social and economic conditions. This variability complicates the development of management systems by making uniform, rigid and often "prescriptive" approaches inappropriate.
- *Social capacity constraints.* In many areas, the social capacity available for management is limited. Either organizations do not exist, financial and other capital requirements are unavailable, or human resources are already fully committed.
- *Persistence of conventional 'water-focused' approaches.* In the groundwater case, this is even more evident as they tend to be very groundwater-focused. They are intended to reduce social and environmental impacts of intensive groundwater use by controlling changes in groundwater resource conditions. It can be argued that this focus misses many opportunities present in the wider socio-economic and political context for mitigating the impact of groundwater overdevelopment on key environmental or social services.

The limitations identified in this section lead into subsequent arguments for the development of a wider policy perspective. The above elements can be seen as the foundation for conventional approaches to groundwater management. However, it is important to recognize that, on a conceptual level, the water management community generally locates groundwater issues within larger concepts of integrated water resource management (IWRM) and sees groundwater as best approached as part of an IWRM package. However, definitions of IWRM are broad. The Global Water Partnership (GWP) (CGWB, 1996; GWP Technical Advisory Committee, 2000) states that: "IWRM is a process that promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems."

The definition is demanding. It requires development and maintenance of a process that is capable of addressing a wide variety of land-use as well as water issues in order to meet multiple, and often contradictory, economic, social and environmental objectives across multiple physical and administrative geographic scales.

Despite their complexity, IWRM concepts are the driving force behind most' conventional' attempts to address the wide variety of water management needs. This implies that the requirements identified above as central to conventional groundwater management are only a starting point. Additional capacities are required if groundwater issues are to be addressed as part of a comprehensive IWRM approach. They range from an abilityto understand and monitor the wide variety of factors that influence land as well as water use to social psychology and the ability of management entities to work closely with a wide variety of stakeholders across multiple temporal and geographical scales.

Finally, there is limited institutional interest attached to highly-distributed low-intensity investments. Integration necessarily involves a set of transaction costs and can be expensive. While it may be possible to concentrate available social capital to implement management in a few high-priority areas, resources are often insufficient to implement management on large space and time scales. Moreover, the amount of capital required increases as resource conditions deteriorate, the scale of a problem emerges to be much larger than anticipated and the social capacity constraints become evident over time.

5.1 Principles *versus* practice: the limits of human organization

As just explained, IWRM involves the development of processes and organizations to promote "the coordinated development and management of water, land and related resources" (GWP Technical Advisory Committee, 2000). Such organizations require foresight and the ability to understand and address multiple, often conflicting, debated and vague objectives over long periods. This seems to contrast with the nature of most human organizations. This paper finds that organizations tend to be most efficient and effective when they focus on clear tasks and immediate needs. Long-term objectives may be addressed – but only where the objectives are very clearly and narrowly defined in ways that draw support across broad sections of the population. It is necessary to examine what supports this assertion and what it means for integrated approaches to groundwater management.

The clear definition of long-term objectives largely depends on political priorities and financial processes. Leadership that is capable of providing high levels of support over the long periods required for sustained management of the water resource base is extremely rare. Leaders are often occupied by the issues of the day and have to devote most of their attention to such issues. As a result, support at a political level forthe broad types of actions necessary to achieve IWRM will, vary considerably over time. Limitations on support at the political level are further complicated by the array of social, technical, institutional and economic capacities required in order for integrated approaches to succeed. It suggests that organizations will probably be most successful when their focus revolves around a relatively narrow set of clearly-defined activities. Building core competencies in the diverse set of fields required for integrated approaches to succeed is at best a complex, long-term process. In many situations, the absence of sustained funding and other support may make it, for all intents and purposes, nearly impossible. Hence, management organizations focus on immediate problems rather than on a wider (and generally much more nebulous) set of objectives. As problems are addressed, attention shiftsto new areas, both geographically and in terms of the types of problems itself. Responses to problemstend to be incremental rather than comprehensive (Moench, 1999a).

Water experts often decry the lack of "political will" as a major factor undermining groundwater and surface water management. As the GWP Technical Advisory Committee (2000) comments: "in many cases, the biggest problem is not lack of adequate legislation but lack of the political will, resources and means to enforce existing legislation." In the case of groundwater, the partial visibility and the largely hidden nature of the resource make the task of separating demand, supply and need difficult (Kakade *et al*., 2001).The emphasis on focus made in business literature is replicated in the literature on the management of common-property resources such as groundwater. This literature highlights an array of factors that research has indicated are common to successful management of common-pool resources (BOSTID, 1986; Bromley, 1998; Ostrom, 1990 and 1993).

Some of the most important factors that emerge regularly in this literature include:

- articulation of the need for groundwater management;
- clear systems of rights or rules-in-use governing access and resource utilization;
- clear boundaries on the resource and the user group;
- mechanisms to control free riders (including ways to restrict access for non-members or those not holding resource-use rights);
- clear systems for monitoring resource condition and use, including documentation of the benefits from management;
- relative economic and cultural homogeneity among group members;

- a proportional equivalence between the costs and benefits from management;
- effective mechanisms for enforcement;
- small primary-management group size, often accompanied by the nesting of institutions where some management functions need to occur at regional or system rather than local scales[1].

Taken together, all of the factors discussed above point towards fundamental social organizational challenges facing the development of comprehensive integrated approaches to groundwater management. While logical from a resource perspective, such approaches do not match the way humans organize. Human society worldwide has faced major problems in responding to "creeping environmental problems" (Glantz, 1999) such as those associated with groundwater. Writing on the underlying structural changes at the root of revolutions, Holling, Gunderson and Peterson (2002) comment that: "organizations and institutions failed to cope with these slow changes because either the changes were invisible to them, or they were so contested that no action could be agreed upon." The same could be said about groundwater: when cast in a "comprehensive, integrated" framework, management objectives are generally too diffuse, boundaries are unclear, too many people, needs and objectives must be involved, and so on. Broad integrated attempts at comprehensive groundwater management are unlikely to succeed in many contexts. These arguments are elaborated on in Moench (2002). They point to the need to focus groundwater management attempts narrowly – on clearly defined problems that are of direct relevance to local populations.

5.2 The risks in doing nothing

The risks associated with the intensive use of groundwater resources are illustrative of two issues:

1) the potentially large social and environmental consequences associated with unregulated intensive groundwater development; and
2) the lack of detailed information for evaluating theactual social and environmental impacts emerging in many areas and the extent to which they represent real problems that society cannot afford to ignore.

Morris *et al*. (2003) have documented how falling water levelsa nd water quality degradation, associated with intensive groundwater development, have significant implications for surface ecosystems, particularly wetlands, in-stream flows and water quality. Implications for basic livelihoods, poverty and social stability have the potential to be equally severe – but are far less well documented. Further, unlike environmental values, which depend directly on groundwater levels or water quality, social impacts are contingent on a wide variety of factors unrelated to groundwater resource conditions. For example, the most severe impacts of water-level declines will probably emerge where drought affects regions with shallow, poorly diversified economies with large populations thatdepend directly on agriculture for their livelihoods. Int his situation, people may not have the ability to diversifylivelihood strategies and move beyond, or otherwise cope with, the lack of water for agriculture. However, in other situations, the depth of regional economies may enable farmers to diversify livelihood strategies and escape from dependence on agriculture – effectively mitigating theimpact of changing groundwater conditions on livelihoods.

Differences in these scenarios point to the complexity of evaluating the larger significance of groundwater-level declines. At one extreme, groundwater overdraft can catalyse local food insecurity, migration and political instability. At the other extreme, intensive and unsustainable use of groundwater can be a mechanism enabling regions to escape from poverty to far more diversified andwealthy livelihoods. The main risk to society lies in not knowing which track it is on in different locations and, as a result, in the inability to develop appropriate and targeted response strategies.

Uncertainty and risk are also at the centre of macro questions about food security. While current analyses suggest that groundwater overdraft has little implication for global food production, this result depends on the assumption that climate and weather changes willnot cause droughts to occur simultaneously across largefood-producing regions of the world. Groundwater isthe primary buffer for agriculture against

[1]This follows from Olson (1965): "unless the number of individuals is quite small, or unless there is coercion or some other special device to make individuals act in their common interest, rational, self-interested individuals will not act to achieve the common or group interests."

drought – and simultaneous droughts in major food-producing regions, while unlikely, could have a major impact on food production unless groundwater remains available as a buffer. However, beyond this, food security is influenced considerably by livelihoods and the functioning of markets and global distribution systems. By buffering local production systems and the agricultural livelihoods that depend on them, groundwater provides insurance against disruptions in regional and global market and food transportation systems. In arid regions, groundwater overdraft can eliminate this insurance and, as a result, increase the vulnerability of populations to food insecurity. Many countries in the Near East and North Africa have major programmes to promote domestic food self-sufficiency because of fears that food could be used as a weapon or that supplies could be disrupted in the case of regional conflicts. In this case, overdraft may undermine the security they are seeking.

All of the above points to the importance of information and improved understanding as a basis for developing effective responses to emerging issues. The risks involved in doing nothing – or in doing the wrong thing – in response to declines in groundwater levels and qualityare potentially huge. As a result, the presence of complexity and uncertainty should not become an excuse for inaction.

5.3 What 'should' be done as opposed to what 'can' be done

This Thematic Paper has indicated a fundamental divergence between the ideals of 'comprehensive' and 'integrated' approaches to groundwater management and the reality in groundwater dependent economies. At the same time, it has highlighted the fundamental social and environmental costs of doing nothing. Clearly, allowing emerging problems to simply compound is not a desirable outcome. However, the distinction between what 'should' and what 'can' be achieved is fundamental. This analysis suggests that conventional approaches to groundwater management will probably only succeed under a relatively limited set of conditions. Although the conditions listed below are not comprehensive, they would include locations where:

- the need for management is clear and widely recognized by both policy-makers and local users;
- the aquifer has a clear strategic value for key uses, such as urban supply or the maintenance of wetlands and in-stream flows, where public "demand" for management is strong;
- sufficient data on aquifer conditions are available to create a recognized common basis for management;
- there are clear technical options for management, and these options do not require substantial sacrifices for large and politically influential portions of the population;
- social, economic and hydrological conditions are sufficiently stable that management can produce clear benefits rapidly.

6. Local Groundwater Institutions and the Scope for Securing Economic, Social and Environmental Benefits through Governance

Is there enough institutional scope to secure both livelihood and environmental benefits or will they be mutually exclusive? What are the types of social changes and mechanisms for coping with water scarcity and water-related problems that are already occurring and which could serve as entry points for more explicitly adaptive strategies? One avenue of direct application has come from leading with groundwater information and the generation of knowledge and practice within self-organized communities. Arguably, this has turned around the livelihoods prospects in parts of Andhra Pradesh, India (World Bank, 2010). A groundwater management platform was also able to promote Integrated Pest Management (IPM) and the use of organic fertilisers (including vermiculture) to avoid the use of expensive inorganic fertilisers and harmful pesticides.

Thematic Paper 8 has highlighted the role of both technology and the linkage with energy management as specific sets of drivers that result in specific patterns of use, but also opportunities in resource conservation. And Thematic Paper 6 has indicated that more groundwater regulation can be expected, but that it may be better to anticipate and avoid formal regulation it through forms of autonomous adaptation. Taken together, these findings and conclusions suggest that long-term benefits can be secured if local institutions are given the policy space to operate. In many ways, this implies that potential instruments of governance that operate through more centralised systems may need to be decentralised significantly in order to adapt to the realities of groundwater conditions and contexts. The opportunities for doing so are discussed in this Section.

6.1 Opening up management perspectives

Conventional water-focused approaches to groundwater management represent only a portion of the policy and institutional space that is available for responding to emerging problems. Many of the impacts associated with emerging groundwater problems depend on a much wider array of social and economic conditions. Consequently, adaptive interventions that affect those wider conditions may be as important for mitigating the impact of groundwater depletion or degradation as those directly affecting the groundwater resource base itself. Approaches which are directed at controlling the resource base and its use may, in fact, have limited application in effecting groundwater resource management.

At the other end of the spectrum lies the relatively unexplored policy space of adaptation. It is this space that requires greater attention, given the rates at which groundwater is being developed and the anticipated impacts of climate change.

Conceptually, three broad, complementary and often overlapping sets of 'adaptive' strategies are possible for responding to the limitations associated with the more conventional or direct management strategies discussed. These are:

- *Incremental approaches to groundwater management.* Strategies are adjusted continuously as new information emerges or conditions change.
- *Indirect management strategies.* Strategies that emphasize opportunities for influencing groundwater use by shaping the context in which groundwater use occurs. They include strategies, such as power pricing, that are part of many conventional management strategies. However, they also include power rationing and potential opportunities for shaping groundwater use through high-level policy and economic changes (such as crop price supports).
- *Specific adjustment to groundwater conditions.* Strategies that emphasize opportunities for adapting social and economic systems to groundwater conditions and dynamics rather than the other way around. These strategies take groundwater conditions as largely given and seek to identify opportunities for reducing or mitigating problems through changing the social and economic context of use.

All three of the above sets of strategies start from the recognition that demand for water is socially constructed. Societies, in general, have little interest in the actual state of groundwater resources, but tend to have very high levels of interest in the environmental, social and economic services associated with

groundwater when it is left*insitu*or extracted for a specific use. The instrumental valueof groundwater derives very much from the utility as ahighly distributed on-demand service. But if management focuses on regulating the service, by for instance, imposing caps on borehole drilling, the distributed access advantage may be lost. It may make better hydraulic and productivity sense to exploit an aquifer with many boreholes pumping at low rates than just a few pumping intensively, although many such decisions would also depend upon the aquifer typology in a region.
At present, groundwater management focuses on the groundwater '"means'" by which services are produced rather than on the '"ends'" – the productive outcomes of use.The implicit goal is to manage groundwater or groundwater use in ways that enable existing services to be produced on a sustainable basis. In some cases – particularly where economies have developed based on intensive agriculture and mined groundwater – this objective is extremely difficult to achieve. In other cases, changes in the way local populations are adapting, or could adapt, to meet fundamental livelihood objectives contain opportunities for addressing or mitigating groundwater problems. In Gujarat, India, farmers often respond to discussions over declining waterlevels by pointing out that the income they generate through unsustainable groundwater use is enabling their children to obtain an education and develop non-farm (often urban) livelihoods. In many regions of the world,the first response to falling water levels is simply "how can we add more water to what is underneath" rather than "can we use less groundwater and obtain the same produce". Although the possibility of managing demand for groundwater exists, it is not an easy task.

At the same time, urban-based economic opportunities are perceived to be increasing, and many people aspire to urban lifestyles even if the reality of urban life is different from what they envision (UNFPA, 2007). A social transition isoccurring that will re-shape groundwater demand in fundamental ways whatever attempts managers may make to control resource use directly. In many locations, the livelihoods of local populations are already shifting. In parts of India, for example, the pull associated with growing opportunities in the non-farm sector and in urbanizing areas is, for many, a major reason for moving out of agriculture. This pull often operates in conjunction withthe evident limitations facing farmers in arid areas where water levels are falling. Farmers generally understandfully the implications of declining groundwater levels for future agricultural prospects, and they are using the capital generated through intensive but unsustainable irrigation to educate their children and develop businesses thatwill ultimately enable them to move beyond dependence on agriculture for their livelihoods. Perhaps, such changes offers opportunities to address challenges in understanding and managing groundwater resources through somewhat unconventional ways including smarter investments in decentralised groundwater regulation and governance.

6.2 Adapting for change

Coping with the conjunction between long- and short-term changes in water availability is particularly relevant in relation to groundwater use and protection. In most cases, systemic changes in groundwater availability are gradual and appear in the long term. Water-level and quality declines rarely occur "suddenly". Instead, trends emerge over periods of years or decades. However, crises are likely to occur when long-term systemic changes are overlain by either short-term seasonal fluctuations in water availability or, more importantly, droughts of several years' duration (Moench, 1992; Moench and Dixit, 2004).

Little research has been conducted on the strategies that communities use to cope when long- and short-term processes coincide, and little evidence has been gathered to suggest that communities have developed effective strategies for coping with the combination of short- and long-term changes to aquifer state and groundwater quality. Most coping responses to short-term and relatively well-anticipated disruptions in water supply fall into five broad categories:

- *Control: eliminate or reduce variability through increases in storage (reservoirs and ponds) or source diversification.* This strategy at both an individual and societal level has been a major factor driving the development of groundwater in locations such as India.
- *Spread risk through diversification: spread risk to reduce impact of water scarcity on overall livelihood equation.* It can be done through established institutions for risk spreading – i.e. insurance companies –, diversification of livelihood strategies and dependence on social networks. At household, business and community level, diversification into non-farm livelihoods (government, business and migration-based) is one of the most common responses to climate variability.

- *Adjust or adapt: plan activities to reflect or accommodate anticipated fluctuations in water availability.* Seasonal changes in cropping patterns to take advantage of periods when rainfall can be anticipated or migrating during dry periods are typical examples of this type of coping strategy.
- *Mitigate: buffer (draw on savings or other forms of capital) or reallocate available supplies, through water markets or other mechanisms, so that the economic value of production is maintained despite the impact of water scarcity on "normal" activities.* Buffering strategies can themselves be risky – for example, buffering the impact of drought can translate into depletion of capital assets, if water supply disruptions are more severe or longer term than anticipated. Where seasonal variability in water availability is high, as in most of South Asia, the evolution of water markets and other mechanisms for flexible reallocation of supplies is a common adaptive response that enables reallocation of water on a short-term basis. In effect, reallocation can mitigate the economic impact of drought by enabling production mixes (of crops or non-agricultural activities) that maintain income levels while using less water.
- *Avert: change activities in ways that, in effect, reduce scarcity.* Scarcity is a relative concept that is only relevant in relation to demand. When people anticipate scarcity, they often take actions that, in effect, change the demand for water and, thus, eliminate scarcity. Diversification of livelihood strategies – in some cases based on long-term migration – is a prime example of averting behaviour. Avertingis different from the implementation of adjusting or short-term migration activities that focus water demand on periods when availability is greater.

6.2.1 Building on Householduser-level coping strategies

In most cases, populations use a mix of the above strategies in order to cope with short-term fluctuations in water availability. The rapid spread of groundwater development can be seen as a first-order coping strategy where control – the ability to reduce water supply variability – was a major motivation for farmers to invest in wells and equipment. Reductions in variability translate directly into increased production and income (Moench, 2001). In many situations, the stabilization value of groundwater – i.e. the value of reductions in variability as opposed to thewater *per se* – is approximately equivalent to the value of the water itself (Tsur, 1990 and 1993). In addition to groundwater development, supply-side coping strategies are a common response to short-term fluctuations in water availability. For example, this is the case with "water harvesting", a strategy that plays a central role in India's approach to "drought-proofing" and rural development. Such water harvesting strategies have traditionally been common in many communities (Agarwal and Narain, 1997), and they are now the focus of major governmentprogrammes. In some situations, they are being advocated as a panacea for addressing water scarcity caused by a combination of groundwater overdraft and drought (VIKSAT, 2001).

Local populations supplement supply-side control initiatives such as the above, with a wide array of other coping strategies in response to seasonal droughts or water deficits. At the household level, research in India by Chen (1991) documents that: "in coping with seasonality, most households attempt to protect themselves from short-term reverses in income and subsistence flows. Adapting or diversifying normal activities, building up or drawing down inventories, seeking employment, share-cropping land, borrowing for consumption or productionand migrating for employment are all common ways of dealing with the risks and uncertainties associated with seasonality. For additional support, households turn to family, kin and caste neighbours or draw upon common property resources. When all else fails, households are forced to mortgage or sell assets."

As Chen (1991) comments: "the above types of coping strategies historically had strong institutional foundations in patron-client relations, local rights structures at the community and village level, and caste, kin and family relations. These supporting institutions are now, however, all eroding to some degree." Such institutions were originally a core part of local community structures. Now, place-based community structures are often changing in fundamental ways as the multifaceted process of globalization, and demographic change alters the larger socialcontext in which they were originally embedded.

It is important to recognize that many of the household strategies for responding to short-term water scarcity are not focused on controlling the variability of water supplies *per se*. Instead, they emphasize adjustment, mitigation and averting. Share-cropping spreads risk, it mitigates the impact of scarcity on individual farm households by splitting the impact of crop losses between the farmer and the landowner. It also enables adjustments such as intensification of activities in relation to the most limited resource. Within farms, research in warabundi systems – surface irrigation systems in India in which water is delivered to areas on a rotational basis – indicates that farmers often respond to scarcity with deficit irrigation practices. They also reduce risks from uncertainty in the availability of water supplies by reducing cropped areas to a level where the supply of water is virtually guaranteed to avoid crop failure and by intensifying cropping on that portion (Perry and Narayanamurthy, 1998). Similarly, in fieldwork in large parts of India and mainly in the States of Gujarat and Maharashtra, farmers oftencrop areas immediately adjacent to wells and share the products based not on landownership but on shared rights in the well.

Risk spreading also occurs through crop diversification (i.e. planting a variety of crops with different durations and water needs) and diversification of income sources. This is a common strategy for coping with risks and temporary crises of all types in addition to those specifically related to water (Hussein and Nelson, 1997). Reliance on kinship or caste networks is a form of risk spreading or buffering. It gives households access to a larger pool of resources than they are able to accumulate on their own. Drawing down stockpiles of food or cash reserves andborrowing are also mitigation strategies, where coping focuses on reducing variability in livelihoods through buffering. Planned migration (regular patterns of seasonal migration) is a form of coping by adjusting livelihood strategies in ways that reflect anticipated variations in water availability. Development of permanent non-agricultural income sources is a form of averting behaviour.

The viability of many of the above household-level averting, mitigation and adjustment strategies varies considerably between locations and the target population. As Chen (1991) documents, women are often at a disadvantage with respect to many strategies. For example, in traditional Indian communities, women are in a weak negotiating position with respect to share-cropping arrangements, and they may be less able to migrate or seek employment outside the home. Furthermore, the ability to diversify income strategies depends on wider factors such as the demand for agricultural and other labour and the overall economic structure of a region.

In many cases, household-level coping responses, such as migration, occur in response to a mix of pull-and-push factors (better wages or specific opportunities in different areas and connections with individuals or communities, along with scarcity or limited opportunities in the homearea). As with other strategies, migration entails costs as well as benefits. Much depends on how it occurs. Migrants often move into low-pay occupations, live in areas with few health or other services, and leave women, children and other dependants with little support in home areas. The social costs can be huge. At the same time, migration of one family member or the household as a whole can provide access to income, livelihood and educational opportunities for entire households that are not available in rural areas.

6.2.2 Institutional responses

In addition to household-level coping strategies, communities often develop institutions for coping with variability and scarcity. Two of the most common community-level strategies are the development of access-right systems and water markets.Access-right systems range from basic religious principles mandating access to available supplies for basic needs – such as the right of thirst in the *shariah* and similar sentiments in Christian, Jewish and other aspects of Islamic philosophy –, to grudging rights of survival (Wescoat, 1995; Brooks, 2001; Faruqui, 2001; Pradhan and Meinzen-Dick, 2002). Such rights systems essentially reallocate available supplies away from the uses that any individual may believe is best in order to meet basic survival needs that are agreed as fundamental at a community level. Communities also often impose other forms of access restrictions on water in times of shortage. For example, ponds are often reserved for livestock, and specific wells may be designated as only for high-priority domestic uses.

As seen earlier, water markets represent another form of institution for allocating available supplies. While markets based on legally-recognized and quantified systems of water rights are globally rare (the best documented being in western USA), informal markets operating at community level are common in developing countries such as India. While the impact of these is widely debated, they are widespread and play a major role in water allocation in periods of seasonal scarcity (Shah, 1993; Janakarajan, 1994; Moench, 1995; Janakarajan, 1999;Dubash, 2000). As water markets have evolved into a common institution for allocating available supplies during medium-term and long-term (fundamental systemic change) periods of water scarcity, their role as a coping strategy has been separately discussed in Section 4.5.

Above the household and community levels, governments are often involved directly in a variety of activities to mitigate the impact of short-term variations in water supply. Such strategies often include:

- crop and drought insurance programmes to mitigate the impact of scarcity on individuals and spread the risk of fluctuations over society as a whole;
- food-for-work or employment-guarantee schemes to mitigate the impact of short-term droughts or seasonal shortages by stabilizing incomes;
- buffering the impact of shortages through stockpiling food and distributing it at subsidized prices through public systems; and
- investments in meteorological forecasting and communication capabilities to warn populations of anticipated scarcity conditions and enable them to adjust activities on their own. For example, improved weather forecasting.

7. Institutional Implications

7.1 Capacity to engage at aquifer scales

Existing approaches to water management are not sufficient to address the particular nature of groundwater and the habits of use that have resulted in depletion and degradation. The capacity to develop, or permit the growth of, more pluralistic institutions representing users at appropriate aquifer scales appears to be a pre-requisite for managing groundwater. Dealing with this at local level is a priority. A clear understanding of the aquifer systems and their systems at their framework of respective levels of development risk and their inherent vulnerability, combined with smart support or policy space for organizations to occur is necessary. For all local initiatives, it is essential to determine who is really implicated in applying principles of 'good' groundwater governance. The overall institutional environment, including national legal frameworks for water management, may or may not be sufficient, but the local institutional arrangements tend to determine outcomes. Before adjusting the former (institutional environment), has enough been understood about the capacity of the latter (institutional arrangements)? Figure 2 attempts to illustrate why the relative scales of organization with respect to aquifers and hydrogeological evolution are important. Large consolidated aquifer systems will present challenges in regional integration while the' atomized' development of thin discontinuous crystalline basement (hard rock) require a set of highly localised skills and capacities. Furthermore, the need to engage over a differential time-span in dealing with groundwater problems is also crucial in this regard. Shorter recharge programmes may significantly address groundwater exploitation in hard rock, strip alluvial and even karst systems, with impacts evident over a short period of time; on the other hand, longer, more engaging recharge programmes will need to be designed for restoring aquifer storages in deep alluvial and some consolidated sedimentary aquifers. Governance mechanisms, therefore, need to give importance to the typology-scale factor at the time of their designing phase.

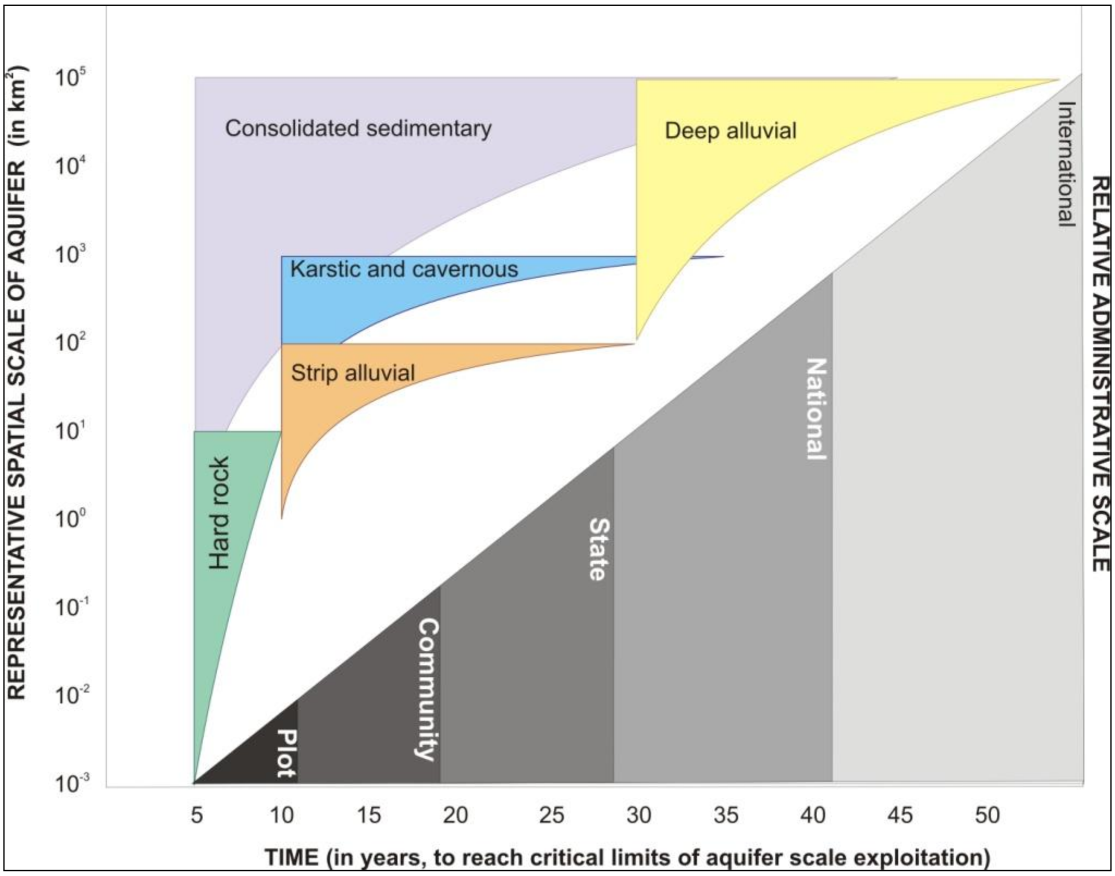


Figure 2: Conceptual diagram explaining aquifer typologies within a framework of spatial, temporal and response scales

A pluralistic institutional environment– composed of five enabling elements as identified below – plays a central role in creating the conditions necessary to address groundwater problems in an integrated manner. This implies that support – whether from external or internal sources – needs to be directed in ways that encourage the growth of such environments. If solutions to groundwater problems depend on a mix of technical/institutional capacity and the pressures/avenues for action generated by pluralistic institutional environments, then external support can play a critical role by catalysing awareness of problems and potential solutions and by supporting the development of appropriate capacities. The ability to develop such support and target it in ways that actually meet the needs in different contexts depends, in turn, on the recognition of both basic principles and commonalities between contexts – i.e. situations in which similar issues are likely to arise, where similar patterns of vulnerability/risk are likely to exist, and where similar response strategies are likely to prove effective.

Where groundwater issues are currently being addressed primarily by government departments– as they are in many locations – then support for the development of civil society and private-sector organizations working on groundwater may be particularly important. This is not to say that such organizations should be encouraged to duplicate regulatory or similar roles where governments are already very active. Private-sector organizations are particularly effective for the delivery of goods and services where such activities have strong market logic. They are less effective in providing public goods, particularly to groups with a limited capacity to pay. Civil society organizations tend to be effective when they represent the interests of specific groups (environmental, cultural, etc.). They can also be effective when they deliver public services to marginal groups, i.e. those who are not well served by the market. Where such organizations are weak, their strengthening represents a key strategy for increasing integration and the social capacity to address groundwater problems as they emerge.

The institutional environment is imbalanced wherever large groups are affected by groundwater problems, but have no organized voice in society and no organizations dedicated to meeting their basic needs. The environment is also imbalanced wherever strong market logic exists for private-sector activity in the delivery of goods and services, but the private sector is weak or its role is undermined. Finally, the context is imbalanced where the market or civil society organizations dominate and face nochecks or balances through the regulatory and standard-setting roles of representative government. Recognizing the mix needed and, where there is a lack of balance, providing forms of support that encourage such a mix to evolve represents a basic starting point.

Five key elementsform an essential capacity foundation for pluralistic groundwater institutions to grow and play effective roles:

1) *Freedom of information.* Where scientific and other information on groundwater conditions and the impacts of emerging problems or potential solutions are not part of the public domain, then the factual basis for effective contestation is undermined. Groups (whether in the government, civil society or the market) cannot be challenged, problems cannot be documented, and there is little factual basis for developing new management responses. Freedom of information is a basic enabling condition.
2) *A right to organize that includes access to appropriate financial mechanisms.* The right to organize is central to the role of civil society and community-based organizations. Unless the right to organize – whether for advocacy, service delivery or basic resource management purposes – exists, civil society cannot play any effective role. It is important to recognize that this applies as much to local community-based organizations for groundwater management as it might apply to a national environmental advocacy organization. Again, despite the fact that many regions exercise such a right, it often does not fall in the formal domain of rights in resources such as groundwater. Furthermore, the right must include the ability to access appropriate financial mechanisms. Where organizations lack the ability to raise funds, they generally lack sustainability and the ability to build capacity. Service delivery organizations require the ability to charge realisticservice fees. Resource management organizations require the ability to assess fees or tax those using or depending on the resource. Advocacy organizations require the ability to accept donations or charge their membership. Financial mechanisms are a core element for translating theoretical rights of organization into reality.
3) *Enabling legal, regulatory and financial systems.* Legal, regulatory and financial systems that enable different typesof organizations to form, and play effective roles in water management, are central to the evolution of pluralistic institutional contexts. In many situations, existing legal

frameworks prescribe very specific organizational forms for activities such as groundwater management. They also allocate key financial mechanisms, such as the ability to charge fees or adopt local taxes, only to agencies within the governmental structure. Community-based organizations generally have no legal right to designate areas for management, raise funds from those benefiting from management, or take any action that either restricts or enables any form of use. As a result, it is impossible for them to develop the capacity to play an effective management role. Key elements in legal systems that contribute to enabling environments include:

4) *Water rights systems that balance public and private interests.* The linkage between groundwater rights systems and the power to effect management in society has not been adequately explored. Rights systems that balance public and private interests– i.e. provide standing for both public and private perspectives on how groundwater should be allocated and used – would enable the types of institutional pluralism that this study contends are central to effective integration. Concepts such as private-use rights within a broad ownership of water held in public trust by the local governance body or the State may represent an avenue for this. Allocation of access –*via* linking the right to drill a well to landownership, drilling regulations and well licenses – is often practical. On the other hand, the introduction of volumetric allocation systems has proved difficult to implement for a variety of social and technical reasons. This is why debates over groundwater rights systems, a central feature of management debates in the 1990s, have made little practical progress. However, it is important to emphasize the inherent limitations and lack of balance in attempts to develop rights systems.
5) *Systems for dispute resolution.* If integration is an outcome based on contestation discussions within pluralistic institutional environments, then systems for dispute resolution are essential. In parts of the USA, specialized water courts play this role. Where groundwater is concerned, dispute resolution is oftenrendered difficult because of the uncertainty in the behaviour of the resource itself. Therefore, unless the previous four key elements are strengthened and addressed, systems for dispute resolution may not evolve effectively.

These five elements (freedom of information, the right to organize, an enabling legal, regulatory and financial frameworks, balanced equitable water rights systems and dispute resolutions systems) represent the basic foundation for institutional pluralism in water. It is this pluralism that gives society the flexibility and capacity necessary for integration and continuous generation of 'solutions' as groundwater problems or other constraints emerge. This is a critical area where regions need to learn from one another. Globally, most efforts to share insights on topics such as groundwater have focused on specific technologies and specific management models. These are often posed as "best practice" examples. However, the focus needs to shift towards basic principles, and to the diverse ways these can be achieved in different contexts and at different phases of development.

Effective responses to any groundwater issue are unlikely to rest on any single set of solutions (such as the development of specific management or allocation systems). Instead, multiple answers that respond to multiple contextsare required. These are most likely to emerge from the ferment present in pluralistic institutional environments. However, there are commonalities between contexts, and these commonalities can assist in developing courses of action that are much more targeted (and perhaps more satisfying) than the broad principles or key elements presented above.

7.2 Agreeing common goals

The flow of groundwater through aquifers may be complex, but actual management practices can be as simple as agreeing maximum acceptable drawdowns in pumped wells or banning the storage and application of pesticides across an aquifer that furnishes potable water supplies. These can be things that a well-identified community of groundwater users can agree upon, if basic information is made available and explained (Thematic Paper 7). How groundwater managers engage with user communities at the outset is important. If water resource agencies have failed to 'socialize' groundwater because of technical preferences for hydraulic management, then a quiet revolution within the agency might be required to establish a legitimate and respected platform to engage groundwater users. Equally, an initiative could be promoted as an autonomous self-governing adaptation, in which case the water agency maysimply have to avoid interference.

Therefore defining mutually acceptable levels of depletion and degradation on the basis of clear information and a fundamental understanding of groundwater circulation through aquifer systems is likely to be a firm starting point.

7.3 Spreading risks: an economic and livelihoods issue

Attempts to insure against fluctuations in precipitation and water availability may be as old as livelihoods based on agriculture. Buffering strategies – the accumulation of food, animals or other forms of capital as a reserve for use in scarcity periods – are common at household, community and national levels.

Some of the specific strategies used to buffer income and spread risk at household level include:

- maintenance of household or community grain reserves between seasons and years;
- investments in assets, such as gold, jewellery or animals that maintain value and can be exchanged to meet subsistence or other needs in times of scarcity;
- diversification of crops between income types (subsistence, cash and, within cash, between market types), seasons, and vulnerability to disruption[2];
- development of patron–client and kinship relations that provide vulnerable members with some assurance of access to essential resources in times of scarcity;
- sharecropping, where risk is spread between cultivator and landowner; and
- income diversification.

These initiatives may be supported at State or national level with:

- formal crop insurance programmes (state or private-sector financed);
- food buffer stock programmes (India is a prime example) that generally involve large purchases of grain during good years accompanied by releases during drought;
- subsidized public distribution systems;
- food-for-work and similar publicly financed drought-relief or employment-guarantee programmes targeted at vulnerable populations (Rao et al. 1988)[3];
- governmental policies designed to ensure food security by subsidizing production within the country;
- governmental purchase of food from international markets with internally subsidized distribution; and
- financial hedging instruments – products offered by commercial banks to farming cooperatives to provide producers with floors on commodity prices (e.g. coffee put options for Ugandan coffee producers).

Even international level support can be significant as with:

- humanitarian assistance programmes through bilateral or multilateral agencies;
- proposed international food buffer mechanisms; and
- international systems for grain trade (markets).

All forms of buffering and risk spreading have costs of their own. India's food buffer stock programme has recently been widely criticized as wasteful with amounts of grain are lost to pests or decay by being stored in poor conditions. As a result there is an increasing belief that shortages can be addressed through global food markets.

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[2] In Kerala, India, home garden systems often contain more than 40 types of crops (from vegetables to trees) with widely different maturities and income characteristics (Moench, 1991).

[3] Chen (1991, citing Rao, Ray and Subbarao, 1988) indicates that such "employment programmes, notably the Employment Guarantee Scheme in Maharashtra, perform an important role in stabilizing incomes and employment across seasons."

7.4 The interaction between forms of coping and the nature of water supply disruptions

In many cases, approaches to coping with short- or medium-term droughts are integral parts of household and community livelihood strategies. They are embedded in existing social institutions, such as kinship networks, informal water markets and patron-client relations. Increasingly, as discussed below, such household-level coping strategies are interlinked with wider changes in society. However, as Chen (1991) notes: “unlike private drought management by individual households, public drought management has been developed in isolation from on going development strategies or chronic subsistence needs.” In most cases, public drought-management responses and humanitarian assistance have attempted to mitigate the immediate impact of drought, but they have done little to alleviate the core problem by addressing more fundamental, systemic development needs.

This is a major limitation in the food-for-work and water harvesting programmes commonly implemented in arid areas of India during droughts. In many situations, these programmes employ thousands of people to “move dirt” and construct small dams. However, evidence suggests that in many cases such water harvesting programmes have a limited impact on water availability and do not address long-term groundwater overdraft problems (Kumar*et al.*, 2006). While they provide employment and place food or money into the hands of drought-affected populations, the populations are encouraged to remain in place and not supported in moving away from vulnerable livelihoods.

Coping strategies range from household-level techniques to “make it through” bad times by reducing consumption up to fundamental changes in livelihood systems. As Box 4 illustrates, in many situations, multiple strategies are used in conjunction or sequentially as water scarcity increases. Furthermore, changes in regional economies induced by coping with temporary water scarcity (i.e. drought) can cascade into long-term changes in economic and social structures.

Box 4 : Coping with drought in Zimbabwe

Drought is part of the normal pattern of life in Zimbabwe. However, in 1991–92, the whole of southern Africa suffered a major drought, a complete failure of crops, and the exhaustion of national food reserves. The situation was monitored, and a pattern of sequential responses was seen.

First, minor adjustments such as diet changes or increased reliance on off-farm income sources took place, followed by the disposal of assets, notably poultry and goats, and major shifts in practice such as outmigration. Understanding this pattern is vital if external support is to complement local coping strategies. Non-farm income-generating activities are critical to people’s survival both during drought and non-drought periods.

With the reduction in real wages and retrenchments caused by structural adjustments, the value of remittance incomes has decreased dramatically in the last few years. During the drought, an expansion in trading activities and the sudden explosion of gold panning were seen. It also prompted widespread diversification of non-farm livelihood activities, among men and women, as well as a shift in investment in agriculture.

Following the death of many cattle, and given the inability of people to afford to purchase new animals, there was a severe scarcity of draught power. Farmers were unable to purchase inorganic fertilizers, except in very small quantities. The result was a shift towards more intensive investment in small gardens and home field plots, using the limited draught power for cultivation and any available organic materials for fertilization. This resulted in the growing of premium crops on prime arable sites, such as low-lying wetlands, where crop yields are more certain.

Source: Mombeshora et al. (1995).

As outlined in Table 2, different coping strategies apply to different types of problems. Risk-spreading strategies (whether formal insurance or techniques such as share-cropping) are useful in response to variability and uncertainty, but generally cannot be applied to situations where changes are either certain or are expected to be long term. Risk spreading is applicable to stochastic processes, where probabilities and consequences can be estimated but the timing or location of impacts is not well known. They are not directly applicable to situations of near certainty – such as depletion caused by sustained groundwater abstraction. In this latter case, other strategies such as migration, fundamental changes in livelihoods, intensification, and reallocation of available supplies are more applicable coping responses.

Table 2: Matrix of coping mechanisms

Predictability of scarcity	Duration of scarcity Short (within years and seasons)	Medium (multiyear)	Long (fundamental system changes)
Certainty	Shortages of a few hours to a few weeks during, for example, planned irrigation or power-cut rotations. Schedule activities to reduce water dependence at times when supply is disrupted. It is necessary to study the disruption patterns in order to cope efficiently; seasonal cropping systems are one example. Seasonality: changes in water availability between seasons within established and stable climate systems. Build in system redundancy and storage	Supply deficits while new supplies are being developed or imported. Example: overdraft in Arizona while waiting for central Arizona project construction. Overdraft in Ahmedabad, Gujarat, while waiting for water imports from the Narmada Project. Unsustainable use of alternative sources while new sources come on line.	Long-term water availability declines where fossil sources are being used or mining is occurring. Ogallala Aquifer depletion is a prime example. Planned changes in water-use systems and water dependency; and gradual, unplanned, adjustments in economies and livelihood strategies as individuals and communities respond to anticipated changes in circumstances.
Stochastic	Variability in precipitation within seasons. Common gaps in water availability of a few days to a few months. Wells to supplement supply and local storage ponds are typical coping strategies. Rapid fluctuations in groundwater levels in low-storage aquifers. Risk spreading – insurance strategies. Predictability is variable. Evolution of institutions for flexibly reallocating water.	Significant variations in precipitation availability between years including the cyclical patterns evident in existing hydrometerological datasets (years to a few decades). Diversification and risk spreading. Long-term fluctuations in groundwater availability related to cyclical changes in precipitation and pumping levels (overdraft in dry years, recharge in wet). Evolution of institutions for flexibly reallocating water.	Permanent (from a human perspective) changes in groundwater availability related to mining of fossil water or long-term climate fluctuations. Avert: change livelihood systems.
Unpredictable	Short-term problems that affect water availability through established supply systems (infrastructure failures caused by, for example, earthquakes, design or maintenance flaws, terrorist actions). The timing of many of these is highly unpredictable. Extreme events (short-term droughts not experienced in historical record). Risk spreading – insurance strategies and evolution of institutions for flexibly reallocating water.	Changes in water availability owing to major political or economic changes (impact of war on economies, etc.). Diversification and risk spreading. Extreme events (medium-term droughts not previously experienced in historical record). Evolution of institutions for flexibly reallocating water.	Changes in water chemistry or water availability owing to lack of basic scientific knowledge concerning the impact of groundwater development (arsenic or selenium contamination, compaction). Changes owing to introduction of new technologies (spread of pumps). Highly adaptive systems capable of making fundamental livelihood changes.

As noted above, the most challenging situation occurs when long- and short-term processes reducing water availability coincide. Drought in conjunction with groundwater overdraft represents a much more fundamental challenge than either process occurring on its own. However, this is a situation where short- and long-term coping strategies could be used in conjunction to enable fundamental changes in resource use and move populations towards more sustainable livelihoods.

8. Institutional Targets – When and Where to Innovate

It is now possible to bring together three governance dimensions:(1) the fundamental featuresin the groundwater environment (aquifer typologies);(2) the broad patterns of change that occur as development proceeds (development phases); and (3) the combination of direct management, indirect influence and adaptive response strategies available on the 'palette'. This convergence is required in order to identify the potential courses of action that those concerned with groundwater could implement in different contexts. Three broad arenas of action exist: (i) direct water-focused management actions; (ii) indirect interventions designed to influence the way water is used within current applications; and (iii) adaptation – interventions intended to support changes in the underlying social structures that determine groundwater dependence and use. The suggestion here is not that the courses of action put on the palette are a final prescription to all groundwater problems, even within a single typology. Instead the palette provides broad guidance on potential responses at different stages of development within typologies. The types of strategies that may prove effective also vary over time (both the phase of groundwater development and the presence or absence of specific windows of opportunity) and the hydrogeological setting (represented here by the aquifer typology).

In order to identify practical courses of action, those concerned with groundwater management need to bring together considerations related to regional hydrogeology, the phase of groundwater development and the socioeconomic context in order to develop a palette of direct, indirect and adaptive intervention strategies that respond to both groundwater opportunities and emerging problems. The goal is not to build a single "integrated" approach but instead to identify incremental courses of action – appropriate at given points of time, in given local hydrogeological contexts – that respond to social needs and to the constraints, issues and opportunities that groundwater conditions present. The goal is to develop approaches that enable actors to identify, and act on, incremental elements – pieces within an ever-shifting mosaic – that improve the wider relationship between groundwater and society

As seen earlier, the response space for managing groundwater involves three dimensions: the nature of the aquifer and groundwater resource base, the stage of development and the socioeconomic/institutional context. Because of its relatively static nature, the hydrogeological context is particularly useful for organizing presentation and discussion of issues. The institutional environment is, however, of critical importance in shaping the array of management avenues that are possible, at a practical level, to address needs emerging at different stages of development and in different hydrological contexts. As a result, 'unpacking' the response space to identify viable avenues for management is an essential first step.

The institutional contexts for local groundwater management range across a spectrum, from ones that are highly organized and structured to others where institutions are weak and actions are dominated by highly individualistic behaviour. Three primary factors can be identified:

1) strength, scale and penetration of hierarchical governmental and quasi-governmental institutions;
2) extent and strength of group, identity or place-bounded institutions (the "village," "tribe" or "community"); and
3) penetration and organization of market networks and the actors (individuals and businesses) within them.

Management possibilities vary greatly depending on the relative balance between these different institutional forms. In areas where governmental, market and community-based institutions are weak (as in many post-conflict zones) most behaviour is highly individualistic. As a result, from a social and institutional perspective, the capacity to proactively "manage" groundwater (or most other) resources is extremely limited, and responses need to focus on enabling individuals to adapt. In highly institutionalized environments, in contrast, more direct and proactive adaptive management approaches may be much more viable. It is important to recognize, however, that the strength of different institutional forms is highly variable in different contexts – strong hierarchical institutions, for example, often exist where markets and community-based institutions are weak and *vice versa*. Since the nature of existing social institutions plays a major role in determining how societies can respond to emerging needs, unpacking this a bit further can provide critical insights into the array of management strategies that are likely to be viable in different institutional contexts.

9. Prospects for Aquifer-Scale User Institutions

9.1 Regulation and hierarchy

Where hierarchical governmental and other institutions are strong and penetrate to local levels, the ability to both regulate behaviour and undertake other direct forms of management activities tends to be strong as well. Governmental institutions may, for example, have the mandate and resources to build and maintain physical structures such as dams, recharge facilities and water transport (irrigation or water supply) systems. Some may regulate a wide variety of factors such as land-use patterns, well depths and spacing or water uses that have a major direct impact on groundwater conditions. There are cases where such strong regulation matters.

However, in the absence of outside pressure from individuals, communities or market institutions, hierarchically organized institutions tend to be driven by "perspectives from the top." They are generally formed around a cadre of professionals who have been trained within the bounds of a specific set of perspectives and tools. They frequently have difficulty in responding to location-specific or rapidly changing and evolving conditions. In addition, they often have difficulty incorporating or responding to sources of information and/or perspectives that fall outside conventional professional spheres of action. "Water resource" departments, for example, tend to emphasize physical management interventions (the building of structures) or regulatory approaches where they have direct control over outcomes, rather than indirect management measures or interventions that would assist local populations to adapt.

In many cases, the ability of hierarchically-organized institutions to actually intervene in ways that affect conditions at the ground level is limited by their degree of penetration. In practice, for example, government organizations may have limited capacity to actually influence the behaviour of individuals or face resistance from community-based and market or other networked institutions. Similarly, while hierarchically-organized institutions can generally build physical structures, for a variety of budgetary and other reasons, their ability (or interest in) operating and maintaining such structures can be limited. As a result, on a practical level, the ability of hierarchically-organized institutions to manage conditions on the ground is often limited.

9.2 Consolidation of community institutions

In contrast to hierarchically-structured governmental organizations, community and other place-based organizations are often able to draw upon a wide array of location- and context-specific information. Over the past three decades, research and practice have demonstrated that a number of conditions are required for effective management of common property resources. If those conditions are met, communities and other group-bounded organizations can contribute to effective groundwater management at the local level. Where communities and other group-based organizations are strong, for example, they can often intervene in ways that directly contribute to management. Such interventions can range from the construction and operation of water management structures to regulations on access to and use of available water supplies.

The conditions under which common-pool resource management approaches are likely to be effective, however, are relatively restrictive. They include:

1) clear boundaries on the resource being managed;
2) transparent information on resource dynamics, use and condition;
3) relatively small group size, homogeneity and clarity on the boundaries of the group; and
4) ability to exclude or control free-riders (those who benefit from but do not contribute to management).

In many cases, the ability of communities or other group-bounded organizations to contribute directly to the management of groundwater resources is limited by: (i) the lack of technical expertise (which undermines the ability to understand resource dynamics, use and condition); (ii) the aquifer scale (which increases group size and heterogeneity); and (iii) institutional feature (such as the legal linkage between rights to accessgroundwater and land ownership in India) that limit the ability to exclude free riders. In addition, communities and other group-bounded organizations are often in conflict with governmental and other hierarchically-organized institutions. Finally, community organizations are often undermined by the rapid evolution of markets and other networks. This shifts both identity and practical dependency away from the local or regional level at which aquifers operate.

Beyond direct management of groundwater, community and other group-based institutions often either enable or constrain management environments, through the role they can play as counterpoints to both hierarchical and networked institutions. Group-based institutions are often politically very active. In some cases, this blocks the ability of hierarchical organizations to regulate water use or take other action within their mandate. On the other hand, pressures may also push hierarchical institutions to move beyond their normal professional or operational "comfort" zone to address certain concerns or take courses of action they would not have taken on their own. Similarly, they can link with markets or social networks in ways that change both use and patterns of dependency on groundwater resources. In Yemen, for example, community organizations financed by remittances from social networks of expatriate migrants are directly involved in regulating groundwater resources. In other cases, environmental organizations are the primary politically active advocates forcing government organizations to regulate water quality and control pollution from market actors.

Overall, the role community and other group-based organizations can play in management depends on the nature of the organization (whether, for example, the group is defined by a shared location or some other form of identity) and their relationship with other institutional forms. Where institutional dynamics create deadlock, this limits the possibilities for direct management of groundwater resources and necessitates greater emphasis on adapting to emerging conditions. Where institutional dynamics operate in synergy, possibilities for proactive management are greater. It is important to recognize that institutional conflicts can evolve in ways that contribute to management as well as deadlock. Political action by group-bounded organizations can, for example, be the essential input required for government organizations to initiate regulatory action. In other cases, however, similar forms of political action by communities or interest groups can block effective action. Understanding these dynamics is, therefore, central to recognizing the role institutions can play.

9.3 Economic incentives to cooperate

Markets generally play a minor to non-existent role in direct groundwater management, but they often play a central role as the primary mechanism for groundwater development (by delivering pumping equipment and well-development services and creating the demand for products with significant groundwater input). Markets are also often directly involved in groundwater service delivery – the tanker-based drinking water markets found in most cities across South Asia and parts of the Middle East-North Africa region being a case in point. Finally, individualistic behaviour of businesses and households (as well as individuals) in markets is the primary mechanism through which adaptation occurs. Individuals, households and businesses (the "agents" acting within markets) respond to the opportunities and constraints they perceive, in any given situation.

During the early phases of groundwater development, the primary challenge has often been to make such agents aware of the benefits of groundwater and to develop the market-based supply and demand chains, which are necessary to provide development services and to link producers with demand centres. This was the case, for example, in India during the 1960s and 1970s and may be the case in large parts of Africa at present. Once market mechanisms have ignited demand for groundwater as an input to production, this becomes a driving factor underlying increasing levels of development. The attendant overdraft and quality issues emerge in later phases. As groundwater scarcity and major quality issues emerge, market mechanisms drive much of the search by agents for alternatives. Where livelihoods are concerned, this provides the pressure for shifting away from intensive groundwater-dependent forms of economic activity, such as irrigated agriculture. It can also create openings for new products – such as bottled-water markets that are common in many parts of the world – as high-end consumers try to avoid health issues associated with low-quality drinking water supplies or seek convenience and other benefits.

Unlike hierarchical government or community-based organizations, markets as institutions do not exist within a framework that defines specific goals, nor do they exercise agency to meet such goals. They cannot be "created" with the purpose of groundwater management and they do not work toward that (or toward adaptation) as an "objective." Instead, markets are largely self-organizing emergent phenomena where agency is exercised by individuals, households and businesses to meet their individual needs in response to the opportunities and constraints they perceive.

Using market mechanisms as part of an overall strategy to respond to groundwater-related issues, during different stages of development, depends on interventions by governments, community-based or other organizations to provide incentives and regulate the functioning of markets and the relations between agents operating within them. Numerous mechanisms for this exist including:

a) *Provision of information.* Information on resources (whether related to availability, scarcity or quality), technologies and users can will shape the behaviour of market actors.
b) *Support for technological innovation.* Historically, substantial governmental investment was directed into the development of pumping technologies and, more recently, into technologies for efficient water use. Improved crop varieties have also been a major focus of investment. Numerous similar opportunities exist that would help regions to adapt to scarcity or quality issues.
c) *Finance and financial mechanisms.* Extension of credit or in some cases subsidies for individuals, households and businesses is often critical in early stages for developing wells and irrigated agriculture; and in later stages for diversifying into other livelihood or business activities.
d) *Extension services*. This could range from technical advice to support for the development of supply chains and market creation.
e) *Investments in the underpinning systems that enable diversification.* Basic systems are the foundations that enable people to shift livelihoods as conditions change. They are essential at early stages of groundwater development to enable the growth of agricultural markets and at later stages of groundwater development to enable the growth of non-farm livelihoods.
f) *Regulation.* This can involve direct regulation of groundwater (source protection, pollution control, etc.), regulating the factors that enable groundwater access (drilling rigs), and regulation of activities (such as bans on water intensive forms of agricultural and industrial pollution) that can shape the demand for groundwater. Depending on the aquifer typology and the governance environment different mixes of regulatory measures may or may not be possible at different phases of development.

Overall, as the above listing illustrates, numerous mechanisms exist to shape the behaviour. While these would often be implemented by government organizations, in many cases community-based or other organizations can and do play a significant role.

10. Conclusions

Trends in local groundwater management institutions cannot be assessed systematically due to the scattered nature of available information. Instead, stocktaking has to rely on anecdotal evidence pulled together from disparate sources and geographies. This disparity exists at different scales – regarding aquifer systems within a contiguous region or across countries. Overall, however, it is clear that local or aquifer-based groundwater user management has been an area of policy neglect. A general conclusion from the baseline literature and this diagnostic is that autonomous self-regulation is unlikely to have any impact, unless the institutional environment is conducive and the rights and obligations with respect to groundwater and groundwater protection are accepted. Furthermore, available experience suggests that even if local policy and resource management issues are addressed, local arrangements will, for a variety of social, economic, institutional and political reasons, be insufficient to address the governance 'gap' required to conserve resources and prolong groundwater-dependant livelihoods. To put it more bluntly, conventional approaches to groundwater management appear insufficient to address emerging depletion, pollution and other groundwater problems.

The analysis in this Thematic Paper suggests that the inadequacy of conventional groundwater management approaches reflects the complex array of social, economic, institutional and political as well as technical factors that determine interests, access and the ability for any group to exercise a degree of control over groundwater conditions. There are inherent limitations to any approach that seeks to protect human interests in groundwater, or any other major natural system, through approaches to management that are 'resource-focused'. Groundwater is, furthermore, a particularly complex resource where, unlike surface water, groundwater access is determined by a combination of overlying landuse/ownership patterns and 'invisible' and difficult to assess hydrogeological structures and processes. As a result, access is spatially highly distributed with few of the clear the social/institutional control points that are present in surface water networks. This creates often-fundamental challenges for the development of institutional rules and organizations that would be required to manage the resource directly. This challenge is intensified because most management approaches emerge from technical considerations related to the groundwater resource base and are also poorly linked to livelihood strategies and the incentives that local populations actually face in relation to groundwater use. For these reasons, the development of a wider policy perspective is essential to frame 'good groundwater governance'.

What does "development of a wider policy perspective" mean? Primarily it means that approaches to for addressing actual or emerging groundwater problems need to focus beyond the resource base itself and engage effectively with the social and economic context that shapes incentives for groundwater use amongst communities of users. Achieving effective management outcomes, we believe, depends on the wider governance environment and the development and livelihood choices that environment generates. Broad recognition of, for example, regional water scarcity can serve as a basis for decisions on regional economic development that emphasize low water intensity livelihoods. This type of approach, which focuses latches on to the wider overall environment governing development pathways, represents an arena of potential opportunity for addressing groundwater problems that is quite different distinct from and relatively less explored than more narrowly focused technical groundwater management strategies. Furthermore, governance frameworks that enable societies to make this type of choice could reduce dependence on groundwater while also potentially creating opportunities for more direct conventional management of the resource base. Clearly, this does not mean moving away from developing improved understanding of the resource; rather, it means improved understanding leading to a much wider thinking about responses to groundwater-related problems rather than a focus on the resource base itself. Groundwater-specific management goals may need to look beyond straightjacket regulatory mechanisms and look for alternative niches in livelihoods, energy use and opportunities offered under adaptation and coping strategies that focus on events such as droughts, floods, economic drivers and even climate change and variability. For this to happen, public and private institutions will have to learn to work effectively with groundwater users and groundwater management organizations. The formation of 'institutional homes' for groundwater at all levels should merit more attention in the future.

11. Acronyms

BP	Before Present
COTAS	*ComitésTécnicos de AguasSubterráneas*
DWR	Department of Water Resources of California, USA
FAO	Food and Agriculture Organization of the United Nations
GWP	Global Water Partnership
IWRM	Integrated Water Resources Management
MRA	Maltese Resources Authority
RNFE	Rural non-farm economy
UNFPA	United Nations Population Fund
USA	United States of America
VIKSAT	Vikram Sarabhai Centre for Development Interaction

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