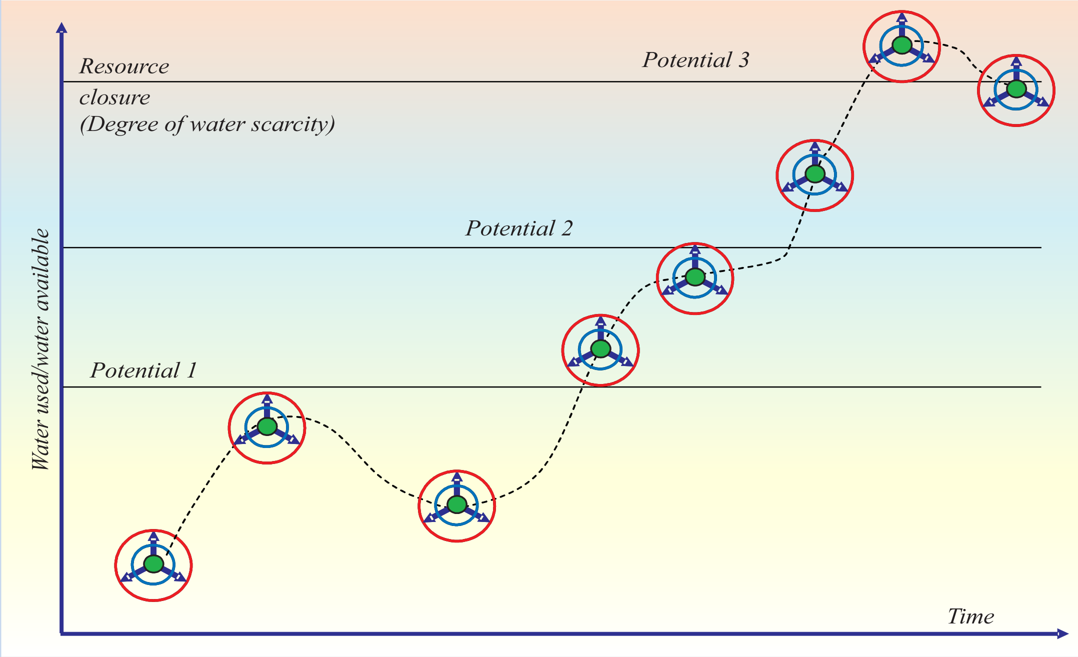
RESEARCH REPORT

72

Development Trajectories of River Basins
A Conceptual Framework

François Molle



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Contents

Summary

The development of societies is, to a large extent dependent upon their resource-base, notably water resources. Access to and control of water, depends primarily on the available technology and engineering feats, such as river diversion structures, canals and dams. As growing human pressure on water resources brings actual water use closer to potential ceilings, societies usually respond by adopting conservation measures and by reallocating water towards more beneficial uses.

Several frameworks and diagrammatic representations of great heuristic value have been proposed to conceptualize the development of river basins along these lines. They have brought into sharp focus the crucial phenomenon of basin closure, making it much more clearer and understandable. At the same time, the simplicity of these representations may not allow one to capture the deeper heterogeneity of the processes that underlie the historical relationship between a particular society and its water resources.

This report first critically reviews various conceptualizations of river basin development that can be found in the literature on water resources. It then shows that distinguishing between several categories of water sources, instead of considering them as a whole, provides additional insight into how water resources are put into use and are controlled. The report proposes a disaggregated view of different categories of water (rainwater, stream water, regulated surface water and underground water), allowing for a better understanding of how the actual and potential use of the different sources of water relate to each other, and of the scope for improvement.

A typology of societal responses to water scarcity is then presented. It emphasizes the need to distinguish between responses devised by the state at the national level and those of individual farmers and small groups or communities, although both responses are partly interdependent. While emphasis is often placed on state policies, adjustments made by local actors also often appear to be very significant. Responses from both the state and the local actors can be further broken down into three types (supply augmentation, conservation and reallocation). It is shown, however, that these categories are not as straightforward as they appear to be. Because of the interconnectedness of users throughout the hydrological cycle (particularly upstream/downstream and surface water/groundwater linkages) they are not purely additive. Whether these responses occur sequentially, is examined by referring to several empirical situations which illustrate that specific historical evolutions and patterns that do not accord with the reviewed frameworks can frequently be encountered. A few elements, which appear to be crucial in shaping responses are then singled out, including the nature of the state and state/citizenry relationships, the impact of “shock events,” the nature of the political economy, and the conditions of agrarian change.

Existing linear visions of basin development tend to be based on economic rationality or on concepts of social adaptiveness that are too restrictive or too difficult to evaluate. Societal responses to the scarcity of resources, at both the local and the state level, are not driven solely by economic considerations or locally perceived needs. It is argued that they must be understood not only on the basis of hydrological, physical or economic constraints, but within a wider political economy framework that considers the distribution of human agency and power among actors, as well as their respective interests and strategies. The last section attempts to devise a new framework that is comprehensive enough to trace the evolution of a wide variety of river basins and to avoid reducing them to a single, oversimplified form.

Development Trajectories of River Basins: A Conceptual Framework

François Molle

Introduction

The evolution of societies and, in particular, the development of their productive activities, are partly determined by the available natural resources. Water resources, defined within their river-basin environments, are mobilized for domestic use and food production, and are, therefore, of paramount importance. In early times, when population density was still low, people adapted agriculture to abundant land and water resources. Crops, cropping calendars and elaborate subsistence techniques were attuned to natural conditions of soil, topography, climate and hydrology. Gradually, entire landscapes and waterscapes were crafted, especially under conditions in which it was easy for a small group of individuals to work together to construct a temporary diversion of river water, or under conditions in which early states exercised tight control over large populations to develop large-scale schemes for flood control or irrigation.

In the face of growing human pressure and in the course of time, however, the supply of natural resources reaches its capacity. River basins, and often land frontiers, "close," in the sense that most water resources are committed or depleted with very few remaining untapped. Water needs come to exceed water availability in river basins and people find that their productive activities are constrained by water shortages. This prompts crises that, in turn, lead to technological innovations and to adjustments and interventions, both in institutions and in the economy. Societal adaptations to changing relationships between people and water-basin resources seem to move through a unilinear sequence of stages, similar to those that Rostow (1962) has theorized for economic growth.

This sequential model of the evolution of the river-basin society has the merit of providing a generic framework to address an issue of worldwide relevance. It also has a great heuristic value, in that it brings into sharp focus the crucial phenomenon of basin closure, making it understandable and straightforward. At the same time, however, its simplicity may not allow us to capture the contingency and deeper heterogeneity of the processes that underlie the historical development of societies. This report first reviews several approaches to conceptualize river-basin development. It then shows that distinguishing between several categories of water sources provides additional insight into how water resources are put into use and are controlled. A typology of responses to water scarcity and a review of some crucial aspects of river basin development, are then used to devise a new framework, that is both comprehensive enough to describe the evolution of a wide variety of river basins, and avoids reducing them to a single, oversimplified model.

Common Views on River-Basin Development

The literature provides a few (and recent) attempts to theorize the phases of water resources development. Molden et al. (2001b), for example, distinguishes between three phases: development, utilization and allocation (figure 1).

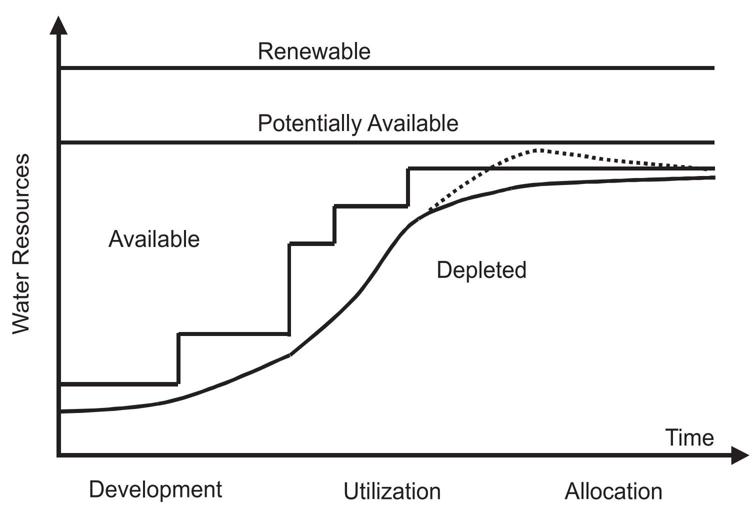
In the first phase of basin *development*, water use is limited to rain-fed agriculture and run-off-river- water utilization. Dams are constructed in the most convenient locations, either to produce energy or to irrigate, while the supply for domestic purposes remains quantitatively negligible. Large-scale irrigation systems, therefore, may be constructed. The amount of water effectively used for agriculture and other beneficial uses is less than what is available, much of which simply flows to the sea or to the next downstream basin. Water management tends to be based on demand, and conflicts, therefore, rarely arise. Water quality remains good and releasing more water from reservoirs easily mitigates pollution. Ecological systems and environmental functions are not significantly altered.

In the next phase, the *utilization phase*, shortages of water begin to appear in the driest years and during unusually dry seasonal spells. Storage dams are added to the river as a safeguard against shortages, but adequate sites tend to be rare. Improving management, rehabilitating infrastructures and conserving water become critical issues, while pollution problems and competition within irrigated areas become apparent.

As the basin nears closure, sectoral allocation becomes a point of tension (*allocation phase*). Efforts are directed at allocating water towards the most economically valuable uses, and new institutions evolve to address inter-sectoral competition and manage river-basin resources in an integrated manner.

The account by Molden et al. (2001b) identifies consecutive responses to water scarcity, starting with water-resources development, followed by improvements in efficiency and sectoral management, and culminating with modernization and inter-sectoral reallocation. The linear logic of this model is

FIGURE 1.
Schematic representation of river basin development.

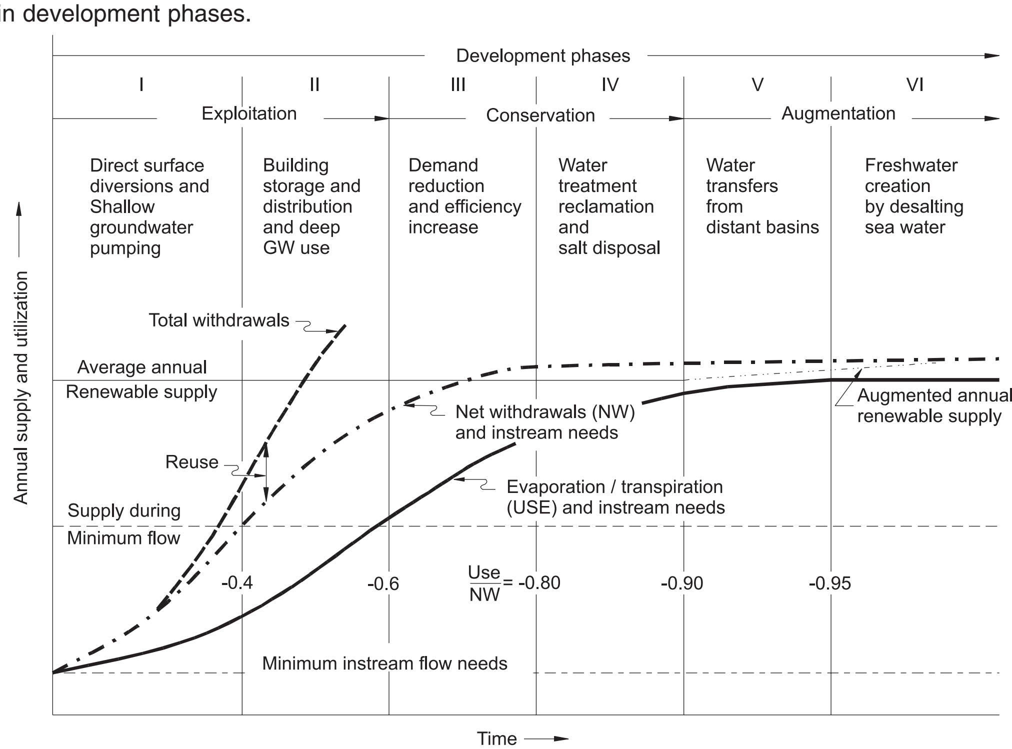


Source: Molden et al. 2001b.

depicted in a table that compares the problems faced by, and the prominent issues associated with, each of the three different phases towards a final situation, where water use is reserved for activities with a high economic value, groundwater and pollution are regulated, and basin-level coordination and integrated management are used to mitigate conflicts.

The description of Molden et al. draws on earlier works of Keller et al. (1998) and Keller (2000), which also break down river-basin development sequences into three phases, each one being subdivided into two further subphases (figure 2). In the first phase (*exploitation*), demand is initially satisfied by the simple diversion of river water and by pumping water from shallow aquifers. As pressure for water increases and these tactics become inadequate, people evolve a second subphase of exploitation, marked by the construction of large-scale storage capacity and by a capacity to pump water from deep aquifers ("a straightforward engineering solution"). When the available water resources in a basin approach full development, the *conservation* phase begins. In the early stage, demand reduction and an increase in efficiency are the usual means to bring usage into conformity with the availability of resources. Return flows are reused, but savings in quantity generally result in problems of water quality (pollution and salinity) that need to be addressed in a later phase (water treatment, reclamation and salt disposal). Despite these efforts, it is not unusual to see imbalances between the abstracted water and the annual renewable supply, especially with the overexploitation of aquifers. The third phase, or the *augmentation* phase, starts when the basin is fully closed and additional supply must be brought from outside the basin, typically from neighboring basins with an excess supply (if any) or from the sea (desalinization).

FIGURE 2.
River-basin development phases.

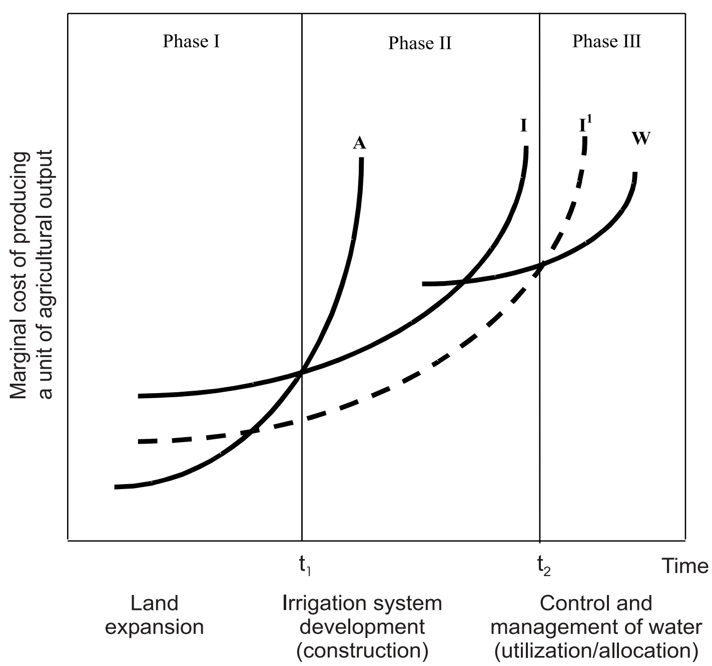


Source: Keller et al. 1998.

This framework is also based implicitly on a linear vision of the development of water use towards a "mature" situation, where uses are attuned to the renewable supply, while water quality is maintained and environmental-flow requirements are ensured. The evolution is depicted as a "*natural* progression of water development in a river basin." The two sequences are similar, but they differ in some details.[1] In particular, the latter sequence specifies a phase of augmentation after demand management has been effectively implemented and it sees groundwater use as a characteristic of the earliest stage, unlike the former.

These stages are broadly consistent with a vision of development, described in economic terms, as shown in figure 3 (Hayami et al. 1976; Kikuchi et al. 2002). Development starts with the expansion of rain-fed agricultural land. A point is reached (point t_1) where the marginal cost of opening up new lands exceeds the marginal cost of developing irrigation. In the *construction* phase, the cost of surface irrigation systems rises as irrigation expands into increasingly marginal areas. However, the development of new technologies, specifically adapted to irrigated agriculture (*green-revolution* technologies), shifts the marginal cost[2] curve downward from I to I^1. Eventually, a point t_2 is reached where the cost of new irrigation exceeds the cost of investment in effective *utilization*. Depending on the situation, more effective utilization and better performance can be achieved in a number of ways, such as through better control and management of surface-water flows, recycling water by pumping from drainage ditches, and by developing groundwater resources (curve W), (Barker and Molle 2003).

FIGURE 3.
Hypothetical development paths of agriculture by means of land and water development.



[1]The former is presumably derived from a situation observed in developing countries, while the latter is clearly influenced by the experience of the USA (more particularly that of California).

[2]This, of course, reflects the situation of the producer and does not account for the costs of developing such technologies.

This economic view focuses on technology and on the costs of development and water management. It neglects the transaction and political costs of institutional reforms. Another limitation of this economic view is that it does not account for the fact that upland expansion may restart at a certain point, because possible irrigated areas are already saturated. New lands are then put into use and a new phase of agricultural expansion in marginal upland areas begins, as seen, for example, in Vietnam (de Koninck 1997).

These generic descriptions of basin development are based on the evidence that water resources gradually come under growing pressure, and that society devises strategies to cope with the new situation, thus relieving the tension, albeit temporarily. Another conceptual framework for water-resources development has been developed by Turton and Ohlsson[3] (1999). They also distinguish between three phases, in which water scarcity is answered by different strategies. During the first phase (*supply*), “the individuals surrender their responsibility for providing water for themselves to a central authority,” which embraces a hydraulic mission devoted to large-scale hydraulic infrastructure. Later, water deficits arise and demand management (*demand phase*) first consists of raising the efficiency of use, and then of operating intra- and inter-sectoral reallocation of water resources. In a third phase (*adaptive*), the society has to cope with absolute water scarcity and must bring water demand in line with a sustainable level, defined by annual renewable resources. This description is similar to the preceding ones,[4] but Turton and Ohlsson’s (ibid.) analysis goes beyond the quantitative analysis of imbalances in supply and demand, and discusses the societal responses induced. They are interested in the links between the nature and legitimacy of the “coping strategies,” devised by decision-making elites and by social stability. In particular, they see the emergence of water deficit conditions (demand phase) as a crucial period, where environmentalism is likely to gain momentum, and where the adaptive capacity of the social entities concerned is put on trial.

Turton and Ohlsson (ibid.) distinguish between a “first-order scarcity” of natural resources (water), and a “second-order scarcity” of the social resources, required to adapt to the former. They have reformulated their framework as the “turning of the water screw,” where engineering development, improvements in end-use efficiency, and allocative reforms, are seen as the three successive responses that are needed to address a persistent water scarcity. Although they claim to go beyond the kind of linear vision described above, this reformulation does not really provide a conceptual alternative, although it adds a more intuitive visualization of the fact that every turn of the water screw is “tighter.” The social resources needed, therefore, to achieve this reformulation are increasingly high.

In addition, Turton and Ohlsson (ibid.) are also concerned with distinguishing between situations in which social resources enable society to adapt, and others, where conflicts and social unrest are likely to be the outcome. In particular, they do not necessarily posit that crises generated by water scarcity will be

[3]Their framework is not specifically focused on river basins but, rather, on water resources at the national level, because of the importance given, in their discussion, to state policies. However, water scarcity is discerned at the basin level and it is, therefore, consistent to apply their concepts at that level.

[4]Although the demand management phase includes both conservation and allocation strategies, the adaptive phase is construed as an additional phase, where social stability is at risk and major societal adjustments are needed.

eventually solved,[5] especially with regard to ecological impacts, thus rightly shifting the attention to the adaptive capacity or social capital of societies.

Disaggregating Basin Trajectories

The first limitation to the development models reviewed above, is that they consider aggregate "annual supply" or "available resources" without distinguishing between the different sources of water. This section proposes a disaggregation and categorization of different "sources of water" that may help better understand how a society manages and uses its water resources. The four categories described here can also be viewed as water sources that can be ranked based on the degree of control that the society has on them.

Water-Source Categories

At the basin level, water availability is determined primarily by rainfall.[6] *Rainwater* is intercepted and evaporates, or is captured directly by cultivated fields, either because it directly infiltrates the soil or because it does so after being retained in the fields by furrows, bunds or small dikes. Part of the water that fills the soil reservoir is eventually consumed by crops (effective rainfall), while the remaining water infiltrates lower layers of the soil, partly recharging the streams. The total effective rainfall depends, of course, not only on the cropping area but also on the terrain (soil type, slope, etc.), and on how crops are cultivated (cropping techniques, mulching, etc.).

Stream water is unregulated water from the river system, generated by direct surface or subsurface runoff. It may be diverted (by gravity) or abstracted (by pumping) for production or other needs. Human intervention is necessary to divert, convey and apply stream water. Stream water occurs independently of reservoir operation although, in many cases, its flow adds to that released from dams.

Controlled water is water that has been stored in surface reservoirs (dams, lakes, etc.), discounting the average loss by spill, evaporation and infiltration, or underground reservoirs (aquifers), and that can be used at will and purposely, once released or extracted. Even for a given set of reservoirs, the amount of controlled water is not necessarily constant and may change over time (e.g., change in dam inflow, siltation of reservoirs, etc.). Likewise, the safe yield of the aquifer may change slightly if the recharge is altered in consequence of changes in the hydrological regime (for example, if water-harvesting infrastructures are constructed). Average values are considered here, which

[5]While the other frameworks do not explicitly state that the evolution of river basins must be seen as a positive move towards a more desirable state, it seems that the ideology of progress is so pervasive that river basin development is often implicitly interpreted as such. This was illustrated, anecdotally, during a seminar in which different river basins were tentatively placed on the time axis of a chart. A Nepalese colleague, uncomfortable with seeing a Nepalese basin occupying the leftmost position, expressed his disagreement with the classification, before being explained that many people wish their basin were still at that stage…

[6]Aquifers may extend beyond the limits of the watershed and trans-basin diversions may also occur, which may alter the typical situation described herein. Desalinization of seawater can also be considered as an inflow of freshwater, not pertaining to the basin itself.

somehow obscure the interannual variability that is paramount to the management of regulated resources.

Potential controlled water is the average total amount of water generated in a basin that can be stored in reservoirs that are technically and economically feasible, societally acceptable, and environmentally suitable, plus the safe yield of the aquifer. This limit is partly relative and susceptible to change. For example, uneconomic options at one point in time (e.g., trans-basin diversion), may become acceptable when the value of water rises or, on the other hand, when dam construction may run into too much opposition from the civil society and may be ruled out. *Actual controlled water* may exceed the potential (renewable) controlled water if groundwater abstraction exceeds the safe yield of the aquifer, and/or if dam management leads to tapping carryover stocks (i.e., if the average yearly release from the dam temporarily exceeds the average net inflow).

Distinguishing between such categories is further complicated by the fact that both the absolute value of the different categories of water and their relative share of the total amount of water used vary over time. If there is a rainy season, rainwater will generally predominate, while in the dry season (or in arid regions), controlled water will be the primary source for the crops. Though a period of one year allows one to get an aggregated overview of the situation, it does not provide any information about the constraints faced in particular periods of that year.

General Evolution of Water Use

Figure 4 provides a view of (hypothetical) evolutionary patterns. It allows us to compare the amount of water, available between the different categories of water sources, used by different activities. It also indicates how the abstraction of controlled water compares with the potential values.

The rainfall quadrant (lower-left quadrant) shows the amount of rainfall that has been utilized in both irrigated and nonirrigated areas (which may also include forests), while the stream-water quadrant (upper-left quadrant) indicates how much water has been diverted from streams for use.

The evolution of "surface water" (upper-right quadrant) exemplifies a (particular) case in which the *potential* available water is slightly declining (e.g., dam siltation or upper catchment hydrological changes), and in which the basin is reopened by a trans-basin diversion (indicated by a last step, *t*), and also indicates the incidence of desalinization (slight increase after step *d*). The amount of water depleted or committed to in-stream and downstream needs (including environmental services) becomes closer to the potential value. The difference between these two curves accounts for the share of dam releases, which is non-beneficial,[7] lost either to the atmosphere (evaporation) or to sinks (including the sea).[8] The groundwater quadrant (lower-right) shows an increase in withdrawals, which exceeds the aquifer safe yield before returning to a level under this limit (an optimistic scenario).

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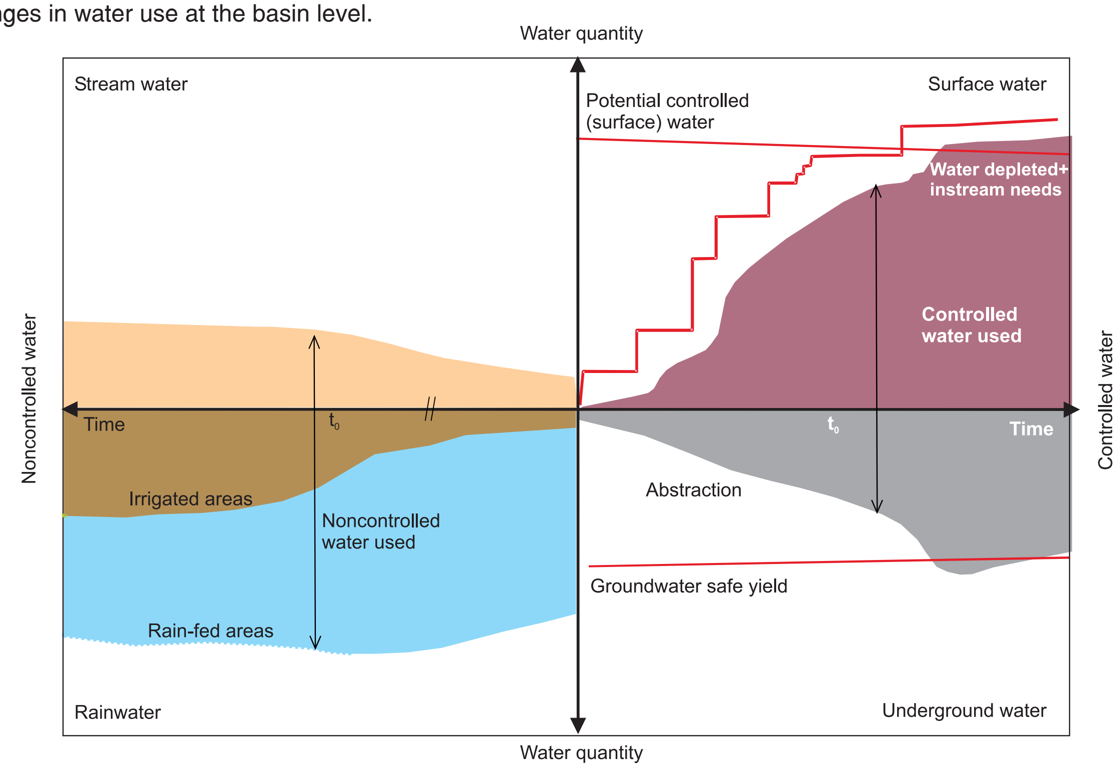
[7]The case of hydropower makes this distinction less straightforward, in that all the water released does provide the benefit of energy generation. In a closed basin, however, providing that hydroelectricity is not the main source of energy generation in the country, the downstream users will generally be granted priority. Their needs will dictate water releases, notably their timing, and hydroelectricity will only be a byproduct of these releases.

[8]For some ecologists, such losses do not exist, since the whole natural water regime is constitutive of ecological systems. We have assumed here that minimal environmental flows can be defined and incorporated as one term of demand.

Figure 4.

Changes in water use at the basin level.

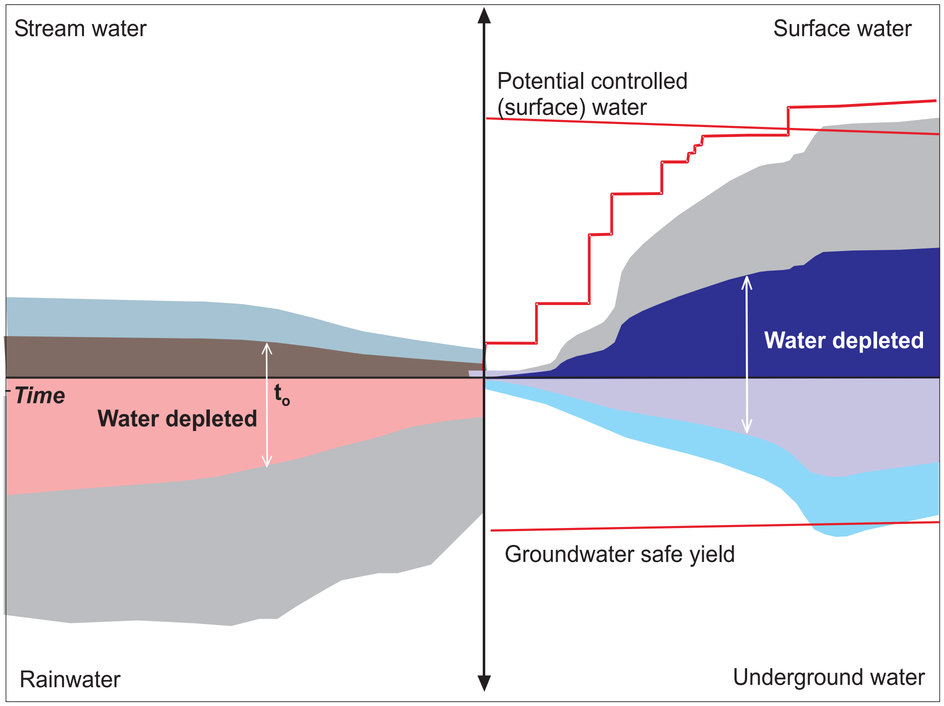


It must be made clear, at this stage, that the above figure does *not* depict a water balance but that it only compares the contribution of the different sources of water utilized by human activities (or needed for environmental services). In that order, the four quadrants disaggregate water sources, from the least to the most controlled, where "control" is taken as a measure of the reliability of the source in terms of quantity and timing at the seasonal level. Underground water is generally safe in the short term and users can extract a predictable volume. Regulated surface water is also reliable, but includes some uncertainty of the coming inflow, and its distribution over long distances may result in an uncertain supply. Stream water is dependent on natural flow (i.e., rainfall and runoff) and is, therefore, subject to little control. Finally, rainfall is the most unpredictable source, in terms of quantity and timing.

The return flow from the use of these four different categories of water may contribute to the potential of another category. For example, the return flow from rainwater may accrue to the stream, surface water or underground-water categories. Figure 5 is derived from figure 4, and shows both water that is abstracted and that which is effectively depleted. The ratio of the two values provides a measure of the efficiency of the use of each category. For rainwater, the depleted fraction is the effective rainfall.[9]

[9]There are some difficulties in establishing the amount of rainfall utilized by plants because they may also tap groundwater that entered the aquifer in other parts of the basin (or even outside of it). In basins with a certain degree of closure, the water table will often be low and the amount of water taken up by plants will generally originate from the *in-situ* infiltration of rainfall (or irrigation water).

FIGURE 5.
Changes in water used and depleted at the basin level.



Breaking down the different types of water use highlights, not only their respective shares and the degree of overall control on water resources, but also the main sources, the potential of which is not fully realized. In practice, sometimes it will be difficult to separate, not only stream water and rainwater (e.g., when water use is very scattered: numerous small tanks and run-of-river systems in Sri Lanka), but also stream water and controlled water (e.g., when there are significant surface or sub-surface side-flows between the dams and the irrigated areas, which add to dam releases). Yet, this distinction is essential for the better understanding of water use: for example, it is often the case that irrigation mainly uses stream water that would otherwise be lost. The meaning and implications of stating that agriculture makes up, almost, 80 percent of total water use, thus differ from a situation in which mostly regulated water is used.

A water-accounting procedure[10] that considers these different categories of water, as well as their spatiotemporal interrelationships, is a more complex exercise than figure 4 suggests. What is clear, however, is that the whole picture of water accounting is changed significantly if we consider controlled water in isolation, in order to estimate potential gains from improved management, or if we include stream water or rainwater in the picture (see Molle and Aloysius, forthcoming, for the case of the Chao Phraya

[10]See fundamentals of water accounting in Keller et al. 1996; Perry 1999; Molden and Sakthivadivel 1999.

and Walawe river basins). Therefore, it is useful to disaggregate the temporal evolutions of the different segments of water resources, to better grasp what the evolutions have been and where we are at present, thus avoiding the limitations inherent in the representations described in the first section.[11] Even with this disaggregation, however, the figure referring to surface water does not indicate the water shortages that may occur in specific periods of the year. Likewise, since the curves are based on moving averages of yearly values, they also do not account for shortages induced by the improper inter-seasonal and interannual regulation of controlled water.

The Demand-Supply Equation and Adaptation to Scarcity

The conceptual frameworks, reviewed above, hypothesize the nature and the chronology of the challenges and responses that society faces, with respect to water resources. The underlying assumption is that population growth puts pressure on water resources and that this, in turn, creates challenges for the society and leads to a gradual closure of the basin. The focus here is on basins with significant and growing anthropogenic pressure, and it is reasonable to retain both the gradual closure and consequent adjustments/conflicts as general phenomena. What is debatable, however (and questioned in this section), is whether the sequences described in these frameworks are found in all basins, and whether the responses are similar, or if a more inclusive framework can be designed.

It is hypothesized here that societal responses to water scarcity comprise a set of strategies, defined both at the individual/community level and at the state level, and is elaborated or induced, based on several location-specific factors, without any other assumption about a possible “natural” order or sequencing.

Range of Responses

While Turton and Ohlsson (1999) emphasize the way “technocratic elites” devise “coping strategies” to respond to water scarcity, they tend to overlook the multileveled adjustment of society to basin closure. In particular, they do not account for local adjustments made by individual users, or groups of individuals, and by local managers/officials, in addition to the state. This constrains the analysis of processes and leads to envisioning future changes as being governed by the decisions of the state and its elites. Broadening the scope for analyzing actors’ responses provides a richer understanding of the processes at work. The distinction between micro/local and macro/global adjustments will be herein, identified.

These two types of adjustments can be further broken down into three categories. (These are similar to the three consecutive steps mentioned by Turton and Ohlsson (ibid.) but, at this stage, no hypotheses are made on the order in which they materialize).

[11]For example, because surface water and groundwater are considered together, the difference between the actual and the utilized regulated water may not indicate where the remaining potential lies, or where excess abstraction occurs.

Supply responses: These consist of solving water scarcity by augmenting the supply from existing sources (foremost, increasing the quantity of controlled water), as well as from tapping additional sources. Typically, this is done not only by constructing new reservoirs or digging more tubewells, but also by diverting water from neighboring basins, by desalinizing seawater (which is tantamount to importing and treating water from a sink), by artificial groundwater recharge or by cloud-seeding.

At the local level, farmers may tap shallow or deep aquifers, and may also invest in local storage facilities (most commonly farm ponds, which are used to store excess irrigation flows or rainfall). They also develop the conjunctive use of water, by using water from drains, rivers, ponds and even by pumping from irrigation canals when the water level does not allow for gravity inflow to their plots. Thus, they broaden their access to a variety of sources and augment their individual potential supply of water.

It is already apparent here that the relationship between local dynamics and the basin (macro level) must be considered. For example, pumping water from drains increases supply locally, but not necessarily at the macro scale, if the pumped water was to be reused downstream.

Techniques and interventions aimed at capturing more rainwater, for example, water-harvesting techniques aimed at increasing groundwater recharge, can also be considered as means to augmenting one's effective supply of water.

At a more global level, the import of foodstuff is also an indirect way to increase water supply, or at least the water supply as a necessary factor of food production and security. This transaction is often referred to as *virtual water*, because of the water used by the crops that comes embedded in foodstuff.

Conservation responses: The key phrase here is "efficiency in use." Conservation refers to making a better use of existing resources, without increasing the supply or the sources of water. Line agencies may not only implement structural measures, such as lining canals, controlling leakage in pipe systems, or treating and allowing the reuse of wastewater, but may also resort to nonstructural measures, such as improving dam or canal management (so that unproductive or non-beneficial releases are not lost[12] to the sea) and establishing rotations or other arrangements for better scheduling. The state is also instrumental in devising and enforcing policies that may elicit water savings, such as water pricing, rationing and quotas. In these two latter cases, conservation aims at "doing as well as before with less supply," rather than "doing more with the same amount."[13] The state may also supply innovations derived from research (plot-level water management, improved varieties, and cultivation techniques).

Improved coordination between users and innovative organizational patterns may also contribute to water savings and can be mentioned here, particularly in the setting of water-user groups or river-basin organizations.

[12]Again, this does not mean that all water reaching the sea is lost, since minimum flows are essential to maintain ecosystems and control salinity intrusion in lower reaches of the rivers. These losses must be understood as the extra water that reaches the sea after abstraction by all other users, including environmental services.

[13]These two situations are rarely distinguished, although they differ fundamentally. In the latter case, the incentive to conserve water is strong, and users are prompted to make effective adjustments. In the former case, users may or may not be willing to take the necessary steps to conserve water.

Subsumed in the "conservation strategy" are, more generally, better management practices that not only tend to conserve water, but may also increase equity or reliability in the supply of water.

At the local level, farmers and groups of farmers are not passive.[14] Water may be saved, for example, by shifting calendars or raising bunds around rice fields (to make a better use of direct rainfall), adopting adequate cultivation techniques (such as mulching, alternating the wet/dry water regime in rice farming, shortening furrows, etc.) or by choosing crop varieties with a shorter cycle. These farmers or groups of farmers may also invest in water-saving technologies, such as micro-irrigation. However, such technologies may sometimes result in better control of irrigation doses and, in an increase in the amount of water depleted by evapotranspiration (see an example for Chile in Cai et al. 2001). The water saved thereby may also be used to increase the farmers' irrigated area (see Feuillette 2001, for an example in Tunisia), further reducing the return flow available to downstream users. Therefore, expected water savings at the basin level may or may not occur and may also have an adverse impact on other users. Here, too, a case-by-case cautious analysis must be carried out to fully understand the relationships between the local level and the macro level.

Allocation responses: A third type of strategy consists of reallocating water from one user to another, either within the same sector (e.g., within or between irrigation schemes) or across sectors. This reallocation may be justified by the need to raise water productivity, but may also be aimed at easing tension on the resources by favoring uses which enhance land productivity, food security or equity, or which reduce conflicts and protests. This broadens the principle that water should be moved to uses that are economically more beneficial, to which reallocation is usually attached, towards an approach whereby reallocation is a means to reduce the overall pressure on water resources.

Reallocation can occur within the farm, when a farmer chooses to direct his/her limited water resources to the crops that give him/her a higher return per m^3 (assuming that risks and marketing conditions are similar for all crops).[15] At the irrigation-system level, managers allocate water, based on a set of factors. This allocation can be more or less even in terms of water duty per hectare, but it can also be driven by other considerations: for example, areas that are too distant or that are endowed with sandy soils may be excluded, because they incur too high losses. On the other hand, reducing canal head-end/tail-end differences is conducive to higher equity and, often, to increased economic efficiency (Hussain et al. 2003).

At the basin level, managers also have the option of reallocating water according to a given priority system. Within the agricultural sector, water can be shifted from one area to another with comparative advantages regarding water productivity (typically, areas with orchards or aquaculture). The rationale for inter-sectoral transfers is generally economic: water is channeled to cities for domestic and industrial uses before to agriculture, where the economic return of one cubic meter of water is much

[14]Contrary to the central argument of demand management through water pricing, farmers facing water scarcity do not need to be taxed to make sense of it. Experience with reduced supply quickly translates into responses that may, however, be encouraged or constrained by public policies (e.g., impact of free rural electricity supply in some states of India upon groundwater depletion).

[15]Again, clear-cut definitions are not always possible. A crop shift can be a conservation measure (less water used), or a reallocation to a more productive (crop) activity (more $\$/m^3$), or both.

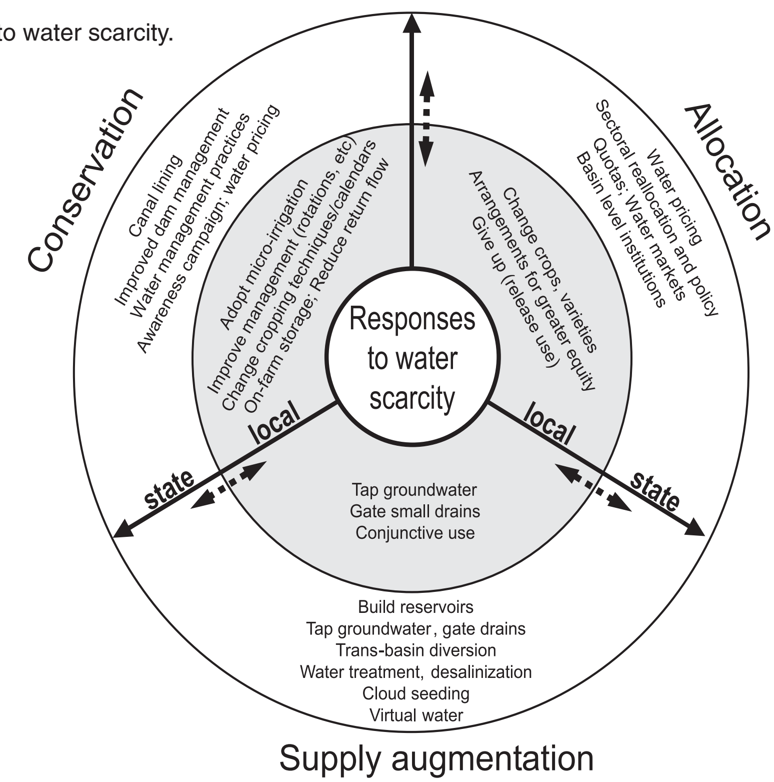
lower.[16] Such allocation decisions are, of course, not only potential sources of conflicts and tension, but are also sometimes mediated by market mechanisms or negotiations. Groups of users within an area (e.g., a catchment or an irrigation scheme) may also agree to renegotiate rights in order to ease tension. To some extent, giving up agriculture (or any other water-consuming activity) can also be interpreted as a strategy that allows one's water allotment or right to be reallocated to other uses.

At a more global level, water can be reallocated to nonagricultural uses at the cost of lower food production, if imports are increased accordingly (see *virtual water* mentioned earlier).

The conservation and allocation responses are often pooled together under the concept of water *demand management*, which can be typified by "doing better with what we have," as opposed to supply augmentation strategies.

Figure 6 synthesizes these different responses and shows how the three categories can be broken down into two sublevels. It must be emphasized that the definition of these categories cannot be totally freed from ambiguity because of the complex relationships between local and basin-level processes: a farm pond dug out by a farmer can be seen as *conservation* if it captures some canal water that would be further lost (to sinks, to non-beneficial evaporation or by flowing out of the system), but it may also be a *reappropriation* if this water was ultimately to be used by downstream users. The pond can also be considered as an augmentation of the *supply* to that particular farmer, if it captures runoff that was lost earlier. In practice, because it is not always possible to establish what fraction of a specific return flow is eventually lost or reused, it may not be possible to define a precise terminology.

FIGURE 6.
Types of responses to water scarcity.



[16]Contrary to the widespread idea that economic incentives are necessary to ensure the reallocation of water to economically more productive uses, inter-sectoral reallocation is often well administered by the state, and it is rather the consequences of this reallocation, in particular upon agriculture, that need to be addressed.

The same difficulty arises when new tanks are constructed in the catchment area of an existing reservoir. Normally, isolated tanks capture runoff and transform it into controlled water but, in that case, the flow captured by these new tanks was already potentially *controlled* by the reservoir into which it would have flowed, if the new tanks had not been added. Overall, there is no or little increase[17] of controlled water; instead there is a mere *spatial redistribution* of the resource. Likewise, trans-basin diversions, and even cloud-seeding, can be considered as supply augmentation from a narrow/local point of view, but they can also be treated as spatial redistribution (or reallocation) when seen on a wider scale.

These examples show that the measures taken at the two levels (individual and collective) schematized in figure 6, are not purely additive. This fact, however, should not be treated as "noise." The relationship between micro- and macro-processes is, in fact, at the core of the analysis. Because the closure of river basins results in a growing interdependence of the users within the basin, one must carefully analyze how the paths of the different surface and underground flows are interrelated, and how any local intervention that modifies the quantity, the quality or the timing of one of these flows, impacts on the whole system.[18] What is stored, conserved or depleted at point A, dictates what is available at point B, further downstream.

Likewise, it is not always possible to dissociate the decisions taken by farmers from the economic environment that is shaped by state policies. The adoption of micro-irrigation, for example, might be an individual decision, influenced by the availability of subsidized credit supplied by the state. (This is symbolized in figure 6 by the arrows that link the two layers).

The types of responses shown in figure 6 can also be distinguished according to the time frame of their implementation. Some of them, particularly those implemented by the state, need many years to be in place (e.g., dams, trans-basin diversion, and water laws), while some responses unfold within a more limited period (one season, one or two years). This is the case of short-term responses to water crises (typically, implementing rotations, changing crops, drilling wells, etc.). In other words, one may distinguish between responses to long-term imbalances between supply and demand, and responses to short-term ones (punctual water shortages or crises).

Actions taken by people may not be motivated by the type of strategy they come under: conservation responses, for example, may arise from an interest in increasing farm income rather than in conserving water.[19] Such actions may not be "responses" or "strategies" directly related to water scarcity, but may have a coincidental effect on the basin hydrology. More generally, responses also have an effect on

[17]An increase occurs if the amount of spill in the reservoir—now reduced—was formerly lost out of the system. This is more or less significant depending on the dimensions of the reservoir in relation to the hydrologic regime (and, of course, depending also on the type of downstream users and ecosystems present).

[18]See Keller (2000) with regard to water management in California, and Molden et al. (2001a) who developed the concept of hydronomic zones, with a call for reason interventions, based on a zoning of river basins. "Hydronomic zones are defined to characterize the combination of hydrologic and water-use settings within a basin. The zones are based, primarily, on the considerations of the outflow of water from the particular areas" (Molden et al. 2001a).

[19]Micro-irrigation provides a good example of such a situation. In many cases (probably a majority of them), it can be shown that the adoption of such technology is motivated not by water scarcity itself but, rather, by labor shortages, the need to better control the quality of production, the ease in applying (liquid) fertilizers, or the use of plastic mulch that precludes more rudimentary irrigation (e.g., Jordan).

factor uses and often change the distribution of benefits. For example, investments in capital and labor-intensive water-saving technology have an impact on local suppliers of equipment, and on the labor market.

Figure 6 also highlights that actors within the system are not passive and inactive. On the contrary, they respond individually and collectively to the growing scarcity of water, just as agrarian systems respond to changes in the relative availability of other production factors. This has been shown by case studies, such as those by Zilberman et al. (1992) for California and by Molle (forthcoming) for Thailand. State-driven responses are only a part of the transformation, although officials tend to see rural areas as globally static, and malleable through public interventions (infrastructures or otherwise), overlooking the constant endogenous adjustment of rural households and communities, as well as of line managers, to changing conditions.

Context-Specific Responses

In addition to categorizing the diversity of societal responses to water scarcity, a conceptual framework must also provide a degree of prediction on the range of adjustments a given society is likely to pick up or, rather, on the measures that are made possible, constrained, or that are ruled out, in the context under consideration.

Keller et al. (1998) place emphasis on the economic logic of the sequence of development. At any point in time, the cheapest solutions are selected, from simple flow diversion through desalinization. Their sequence follows the cost of the main options available in large basins of the western USA. In Ohlsson and Turton's (1999) approach, the logic of the succession is based on a scale of complexity, with the solution of water-scarcity problems demanding ever-increasing levels of social resources. It is thus assumed that hydraulic development is the easiest response, and that its exhaustion leads to conservation efforts, later followed by allocative decisions and adjustments. The latter two are regarded as much more sensitive and are prone to generating social conflicts and widespread disruption. These two analytical grids probably apply to many cases, but may not capture important nuances found in varied situations. The following examples provide instances in which the "natural" sequencing, or part of it, as proposed by one of the abovementioned frameworks, does not satisfactorily represent the historical transformations observed.

- Sakthivadivel and Molden (2001) have compared five basins said to be at different stages of evolution, and have found that the problems faced by these basins were different. However, some of the problems encountered were not those that would be typical of the phase in which each basin was assumed to be. For example, in the Singkarak-Ombilin basin in Sumatra, which is considered to be at the beginning of the utilization/ conservation phase, it seems that water allocated to nonagricultural activities and trans-basin diversions threaten to throw the basin directly into the third phase, where water rights and reallocation rules need to be defined. The East Rapti basin in Nepal is an open basin, with only 5 percent of the water resources being used by agriculture. In spite of this, water pollution from industries, competition for river water during the dry season among wildlife sanctuaries, tourist requirements, ecological requirements and human use are apparent problems that are normally associated with the later phases of development.

- More generally, most of Africa, with the exception of northern and South Africa, is still characterized by limited development of infrastructures. The number of large dams in a continent that makes up 20 percent of the world area amounts to only 1,192 out of a total of 24,864 dams worldwide (IWMI 2002). Likewise, the irrigated area makes up only 6 percent of the total cropping area of the world. The reasons that seem to have prevented the emergence of the development phase are not fully elucidated.[20] The decline in crop prices in the recent years compounded this situation, making both subsidized/public and private investments in agriculture/ infrastructure, economically unviable. This means that a conjunction of endogenous and exogenous factors has constrained the large-scale development of water resources, while problems related to other phases have emerged.

- In some basins, the tapping of shallow aquifers occurred in the inception phase of development (Keller et al. 1998), but in many other cases, the spread of wells was a late reaction to poor access to surface water (see Thailand, Bangladesh, India, etc.). The availability of technology and the investment capacity of users must also be considered.

- Very often too, large dams were not constructed to increase supply, but to control floods and generate electricity. Because their potential has been then—often later—taken advantage of to develop irrigation areas, demand consequently built up as a result of the new supply, rather than demand for water being a driver of supply development. This has often been the case in the river basins of the United States of America (Wengert 1985).

- Problems of pollution are generally associated with late phases in which the scarcity of the resource does not allow adequate mitigation by dilution, but it may also happen very early if there are significant point sources of pollution, with little regulated water to ensure dilution (such as with mines in South Africa).

- The need to design more complex and integrated forms of organization at the basin level, are associated with an ultimate phase of “allocation” of very scarce water resources but, in some cases, as with the case of France in the 1960s, it was the problem of water quality, and not quantity, that was the driving force behind the establishment of the “Basin Agencies” (despite both aspects being interlinked).

- Trans-basin diversion is generally considered as a possible way in which to “reopen” the basin after it has closed, but this option is often taken at much earlier stages of development (at the first stage), especially in small and medium basins. This was commonly achieved in Sri Lanka, at least as early as in the fifth

[20]Koning (2002) argues that this is partly because Africa’s elite is caught up in personal patronage relations and lack strong farmer movements that could ensure adequate support to agriculture, including trade protections.

century (Mendis 1993), and has remained a basic principle of water-resources development, ever since. Such transfers are also typical of irrigation in mountain interfluves, where irrigated areas straddle the boundary of two adjacent basins (e.g., in the Andes).

- It seems that, in many cases, the later phases of basin closure employ, not only allocation strategies but, more pragmatically, all the options that may help relieve pressure. The case of California, as described by Turral (1998), clearly shows not only that efficiency and allocative measures are both simultaneously sought, but also that the gains they provide are more limited than are commonly believed and need to be accompanied with a substantial amount of supply augmentation. Closure does not end up with allocative strategies but, rather, elicits continuous improvements on the three “fronts” (conservation, allocation, and supply).[21]

- In contrast to the impression that the current focus on the economic value of water is characteristic of a late phase of water-resources development, the British period of the Indian history clearly shows that all the questions currently debated on the economics of irrigation were already prominent ones. The questions of who was to finance infrastructures (local revenue, the Crown, or private interests), whether and how a water fee should be charged and what its impact on different categories of people is, whether it should be increased (opinions diverged among the British Government, the Government of India, local government, canal engineers, etc.), whether it could influence crop choice or water-use behaviors, to cite a few examples, were fiercely debated from the beginning of the nineteenth century onwards. Privatization, bulk volumetric pricing and crop-based differential rates were experimented with.

- Not all trajectories are upward. Historical examples of civilizations that have not successfully maintained their resources base and that have collapsed can also be easily found. For example, aerial photographs of some basins in Sri Lanka reveal a very high density of small tanks that have been abandoned, silted or destroyed. After Independence (in 1948), new water-resources developments have sometimes been superimposed upon the older systems, and larger dams have been built. Other examples include ancient Mesopotamia in the ninth century (cf. Pointing 1991) and, more generally, all the impacts of climatic change, salinization or tectonic change that are often overlooked in historical studies (Brown 2001).

- The “averaged” vision, inherent in the trajectory concept, may also obscure the heterogeneity of on-the-ground reality. Subareas in the basin are often at different stages of evolution and the problems they face, as well as their solutions, vary significantly. Molden et al. (2001a) have attempted to address this issue by defining “hydronomic zones” within a basin.

[21]If we reexamine figure 3 on such grounds, we might draw a different pattern, where the different curves tend to converge, in the long run, to the same order of magnitude.

- Spatial heterogeneity is paralleled by human heterogeneity. When considering the diversity of farming systems, one finds at the same time, different individual responses: water conservation, intensification, diversification, giving up agriculture, etc. Factor endowments, farmers' agency and market opportunities, among other things, shape individual strategies and, therefore, it is not always possible to describe the resulting aggregated trend at the basin level in a simple way.

Critical Elements in Basin Development

The above examples suggest that specific historical evolutions and patterns can be easily encountered. Investigating in detail the causal correlations between particular physical/societal contexts and historical transformations of river basins is, beyond the scope of this report, but this section attempts to single out a few elements that appear to be crucial in shaping responses.

The Nature of the State and State/Citizenry Relationships: The state is often described as the main actor that shapes all river-basin evolution by virtue of its investments and policies. Turton and Ohlsson (1999) identified the building up the state's power with the launch of the "hydraulic mission."[22] As mentioned earlier, this emphasis tends to obscure the magnitude and significance of endogenous efforts undertaken by local actors, especially in view of the development of the conjunctive use of water. It also fails to account for situations in which resources are principally managed by the users themselves, such as in the case of the tank systems of south India or of the mountainous regions of the Andes, Nepal or upland southeast Asia.

The nature of the center/periphery and state/citizenry relationships defines the scope and the room for maneuver and adjustment allowed to the different actors in the system. Authoritarian or despotic states may be more often associated with large-scale development and centralized management (regardless of how the causality is theorized), while weak states may leave more scope for local initiatives. The degree of decentralization and democratization also obviously influences how negative impacts (particularly on health or the environment) are both perceived and addressed.

The role of the state often changes over time. Ruf's (2001) description of the Prades Valley in the south of France shows that, during its five centuries of existence, the irrigation system has been managed, in turn, by the state, communal associations and private entrepreneurs, and that these changes could be traced to the prevailing nature of the center/periphery relationships, defined within the wider political and historical context. Theories of induced institutional change tend to see changes as occurring by necessity, in response to a mismatch between demand and supply, and these theories do not account for the (numerous) cases where the power and political structure eventually dictates and supplies new institutions and forms of organizations (see below).

Potkanski and Adams (1998) describe the response of the Sonjo, in Tanzania, to water scarcity and show the interrelationship between agricultural commercialization, property rights and water scarcity, on the one hand, and the

[22]It is not always very clear whether Turton and Ohlsson (1999) refer to river basins or countries.

complex and tightly interactive relations between local institutions and the state, on the other.[23]

Economic power and political will are often associated together, and small communal schemes may be captured and enlarged when new actors, such as local lords or colonial estates, come into play. Larger-scale interventions that are beyond the scope of local actors may be later undertaken by the state or by some capitalistic private entity.[24] When basins are developed in stages, defined by successive historical, economic and political contexts, then several phases of supply augmentation, followed by growing water scarcity and resulting conservation/allocation measures, are likely to take place. This scenario differs from that of the above frameworks, which tend to hypothesize one, single, compact phase of state intervention and "heroic engineering" that exhausts (or nearly exhausts) the physical opportunities for such interventions.

Turton (1999) posits that a popularly supported legitimate government will be able to introduce measures that an unpopular government will not be able to introduce. This is consistent with the hypothesis that reallocative strategies are likely to be unpopular, but the link with the dichotomy of democratic versus authoritarian regimes, is not developed. In fact, it is evident that the latter may sometimes reallocate water with more facility, irrespective of whether this is done in a sound manner or not.

Last, things get even more complex for international rivers, where political relations between states come into play. Scenarios may differ significantly from those described above.

The Political Economy of Water Resource Development: Clearly, the economic rationality described by Keller et al. (1998) has a strong impact on the choices that are made. However, it is necessary to go beyond a formal model of rationality and towards a political and economic approach, where decisions are understood not only on the basis of their actual financial costs, but also on the basis of the benefits and increased power that accrue to the different categories of actors within the society, and sometimes beyond.[25] Costly (and even absurdly costly) solutions, such as groundwater recharge by injection or trans-basin diversion, are sometimes justified and implemented in lieu of demand-management options, because they fit the logic of pork-barrel politics and serve as substitutes of other more politically risky options. The conflicts between politicians, construction firms, consultants, local population and environmentalists, provide the best example of how the decision of building a dam is eventually debated in a political arena, where financial or political interests coexist with environmentalism, communitarianism and concerns for local livelihoods.

Another way to look at these societal debates, is to weigh the monetary costs of infrastructural development (and their financial benefits) against the transaction and political costs of more demand-management-oriented

[23]This study shows, in particular, that not all endogenous institutional innovations provide benefits for the whole community, and that if the state may be intrusive, it may also be instrumental in preventing the outright and inequitable appropriation of resources by any group of individuals.

[24]Ruf's (2001) paper also provides such an example in the Ecuadorian Andes.

[25]Barker and Molle (2003) stress how investments in large-scale infrastructure during the cold war can be partly ascribed to geopolitical considerations. The "lending culture" of development banks has also been criticized as reflecting either the interest of western construction firms or that of the banks in increasing the scale of their interventions.

options. The difficulty of reforming management, including efficiency and equity aspects, varies depending on many cultural, social and political factors. But it is recognized that "regional politicians have a powerful intuition that economic principles and the allocative measures, which follow logically from them, must be avoided at all costs" (Allan 1999). This largely explains the persistent gap between the rationality of consultants and experts and the actual adoption of policy measures in the real world. It also provides hints on why strict economic logic is not always the best criteria to understand the succession of state investments and responses. Resource capture can occur at any time, depending on the power balance within the society, and is perhaps more frequent than rational allocation. More generally, the responses given to water shortages depend on which constituency succeeds in making its discourse legitimized and accepted (Ingram 1971). The example of water conservation in the Imperial Valley Irrigation Scheme, southern California, given by Waller (1994), neatly shows how local, influential farming elites associated with irrigation managers could legitimize policies which shifted the cost of conservation onto other parties. Rather than accepting on-farm conservation systems, which would have raised the amount of time and effort needed in farming, as well as the reliance on hired labor, these elites successfully pushed for temporary measures of land fallowing, for which they would be compensated.

This leads Wester and Warner (2003) to call for a vision of water as a politically contested resource, and the closure of river basins as a political process, where the overexploitation of resources is accompanied by the changing patterns of access to water, and by the legitimization of certain forms of basin management through the production of dominant water discourses.

It is interesting to note that the financial costs of the three main responses (supply augmentation, conservation, and allocation options), are generally in a decreasing order.[26] The lesson that can be drawn from this is that decision makers in most societies have an inverted perception of what the costs to society are, or more to the point, of how the political and financial "benefits" accruing to them and to their supporters, compare with the political costs and the risks of societal discontent incurred.

Shock Events: The responses and behavior of water users and of the society at large, regarding water use and water-related problems, depend on their perception of the magnitude and severity of these problems. This perception, in turn, is often sharply influenced by extreme natural events, such as typhoons, droughts and floods, which are generally accompanied by food shortage, disasters, and the disruption of livelihoods. Waves of dam construction are often launched after severe droughts or famines, such as in Burkina Faso or northeast Brazil (see Molle 1991). The drought periods of 1987-1991 in California (Zilberman et al. 1992; Keller 2000), of 1992 in Turkey (GDRS and IWMI 2000), of 1982-83 in Australia (Turral 1998), of 1986 in Israel (Allan 1999), and of 1991-94 in Thailand (Molle et al. 2001), to mention a few examples, have catalyzed a series of significant local and global responses. Dams are also designed in response to floods, as the case of the Tennessee Valley Authority well exemplifies.

[26]Except for the case of water treatment. It can be posited that investments in urban water supply and sanitation create the potential for a "new construction bonanza" (Turral 1998), similar to that of the earlier "hydraulic mission."

The most significant example of a crisis, however, remains the El-Niño-related climatic perturbation of 1972, which severely affected grain production and sent prices rocketing up. The psychological impact of this event, on both national decision makers and western countries (engaged in the Cold War and bent on investing in countries potentially threatened by the spread of communism), was so high that much of the huge investments in dams and irrigation infrastructures that were to follow, can be ascribed to the threat of food shortage in the particular geopolitical context of the time (Barker and Molle 2003).

Shock events often allow politicians to impose policies that would have been otherwise unpopular and opposed. Allan (1999) has remarked that politicians are, therefore, likely to wait for the exhaustion of resources and the surge of crises, before embarking on draconian reforms.

Other shock events, which have a dramatic impact on agricultural development in general and water resource use, and development in particular, are political events, such as wars, revolutions, agrarian reforms, etc. The periodization of water-infrastructure development in Vietnam (Tessier and Fontenelle 2000) or in China (Lohmar et al. 2002), for example, neatly dovetails with that of political upheavals and reforms. Likewise, the collapse of the Mesopotamian irrigation in the early Middle-Ages owes much to the impacts of wars and epidemics (plague), (Christensen 1998).

"Spatial Equity" and Regional Politics: Another important point, which drives the choice of supply augmentation as a response, is that the economic rationality at the basin or country level has to be combined with a notion of "equity" that pervades regional politics and, more often than not, conflicts with economic criteria. The regions with lower comparative advantages stand to lag behind other regions, and often display higher levels of poverty. These "problem" regions, therefore, turn out to be the target of special investments, which generally have a low return, and which are dictated by political and socioeconomic concerns.

An example in point is that of "overbuilt basins," where regulated water resources are insufficient to serve the existing irrigated areas, but where more irrigation schemes are built, based on the claim that the regions not benefited hitherto, also have a right to receive investments. This, Ingram (1971) noted, is supported by the strong local sentiment that water is always locally thought of as "our" water. Local sociopolitical dynamics and strategies conflict with macro considerations and logic, thus depicting a typical example of a basin-level issue. When decentralization means that local regions or provinces have the mandate to design local strategies without considering their impact at a wider level, these situations are often very salient. The Mekong delta offers a good example of how provincial plans are based on the same freshwater resource, and how their combined impact on the whole delta hydrology might have catastrophic consequences on salinity intrusion in dry years (Can Tho University and IRD 2001). In other words, the micro/macro dialectic of water use within the basin is paralleled by a similar spatial interconnectedness with regard to economic planning. The result is often "artificial" scarcity created by the overcommitment of resources, fostered by flimsy knowledge or consideration of hydrology, and promoted by developmentalism. In Algeria, for example, the World Bank supported both irrigation projects and urban water supply networks in competition for the same scarce resource (Winpenny 1994).

A particular form of the impact of regional politics on water resource development is well exemplified by the case of the U.S.A. The states, wishing to see their local projects funded by federal agencies, need to muster support from other states in order to obtain congressional acceptance. This “pork barrel” politics leads to the spread of projects with very low returns and, often, with environmental impacts. The case of the Central Arizona Project (CAP), discussed by Welsh (1985), shows how Colorado garnered projects for its vote authorizing the CAP, and how other states like New Mexico, Utah, and California could take advantage of the CAP to claim for their own projects. The CAP itself, most particularly the projected Orme dam that was part of it, was an extravagant example of a project with low returns, critical impact on wildlife, spoliation of Indian land, which was pushed by the Bureau of Reclamation, despite strong opposition and numerous alternatives (Welsh 1985).

Agrarian Pressure and Agrarian Transition: Individual and societal responses are also strongly governed by the alternatives of livelihoods offered to people, and to, what can be termed as “agrarian pressure.” If strong population growth occurs in a context where, nonagricultural sectors are unable to absorb the excess rural labor, then the pressure upon land and water resources is likely to increase. This translates, not only into greater agricultural intensification and water conservation, but also into water-quality degradation and conflicts. If the water supply to agriculture is squeezed, then the social consequences on the rural world (and also the possible political clout of the farming sector) are likely to trigger state responses (as exemplified by the subsidizing of western agriculture). On the other hand, if favorable alternatives are supplied within the wider economy, water users with deficient supplies will be encouraged to diversify their activities or to simply give up farming, thus easing the tension on resources.

Agrarian pressure is also, directly linked to household incomes and, therefore, at least for those products with a degree of import/export, linked to the price of commodities in the world markets. This price, in its turn, depends on a more complex and global equation that includes food production, population growth, productivity, as well as all other variables that impact on, or distort markets. The Middle East provides a good example of a region, where water policy is “subordinate to the political economy of global trade in staple food” (Allan 1996).

The intensity of societal demand for change, the individual responses to the deterioration of access to water, the relative growth of the different economic sectors and the impact on water use, are all interrelated with macro-economic settings.

Demand/Supply-Driven Innovations

Molden et al. (2001b) argue that as basins develop, new forms of organization and rules are required, but they take the view that new “institutions (inevitably) evolve to fulfill management requirements,” and do not address the issue of whether, and how these institutions emerge. The few points mentioned in the above section already suggest some agents of change. The more general question of the causation of institutional and technical changes cannot be addressed in detail in this report, but it can be useful to recall here, a few theoretical postures, and to sketch out the driving forces at work.

Social Adaptive Capacity: The evidence that some societies seem to avert crises (as well as to “reconstruct” resources after their degradation) through the mobilization of appropriate innovations and new institutions, while others do not, has led some social scientists to investigate which factors could be singled out to explain this situation. Ohlsson (1999) has recently developed the idea that some societies were endowed with “adaptive capacity,” which should be considered as a resource, and that the lack of this resource could be termed "second-order scarcity," in addition to the physical first-order (water) scarcity.[27] Turton (1999) built on such concepts and reasoned that this capacity has both supply and demand aspects. He distinguishes first a social component, "existing in the hearts and minds of the governed," which basically defines the willingness and ability of the people to accept the measures to be taken, as well as the ability and legitimacy of the regime to generate the needed strategies. The second component can be engineered to some extent and consists the capacity to mobilize and analyze data and information, and to derive adequate strategies, all of which—according to Turton—can possibly be provided, either by local or foreign sources. This division is useful in emphasizing some supply and demand sides of the problem but, while stressing the importance of quantitative information and human resources, does not fathom the societal term, which "is the difficult one to come to terms with."[28]

Allan (1996) posits that the development of a "diverse and strong" economy is a prerequisite to the implementation of the measures needed to manage the closure of water resources (with the implication that in the opposite case, there is a failure to manage it). Factors that are highly correlated with economic development include, for example, a certain degree of intellectual capital to acquire and process data, and capital availability and institutional capacity to devise measures and to enforce them. Redressing environmental degradation and improving water quality also require both, very high outlays of capital and the political capacity to enforce a legal framework, where these funds are effectively mobilized (from both public and private sources).[29] In addition, there is a degree of formalization of rights, of recourses available to citizens to voice their opinions, and altogether a more democratic participation of civil society, all of which are also paramount in shaping the decisions of politicians and policymakers.

However, it may be argued that developed countries are also those in which pressure over resources, water-quality problems and environmental degradation has first occurred, precisely because of their earlier economic development. Therefore, their capacity to manage basin closure could be seen as induced by pressing needs and enabled by their financial capacity, rather than as an intrinsic preexisting quality. It might be hypothesized too, that changes become easier to implement when structural changes in the economy have reduced the importance of agriculture and, therefore, have reduced its political weight, and sometimes the very amount of water it needs (in which case, policy changes are facilitated by structural changes). Finally, the very perception of environmental damages, by people (and consequently their motivation to act against them), is highly linked to their standard of living and is, therefore, weaker in developing countries. In other words, it might well be that it is the consequences of economic development that (partly) facilitates basin-closure management, rather than the factors that are believed to be conducive to development.

[27]Ohlsson (1999), however, does not provide many clues on what makes societies endowed or deficient in "adaptive capacity." Therefore, stating that some societies adapt because they have enough "adaptive capacity" might be seen as tautological.

[28]This can be compared with Ruttan's (1989) recognition that, if it is intuitively admitted that cultural factors exert major impact on behaviors and responses to opportunities, the lack of analytical means to take this factor into consideration, is a "deficiency in professional capacity."

[29]In the two decades following 1972, the USA has spent more than US$500 billion on preventing and cleaning up water pollution, so that environmental costs have already exceeded the cost of subsidies in infrastructure (Frederick 1998). It is difficult to envision such a response in developing countries.

Supply and Demand Models: Much of the theories of institutional changes, derived from the works by Hayami and Ruttan (see for example 1985), as well as later New Institutional Economics (NIE) approaches,[30] tend to favor the demand side of change, with emphasis on changes in relative resource endowments and technical aspects. Individuals, seen as rational entrepreneurs, respond to both "deadlock situations" and opportunities. In the first case, the design of new institutions is needed to adapt to changing conditions, which have raised transaction costs. In the second case, individuals recognize the existence of uncaptured potential gains and devise arrangements that allow them to tap these gains. Regarding water resources, the first case is well exemplified by rotational arrangements in irrigated schemes, which need to be implemented so as to deal with water scarcity, or by basin-level management of water quantities and quality. The second case can be exemplified by negotiations for trans-basin transfers or, more self-interest-centered, by the capture of benefits by a given interest group (such as sometimes would occur in processes of privatization).

This last example shows that it would be naive to assume that the constraints faced by a society give way, through a perfect, market-like mechanism, to a solution that minimizes transaction costs and improves efficiency (Wegerich 2001). It must be acknowledged that the distribution of power, embodied in the access to (water) resources, is a societal, historical construction, where equity and efficiency might not be the chief aspects. This takes us beyond the economics of transaction costs, to include political economy and rent-seeking behaviors (Roumasset 1995).

This leads us to also give consideration to top-down approaches of institutional change that emphasize the supply of innovations by the elite or by outsiders. This is not the place to expand on theories of elite behavior and decision making, but one may note, as emphasized by North (1995), that "institutions are not necessarily, or even usually created to be socially efficient; rather they, or at least the formal rules, are created to serve the interests of those with the bargaining power to create new rules." This is also emphasized by Feeny (1988), who sees the benefits and costs to the elite as a main determinant of change. A policy implication of this is that ignoring power structures is likely to doom bottom-up movements or policies, to failure (Wegerich 2001; Schlager and Blomquist 2000).

What triggers elite decision making is complex, but it seems that immediate political consideration generally overruns what some would like to see as the result of rational planning (Schlager and Blomquist 2000). In practice, changes are very much demand-driven "by the need to find solutions to relatively immediate, specific problems, not grand visions of river basin or regional development" (Whittington 1991; see also Winpenny 1994). Historical changes in water institutions, for example, have often been spurred by flood or water-shortage crises (Livingston 1993; Wengert 1985).

Disaggregating "Costs and Benefits": Here we may build on Wegerich's (2001) conjecture that both institutional change and adaptive capacity are linked to the power of stakeholders, while redefining power as the possession of resources, information or legitimacy that allows actors to select an option that best suits their interest.

[30]For North (1995), "the fundamental source of change is learning by entrepreneurs of organisations (*sic*)… and the rate of learning reflects the intensity of competition amongst organisations (*sic*)."

From this viewpoint, both decision-making and the implementation of reforms, are seen as the outcome of a process in which the financial, economic, social (status) and political interests of all actors are confronted. Actors typically include states, other administrative units like municipalities, politicians, line agencies, construction companies or water utilities, banks and development agencies, experts, lawyers, environmentalists, lobbyists, NGO leaders and activists, farmers[31] and other water users.

Part of the relative "weight" of these categories of actors in the process of change (or nonchange) is embodied in the institutions. They partly define actors' rights and, more generally, how they are allowed or able to, voice their concerns and have their opinions taken into consideration, as well as to exercise their agency. This also means that part of the change is due to the responses to specific water scarcity issues that individuals or small groups of people are able to design locally. As seen earlier, such responses include innovations in cropping techniques, adjustments of farming activities, improved individual and collective water management, tapping local water resources and also attempts to participate or intervene in more macro-level issues, where the fate of their access to water is mainly determined.

We may also retain the idea of "costs" as determining societal responses, but "costs" must encompass several dimensions: economic costs (in infrastructure, of foregone benefits owing to water deficits, etc.), transaction costs (in decision making, conflict-solving, accessing information, etc.) or political costs (unpopular measures). These costs are paralleled by "benefits," which accrue to particular actors (increased water supply, more companies, lawyers, politicians, etc.).

Last, this political economy of societal response to water scarcity, is obviously shaped by the physical/climatic context (aridity, humidity, variability in precipitation, etc.), the available technology (defined as "tools plus knowledge" [Livingston 1993]), and the preexisting sociocultural and institutional context. The understanding of institutional change in the management of water resources is a field of investigation that clearly needs to be further researched on (Ingram 1971; Livingston 1993).

Basin Trajectories

Acknowledging the variety of societal responses to water scarcity and the complexity of determining which particular response appears at a certain point in time, a river-basin development trajectory may be represented by the graph shown in figure 7. The schematization retains the general evolution towards basin closure, although it is also recognized that a basin can be "reopened" (see below). The succession of circles (corresponding to that of figure 6) represents successive adjustments to water scarcity, which are made by the implementation or the inducement of a range of individual, collective and state responses that come under three categories (supply expansion, conservation, and allocation). (The varying

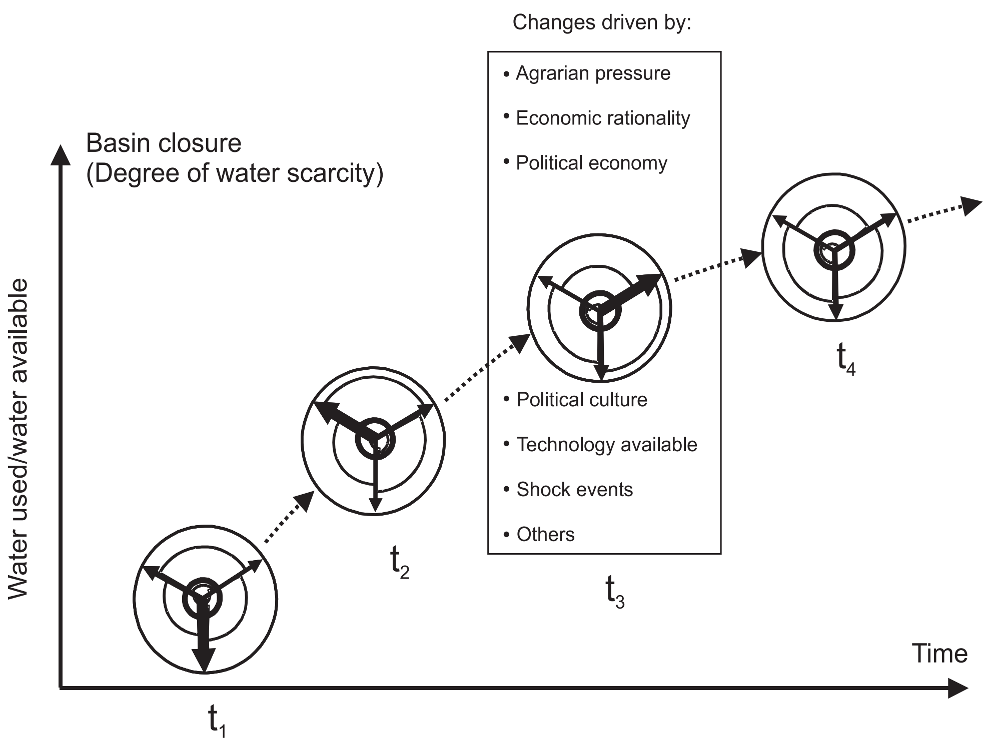
[31]Listing categories does not mean that these are homogeneous: different farmers, for example, are in distinctly different positions, both in physical terms (with regard to the water supply network) and in socioeconomic terms (see Schlager and Blomquist 2000).

respective shares of the inner circle (local) and the outer circle (global), as well as the varying sizes of the arrows, symbolize that the relative importance of each response varies depending on the point in time).[32]

Which strategies have been implemented at a given point in time, and similarly what options are more suitable for the current situation, can only be determined by a sound analysis of all the relevant physical, economic and societal factors. The preceding section provided examples of issues situated at the convergence or interface of several of these important factors.

Figure 8 proposes a variant of figure 7 and introduces two visual modifications. The first one represents a possible (albeit transient) breakdown of the system, while the second, indicates successive potential ceilings toward "resource closure." This accounts for the fact that if total renewable basin resources can be hydrologically defined, the share that is available at one point in time, often depends on the existing technological level. In other words, societies are faced with different ceilings that may shift with time, but that are sensed as absolute ceilings for a certain period. Basins can be reopened, and often are, by achieving a new increment in supply through a costly investment that was formerly thought not to be technically or financially feasible. This, in particular, includes trans-basin diversions, which are much more common than is usually believed. Only 20 percent of the water used by south California, for example, is generated locally, as the region is mostly supplied by water from the Colorado River (57%) and from the north of the state.

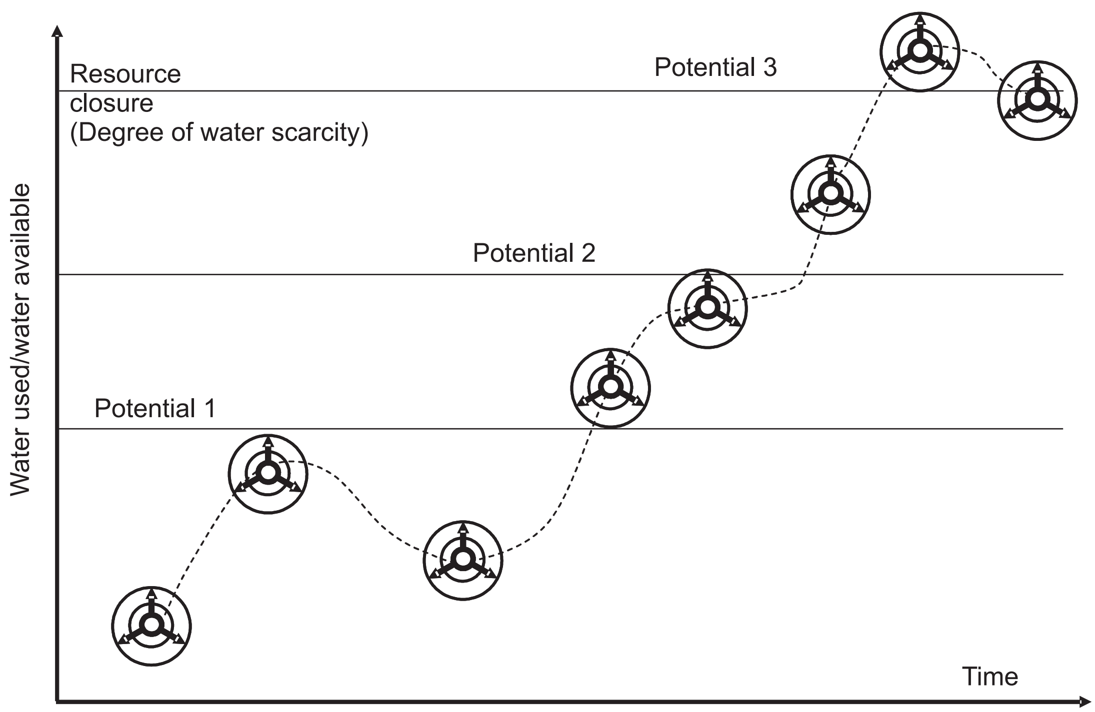
FIGURE 7.
Basin trajectories (1).



[32]The sizes and shares indicated here are arbitrary. This graph should be taken as a conceptual representation, rather than as a concrete visualization of a particular change.

The figure also reminds us that unsustainable management may lead to using resources beyond the potential threshold. This means that aquifers may be "mined" (or depleted faster than they are replenished), and reservoir security stocks can be tapped during a few consecutive seasons. It is not certain whether unsustainable management will always be tackled in an appropriate manner, since many aquifers are probably doomed to be mined until exhaustion (or, in practical terms, until abstraction becomes economically unviable).

FIGURE 8.
Basin trajectories (2)



Conclusions

Population growth and economic development translate into growing pressure on water resources. In the course of time, the interdependence of users in the basin increases and conflicts arise. Scarcity elicits adjustments in water-supply augmentation, water-use efficiency and in water allocation. Several existing conceptual frameworks that provide a description of basin development have been examined. The great merit of these frameworks is that they offer simplicity of reading that conveys the notion of basin closure with great strength. They are based on a sequence of phases that is widely relevant to depict the evolutions observed during the twentieth century in many basins or countries. The downside of these approaches, however, is that the simplification of reality does not always allow one to fully capture or understand the geographical and historical diversity of river-basin development.

A first drawback resides in the representation of the exploitation of water resources by a single curve. A "disaggregated" diagram has been proposed, that distinguishes between different types of resources (rainwater, stream water, and controlled [actual and potential] water), and that allows a clearer view of the status of water use in relation to supply, and specifies the part of the supply that is controlled by man.

A second limitation in these frameworks resides in their simplification of the succession of different types of responses in sequence. These responses often occur concomitantly or sequentially, but not in the order proposed. Adjustments in water-supply management, allocation and institutions are made, not only by the state, but also by individuals and groups, and are characterized by their interrelatedness. Each time a decision, taken either locally or at the global level, impacts on water flow paths, in terms of quantity, quality or timing, other users are likely to be affected somewhere else in the basin. The characteristics of each basin command a particular pattern of evolution, which may include gridlocks, collapses and the diversion of water flows across basin boundaries.

Existing linear visions of basin development tend to be based on economic rationality or on concepts of social adaptiveness that are difficult to evaluate. Societal responses to scarcity of resources are driven not only by economic considerations or locally perceived needs. Rather, societal responses must also be understood in a wider political economy framework, in which costs and benefits are attributed to different categories of actors who, often, have antagonistic interests that are not even internally homogeneous. The particular blend of responses, selected by a society at a particular point in time of its history, to address water-resources problems must, therefore, be understood within a framework that spans not only hydrological, physical or economic constraints, but also the distribution of agency and power among actors, and their respective interests and strategies.

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