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Technical and Institutional Responses to Basin Closure in the Chao Phraya River Basin, Thailand

Dr. François Molle, *International Water Management Institute, Colombo, Sri Lanka*

Abstract: *When the water supply available in a given river basin is insufficient to cater to the needs of its population, users usually devise individual and collective responses to water scarcity. Generally, this leads to more reuse of water along the river system, with little water being lost out of the basin, and leads to reallocation of resources. This paper recounts the development of the Chao Phraya river basin over the second half of last century and shows how supply and demand have evolved in parallel and how changes and innovations have emerged in response to growing imbalances. Various adjustments have been made in agricultural practices and significant changes have affected efficiency, water management, institutions, and policy making. These changes appear to be driven not only by planned state interventions and policies but also by local actors. The paper provides an example of dynamic reading of the water status in a basin and shows that the concepts of supply and demand need to be qualified to better understand how short- and long-term changes are linked to imbalances between the two terms. The study suggests that the scope for achieving water savings and/or economic gains by demand management is far more limited than is commonly assumed and that potential reform benefits will be rather in terms of equity and better service through users' empowerment.*

Keywords: *River basin, water management, demand management, water scarcity, efficiency*

Introduction

In an initial phase of development, when the population is still sparse and the means of abstracting water from waterways is limited, water use is generally characterized by an open access regime and the quantity of water available far exceeds the needs of the population. When rainfall is irregular, however, and when river flows reduce to a trickle in the dry season, some storage appears necessary. With growth in population and the development of both irrigation and non-agricultural uses, the ratio of supply to demand may become critical in some periods of the year. As most of the accessible water is eventually consumed and little water leaves the basin as outflows to sinks or the sea, river basins are said to be closing. Consequently, these basins are found to operate with high overall water use efficiency, and focusing on relatively low water efficiency at local levels can be very misleading (Keller et al., 1996; Perry, 1999; Molden and Sakthivadivel, 1999). The closure of a basin induces innovations – or sometimes breakdowns and crises – aimed at augmenting supply, controlling demand, and conserving or reallocating water. Such innovations occur in several domains: agricultural practices, water management, and social organizations, and may trigger institutional or political change.

The Chao Phraya basin is the largest river basin in Thailand (160,000 km^2, or 30 percent of the area of the country) and is also the most important in economic terms as it encompasses the bulk of the irrigated area as well as the Bangkok Metropolitan Area (BMA). During the twentieth century, the basin shifted from a status of an uncontrolled basin, where rice cultivation was attuned to the natural hydrologic regime and expanded where allowed by it, to a status of a highly developed basin, with multipurpose storage dams, extensive canal infrastructure serving around 2.2 million ha of irrigated land, a complex mix of economic activities, and sprawling urban areas. The agricultural potential of the basin cannot be fully realized, as the water resources available in the dry season do not allow the irrigation of the full irrigable area. This deficit is compounded by the growing share allocated to the BMA and, within the agriculture sector, by the imbalances resulting from the growth of water use in the upper and middle parts of the basin, which reduces the share effectively allotted to downstream areas (the delta).

This paper recounts the development of the Chao Phraya river basin over the second half of last century and shows how supply and demand have evolved in parallel and how changes and innovations have emerged in response to growing imbalances. These multi-faceted responses to water scarcity appear to have been mainly initiated by line agencies and farmers (more generally water users) and these responses have allowed improvement in irrigation efficiency at both the micro and macro levels. The policy implications of these evolutions are then discussed.

Basin Development and the Changes in Supply and Demand

Development of Water Resources and Storage Capacity

Despite the early excavation of canals in the delta flats and some attempts to establish gravity irrigation schemes (Ishii, 1978), the effective development of large-scale irrigation schemes and water control dates from the 1950s. It first consisted in the construction of 400,000 ha of irrigated areas served by a diversion dam located at the apex of the delta (and connected with 500,000 additional hectares in the delta flats), later followed by two main storage dams (the Bhumipol dam in 1964 and the Sirikit dam in 1972. See Figure 1).

After the completion of the Sirikit dam, approximately 12 Bm^3 (or km^3) of total runoff could be captured every year on average. This capacity was later incremented only marginally, with the construction of the Krasiew, Mae Ngat, Thap Salao, and Mae Kuang dams, each with a capacity

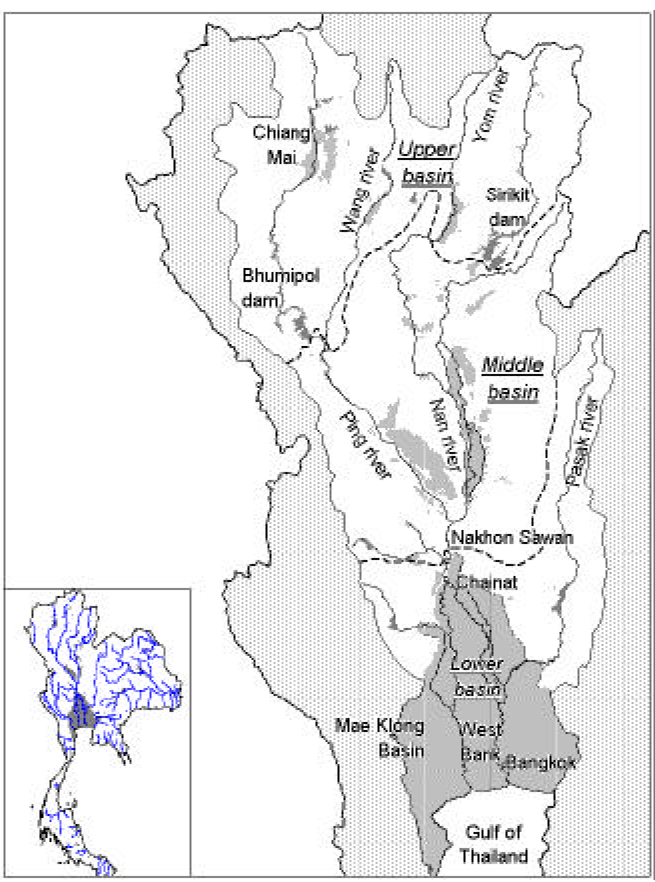

Figure 1. Layout of Chao Phraya Basin

of approximately 0.25 Bm^3, but these resources were mostly committed to nearby irrigated areas that were expanded concomitantly. A boost to dry-season cropping in the lower delta was also allowed by the diversion of 70 m^3/s of water from the Mae Klong basin to the lower west bank (see Figure 1). The use of this water was further facilitated by the construction of pumping stations in the early 1990s, which gradually increased the flow into the west bank at low tide (up to 0.5 Bm^3/season at present).

Groundwater resources have also been increasingly tapped. BMA's demand rose from 0.17 Bm^3/year in 1978 to approximately 2.7 Bm^3/day in 2000 (a 16-fold increase in 22 years), including a contribution of approximately 1.1 Bm^3/day from underground water, most of which is used by industries (90 percent of which rely on the aquifer) (TDRI, 1990). Water diverted from the Mae Klong River through a new canal is now also contributing to the supply of the BMA (a discharge of 5-10 m^3/s, planned to be increased up to 45 m^3/s within ten years). The overdraft of underground water in the area (sustainable rates are estimated at 0.4 Bm^3/year), with its severe externalities in terms of land subsidence and flood damage, reduces the amount of surface water that has to be diverted to the capital but only shifts the pressure onto the aquifer. Volumes abstracted for non-agricultural uses outside the BMA are relatively small (under 0.1 Bm^3/year). Irrigation, based on deep aquifers, has been developed in the middle basin (Sukhothai Project) in the 1980s, while shallow aquifers have also been gradually tapped wherever available (more on this later).

The growing share of water diverted by the BMA has thus decreased the stock available for agriculture downstream of the storage dams (middle and lower basins). This trend has been compounded by two main factors: the decline in both direct rainfall and dam inflow. A decrease in precipitation has been observed in the upper part of the basin (Kwanyuen, 2000) but it is much more limited than in the delta proper (Molle et al., 2001a). Figure 2 provides the example of the Suphan Buri station, for which annual rainfall shows a sharp decline in the last 50 years, a trend also apparent in most other stations in the delta. With population growth and the development of irrigated areas, the upper basin has also significantly increased the share of the natural runoff that is locally stored and used. It is estimated that all these changes have roughly curtailed annual dam inflow by an average of 2 Bm^3 (out of a total of 12 Bm^3) over the last 30 years.

Altogether these changes imply that the dam and rainfall water available for dry-season agriculture in the medium and lower parts of the basin as well as for energy generation has been on a declining trend. The basin is therefore undergoing seasonal closure during the dry period (January to June). In the wet season, runoff is usually abundant and significant outflow to the sea occurs. (However most of this water is uncontrolled and cannot be stored). The following discussion focuses on water scarcity in the dry season.

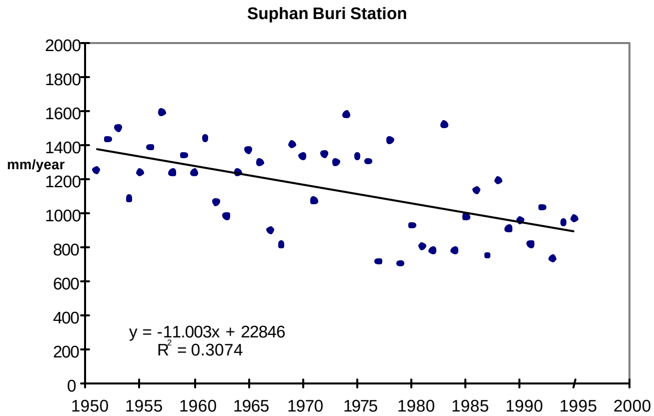

Figure 2. Trends in annual precipitation (Suphan Buri station)

The Growth of the Effective Demand

The hydraulic network of the Greater Chao Phraya Project was designed to supplement water to wet-season crops. Growing field crops in the dry season was hardly mentioned in the feasibility studies. With the advent of high-yielding varieties (HYVs) and the improvement of the on-farm level in some pilot areas, the idea of double-cropping gained momentum and, in the late 1970s, the government embarked upon a campaign aimed at fostering it. In less than ten years, dry-season cropping shifted from a status of initiative supported by public agencies to one of an activity that needed to be controlled, and sometimes curtailed, over a command area of approximately one million ha.

The development of dry-season cropping in the delta stirred the demand for irrigation infrastructure in other provinces. The large paddy areas of the lower reaches of the Ping and Nan rivers, located in the middle basin (see Figure 1), also needed to have their production stabilized through irrigation. This led to the development of additional areas (250,000 ha, 80 percent of the area with rice) in the late 1980s, which also gradually requested water for dry-season cropping. It was already apparent that these irrigation schemes would, at least in the dry season, compete for the dam water that was already implicitly committed to and used in the delta. This led to a situation described by the World Bank, which earlier funded these projects, as "overbuilt."

The expansion of irrigated areas occurred in several places. Foremost was the development of the Royal Irrigation Department (RID) Projects in the middle basin but these investments were paralleled by the introduction, from the early 1980s onward, of an estimated 300 pumping stations fostered by the Department of Energy Development and Promotion (DEDP). These stations feed on the rivers and usually serve an area of 2,000 *rai* (320 ha; one *rai* equals 0.16 ha); they are planned without real concern for the overall availability of water in the basin and with no coordination with the RID. Another major newly-irrigated area is the marginal uplands located along the trunk canals that delimit the irrigated delta and that have also gained access to canal water with the technical and financial help of provincial authorities (including RID regional offices). Along the western side of the delta, these areas now total at least 15,000 ha. In addition to these "official" areas, there are also some uncontrolled or semi-controlled cases of water abstraction by private pump owners along rivers and main canals.

Overall, the middle basin has seen its supply increased dramatically over the last 20 years. The share of dry-season dam releases "diverted" by the middle basin, to the detriment of the delta has moved from 5 percent up to 35 percent in recent years. Not only does this mean that the delta has received less water from the dams but also that the inflow has been marked by a higher degree of uncertainty and fluctuation, as part of these diversions are uncontrolled. Water users in the middle basin have increased in area but have also managed to get effective supply closer to their demand by diverting water from the rivers (and engaging in triple-cropping in recent years). This is tantamount to a breakdown of the allocation process and recapture of water by a specific sub-group of users. It also illustrates the lack of water rights in a system where allocation is centrally defined.

A second reason for the expansion of demand is the gradual development of on-farm infrastructures, notably in the peripheral part of the delta's flood-prone area that grows traditional varieties of rice on uneven natural land. These areas, when receiving some leftover water from the main canals in the dry-season, have also been encouraged to expand the network of field channels as well as the leveling and bunding of plots, so as to be in a position to grow dry-season crops. This was eased by the relatively cheap and abundant supply of machinery and was financed by farmers and local public budgets. Large releases of water aimed at allowing farmers to grow a dry season crop following years with flood damage (such as in 1995 and 1996) triggered significant expansion of on-farm facilities.

The understanding of imbalances in the water-supply ratio requires a more qualified definition of both terms than usually used. How can water demand be characterized? It is often equated to the *potential* demand, as expressed, for example, by the physical area which is in a position to receive water. In demand-driven schemes, it will be the sum of all the orders posted. In water short systems, demand is a much more relative, fluctuating, and qualitative reality that might be termed *relative demand,* and is not directly known by managers. Demand is not a given parameter and is dynamically shaped by supply itself, as well as by other socio-economic factors. Seasonally, the relative demand depends on the price of rice and possible crop loss in the preceding wet season (pest pressure, flood damage), and is governed by the availability of water behind the dams: in some years, a relatively low stock may discourage farmers in unfavorable locations to engage in dry-season cropping and compete for water. In other circumstances – for example a high price for rice – the contrary may occur. The relative demand is also clearly shaped by long-term trends, especially in the wider economy, that define whether poor or conflicting access to water can be dealt with by avoidance (developing individual-based alternative strategies, shifting partially or totally to other activities) rather than by cooperation or conflict.

While the relative demand is partly dependent upon available water stocks, the effective supply will also be governed by the expression of the demand itself (as supply is not only a technical, but also a highly political issue). Effective supply will be a measure of the pressure farmers are likely to pass on to the agency through the various channels at their disposal (foremost, politicians, but also direct demonstrations, etc.). In other words, the relative demand and effective supply are rather elusive variables that cannot be easily forecasted or assessed.

Growing Water Scarcity and Adaptations

The conjunction of the overall decline in supply and the growth of demand define a framework of growing scarcity that actors in the system have been responding to in many ways. This section provides an overview of the system's main adjustments to changing conditions.

Dam Management

The Bhumipol and Sirikit dams are multi-purpose reservoirs, but were initially designed as important sources of energy for the country. As such, their management had been entrusted to the Energy Generation Authority of Thailand (EGAT). In 1972, dams made up one-third of the Thai energy-generation capacity, and therefore, water releases were mostly dictated by the national requirements in electricity. As a consequence, releases were sometimes made in time when the demand of downstream users was low and the water going through the turbines was eventually "lost" to the sea (that is the discharge was in excess of the 50 m^3/s required to control salinity intrusion). In the 1970s, an average of 3 Bm^3 of dam stocks were lost every year in this manner.

With the increasing demand for water, EGAT's management came under growing scrutiny and the wasting of huge amounts of water repeatedly triggered the wrath of NGOs and other observers. At the same time, the structure of the Thai energy generation sector was gradually modified, with hydroelectricity producing now no more than 5 percent of the total energy. With a contribution of Bhumipol and Sirikit dams at around 1 percent of Thai electricity production each, EGAT was able to better attune its releases to downstream requirements. In the 1990s, with the exception of the year 1996, the water wasted to the sea was brought down to approximately 5 percent of the yearly average dam inflow (Molle et al., 2001a). In other words, the basin is closing off.

Dam management also relates to the "security stock" or "minimum level," which has to be defined based on several considerations (stock reserved for consumption, carryover stock calculated to limit risk in subsequent seasons, desirable water levels for the generation of electricity, etc.) and which lends itself to some interpretation/negotiation. A lack of concern for inter-annual regulation leads to increasing the risk of shortage in the system but is a way to gamble short-term political gains in years of limited stocks: conflicts between technical criteria (water must be used with due consideration given to carryover stocks, which govern the level of risk in the subsequent seasons) and political criteria (farmers' demand should be met if there is water in the dams, as the next rainy season will ["no doubt"] fill them up again) have been increasingly apparent. This mismanagement of carryover stocks largely explains why the low rainfall years of 1994 and 1999 have paved the way to water crises, leading to the rationing of the water supply to the BMA. This can be interpreted as a last-ditch strategy to avoid passing on the effective water deficit to agricultural users by raising supply through the mobilization of water that should normally be kept for ensuring the security of the system. The (immediate) effective supply is raised at the expense of (mid-term) security.

Adjustments in the Farming Sector

Common knowledge sometimes suggests that the agricultural sector continues with its wasteful practices, despite the pressure on water resources, and is thus the main cause of the water shortage. Contrary evidence from the present case study shows that several far-reaching endogenous adjustments have been made in response to the closure of the basin, both by farmers and by the line agencies, RID and EGAT.

A first set of adjustments concerns the efficiency in use. Most main and secondary drains have been equipped with regulators in order to better retain water in the dry season (they capture surface and sub-surface runoff), and little water is now passed on to downstream areas. This was done by the RID, often at the request of local villagers. Farmers are commonly seen pumping along these drains and such locations are sometimes considered more convenient than irrigation canal banks.

The development of tube wells was driven by a need to access reliable water sources for both diversification and intensification and was a response to the water shortage experienced in the early 1990s. This need was often satisfied by the farmers themselves but several provincial initiatives taken in the early 1990s were aimed at drilling thousands of (free) wells in the countryside (official statistics point to a total of 50,000 wells in the central region). A survey carried out in 1994 at the village level has inventoried 89,000 of them in the central plain, mostly in the upper Chao Phraya delta and the upper Mae Klong project (Kasetsart University and IRD, 1996). Local storage of water has also been enhanced by the digging of public reservoirs in swampy low-lying areas, which are sometimes used for dry-season cultivation.

As mentioned earlier, tapping these secondary sources has been made possible by the boom in individual pumps. Statistics on their number are sometimes contradictory but over 80 percent of farmers have one or more pump sets in the delta. A consequence of the wide dissemination of pumps (even in areas where it is possible to get irrigation water by gravity) has been an increase in efficiency. As accessing water has a cost, farmers tend to limit pumping operations and avoid the loss of water at the plot level (Boss and Walters, 1990), and they also eventually reuse the water that had infiltrated earlier. The impact of the cost of pumping on water use is well revealed by the analysis of sugar cane cultivation in the Mae Klong area, where it can be shown that poor yields are mainly due to a low level of water use (Srijantr et al., 1999). The average efficiency of irrigation in the delta in the dry season (beneficial depletion by crops/net water diverted) has been estimated at 60 percent (Molle et al., 2001a). When considering a larger scale, losses by infiltration appear to be reused either locally (shallow aquifers) or in the BMA (via the deep aquifers), and the amount of beneficial water depletion is even higher: 88 percent in the dry season.

Whether water scarcity has induced a shift towards crops with lower water requirements or higher economic profitability (in terms of income per m^3) is unclear but, as a general rule, this is little supported by empirical evidence. Changes in cropping patterns have been very significant, with a growing share of non-rice crops, but this has to be related to other dimensions of agrarian transformations in the delta. It is apparent that pressure upon land resources and the decrease in labor supply, for example, have been overriding factors of the evolution in the countryside (Kasetsart University and IRD, 1996; Molle and Srijantr, 1999). From the post-Second World War period up to 1993, the average farm size in the delta declined from 30 rai down to 22 rai (Molle and Srijantr, 1999). Although the productivity of land has risen (HYVs and multiple cropping), the income per rai of rice remains depressed and rice does not constitute an attractive and sustainable economic option in comparison with other activities. Wherever possible (mostly in the southern delta and in the Mae Klong area, because of better water conditions) and when markets allow it, farmers have tended to adopt other high-value crops, the epitome of such changes being the spectacular development of inland low-salinity shrimp farming (Szuster et al., 2003).

While in other settings, such as the Red river delta, in Vietnam, the necessity to raise the carrying capacity of the land led to extremely high levels of intensification (which would require more water and increase pressure on resources), the Chao Phraya delta agrarian system has followed a more balanced trend, with much of the agrarian pressure that had built up around 1970 being subsequently diffused (Molle and Srijantr, 1999). This was made possible not only by crucial changes such as the demographic transition, the provision of institutional credit and the intensification of rice production but also, and foremost, by dramatic structural changes in the economy. During the decade preceding the 1997 economic crisis, one million people out of 3.5 million transferred their labor force from agriculture to other sectors. The supply of job alternatives has decisively, albeit not entirely, weathered agrarian pressure and tension on resources, notably land and water.

Breaking Up Cropping Calendars

An important response to water scarcity has been the increase in effective supply derived from the breakdown of formal scheduling. While in the past, dry-season cropping was scheduled to start only in February (after a period of two months when water was cut to allow maintenance, and the harvesting of sugar cane and floating rice), this calendar was challenged by a chaotic pattern of planting promoted by the farmers: instead of waiting for hypothetical late deliveries, some of them decided to start growing their crops before the official beginning of the season, thus capitalizing on the residual field wetness and drastically reducing water requirements for land preparation. (It can be shown that a rice crop planted on the November 15 consumes 25 percent less water than when planted in February [Molle et al., 2001a]). This was made possible by a series of concomitant changes. First, the shift from transplanting to wet broadcasting eliminated the constraint of matching water supply with the time for transplanting, fixed by the establishment of the nurseries. Farmers no longer had to attune their calendars to the schedule announced by the RID and could start their crop at any time. Flexibility has also been facilitated by mechanization (in particular that of harvesting) and by the use of shorter-duration rice varieties (90 to 105 days instead of 120 days), allowing triple-cropping in particular. Second, such flexibility was facilitated by the development of secondary water sources, including reservoirs excavated in public lowlands, tube wells, and gated drains. Third, the access to these sources has been made possible by the spectacular development of individual pumping devices, mostly low-lift axial pumps. With such equipment, farmers are now in a position to tap whatever ponding or running water is in sight, which has considerably raised the overall efficiency of water use. Farmers have thus succeeded in increasing their effective supply in three respects: first, by broadening the time interval when supply is possible; second, by forcing the RID to release unplanned water (it is common knowledge that the RID ends up feeling compelled to deliver water to avoid the loss of standing crops); and, third, by tapping secondary resources and low canal flows. In addition, early and late cropping calendars made better use of residual field wetness and better adjusted to actual rainfall. All these gains, on the other hand, critically weakened the meaning and the proper existence of scheduling.

Social and Institutional Induced Changes

The imbalance between supply and demand has also sometimes induced changes in the collective behavior of farmers. Innovations, for example, have emerged to solve the problem of water sharing along a given lateral canal, when the inflow by gravity is not possible and pumping from the main canal is needed (Molle et al., 2001b). Pumping at the head of a lateral is achieved by farmers with the use of their low-lift axial pumps *(tho phayanak*), generally powered by a two-wheeled tractor. Sometimes, up to 15 individual pumps can be set at the same time, although five or six are generally the maximum number of pumps activated at the same time. Arrangements define in what order farmers pump and also how to divide the flow among the plots of those who are pumping, which generally requires a synchronized second lifting operation at the ditch or plot level.

Unmet demand for water also recently triggered unprecedented protests from those located at the tail end of the water supply scheme threatened to be deprived of water in years of abundant supply: the relative demand rose because those (tail enders) who in "normal" seasons conform to the obvious reality that they will not get any water also wanted to benefit from these deliveries. In fact, they strongly interceded with local politicians, district and provincial heads to obtain an arrangement that would allow them to grow a second crop (while head-enders were about to start their third crop). This resulted in an unprecedented mobilization of the administration, including the police, to enforce a rotation. This also shows that equity, as a social construct, is not static and circumstances may depart from what is acceptable at a given point in time. Such shifts in social norms may also be facilitated by a general context of political decentralization and democratization at the local level, where more space for negotiation is being opened (Arghiros, 1999).

The growing independence and "individualization" of farmers in their quest for access to water also reverberated on overall patterns of water management. One of the main difficulties faced by the RID is the management of low flows in canals that have been designed to provide gravity supply only at or near full supply. While such operational constraints have been a driving force of the development of farmers' pumping capacity, it is all the more true that – in return – this has discouraged whatever regulation improvements the RID would have otherwise been pushed to achieve. Rotational arrangements are part of the paraphernalia but as their implementation entails significant transaction costs, RID officials understandably prefer the actual *status quo* where their role is to ensure water in the canal, even with a low level. The embracing (or the strengthening) of a pervasive individualistic concept of gaining access to water implicitly reinforced the acceptance of the *first-pumping-first-served* principle, and the idea that locational advantages necessarily translate into privileged access to water, thus choking claims of greater equity.

Pressure on water resources has also altered the role and power of the RID as water manager. The decline in its authority was brought about not only by the development of farmers' pumping capacity, growing access to secondary water sources (breakdown of scheduling), and uncontrolled diversion (breakdown of allocation) but also by the growing role of politicians in mediating conflicts and special requests for water. As in most countries worldwide, politicians were quick to understand how they could politically benefit from using their power upon the administration to influence, through the political parties in the government, water allocation to the benefit of their constituencies. Local patronage networks are regularly activated to obtain extra supplies in time of shortage and risk of crop loss.

As water becomes the determining factor of agriculture in the basin, the control of the Ministry of Agriculture and other relevant agencies becomes a highly coveted political objective, with negative impacts on their performance, prompting a high-ranking official of the Ministry of Agriculture to admit that "the agencies are unable to coordinate their policies because they are *supervised* by different parties in the ruling coalition" *(The Natio*n, 2000; emphasis added).

Institutional innovations have not hitherto caught up with necessity. An attempt to better coordinate the dry-season allocation process was initiated in 1981 when demand started to fully express itself. The Cabinet appointed the Dry Season Cropping Promotion Committee, chaired by the Ministry of Agriculture, to prepare an annual plan, objectives, and promoting measures for dry-season cropping but, during the 1991 to 1994 drought period, it proved impossible to manage the system according to the plan and the committee ended its work (Binnie and Partners et al., 1997). However a sub-committee continues to meet yearly to achieve some degree of coordination between agencies.

Environment and water quality are also issues that have come to the fore and motivated legislation. In 1992, the Factory Act and the Enhancement and Conservation of National Environmental Quality Act ("Environment Law") were passed, in a bid to control industrial pollution, define effluent standards, and adopt the "polluter pays" principle, but there are several flaws in the laws and little enforcement capacity (Wongbandit, 1997). The closure of the delta has had a clear impact on water quality, especially in the lower west bank and in Bangkok, but the absence of rules works against the allocation of the amounts needed to fully dilute pollution. The basin is entering into a phase where the recycling and treatment of water are necessary, as shown by the current project to build a large-scale plant in the southeast of Bangkok. Treatment of wastewater is also a way to increase supply to peri-urban agriculture which needs to be explored. A growing environmental concern within the civil society is likely to lead to investments and innovation in that field (see *The Nation* [2002] for an example regarding the Tha Chin River).

Policy Debates

Finally, the closure of the basin and the resulting pressure on water resources have stirred the debate on what solutions are to be given to the challenges faced, presently and in the near future. The different answers are the reflection of the power game around the water issue and

Table 1. Summary of the historical evolutions

	Structural, physical and climatic changes	The society and its productive activities	Management, rules, institutions
1955			(Old irrigation law: 1948)
	Greater Chao Phraya Irrigation Project (50s)	Migration to uplands (55-70)	
1960			
		Rural stagnation	
	Bhumipol dam (64)		
1965		Demographic transition (60-90)	
1970		« 1970 » crisis	
	Sirikit dam (72)	Green revolution(70s) Double-cropping	
	On-farm development (pub.)		
1975		Pumps and two-wheeled tractors	
	Overdraft of aquifers (70-)		Failed attempt to develop WUOs
1980	DEDP pumping stations (80-)		Dry-season Committee
	Irrigation in middle basin (84-)	Shift to wet broadcasting	
1985	Diversion from Maeklong1 Drains closure (80s-90s)	Diversification	
		High growth of non-agricultural sectors (85-97)	- 'Individualisation' of water management strategies
1990	Drought (91-94) Private wells (90-)		-Environmental law (92) -Loss of control on use and calendars (90s)
1995	Flood (95-96) on-farm development (indiv.) Low-land reservoirs	Triple-cropping Mechanical harvesting	-Improved dam management -New rotations (96-97) -Decentralisation
2000	Diversion from Maeklong2		-Administrative reform and policy matrix (1999)

are widely shaped by disciplines, ideology and interests (for more details, see Molle, 2003). Recent administrative reforms, including the definition of a policy matrix with targets to be implemented, has recently been set up at the instigation of the Asian Development Bank but it is too early to assess the impact of policy orientations that are largely driven by an exogenous thrust. The changes in the water sector are not independent of wider societal changes, which include a redefinition of the roles of the state and the citizenry. They are not only influenced by these transformations but also, in return, impact on them, as the issue of natural resources management becomes more critical and calls for societal and political responses and innovations. Table 1 summarizes the historical evolutions described in what precedes and breaks them down in three parallel categories, wherein the causal relationships described earlier also appear.

Supply/Demand Adjustments and Perspectives for the Future

The above observations point to an interplay between the relative demand and supply. Despite the decline in dam inflow and the growth of the amount of water diverted to the BMA, several counterbalancing realignments have occurred. Figure 3 attempts to quantify the impact of these changes on the available water stock for the dry season (Molle et al., 2001a). It presents an average picture of long-term trends, which does not take into account the high year-to-year variability (and in particular masks the draught period of 1991 to 1994). The balance was made considering the changes in supply (including groundwater and diversion from the Mae Klong basin) and in non-agricultural demand (including energy generation), the closing term being what is left for use in the dry season for agriculture. This term, in its turn, includes a share that is released exclusively for energy generation and a larger one, which is used for both energy generation and dry-season cropping. It can be seen that the available water increased in the 1980s as a result of improved dam management in the wet season, offsetting the decline in dam inflow. At the same time, the volume used *only* for energy generation in the dry season also decreased, stabilizing the average volume available for irrigation at around 5.5 Bm^3. In the late 1990s, however, the gains from dam management were largely realized and the amount of water for dry-season agriculture set on a declining trend.

How did the cropping area vary during the same period? It can be seen from Figure 4 that the average cropping area first reached around 500,000 ha in the 1980s (i.e. roughly 55 percent of the total project area and 60 percent of the rice area in the wet season). This can be taken as an indication that since the inception of dry-season cropping, the dam water stocks have been insufficient to allow the full expansion of double-cropping. This is, however, only partially true, as the insufficient capacity of irrigation canals and the poorly developed on-farm level largely accounted for that situation. Therefore, the non-realization of the full potential was not perceived as a result of insufficient resources. This situation was to radically change in the last two decades.

The apparent contradiction between Figure 3 and 4 is that despite the double-squeeze on water supply due to the reduction in dam inflow and the growing diversion by the BMA, the cropping area has been on the rise (the

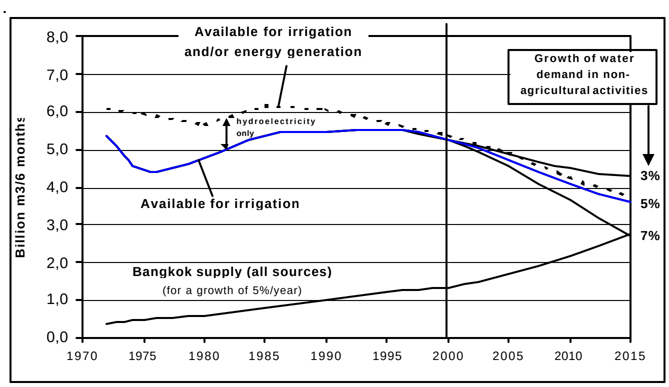

Figure 3. Evolution of the available water stock for dry-season cropping

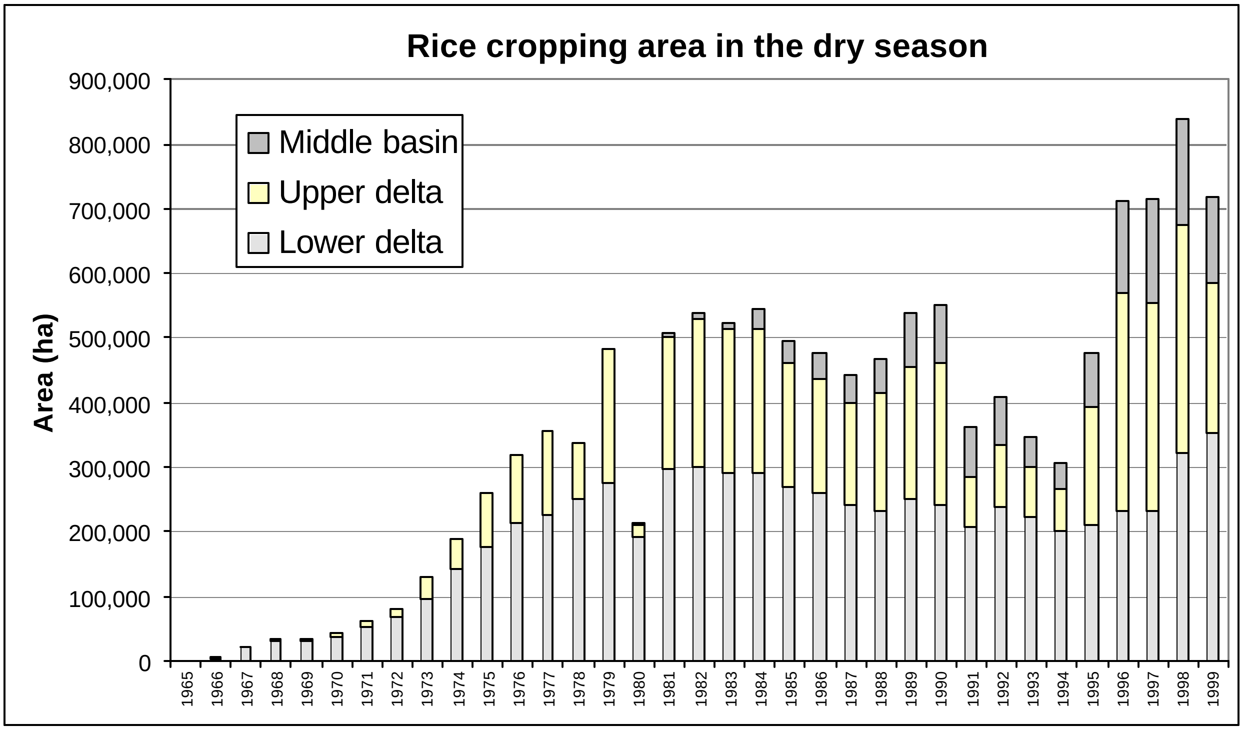

Figure 4. Growth of dry-season rice cropping in the Chao Phraya River basin

1991 to 1994 dry period is atypical). It is therefore hard to identify a situation of crisis and declining supply when more people than ever have been growing rice in the past six years. Several reasons explaining this situation have been mentioned earlier. They include the facts that secondary water sources have been tapped, irrigation efficiency has been improved, and shorter rice varieties have been introduced. The two main factors, however, were the better control of dam release (see Figure 3) and the deregulation of calendars, the latter with its series of gains, as commented earlier.

Despite such spectacular achievements showing dramatic success of the *relative demand* in “expressing itself” (or eliciting responses conducive to its [partial] satisfaction), the pressure on water resources stemmed from the fact that the relative demand grew faster than the effective supply (all savings considered), due to the expansion of irrigated areas, on-farm infrastructure, pumping facilities, flexibility in cropping operations and access to water, and willingness to grow rice (especially in periods of higher prices).

What then, are the perspectives for the future? The slopes of the extrapolated trends shown in Figure 3 are, of course, quite dependent on the further decline of dam inflow (taken here as – 1 Bm3 over the next 25 years) and on the projected increase of water use in the BMA. The figures show that with no new water resources development, the decline over the next 15 years is bound to be very significant, even with reasonable annual growth rates of 3 or 5 percent for BMA (it also suggests that the continuation of the pre-economic crisis 10 percent rate would have had catastrophic consequences).

Several possible adjustments are likely to be brought about by such a trend. They include the establishment of basin-level institutions and the possible formal redefinition of the priority in dam management, from power generation to other uses. As noted earlier, despite active ongoing debates, the effective institutional response has hitherto been limited. The growing water deficit will also be a push factor towards more demand management and a justification for an economics-based regulation (despite the limited prospect for significant gains: see Molle, 2001a; b). If no more water is tapped into the system and no formal rights granted to farmers beyond using the water that is left, would an inevitable agricultural decline result? An optimistic (pull) scenario is that this situation would be paralleled by a sustained growth of non-agriculture sectors, whereby the demise of agriculture would have less economic consequences. A pessimistic (push) scenario is one of an agrarian crisis in which rural stagnation cannot be avoided. It is all the more likely that such a situation would create the political conditions for more water-resources development: water transfers from the Mekong or Salaween rivers have already reached the stage of the feasibility study and a few more storage dams have also been planned. Reality might well be something in between, combining a more productive use of water (diversification), the reduction of rice-cropping areas, and a degree of water-resources development.

Conclusion

This brief retrospective analysis of the gradual closure of the Chao Phraya basin provided insights on how a *hydrosystem* (a society where economic [and other] activities are intertwined with the natural hydrologic cycle and manmade hydraulic networks) tends to adapt to changing circumstances. Water scarcity was shown to induce changes in the agricultural sphere (agricultural techniques; calendars or varietal choice; individual pumping capacity to access secondary sources of water), in social organization (new arrangements to cope with varied patterns of water shortage; shifts in farmers/agency relationships), water management (dam management; blurring of cropping calendars and dissolution of scheduling; intra-basin reallocation; undue use of carryover stocks), and politics (political interference and generation of policy-reform proposals).

A dynamic reading of these transformations suggests that both demand and supply fluctuate in a way that cannot be easily captured. Demand in the dry season is not technically given or known and is shaped by the available supply itself, by incentives defined by actual conditions (e.g. rice prices) and long-term trends (the relative performance of agriculture within the wider economic sphere), as well as by the weight of farmers in the national political arena. Effective supply and the relative demand are not independent variables and their relationship is not straightforward. It was observed, for example, that recent protests by tail-enders for more equity had not stemmed from a situation of water scarcity but, on the contrary, had surfaced during a dry season in which deliveries were at the highest.

Effective supply in the basin was enhanced by several conservation strategies, including gains in dam management, the development of secondary sources, the shifting, stretching and deregulating of cropping calendars, and raising the risk of system failure. Meddling with security carryover stocks typically generates short-term benefits for farmers and political retributions for those who have mediated requests for more water, but it raises the probability of a major crisis. These increases in the effective water supply and reuse have, by and large, offset the effective decline in dam inflow and direct precipitation and partially met rising demand but the mid-term projections point to a bleaker situation, if no new water resource is developed, as potential savings are now limited.

The main conclusion, probably of much wider validity (Keller et al., 1998), is that the pressure over water resources in the Chao Phraya basin translated into the improvement of both the local and overall efficiency in water use, which defines the closure of the basin. Crop-water productivity (kg/m^3) has been improved by shifting calendars and reducing ET. Crop-economic productivity ($\$/m^3$) has also been increased by the development of cash crops but the trend is primarily dictated by market conditions. The overall economic productivity ($\$/m^3$) is ensured by the priority in allocation given to non-agriculture sectors (inter-sectoral reallocation is implicit and hardly economically constraining). Water accounting shows that in the dry season only 12 percent of controlled water (dam releases and aquifers) is now lost in the basin (non-beneficial evaporation or outflow to the sea in excess of environmental needs). Interestingly, all these adjustments have taken place despite the fact that water is free, which does not accord with the motto "water is wasted because it is not priced" (Molle, 2002).

In contrast to the common picture that water shortages and crises are provoked by wasteful practices, this case study suggests that significant endogenous adjustments are made in response to water scarcity and that crises may be ascribed to the propensity of managers/politicians to reduce the pinch of water scarcity by increasing supply at the expense of security. Actors within the system are not passive and inactive; on the contrary, they respond individually and collectively to the growing water scarcity, just as agrarian systems respond to changes in the relative scarcity of other production factors. State-driven responses are only a part of the transformation, although officials tend to see the countryside 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. This attitude is typical of "the widely shared opinion that 'substantial' or 'adequate' development depends critically upon intervention, in other words, on the introduction of packages consisting of various mixtures of expertise, capital, technology, and effective modes of organization" (Long and van der Ploeg, 1989). This bias also appears in some linear descriptions of water resources development. Because initial phases of large-scale hydraulic development are seen as a time in which the individual "surrenders the responsibility for mobilizing water to a centralized authority of sorts," it is implicitly inferred that the response in the next phase will also have to come from "technocratic elites" devising "coping strategies" (Turton and Ohlsson, 1999).

Basins where competition over water is highest are thus also most probably those in which the scope for efficiency gains is the most limited. This critically weakens the prospect that significant gains can be achieved through demand management, in particular by economics-based tools. This points to a common overestimation of the potential impact of exogenous policy reforms on water use efficiency and productivity, both because the scope of these policies is reduced and because their efficacy in particular contexts is debatable. In the present case, reform proposals are based on a misunderstanding of water use within the basin, on the lack of recognition that diversification to cash crops is first and foremost governed by market conditions, and on the fallacy that inter-sectoral water allocation is a serious economic constraint (Molle, 2001a). This must not be misunderstood as a case against policies per se but, rather, taken as a caveat against basing their justification on both overenthusiastic projections and erroneous analyses.

While the Chao Phraya basin is undoubtedly nearing seasonal closure, it can still be described as "immature," and centralized intervention is needed to design or enable institutional reforms that tend to be postponed. However, it cannot be overemphasized that the main potential gains of these reforms are less in terms of water use efficiency or economic productivity, than in terms of equity, control of further growth in demand, and empowerment of users in water management and in the negotiation on seasonal entitlements. This, in the long run, should be conducive to a growing formalization of rights in the basin. The crux is now whether the combined logics of politicians and of the administration can be conducive to the institutional changes needed. While the theory of Hayami and Ruttan (1985) on induced institutional change suggests that endogenous adjustments would result from the increasingly conflicting and complex interactions within river basins, it seems that emerging initiatives have, up to now, been mostly driven by exogenous pressure and it is not clear whether they are also endorsed by insiders. In other words, changes are on the way but their nature, time frame, and impact are neither mapped out nor likely to meet the expectations of those committed to reforming the Thai water sector.

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About the Author

François Molle is a Senior Researcher at the Institut de Recherche pour le Développement (IRD, France) and is currently seconded to the International Water Management Institute, Columbo, Sri Lanka. Dr. Molle has worked many years on issues of irrigation management, river basin development and management, water policies, and relations between water and societies. He has been involved in research in Brazil, Western Africa, and Southeast Asia. Dr. Molle He can be reached at the International Water Management Institute, PO Box 2075, Colombo, Sri Lanka. f.molle@cgiar.org

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