A Review on National Groundwater Policy Instruments – Grasping Institutional Aspects for Transboundary Groundwater Governance

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Abstract

A profound understanding of different options for national groundwater governance and of the experiences gained with them is a precondition for developing policy recommendations for transboundary groundwater governance, likewise. The question raised is what can we learn from a comprehensive empirical review of national groundwater governance about institutional constraints of transboundary governance. The paper reviews and analyzes current national groundwater policy instruments, mainly from South-East Asia. The paper discusses crucial institutional aspects of groundwater governance derived from this review: 1) voluntary compliance, 2) tradition and mental models, 3) bureaucracy, 4) conflict resolution mechanism, 5) political economy, 6) information. Each of them adhere specific institutional challenges that either hinder or foster effective policy implementation. The six items help to account for relevant institutional aspects, for instance with the debate on either extending the mandates of existing river and/or lake basin organizations for transboundary groundwater governance or establishing new aquifer management organizations that cover the whole resource systems.

Keywords: *Groundwater governance, institutions, transboundary, policy instruments, South-East Asia*

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1 INTRODUCTION

In contrast to transboundary rivers, the recognition of transboundary aquifers in international water policy and legislation is very limited (Puri and Aureli 2005). At present, separate, unilateral national development and management is the predominant feature of transboundary groundwater use. This might be justified if use ratios are low, and if there is no transboundary impact. However, separate national management becomes problematic if use is highly asymmetric because states are establishing rights-of-prior use. If use patterns intensify and interdependencies show up, the critical issue is to put in place a transboundary management system. A profound understanding of the options for national groundwater governance regimes and of the experience gained with them is a precondition for developing recommendations for transboundary groundwater policy reform. This procedure has two additional reasons: First, transboundary problems occur as a result of ineffective national governance structures and rules-in-use of daily groundwater use. Second, transboundary groundwater management relies on effective and functional national structures to enforce or facilitate transboundary agreements.

Besides geo-physical and economic characteristics, the institutional aspects must be considered in analyzing the reasons for inefficient use and depletion of groundwater (Chermak, Patrick and Brookshire 2005; Puri and Aureli 2005). As *Ostrom* (1962) stated nearly 50 years ago: "Few areas ... offer a richer variety of organizational patterns and institutional arrangements than the water resource arena". At present, little is known about the institutions and policies that govern groundwater use in many different societies (Mukherji and Shak 2005). The incorporation of these factors gets even more compounded when we switch from an aquifer within a single, man-made boundary, to transboundary aquifers (Utton 1982). The question is how to approach the institutional aspects. This paper does not focus on institutional aspects, such as heterogeneous knowledge, time horizon, discount rates of actors, or different market rules, which make model predictions for sustainable water use difficult (Chermak, Patrick and Brookshire 2005). The paper provides insights into a much broader analysis of institutional constraints for effective policy implementation. This is done by a systematic review of well-documented cases of national groundwater policy instruments, from South-East Asia, and particularly for collective action regimes from Western USA, first.

India, Pakistan, Bangladesh and China account for the bulk of the world's groundwater use in agriculture. In addition, many development aid organizations currently focus on assessing the opportunities for transferring experiences gained in the manufacture and maintenance of irrigation equipment from India and China to Africa, and the appropriateness of doing so. In Tanzania, Malawi and Zambia, for example, the application of modern irrigation technologies is expected to facilitate economic development (Kandiah 1997). Water use for irrigation in Africa will continue to increase. Therefore, it is extremely relevant to study not only the water technologies themselves but also the experience gained to date in governing groundwater systems.

The paper begins by classifying transboundary groundwater as a common-pool resource and presenting its special characteristics. Than, it introduces three types of policy instruments (regulatory, economic, voluntary) which are used as a classification system to present empirically cases of implemented national policy instruments. Thereafter, six items are discussed, each of them adhere to specific institutional challenges for groundwater governance: 1) voluntary compliance, 2) bureaucracy, 3) tradition and mental models, 4) conflict resolution, 5) political economy, and 6) information. Finally, conclusions will be drawn regarding transboundary groundwater management.

2 TRANSBOUNDARY GROUNDWATER AS A COMMON-POOL RESOURCE

Groundwater can be classified as a common-pool resource with the characteristics of subtractability and low excludability. According to Ostrom (1990, 31-32), subtractability—which means that the resource units used by one person are unavailable to others—is typical for a common-pool resource and involves the possibility of approaching the upper limit of resource units which can be produced. In the context of groundwater, this means that the water level drops with every unit extracted and that the resulting increased lift increases the cost of pumping the next unit. Low excludability means that it is difficult to exclude water users, in particular landowners, from pumping water from aquifers.

The consequence might be that water will be extracted at a rate greater then the social optimum. The exploiter of the resource pays only the recurrent costs of pumping and the capital costs of well construction, since the costs of externalities are often overlooked. Moreover, users sometimes extract as much groundwater as possible in order to maintain their water rights. This is widely discussed as the tragedy of the commons and denotes the environmental degradation that occurs whenever a large number of individuals share a subtractable resource. However, it can be shown that it is actually the "tragedy of open access" that matters (Feeny et al. 1990; Grafton 2000). In regions where depletion is in progress, rules related to withdrawing resource units from a resource system are not effective. Rather, unrestricted open access has been the general rule, as can be shown for Asia (*Shah et al.* 2001, 7). The frequent failure to distinguish between a common property regime and no property regime at all is often responsible for pessimism regarding collective action. This conclusion has often led to proposals for institutional change in the management of common-pool resources in the direction of either full private property rights or state control. However, there are many empirically documented cases in which communities have contributed to sustainable resource management by establishing appropriation rules, monitoring the situation of the commons, controlling rule violation, and assigning penalties. Failure and success in solving commons problems have been widely studied for local irrigation systems, in Asia as well (Wade 1994; Lam 1998; Ostrom 1992]. However, the focus of these studies has not been on groundwater aquifer management. Studies of self-governance of whole groundwater aquifers are rare. Yet, cases from California show that sustainable groundwater management can also be achieved on the basis of collective action (Blomquist 1992).

Besides subtractability and low excludability, other characteristics of groundwater resource systems call for specific governance options. In comparison to international rivers – on which an immense body of literature exists - the characteristics of aquifer systems are displayed in the following. In particular, the hydrogeologic heterogeneity of the aquifers makes rigid legislative classifications very difficult (Puri and Aureli 2005).

- Irreversibility and time lag: Once a groundwater aquifer is seriously contaminated, it may be difficult, costly, or even technically impossible to reverse this contamination. In contrast to rivers where direct human intervention may immediately emerge downstream, in groundwater aquifers it may become evident only at a considerable distance from the point of intervention. Adding to this is the long time lag which may occur before an impact on a resource becomes noticeable. Moreover, the replenishment period of aquifers is long and the provenance of groundwater generation is often unclear. Management and monitoring regimes for aquifers have to account for this slow response.
- Indivisibility: Although resources (like land) can be divided into individual units for ownership and use, this is not the case with aquifers, since they are interconnected hydrological systems. Although contamination can progress by degrees, it is not possible to fence off part of an aquifer and allow only that part to be contaminated. Groundwater dissipates beneath the surface irrespective of national boundaries.
- Fuzzy boundaries: Defining the exact hydrogeological boundaries of groundwater resources is extremely challenging. There are uncertainties about the recharge areas, the flow and discharge characteristics and the interrelationships with surface water bodies. Alike it is a complicated process to specify the stakeholders who are involved in the system and to set the social boundaries of the aquifer system.

Transboundary groundwater aquifers are those shared by two or more states. Significant aquifers of the world are of transboundary nature, e.g. in Europe alone, 89 transboundary aquifers have been identified (Puri and Aureli 2005). The aforementioned hydrogeological features have implications for transboundary groundwater governance because they establish a physical interdependency between the riparian countries. Activities in one state have potential or actual implications on another riparian state. Additional characteristics describing groundwater systems are:

- Decentralisation of abstraction: A main determinant for regulating groundwater usage is whether countries have a centralised or decentralised (local) system of water abstraction. Technological developments for the local scale may on the one hand decrease investment costs for small users, but on the other hand increase monitoring costs. A major factor of agrarian growth in e.g. India, Pakistan, Bangladesh and China is the increase of groundwater irrigation by means of small pumps and wells financed mostly by private farmers. In irrigated agriculture, groundwater use is more likely to reflect small to medium-scale, low intensity investments on the part of millions of individual groundwater users.
- Externalities: Typical of transactions related to groundwater usage is the difficulty of attributing external effects to pumpers or polluters. For example, individual farmers may contaminate groundwater as a by-product of their farming activities. The effect of this on others is not accounted for in their profit-maximisation decisions because it has no financial cost for them. However, it certainly produces social costs. The complexity and time lags inherent in many aquifer flow regimes mean that the causes and effects of human actions often tend to become decoupled from one another with regard to both groundwater abstraction and pollution. Individual misconduct is almost impossible to measure. Due to the slow

response, impacts from neighboring countries in a transboundary aquifer can take decades before recognized in the reparian state (Puri and Aureli 2005).

- Information asymmetry: In groundwater management there is much asymmetry between the information level of the state, that is, the monitoring agency, and that of polluters or abstractors. This has to be considered in policy design, since the transaction costs of the state for monitoring pollution and abstractions are prohibitively high.
- Uncertainty and data needs: Reliable groundwater-related data is imperative for making knowledge-based decisions. In most countries, the data available on both groundwater quantity and quality are poor compared to the data available for surface water (Biswas 1999, 8). Moreover, the data are not homogeneous. National data collection and knowledge about the interrelationships between human actions and the extent and timescale of groundwater degradation are lacking. The transmission paths by which contaminants enter aquifers are unknown and, in particular, the potential health effects are uncertain.

On the basis of following five additional geopolitical and hydrogeological characteristics, Eckstein and Eckstein (2005) have developed a system for classifying six different types of riparian constellations associated with transboundary aquifer systems.

- The geographical location of one riparian state vis-á-vis the other.
- The location of the respective transboundary aquifer in relation to national borders.
- Recharge, flow and discharge of groundwater in relation to national boarders.
- Possible hydraulic links between the aquifers and surface water bodies.
- Whether the aquifers are confined or not.

Based on the aforementioned characteristics and geophysical interdependencies the riparian states of transboundary groundwater systems face typical cooperation problems. In general we can differentiate between a) unidirectional problems (externalities) and b) collective problems (Scheumann 2008). The most prominent example for unidirectional problems are cases where the recharge area of an aquifer is located in one country while its flow and discharge area underlies a second riparian's territory. These unidirectional implications can be positive, when one country's water extraction reduces waterlogging of soils in the other riparian territory or negative when land use changes, e.g. deforestation, may effect the recharge capability of the aquifer systems in the dependent riparian territory. Collective problems occur if all riparian states are mutually affected by difficulties in managing water quantity and quality, such as aquifer pollution due to infiltration of contaminants or groundwater levels decline due to overextractions for irrigation. In reality there will never be such a clear distinction between cases of unidirectional problems, and collective problems.

3 POLICY INSTRUMENTS TO IMPACT ON GOVERNANCE STRUCTURES

We classify three types of policy instruments regulatory, economic and voluntary/advisory. Similar distinctions are made by environmental economists (e.g.

Stavins 2004). These instruments are ideal types and no policy option ever relies purely on one type of instrument (Stone 2005).

a) Regulatory or command-and-control policy instruments such as laws, well registration, and allocation of user rights, are compulsory. Due to the large number of small groundwater users it is difficult to implement top-down groundwater management, since effective monitoring of the use of groundwater would be very costly. Enforcement must therefore be rooted in local acceptance.

b) Economic policy instruments make use of financial (dis)incentives such as subsidies, taxes, tradable pollution permits, and groundwater pricing.

c) Voluntary/advisory policy instruments are those that motivate voluntary actions or behavioral changes without the need of fiat or direct financial incentives. Collective action, a specific hybrid form of governance structures, is of particular interest in managing a common-pool resource like groundwater (Ostrom 1990). In most cases, participation and collective action is facilitated by voluntary/advisory policy instruments. The reason for this is that collective action can be encouraged to a large extent by providing (scientific) knowledge (for example, by making hydro-geological information accessible to and understandable for the real stakeholders), by contributing practical experience, and by providing information that persuades those involved to participate. In addition, collective action is often also motivated by economic policy instruments such as the subsidization of water prices for group members. Such local forms of self-governance must also be supported by legislation which, for example, allows group members to set and change their own statutes, by public oversight (e.g. water quality control), and by regulations (e.g. by defining abstraction quotas). Assuming that the latter locally agreed rules can be enforced, it is already a combination between voluntary/advisory instruments and others.

The aim of policy instruments is to have an impact on governance structures. Governance structures are the organizational solutions for making rules effective, i.e. they are necessary for guaranteeing rights and duties and their implementation in the co-ordination of transactions. Almost every governance structure in the real world is a hybrid form somewhere between the polar cases of hierarchy and market. In practice, various forms and combinations of governance structures are used to coordinate agri-environmental problems (Ménard and Klein 2004). In particular, the range of suitable, horizontal non-market coordination mechanisms is arguably high in the filed of agri-environmental transactions. The latter are e.g. transactions between farmer(s) and the community concerned, such as polluting groundwater by applying pesticides on farmland. Hybrids, such as horizontal non-market coordination have been suggested and are particularly seen as a possible way to manage common-pool resources. They include cooperation and collective action, formal and informal networks as knowledge and information systems, infrastructure for measuring, monitoring, and evaluating environmental damages and benefits, conflict resolution mechanisms and incentives and opportunities to promote innovation and learning (Hagedorn et al. 2002). Empirical evidence shows that it is very difficult to find and facilitate with the help of policy instruments, suitable combinations of governance structures for ensuring sustainable resource management. Every policy to be implemented meets a ground where already certain institutions are in place. Box 1 shows the institutional and the social-economic background for groundwater governance in South Asia (Mukherji and Shah 2005; van Steenbergen and Oliemans 2002).

Box 1: Institutional environment for groundwater governance in South Asia

- The region has a high population density with predominantly small landholders and an overwhelming dependency on groundwater for agricultural production.
- Governmental intervention primarily concerns supply quantities with little concern about overexploitation of aquifers.
- Water quality issues are almost completely absent in public discussion and have not yet been politically addressed.
- New groundwater laws are not enforced.
- Groundwater rights are attached to land ownership; withdrawal rights are not regulated, with the accompanying risk of overdraft.
- Community resistance to regulations restricting water use is high and has a strong political impact due to voting power in these parliamentary democracies.
- The projected costs of metering and monitoring are prohibitive due to the high number of scattered water users.
- Informal water markets have developed which are not subject to any kind of regulatory authority. This leads to an increase in pumping and the sale of groundwater, thus hastening resource depletion in areas where the groundwater base is already scarce.
- Provision of electricity is practically the only point of contact between the government and water users in the region.

3.1 *Regulatory groundwater policy instruments*

This section explains how the assignment of disaggregated property rights and duties to groundwater causes incentives or disincentives to manage the resource. The subsequent paragraphs describe emerging trends in national groundwater legislation and regulatory provisions in the ongoing fight against depletion and pollution. Mechanisms for national groundwater legislation are often combined with market and voluntary/advisory policies. Like most countries, South Asian countries rely to some extent on regulations and legislation to regulate groundwater use. But with a high number of scattered water users, high monitoring and control costs appear and with this the need that formal rules be structured in a way that authorities can count on voluntary compliance.

3.1.1 Property rights and their assignment

A crucial characteristic of groundwater governance is the difficulty in assigning property rights (Dalhuisen et al. 2000). Here it is important to distinguish ownership rights from property rights. In general, ownership rights to a physical entity include: a) the right to make physical use of physical objects, b) the right to alter them and derive income from them, and c) the power of management, including that of alienation (Furubotn and Richter 2000, 77. Even when the state claims ownership rights to natural resources, individual or collective users may nevertheless hold specific rights. For instance, the state may have ownership rights to a body of groundwater while the irrigators themselves determine who has access and withdrawal rights. Those involved may attribute value to a physical good because, whoever has a right to it enjoys certain benefits; but, its value may diminish if the rights to it are burdened by cost components. *Schlager and Ostrom* (1992, 250-251) divide property rights generally into 1) access rights, 2) withdrawal rights 3) management rights, 4) exclusion rights and 5) alienation rights. Property rights may be structured so as to include or exclude any of these five distinct types of rights. The five may be more or less well defined, and how they are combined has an impact on the incentives of those involved to govern and manage their system (Ostrom 2003). When a system of groundwater rights is introduced it is usually referred to as the right to abstract and the right of use. These rights are subject to terms and conditions which determine how each is to apply, for example in terms of duration, locations for water abstraction and use, purpose of the use, rates of abstraction, specifications for water works, environmental requirements, fees and costs for possession of the right, records of transactions, loss or reduction of the right, suspension of the right, review of the right, and renewal of the right (Garduno et al*.* 2002-2006).

3.1.2 Ownership rights to water and land

Both traditionally and on the basis of Roman law, groundwater has been regarded as the possession of the owner of the land above it. For centuries, the owner of surface land was also the owner of water under it. In general, this unspecified stage of property rights implies that the landowner can extract as much water as he desires without any kind of restriction. To prevent overuse, the respective local or national government has the option of limiting unrestricted withdrawal by imposing requirements on groundwater abstraction and use.

Some Islamic schools of thought, such as "Sunnism", distinguish between land rights and water rights: the digger of a well—whether on his own land or on unoccupied land—automatically becomes the owner of the well's water as soon as digging is completed. The owner of the well is the sole beneficiary of the right of irrigation (Caponera 1992, 70).

3.1.3 Regulations for use

The landowner's water rights can be regulated by limiting the amount which he may extract. For example, he may be obliged to obtain a permit or authorization before constructing a well or drilling a wellhole. In turn, the permit itself may be subject to conditions governing such factors as maximum depth or maximum abstraction rates.

3.1.4 Statutory vestment in the public domain

For a government to control groundwater, it must declare that the respective groundwater resource is located on property which is in the public domain. The resource is then regarded as being held by the state in trust for the public. This declaration turns the former owner into a user who must himself apply to the state for rights of water abstraction and use. The situation is exemplified by the South African National Water Act of 1998 (Burchi 1999, 58]. A critical issue there is whether former owners of groundwater are entitled to compensation for such disenfranchisement.

Property rights in this case become separated from water rights, and only the right to water abstraction and its use accrues to the owner of overlying land or others. In addition, these rights may be cancelled if the resource is not used or upon failure to comply with the law. In detail, such institutional arrangements may also include a broad array of conditions governing the duration of such rights and the quantity and rate of abstraction. For instance, the U.S. State of Iowa restricts the duration of groundwater abstraction permits to less than ten years when aquifer capacity is uncertain (Burchi 1999, 58).

3.1.5 Supervision of well construction activities

Groundwater legislation may also regulate the licensing of well drilling contractors or may impose controls over the import of pumps and drilling equipment, especially in the case of large-scale, sophisticated facilities requiring external expertise and labor (Nanni et al. 2002-2006). In South Asia, in contrast, pumping facilities are mostly on a small scale and are constructed by the well users themselves.

3.1.6 Land surface zoning

Land surface zoning as a policy instrument can be used for quantity control and quality protection of groundwater resources. For example, water administrators may pass laws creating special control areas where exceptional restrictions apply. Such areas may be a) resource conservation zones for the control of groundwater abstraction, b) resource protection areas in areas where aquifers are highly vulnerable to pollution. Restrictions on crops, pesticides, and fertilizers are common in such areas as a means of preventing percolation into the groundwater. They generally reduce land values and raise the question of a legal right to compensation payments. Laws governing such areas may be purely mandatory or may also be supported by voluntary policies involving education programs or the promotion of codes of good agricultural conduct. This has been attempted in some regions of South Asia, but the zoning system there is only weakly enforced (Shah et al. 2001, 21).

3.1.7 Wastewater discharge licensing

To protect groundwater against pollution a licensing system for wastewater discharge can be implemented. This type of legislation follows the "polluter-pays-principle" by which a polluter is charged for the amount of pollution he produces. However, this principle is very difficult to enforce due to the time lag before pollution becomes apparent and the persistence of certain groundwater contaminants. Economic incentives are therefore also required in order to induce the industrial sector and water utilities to invest in adequate wastewater treatment and recycling.

3.1.8 Aquifer and land use planning

The management of water resources, including their protection from pollution, can be facilitated through long-term groundwater planning in order to ensure informed, forward-looking and participatory decision-making. Such plans can provide for an integrated assessment of all factors involved. For instance, a distinctive feature of the French water-planning system is the participation of civil society in the formation and adoption of the related plans. As can also be seen in France, such plans can have a legally binding nature and can even be challenged in the courts. In the case of France, the present planning is seen as "the best tool for conservation and protection of aquifers which is available under French law" (Burchi 1999, 63).

3.1.9 Conjunctive use

"Conjunctive use" of surface and groundwater means that both types of water are used in combination in such a way as to minimize the undesirable physical, environmental and economical impact on each and to optimize the balance between water demand and supply. Policy measures directed to conjunctive use may comprise an augmentation of the water supply, allocation of costs, groundwater recharge, the storage of surface water, and a coordination of rights involving the interrelationships between the two kinds of sources.

In India, for example, technical solutions have been developed for channeling monsoon river flows through earthen canals for the irrigation of wet-season crops while recharging underlying aquifers at the same time (Road and Vidyanagar 2002). Putting such a technique into practice naturally requires the cooperation of the respective administrative departments, along with measures to protect the domestic water supply during the monsoon season.

3.1.10 International water law

Based on the history of the development of international water law, with the Helsinki Rules issued by the International Law Association in its meeting in Helsinki in 1966, - which were soon accepted by the international community as customary international law -, it was the first time that transboundary groundwater was addressed by any international legal instrument. Yet, the legislation is still restricted to groundwater resources which are linked to surface waters.

In the Seoul Rules of 1986, which where an extension to the Helsinki Rules the groundwater definition was set broader, including transboundary aquifers that do not contribute water to, or receive water from, surface waters of an international drainage basin (Salman 2007).

The UN Water Course Convention which was opened for signature in 1997 does include groundwater however only when it is connected to surface water. Finally, the Berlin Rules on Water Resources from 2004, which are an update and extension of the Helsinki Rules cover groundwater again in its broader definition under the particular Chapter VIII.

The UN Water Course Convention has still not entered into force and the Helsinki Rules and the Berlin Rules are not legally binding per se. Thus, until today shared water resources including groundwater aquifers are not yet regulated by a binding international convention or treaty.

3.2 Economic groundwater policy instruments

Economic policies may employ financial incentives and disincentives to change behavior in order to facilitate sustainable resource management. When discussing economic instruments, such as setting a price on water abstraction, one has to be aware of the fact that in developing countries market systems are largely ineffective due to corruption and rent-seeking.

3.2.1 Direct and indirect groundwater fees

The levying of fees directly for water abstraction is a straightforward economic policy instrument. The fees may vary according to volume, area, location, and source. The crucial factor, however, is that water metering is needed for this – an impossibility in India, Pakistan and Bangladesh, for example, since the costs of metering and billing some 14 million scattered small users would be prohibitive. This is even more the case if the users have no incentive to comply. In addition, administrative bodies in these countries are regarded as ill-equipped, inexperienced and short of field staff (Shah et al. 2003, 3). One solution for indirect measurement of groundwater abstraction in such situations is to take the size of an irrigated area as a basis. Supervision of groundwater use also has become more enforceable with the development of remote sensing technologies. These make it possible to map crop distribution and to estimate actual evapotranspiration with high-resolution photographs.

Another solution proposed by Shah et al. (2003) is indirect groundwater pricing by introducing an equitable flat tariff for energy (electricity or diesel fuel), e.g. the provision of a certain number of hours of electricity per day. This avoids logistical difficulties and transaction costs, and also circumvents the risk of strong farmer opposition associated with metering water. However, energy fees in many areas of the world are heavily subsidized at present. While it can be legitimate to subsidize poor farmers to improve their livelihood, measures such as lump-sum payments to poor farmers will have a less detrimental effect on water resources than the allotment of subsidies for groundwater abstraction.

3.2.2 Groundwater markets

A water market is a set of arrangements that permit water rights (for abstraction and use) to be traded. The ability of water rights owners to exchange, lease or sell their rights is essential for successful groundwater management (Blomquist 1992). In some water markets, rights can be sold and bought separately from land rights. This is the case, for example, in Colorado, Nevada and Utah in the USA.

Water markets cannot operate without stable, clearly defined and enforceable water rights. Blomquist (1992) emphasizes that pumping rights, for example, must be clearly assigned and controlled. Unlimited pumping rights lead to a loss in efficiency, since users who stop pumping from a water basin benefit other users but receive nothing in return. Thus basin users have no means of transferring groundwater production to higher-value uses when transferable pumping rights have not been defined. In addition, there must be a requirement that water rights be put to effective and beneficial use (Solanes 1999, 73]. Otherwise there is a negative effect on water transaction, on water markets, and on efficient water allocations. In the Western states of the U.S.A., water rights transfers are increasingly being considered as a policy alternative for encouraging the optimal use of scarce water resources through private reallocation. Water markets generally have the purpose of moving water from low-value to high-value uses, but they may also exacerbate the problem of over-exploitation in areas with fragile groundwater ecology, since they set no limit on total groundwater use. To prevent this, control measures must be worked out and enforced to reduce the total volume of water rights over time.

In contrast to the water markets discussed above, in informal water markets, such as those in South Asia, water sellers produce water to sell, not selling the water they would otherwise use themselves. The latter is, however, an important requirement to prevent monopolies. In India, Pakistan and Bangladesh, water markets are rather seen as tools to improve access to the resource pool to those who do not have their own source of irrigation (Solanes 1999).

3.2.3 Subsidies and taxes

Since electricity or diesel power is required to pump groundwater to the surface for use, there is a strong link between groundwater and energy. Instead of direct subsidies, farmers often receive electricity subsidies; this results in overuse of energy and water in groundwater-irrigated agriculture. Heavy subsidies to the farming sector have been one reason for the collapse of many state electricity boards in India (Biswas 1999, 9). Annual groundwater withdrawal for agriculture in some of the most overexploited areas in India might be reduced by 12-20 cubic kilometer simply by eliminating electricity subsidies (Mukherji and Tushaar 2005, 341).

Another form of economic incentive lies in providing subsidies which encourage the use of more efficient irrigation technologies to achieve real water savings. Incentives to reduce agrochemical leaching are needed in order to control pollution from agricultural cultivation. Subsidies for fertilizers and pesticides can be re-targeted. A further step might even be the introduction of an environmental tax on fertilizers and pesticides.

3.3 Voluntary/advisory groundwater policy instruments

Policy instruments encouraging user participation are mainly voluntary in nature, since farmers may choose to participate or not. However, participation can also be enforced from the top down, as in the special-purpose water and land associations in Germany. Similarly, participation may be encouraged by economic instruments such as reduced water tariffs for group members.

Yet, decentralization of decision making has social and political tradeoffs that need to be considered. Changed entitlements may imply more security for those who before the decentralization had no information about their water resource and no voice in allocation issues and less security for those who could always count on getting their allocation from the central authority, whether by right, by payoffs or by influence (Kemper et al. 2007, 5).

3.3.1 Encouraging local self governance

Stakeholder and community participation is a hybrid form of governance structure which takes place at various levels. Groups which practice self-governance by distributing groundwater from wells to their members, mostly for irrigation, are widely known as "water user associations" or “water user cooperations”. In the case of groundwater aquifer management, there is an additional need for so-called "aquifer management organizations", that is, systems of higher-level user and stakeholder participation.

In southern California, groundwater management is managed by local organizations, and numerous local governance structures have been created to design and implement management programs for many of the groundwater aquifers. Eight water basin examples from Southern California show that centralized governmental control is not required when citizens have the opportunity to engage in self-government. In Orange County, for example, the management regime has proved effective in reversing critical overdraft of the aquifer and preventing its destruction through overextraction and seawater intrusion (Blomquist 1992).

Groundwater management can be successful if it is embedded in other governance systems, that is, if it is coordinated with other organizations and if conditions for adaptability are provided. In the latter case, water users must be provided with institutionalized means for modifying watershed programs to meet variable water conditions, or the water user associations must have the option of attaining legal status in order to benefit from agricultural credit programs. This situation is termed a "facilitative political regime" (Ostrom 1990, 137; Blomquist 1992, 335ff.). Blomquist (1992) has stressed that the attitude of California's state officials toward local self-government and local water management has been crucial for the formation of basin governance structures which make collective decisions on basin management. Here, the state government acted as an active facilitator of local management.

In contrast to this, all groundwater policies, e.g., in Pakistan in the last 50 years have been initiated and implemented from the top down, that is, from the provincial or federal down to the local level. There has been no involvement of local farmer organizations or local governmental bodies (van Steenbergen and Oliemans 2002, 328). The only exception to this was the Groundwater Rights Administration Ordinance of 1978, which was enforced in the mountain province of Balochistan in Pakistan. The legislation facilitated common-property management and provided a framework for local resource management by involving both local administrators and tribal elders and by allowing flexibility in determining usage rules. Unfortunately, local self-governance failed to develop, because community initiatives did not evolve spontaneously. Nevertheless, water user associations are seen by some as the only viable solution for some regions of Pakistan (van Steenbergen and Oliemans 2002, 337ff.).

An attempt to transfer institutional approaches to water management from the industrialized world to developing countries may fail due to high population densities and multitudes of tiny water users in the latter. In India, for example, the number of diesel and electrical pumps leaped from 87,000 in 1950 to 12.6 million in 1990 (Burke et al. 1999, 40). In a successful collective action example is the Santa Clara Valley Water District south of San Francisco the total number of farmers is probably less than a thousand, whereas an area of comparable size in Asia would contain 100,000 farmers (Shah et al. 2001, 22). Yet, it is a misconception that common-pool resource regimes based on local, self-governing are applicable only to small groups of resource users. Rather, the key is a collective understanding of the scarcity of the resource and effective operational rules, as shown by the Tampa Bay region in Florida. Here, a cooperative resource management system has evolved which successfully manages the shared groundwater resources of 2.1 million users (Rowland 2000).

4 INSTITUTIONAL ASPECTS OF GROUNDWATER GOVERNANCE

The aforementioned simplistic and straight forward classification of policy instruments provided an overview of current policy instruments of national groundwater governance. New insights into crucial institutional aspects of policy implementation can be derived from this systematic and comprehensive overview.

4.1 Groundwater governance has to do with voluntary compliance

Water users sometimes ignore or violate restrictions imposed on them. Voluntary compliance is therefore a key issue (Pistor 2002), since supervision is costly due to the resource system's characteristics and the high number of potential water users. As the number of water users increases, the costs of enforcing national groundwater legislation may become prohibitively high.

Moreover, the transfer of modes of governance which have been successful in other parts of the world should be approached with caution. For example, such transferred laws can be enforced in recipient countries only if four premises are fulfilled: First, formal legal systems and organizational forms and institutions which are imposed must respond to and foster demand. Second, there must be an alignment of formal norms with underlying social norms and beliefs. Third, the laws or institutions in question must provide solutions for actual conflicts and take the various interests behind such conflicts into account; otherwise, they will be ignored (Pistor 2002). Fourth, voluntary compliance implicitly assumes a certain level of common understanding and knowledge about the resource at stake.

If people are skeptical about such transferred formal structures, whether they are in the form of democratic systems such as water user boards or hierarchically imposed rules, voluntary compliance will be lacking. Users will continue to ignore the new governance structures and will seek other solutions to their problems. The primary challenge for groundwater agencies in this regard thus lies less in formal regulations for use than in being able to communicate with a wide array of groundwater users to encourage sustainable use of the resource.

Taking California’s groundwater management as an example, Blomquist (1992, 302) has shown that compliance with formal rules can be extraordinarily high. According to him, the high rate of compliance there is due to two factors a) management programs were generally developed by the water users themselves, and b) the management programs included some form of monitoring which made the actions of each user known to all fellow users. This feature is often discussed in combination with a system of graduated sanctions in which the participants themselves undertake monitoring and sanctioning and where the initial sanctions are surprisingly low (Ostrom 1992, 69ff.). Quasi-voluntary compliance (sometimes also referred to as "contingent contracting") therefore appears to be a viable concept. In other words, as long as all users acknowledge the rules, the individual user will follow them. Each user’s compliance thus depends on the compliance of the others. Users are thus motivated to monitor each other's behavior in order to be sure that the rules are being followed. Monitoring can also be a by-product of existing rules, as is observed in rotating irrigation systems.

In India and Pakistan, drafts of groundwater laws have been discussed for decades, but there is no political will to enforce them. In India, such laws would have to be enforced upon millions of farmers operating irrigation pumps scattered throughout a vast countryside. This is almost impossible when voluntary compliance is missing.

4.2 Groundwater governance has to do with mental models and tradition

It is often repeated that traditional local practices are not to be ignored when new management schemes or technological innovations are implemented. Nevertheless, this still happens. A typical example is found in parts of Eritrea, where traditionally a system for protecting and allocating well water is established during drought periods to conserve water. This system of informal rules was sustainable under previous abstraction regimes but is now endangered by a program of upstream dam construction which will alter the traditional recharge regimes *(Burke et al.* 1999, 48). The contrary has been reported in Ethiopia, where the traditional system of rudimentary irrigation has no control structures and farmers have no way of regulating their water supply (Kandiah 1997). Here too, the lack of local rules has implications for the imposition of rules transferred from the outside, since the local population is not accustomed to follow rules of allocation.

Voluntary compliance with regulatory provisions is strongly linked with the mental models of actors in each region and their social and cultural context. Traditions and religion shape these mental models. For instance, the basic principles of Islamic water law are still observed and strictly followed by the local population (Caponera 1992, 68). In Moslem tradition, water is a public commodity, a gift of God which cannot be owned. Although it would be a misconception to think that water can never be priced in Islamic countries and must be accessible to everyone there without limitations, Muslims do in fact regard water as a present from heaven and see no need to manage it. This has long been observed in Asia (Shah et al. 2001, 31). Yet, Farugui et al. (2000) found that Islam allows water providers to recover their costs. Although water itself cannot be sold, because it is considered a social good and owned by the community, fees may be charged for the provision of water services. Governments, municipalities, and contractors can thus recover their costs for collecting, storing, treating, and distributing drinking water, and for treating wastewater. In Iran, for example, private water companies are allowed to charge prices amounting to the average total cost of providing water services. However, they must also provide 25 liters of water per capita per day for free, as a "lifeline". Islamic law also sets penalties for those who do harm to others, thus opening the door for legal penalties against water polluters.

4.3 Groundwater governance has to do with bureaucracy

The "problem of fit" occurs if the boundaries of a biophysical system, here a groundwater aquifer, do not match the jurisdictional areas of political institutions responsible for managing this resource (Young 1999; 2002). In order to achieve successful implementation of decentralized water resource management the institutional arrangements have to be clearly defined and reasonable well matched to the aquifer system. Poorly defined boundaries may impair collective decision making by including actors or communities who are not actually stakeholders of the particular resource system, or excluding others who have a stake (Ostrom 1990). Such institutions may then be incapable of managing the water resource in question since the costs of coordination would be prohibitively high in terms of both time and funds. Institutional change in this case may also be hampered if adverse but historically-deep-rooted structures are already in place. Studies of the implementation of river basin management in Europe, as required for example by the Water Framework Directive, found that federal administrative and political systems like those in Germany are likely to make basin management more difficult (Moss 2003).

Burke et al. (1999) have extended the problem of fit to social systems. They emphasize that biophysical boundaries and political and administrative boundaries must be in congruence with social boundaries. Since social and cultural variation is often as great as hydro-geologic or climatic variation, this may present an even greater challenge to the development of groundwater management systems. In contrary, Kemper et al. (2007) state for the case of river basin management, that transaction costs in terms of time and effort are expected to be lower when relating to existing organizational forms. This argument is taken up by advocates arguing to expand the mandate of existing river basin management organizations to groundwater aquifer management duties and responsibilities. Furthermore, in some cases, administrative structures for groundwater management may not exist at all. This, however, can be an advantage rather than a disadvantage, since it offers the opportunity of setting up administrative structures which are more tailored to natural aquifer boundaries. Of course, in most cases there will be a tradeoff between, on the one hand, relying on existing political jurisdictions that do not fit resource boundaries, and on the other hand, creating new jurisdictions that fit resource boundaries but may not be familiar to or easily accepted by the resource users whose "social boundaries" are not the same as the resource boundaries.

The "problem of interplay" occurs when resource management requires the interaction of different levels of the political and administrative hierarchy (national, federal, regional, etc) and/or horizontal interaction across different sectoral units and the related organizations (e.g. spatial planning, agriculture, or water protection) (Young 1999; 2002; Moss 2003). Moreover, when different authorities need to work together, ambiguity often exists in the definition of their respective central and local responsibilities. It is often the case that the central level basically tries to retain control over local decisions while simultaneously reducing expenditures for regional development. In Mexico, for example, a multiplicity of overlapping and even contradictory legal requirements has been described (Biswas 1999, 9). Although aquifer management councils have been established there which provide for self-governing and innovative solutions on the part of water users, there is an unclear division of tasks and responsibilities between these councils, the irrigation water user associations, the federal and state water management agencies, and the river basin councils (Wester et al. 1999).

Any administration that needs to implement new formal rules will show some reluctance to implement policies involving substantial changes in procedures. This is understood as political and administrative "inertia". It is due among other things to the high transaction costs faced by civil servants (time, meetings, memos, etc.) in order to become acquainted with the new policies and to build new procedures for implementing them properly (Schleyer et al. 2006). National governance needs to move from a resource development approach to a resource management approach.

In Eastern India and in Bangladesh, for example, the governments' goal still is to bring about an agrarian boom through groundwater exploitation. A similar phase in groundwater use can be seen in Africa. Due to high evaporation rates in West Africa, surface water is not always available at the right moment and in adequate quantities for crop requirements. Supplementary irrigation from groundwater resources is seen as having a high potential for irrigation development (Sonou 1997). Likewise, groundwater use in Sub-Saharan Africa is still a matter of small-scale irrigation development for food production and for securing food requirements (Kandiah 1997). However, policies have been changing in response to new challenges: water management must now address substantive overexploitation and groundwater quality issues in the region (van Steenbergen and Oliemans 2002). Inertia and a lack of information on the part of the authorities constitute a hindrance to administrations in making this transition (Shah et al. 2001, 20-29).

Measures aimed at a major transformation of the activities of local administrations can be expected to meet with strong resistance. This is particularly the case when long-established relationships persist, which involve corruption and opportunities for side-payments. New measures, which might change these interrelationships, are thus strongly opposed or are circumvented by both parties to the corruption arrangement. In addition, a policy that aims to encourage local initiative and self-organization often includes economic intervention in the form of subsidies. This may imply a loss of power for some in the region, particularly elected representatives. Resistance on the part of these local representatives stems from the fact that they would lose decision-making power and their previous authority to distribute local funds should the participation of other, non-elected, rural groups increase (Schleyer et al. 2006, 128).

4.4 Groundwater governance has to do with conflict resolution mechanisms

The conflict potential within a country is a good indicator of how conflicts are resolved locally, that is, either through negotiations or by armed confrontation (Heidelberg Institute for International Conflict Research 2006. The prevalence of armed conflicts in a region indicates that there is a need for learning how to resolve conflicts through negotiation. One possibility might be to empower mediators as authorities accepted by all rivaling parties. Thus, aquifer management, involving rivaling ethnic groups, whether they are transboundary or not, is a challenge. Moreover, when one local ethnic group is very powerful, the influence of national and local administrative authorities is very limited in all areas, including the water sector.

In general, political negotiations across national boundaries often involve a compromise on conflicting issues such as access to water, land, mineral resources, and political power. Agreement on each issue, including transboundary groundwater, becomes increasingly complicated as the number of issues on the political agenda increases. However, despite the tensions inherent in such settings, riparian nations have shown tremendous creativity in approaching regional development, often through preventive diplomacy. Examples of cooperation in the history of hydro-political relations overwhelmingly outnumber the incidents of conflict (Jarvis et al. 2005).

4.5 Groundwater governance has to do with political economy

When water legislation is introduced or updated, difficulties arise due to the social pressure placed on water users and their political associates to grant exceptions. Particularly in developing countries, this has a negative impact when resource management is controlled by rent-seeking stakeholders. Well-organized special interests in such cases promote self-serving policies in the absence of a transparent governmental and information system which would allow other stakeholders to counterbalance their influence (Burke et al. 1999, 52).

All countries in South Asia have adopted parliamentary democracy. There is evidence that one consequence in these infant democracies is an inability of politicians to enforce measures which affect the livelihood of the people. In India, the ruling party was defeated in recent parliamentary elections precisely in states with a precarious groundwater situation. Moreover, groundwater irrigators in Asia have emerged as a huge, powerful base of voters which political leaders cannot ignore when discussing energy subsidies or financial support measures for agricultural product markets (Shah et al. 2001, 21). Likewise, registration of wells and supervision of their operation remain unrealistic in India or Pakistan. Thus, community acceptance and an understanding of water requirements are prerequisite for ensuring support for measures aimed at protecting natural resources.

4.6 Groundwater governance has to do with information

Groundwater data is often patchy, outdated, or inaccessible. Often there is scientific uncertainty regarding the health of the resource, the impact of human actions on it, and its potential future. Uitto and Duda (2002) concluded in their study on managing transboundary surface water resources that sharing information and joint scientific fact finding is essential enhancing cooperation between countries for sustainable development. Without an understanding of the complexity of the groundwater system, the irreversibility of groundwater depletion, and the necessity of precautionary protection, cooperation will be ineffectual. Even in Pakistan which has based its agricultural boom on irrigation and has conducted many scientific studies on irrigation technologies and local management, there is an urgent need for improved monitoring of groundwater levels and groundwater quality (van Steenbergen and Oliemans 2002).

This lack of information has three implications for groundwater governance: First, a common understanding of the operation and interrelationships of a management system is a prerequisite for self-organization (Ostrom 2000). Without sufficient information on groundwater aquifers, the local population cannot understand the dangers threatening these natural resources and will willingly fool itself that the aquifers are in good condition. Second, as described above, one prerequisite for voluntary compliance with groundwater regulations is public awareness. When knowledge about the extent of depletion, the danger of groundwater pollutants for personal health, or the irreversibility of falling groundwater tables is inadequate, it is difficult to motivate humans to change their behavior voluntarily and to refrain from otherwise profitable actions. Third, a lack of information prevents administrations from taking the step from resource development to resource management and addressing the issues of overexploitation and groundwater quality. For instance, the Kafue Basin's development in Zambia is based on a very limited understanding of the basin’s overall resources. As a result, measures to protect this aquifer from urban, industrial and mining pollution have thus far been ignored by the local water users (Burke et al. 1999, 48).

5 CONCLUSIONS FOR TRANSBOUNDARY GROUNDWATER GOVERNANCE

Transboundary water development poses the question of how to achieve sustainable governance of transboundary groundwater aquifers. With the exception of a few hydro-geological studies, investigations of institutional transboundary groundwater aquifer management have been rare. As the present review has shown, there is much to be learned from well-documented cases, mainly in South Asia, of different combinations of policy instruments leading to complex national groundwater governance. Without a functioning system of national groundwater governance it is difficult to establish transboundary governance, since part of the required structures would be lacking. The systematic review of national policies allowed to extract six aspects relevant in framing groundwater governance systems from an institutional perspective: 1) voluntary compliance, 2) traditions and mental models, 3) bureaucracy, 4) conflict resolution mechanism, 5) political economy, 6) information.

The objective of the reminder of the paper is to discuss how these crucial institutional aspects aggravate when considering transboundary groundwater governance. Specific characteristics of the aspects become particularly relevant for transboundary perspective.

Groundwater aquifers are very complex natural systems which require flexible adaptive governance solutions. The hydrogeological and geopolitical characteristics of transboundary groundwater aquifers have shown that in particular the irreversibility and time lag calls for governance solutions of a precautionary nature to prevent and protect the necessary water quantity and quality. Groundwater management can be regulated by a fine-tuned balance of regulatory, economic, and voluntary/advisory policy instruments. There is no model of transboundary groundwater governance that can be implemented in varied locations. As Kemper et al. (2007, 232) state for river basin management applies for groundwater governance systems, too: there is no reason based on theory or on empirical analysis to believe that a particular style of management arrangement will perform well in diverse settings. The governance of global environmental resources, such as groundwater bodies, is increasingly based on multi-level solutions operating at the local, national, international and intermediate levels simultaneously. This offers possibilities to deal with the necessary institutional diversity (Paavola 2007).

There are two options for inter-state transboundary groundwater governance regimes which are discussed at present among development cooperation organizations (Scheumann 2008): a) extending the mandates of existing river and/or lake basin organizations even if the aquifers’s boundaries extend beyond the organizations’ sphere of responsibility, and even if not all riparian states to an aquifer system are part of that organization. Due to interrelationships with surface water systems, it might be an option to transfer groundwater aquifer management to existing surface water organizations. Yet, this option requires dealing with the implications of the "problem of fit" due to the mismatch of institutional and biophysical boundaries. b) Establishing new aquifer management organizations that cover the resource system and include all riparian countries. When establishing such a supra-national level of bureaucracy, there are different national legislation, which have to be harmonized, the responsibilities remaining to the national level have to be coordinated, and there is an additional bureaucratic layer with all its difficulties (e.g. the problem of interplay and administrative inertia). In fact, both of these stylized inter-state arrangements imply additional aspects of the political economy which have a lot to do with state sensibilities for absolute territorial sovereignty.

Another fact, when boundaries are drawn among a larger territory to encompass a transboundary aquifer, is that the number of water users and the number of different stakeholders to be considered increase, alike the prevailing cultural and social differences. When the number of resource users is larger, regulatory agreements (including international agreements) are difficult to monitor and control. Governments must rely on voluntary compliance. The formulation of any regulatory framework in such cases should be supported by public awareness campaigns. In particular, a heightened awareness is required in order to establish a change in focus from groundwater development to sustainable groundwater management. Much of the thinking of both local users and administrators is still dominated by the views of eras when groundwater exploitation to facilitate agricultural development was a top priority. Without this awareness, it will be difficult to obtain compliance and to enforce any regulation. Moreover, it remains essential to recognize regional traditions and local rules-in-use.

Finally, collective action has proven to be a successful way of groundwater resource management at the local, regional and even national level. It needs to be considered to what extent collective action can contribute to transboundary groundwater management. The prerequisite for engaging in collective action is the conviction that there is a problem. Therefore, a focus on gathering data and scientific knowledge to reduce the uncertainty on many aspects of the aquifer system is required in line with the provision of an institutional environment that facilitates bottom-up knowledge elicitation and exchange. In addition, mechanisms for sharing information and acquiring homogeneous data must be improved between countries (Arnold and Buzás 2005).

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