WATER RESOURCE MANAGEMENT IN THAILAND: AN ECONOMIC PERSPECTIVE

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Abstract

In Thailand, water is life. Recently however, water has been more associated with conflict and problems, both natural and manmade, from drought to floods to dams to pollution. This paper investigates two major problems related to the management of water resources, dry-season allocation and water quality. In Thailand, water allocation has been considered an administrative problem and solutions have largely been supply-oriented. Economic instruments have not been used to solve them. In dealing with water quality as well, economic instruments have largely been neglected. This paper outlines some of the major problems of water use in Thailand, including conflicts over the quantity and quality of water. It provides some examples of both the political and economic consequences of government policy, specifically the "open access" regime which ignores the true costs and benefits of various types of water use. The paper then goes on to discuss economic instruments for the management of water resources, especially water pricing and pollution charges. Finally, the paper presents conclusions to be drawn from the various studies of water resources in Thailand.

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1. INTRODUCTION

Water, by its very nature, is a symbol of abundance and happiness. Buddhist monks generally bless followers with holy water. At a wedding, the crux of the ceremony is to pour holy water over the palms of the bride and groom. In the midst of the dry season in April, Thais celebrate their lunar New Year by pouring water on the palms of elders while youths enjoy splashing water on each other. On the night of the full moon of the twelfth Thai month, Thais celebrate the Loy Krathong festival releasing *Krathong*, i.e., floats lit with candles and incense, into rivers and streams. In Thailand, water is life.

Recently however, water has been more associated with conflict and problems, both natural and man-made, from droughts to floods and dams to pollution. This paper investigates two major problems related to the management of water resources, dry-season allocation and water quality. In Thailand, water allocation has been considered an administrative problem and solutions have largely been supply-oriented. Economic instruments have not been used to solve them. In dealing with water quality as well, economic instruments have largely been neglected. This paper first outlines some of the major problems of water use in Thailand, including conflicts over the quantity and quality of water. It provides some examples of both the political and economic consequences of government policy, specifically the "open access" regime which ignores the true costs and benefits of various types of water use. The paper then goes on to discuss economic instruments for the management of water resources, specifically, water pricing and pollution charges. Finally, the paper presents conclusions drawn from the various studies of water resources in Thailand.

2. EXISTING LEGAL AND INSTITUTIONAL FRAMEWORK

Water Supply and Allocation

Currently, there are more than 30 pieces of legislation related to water. Of these, three major laws deal with water allocation; they are: the Private Irrigation Act of 1939, the State Irrigation Act of 1942, and the Dikes and Ditches Act of 1962. Among these three, the State Irrigation Act is the most significant.

The State Irrigation Act of 1942 authorizes the Royal Irrigation Department (RID) under the Ministry of Agriculture and Cooperatives to construct, manage, and maintain the State irrigation systems. It also allows the RID to collect water fees of up to 50 satang (0.5 baht or about 2 US cents) per cubic meter from the water users.

Three other agencies are involved in a major way in water supply and regulation:

- The Electricity Generating Authority of Thailand (EGAT) which, charged with hydropower development, has control over water through the construction and operation of dams for hydropower,

- The Metropolitan Waterworks Authority (MWA) which supplies water to Bangkok, and
- The Provincial Waterworks Authority (PWA).

Apart from these three, 27 department-level agencies under eight ministries are also involved to a certain degree in water management.

Water from two major dams, the Bhumibol and the Sirikit, is first used to generate electricity and then released into the Chao Phraya river for use by farmers in the Chao Phraya basin and by Bangkok during the dry season. EGAT has the responsibility for making sure that there is enough water in the two reservoirs for power generation. The MWA, the PWA and any government users can freely draw water from the river and irrigation canals. Therefore, when planning water allocation each year the RID has to include the amounts which will be requested by these agencies.

Although the RID legally controls irrigation water, in practice it has little power over allocation to any users except farmers in its irrigation projects. Priorities are generally given to the urban sector for consumption and to power generation. After all other priorities are met, the remaining water goes to farmers.

Water Quality Control

The Polluter-Pays-Principle was endorsed for the first time in the Seventh National Economic and Social Development Plan (1991-1996). The most important breakthrough, as far as pollution control is concerned, has been the enactment of the Enhancement and Conservation of National Environmental Quality Act B.E. 2535 (1992) which has many innovative features. First, it attempts to manage environmental problems in an integrated manner through an inter-ministerial committee with short- and long-term plans. Second, it decentralizes authority and delegates environmental management to provincial authorities. Third, it recognizes and encourages the participation of the people and non-governmental organizations (NGOs) in environmental protection. Fourth, an Environment Fund of about US$ 200 million (Baht 5 billion) has been set up to promote investment in pollution control and to translate the Polluter-Pays-Principle into practice.

In accordance with the 1992 Act, an end-of-pipe or point-source standard for water quality is to be established with a prescribed procedure for taking samples, allowing environment monitoring agencies to take action against polluters, which could lead to imprisonment for up to one year. Moreover, as mentioned earlier, individuals and NGOs are also allowed to take legal action against polluters. Enterprises discharging effluent may be required by law to pay service fees to central treatment facilities or set up their own treatment facilities. Earlier, the Thai government had no legal basis to charge such a fee.

The most important constraint to the enforcement of the Act is the lack of manpower. Thailand now has more than 100,000 factories and hence monitoring and enforcement is undoubtedly an uphill battle. Moreover, since most cities are located on the banks of major rivers, enforcement of the Polluter-Pays-Principle requires heavy capital investment in central wastewater treatment at a scale many times larger than the Environment Fund. To overcome the monitoring problem, the concept of environmental auditing is being considered. To cope with the second problem of the large number of polluters, across-the-board economic instruments could be used to reduce consumption and effluent.

3. WATER MANAGEMENT PROBLEMS IN THAILAND

Water has historically been considered an abundant resource in Thailand. The traditional institution governing the use of water is an "open access" system, which basically means that water is allocated on a "first-come, first-served" basis. In Northern Thailand, thousand year old traditional methods of governance of irrigation water are still practiced, though they are disappearing rapidly (Box 1).

Box 1. Local customs: the Northern *Muang Fai* rules

Muang Fai is the traditional irrigation system practised in the Northern region of Thailand. The upper Northern part of Thailand is predominantly mountainous with limited flat terrain suitable for agriculture. The local irrigation system—*Muang Fai*—came to existence in this area over a thousand years ago to store water for year-round consumption. *Muang Fai* requires only small scale reservoir which uses a relatively little area for water storage and thus does not interfere significantly with forest stands or cultivated areas.

The *Muang Fai* technology includes the Fai (weir) which is constructed by the villagers to block or divert streamwater into irrigation canals before draining into rice fields. Along the irrigation canals are water dividers called Keang or Dae. These dividers measure and divert water just sufficient for each rice field. The Dae, sometime made of bamboo, varies in diameter and transports water to the destinated rice field.

Muang Fai system is governed by the local organisation. The *Muang Fai* organisation comprises the following committee members:

(1) Kae Fai (weir chief) is the *Muang Fai* head who is responsible for the whole irrigation system. His responsibilities include organising meetings of members (water users), construction, maintenance, water allocation, conflict resolution and imposition of fine when agreements are breached. Kae Fai is usually a respected member of the village with knowledge and experience;

(2) Kae Muang (canal chief) is similar to Kae Fai but his responsibility is limited to sub-irrigation system;

(3) Laam Muang are the liaison officers who assist in the communication between the Kae Fai, Kae Muang and water users; and

(4) water users who elect the *Muang Fai* committee members and abide to the *Muang Fai* agreements. They also report to Kae Fai and Kae Muang of any misconduct by other members.

The essential element of *Muang Fai* system is the group commitment which varies from location to location. The agreement will be read to water users at the beginning of each growing season to inform them of their rights and obligations. Water users are obligated to invest their labour or other means in maintaining the irrigation system. The agreement is based on fairness and morality aiming for the survival of all the villagers—both upstream and downstream as well as large-scale and small-scale farmers. Water users are willing to compromise, respect the agreement and each other's rights and are treated equal in terms of water allocation and labour sharing. Currently, there are more than 4,000 *Muang Fai* systems in various watersheds in the Northern region of Thailand. As the story tells, people's participation in the system management has no doubt been the driving force behind the success of *Muang Fai*.

Source: Kannika Promsao, 1992.

As demand for water grows along with a rise in irrigated agriculture, urbanization and industrialization, conflicts at all levels have been increasing—between farmers, between communities, between economic sectors, between the government and environmentalists, and between government agencies themselves. Conflicts over water quality are also mounting as the rivers, the country's lifelines, become threatened by residential and industrial pollution.

Water Quantity

"Open access" has often been treated as an equity rule in Thailand. This is a reasonable institution for managing water resources when water is plentiful. As water becomes scarce, the equity rule breaks down. When conflicts occur under the open access regime, wealth, access to technology and "good connections" are more often than not the factors that determine who receives the water.

One TDRI case study highlights the water shortage faced by rice farmers in the Chao Phraya river basin.[1] The Royal Irrigation Department (RID) was urging farmers to forego planting a second paddy rice crop during the dry season to conserve water, suggesting that they plant crops such as soy beans, which consume less water. At the same time, the Department of Mineral Resources (DMR) was offering incentives to encourage the digging of wells for ground water. As the competition for water intensified, farmers sank deeper and deeper wells, causing depletion of aquifers and drying up some wells.

Part of the problem lies in the historical development of the institutions that manage the supply of water. They were created for the purpose of water *provision*, and thus there is no agency with a mandate for handling water *allocation*. The lack of such an institutional arrangement has meant that water conflicts are forced into the political arena, largely without policies to guide any resolutions.

Governments have two main options regarding institutional arrangements for the allocation of water; they can use Command-and-Control (CAC) methods, or they can create a market for water. The second option requires the establishment of well-defined property rights over water. These rights can be owned by individuals or communities who can then buy and sell water depending upon their needs.

Generally speaking, the market provides an efficient means for the allocation of resources and products. Price in a competitive market reflects the true cost of the resource; the market mechanism ensures that those goods in high demand are highly priced. But many resources such as forests and water are not priced or are priced at a level that does not reflect their true cost. For these resources, the market fails to be an efficient means for allocation when the property rights of these resources are not defined and are not enforceable, leading to over-extraction.

Up to now, the Thai government has relied upon CAC methods for the allocation of water, usually on a case-by-case basis. For CAC methods to be efficient, decision-makers have to know the marginal value of water for competing uses. If the marginal

[1] See the study by Thitinan in TDRI, 1994.

value of water is higher, say, in Bangkok than in the Mae Klong river basin, then a diversion of water from the latter is justified. So far, however, little effort has been made to value water in this regard. Thus when conflicts arise, the outcomes are based more on interest-group competition and less on a well-informed analysis of the situation.

A case study of rural and urban users in Central Thailand illustrates the sectoral and regional conflicts for water that occur during the dry season between November and May when rice production competes with the Bangkok Metropolitan Region's (BMR) water needs.[2] The attempt to divert water from the rural Mae Klong and Tha Chin river basins to the Chao Phraya basin which feeds the urban areas of the BMR, is a prime example.

Recently, the supply from the Chao Phraya river basin has become insufficient for the BMR's water needs, due to the rapid economic development and population growth of the area.[3] With the increase in upstream water use, the dry season supply is shrinking steadily. In order to increase the supply for Bangkok in the dry season, water is diverted from nearby basins that primarily serve the agricultural community.

However, the provincial Chambers of Commerce of Kanchanaburi, Ratchaburi and Samut Songkhram, provinces that draw their water from the Mae Klong basin, are strongly against the water diversion plan (see Map 1). Citing a decline in their own water resources, concern was expressed about the adverse affects of and inadequate compensation for the withdrawal of water by the BMR. There was a sentiment that Bangkok was favored at the expense of the outlying provinces in their quest for more water.

The RID officials have repeatedly confirmed that the users of the Mae Klong Basin will be accorded a first priority access to the water resource in their own basin. This confirmation is, however, not supported by the current legislative framework.

The diversion of water from the Mae Klong river is one of several such diversions carried out by the RID in various parts of the country. As mentioned earlier, the diversion may in fact be economically justified if the marginal value of the diverted water is higher than the marginal value of water in the Mae Klong basin. This valuation of the water must include any future projections of water demand, which is likely to rise in the Mae Klong basin as demand from tourism and industry increases. The RID claim that the Mae Klong has excess water does not account for changes in the future.

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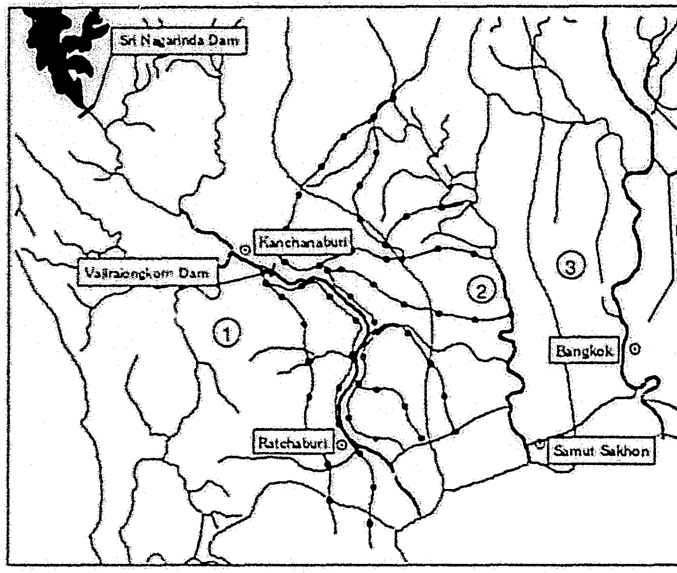
[2] See the study by Thitinan in TDRI, 1994.

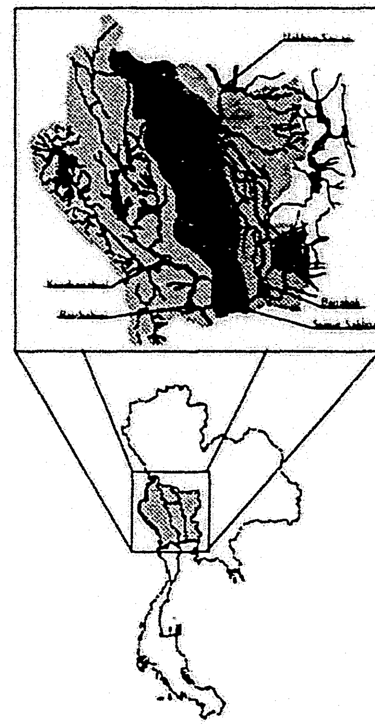
[3] Currently, the Metropolitan Waterworks Authority (MWA) provides water to four provinces: Bangkok, Thonburi, Nonthaburi, and Samut Prakarn, covering 3,082 km^2 and 7.5 million users. Demands are growing so fast in this area that the MWA can guarantee provision only until 1997 unless new supplies come on stream.



Greater Mae Klong Irrigation Project

LEGEND

- Provincial capital
- Irrigation/Drainage Canal of the Greater Mae Klong Irrigation Project
- Water Reservoir
- Main River
- Secondary River
- Watershed outline
- (1) Mae Klong Basin
- (2) Thachin Basin
- (3) Chao Phraya Basin



The economic value of water is most vividly demonstrated by TDRI's study on the use of water from the Mae Taeng Watershed (Vincent *et al.*, 1995). Water from the Mae Taeng river is diverted for two main uses—for farmers in the government-run Mae Taeng Irrigation Project area, and for urban users via the Umong water treatment plant in Chiang Mai. Prior to the floods of the past two years, farmers in the Irrigation Project suffered severe shortages of water during the dry season, and the Umong treatment plant had to be shut down completely. To compensate for the increasingly short supply of water, officials are building a 60 million baht pipeline to divert water from the Ping River to the Umong treatment plant. There are also plans to draw water from the Mae Kuang Dam by 1997, with a projected cost of 900 million baht.

Much of the decrease in runoff from the Mae Taeng watershed is attributable to lower levels of rainfall. However, statistical analysis shows that even after accounting for the decline in rainfall, less water is coming out of the watershed (Appendix A). Therefore, changes in land-use patterns in the uplands must be causing runoff to decline. The major changes in land use in recent years have been increases in permanent irrigated agriculture in the highlands along with steadily growing areas of pine plantation, both of which probably demand more water than previous types of land use. TDRI estimates that dry season runoff from the watershed, holding rainfall constant, declined by an average of 2.9 million cubic meters per year between 1972 and 1991.

TDRI also estimated the economic costs of this decline (Appendix B). Using econometric techniques, researchers established that the marginal value of water to lowland farmers in the irrigation project area ranged from about 1-1.5 baht per cubic meter. Assuming that the decrease in runoff lowered both the crop area and yield, estimates of annual agricultural revenue loss ranged from about 25-90 million baht.

There are also economic costs to urban water consumers, in the form of higher charges for water (unless the State provides subsidies) to cover the costs of expanding the supply. Currently urban users pay between 3.75 (households) and 17.75 (industry) baht per cubic meter for treated water. Marginal values for this water were estimated at 0.60 baht per cubic meter for industrial estates, 6.99 baht per cubic meter for industrial users, and 3.79 baht per cubic meter for households. Note that with the exception of the industrial estate, these figures are higher than the marginal value of water in agriculture. The TDRI estimate of the marginal cost of obtaining water from the Mae Kuang Dam is 7.14 baht per cubic meter.

Therefore, in theory, it would be much cheaper for urban users to purchase water from farmers than to obtain new supplies. Specifically, Chiang Mai Waterworks could have paid as much as 3.79-6.99 baht per cubic meter for marginal units of water during 1993 without any increase in water rates, while the value of water to farmers was only around 1 baht per cubic meter. Both parties would be made better off by this transaction, thereby increasing efficiency and delaying the costs of having to construct additional infrastructure.

Of course, there is no mechanism at present to conduct this type of transaction. The institution of well-defined property rights over water would allow the creation of such a market, thus ensuring that farmers will not suffer financially when cities demand the use of their water. Without the existence of a market for water, more information is needed—specifically the marginal value of the water in question—before decisions can be made on the economically efficient allocation of water.

When command-and-control mechanisms are used (as in the Mae Klong basin example) the decision-making should be transparent. Had the RID carried out a study comparing the marginal value of water in the Mae Klong basin versus the Chao Phraya basin, they probably could have justified the diversion of water more easily.

Water Quality

In urban areas, particularly in Bangkok, the pressing water resource problem relates to the quality of water, increasingly threatened by population increase. Concentration of economic growth in urban areas has triggered migration from rural areas to urban centers. Public utilities in urban centers have inevitably lagged behind the accelerated growth of urban populations. Residential wastes are commonly discharged into waterways at such a rate that the water in Chao Phraya River, the nation's lifeline, has become unsuitable for domestic use (Table 1). The BOD (Biochemical Oxygen Demand) load was often higher than official standards and the concentration of coliform bacteria is on the rise. It is estimated that about 93 percent of the total BOD load to the Mae Klong river in 1990 and 75 percent of the same to the lower Chao Phraya river in 1988 were attributable to domestic effluent (Thailand UNCED Report 1992).

Table 1. Water Quality of the Chao Phraya River, 1981-1993

Year	Dissolved oxygen (DO) mg/l			Biochemical Oxygen Demand (BOD) mg/l			Total Coliform Bacteria (TCB) MPN/100 ml		
Portion	Upper	Middle	Lower	Upper	Middle	Lower	Upper	Middle	Lower
Standard	≥ 6.0	≥ 4.0	≥ 2.0	≤ 1.5	≤ 2.0	≤ 4.0	≤ 5,000	≤20,000	NA
1981	-	4.1	0.5	-	2.1	2.7	-	39,250	92,400
1982	-	4.1	0.3	-	1.6	2.4	8,000	13,870	164,750
1983	5.7	3.4	0.4	2.2	1.8	2.9	4,000	4,050	4,970
1984	6.0	3.4	0.4	2.0	1.9	2.8	20,430	14,000	221,650
1985	4.3	3.3	0.2	2.1	2.1	3.8	6,500	22,000	243,000
1986	6.4	3.8	0.4	1.4	1.9	3.1	13,000	19,500	355,000
1987	5.7	3.0	0.4	1.7	1.8	4.1	8,000	29,000	171,000
1988	5.3	3.5	0.9	1.8	4.3	1.9	8,200	13,000	242,000
1989	6.0	2.5	0.3	1.2	3.0	2.2	18,665	35,000	705,000
1990	5.6	3.0	0.5	1.5	1.5	3.0	28,000	30,000	1,002,060
1991	5.6	1.3	0.4	1.9	2.3	7.5	23,000	18,000	1,650,000
1992	5.6	3.8	0.3	2.3	1.7	8.2	210,000	207,000	-
1993	5.9	4.9	1.5	1.7	2.3	2.7	39,700	248,700	257,700

Note: Percentile Value of the total sample test: DO (20%) , BOD (80%) , TCB (80%)
Source: Pollution Control Department

The growth of the industrial and service sectors has not only increased demand for water but also released more effluent into waterways. A good example is the pollution of to shape the behavior of polluters or it can create a market. It can also use combinations of the above.

Unlike in the water allocation problem where few economic instruments have been used to alleviate the management problem, economic incentives have been used as carrots to induce concerned agencies to respond more positively to environmental conservation. Low interest loans from the Environment Fund are available for local administrations (municipalities and sanitary districts) and private businesses which are required to set up treatment facilities. The city of Pattaya would be the first to utilize this fund for its central waste-water treatment plant.

Other promotional measures include the reduction of import duties to no greater than 10 percent for equipment used for any treatment facilities. This has been granted since 1983. Between 1984 and 1989 only 130.9-million-baht (US$ 5.14 million) worth waste-water treatment equipment had been imported under such incentives (UNIDO, 1993).

These soft loans and tax incentives are compensatory measures, designed to encourage pollution abatement activities. As with projects to build reservoirs or water diversions, they are supply-side solutions in that they do little to encourage conservation or a decrease in the production of wastewater. Full-cost pricing, however, would incorporate the costs of wastewater treatment into the price of water, thus raising the price and lowering consumption.

Full-cost pricing

The price of water set by the Provincial Waterworks Authority follows the same standard scale all over the country. These prices are often far from the full cost of the resources. Full cost pricing of natural resources entails the recovery of all costs of extracting and delivering that resource, including production costs, user costs, and external costs. This assumes that users should pay not only for the costs that the producer incurs in supplying the resource, but also for the scarcity value (user cost), and environmental damage (external cost) of providing that resource. For water, the user costs are best reflected in the increase in prices of water during the dry season, while the external costs can be viewed as the cost of treating wastewater, the by-product of any water supply.

A TDRI study of water pricing in Phuket attempted to estimate the full cost of water, along the people's willingness to pay for improved water supply and wastewater treatment (Patmasiriwat *et al.*, 1995). As an increasingly popular international tourist destination, the Island of Phuket is one of the fastest growing areas in Thailand. However, this unprecedented rate of growth has outpaced the capacity of the government to provide proper infrastructure, leading to problems such as water shortages and pollution along the beaches. Thus Phuket finds itself caught in a potential low-level equilibrium trap, whereby the increasing number of tourists may eventually degrade the environment to the extent that Phuket is no longer an attractive tourist destination. In order to avoid this trap, appropriate resource policies, especially regarding water supply and wastewater treatment, are critical.

Currently, water shortages are apparent during the dry season, when many residents, hotels and other businesses are forced to purchase water from private vendors. TDRI projections suggest that annual water demand will outpace supply within the next 15 years unless additional supplies can be tapped. This same study suggests that people are generally willing to pay higher prices for tap water—up to 8.5 baht per cubic meter—if the quality of the service and the water can be improved. If one considers that some households are actually paying much more for bottled drinking water, the actual willingness to pay may in fact be higher.

The policy implication of the higher willingness to pay and the need for additional infrastructure is that water is currently underpriced. Full-cost pricing of water on Phuket would ensure that adequate funds were available to meet future demands for water and wastewater treatment. The TDRI estimate of the full cost of producing water on Phuket is 6-8 baht per cubic meter, not including user and external costs (or 14-18 baht including both), suggesting that full-cost pricing would be a politically difficult option given the current willingness to pay. For wastewater treatment, the average willingness to pay was about 2.08 baht per cubic meter, far below the estimated cost of treatment of 7 baht per cubic meter.

The study also recommends that water prices be set according to local conditions. Currently, the Provincial Waterworks Authority sets prices uniformly throughout the country, regardless of the relative demand or availability of supply. In addition, the study recommends the establishment of an independent water control board that would oversee pricing, and infrastructure development and mediate conflicts.

It should be noted, however, that government measures can themselves be the causes of environmental degradation (Panayotou, 1993) if not used with adequate discretion and foresight. First, government interventions may unintentionally disrupt a well-functioning market. In the district of Tron, Uttaradit Province of Thailand, a local community used to make collective investments to pay for the cost of pumping water from a river for irrigation and share the cost by charging fees according to the volume required by each crop. The government later emulated the system in other villages but provided free water to everybody, thereby destroying the more efficient market mechanism that potentially exists in local communities.

Secondly, governments often fail to factor, in full, the true cost of the resource, including the environmental cost. As indicated earlier, the price of the irrigation water has been legally fixed at a level far below the operation and maintenance cost of the system. The difference is already large even without taking into account the cost of fixed capital outlay and the environmental and social costs related to the construction of storage dams. Low fees coupled with the inability of the RID to use this revenue directly for further investments reduce the incentive of the organization to collect any fees, resulting in low revenues and inefficient operations, allocation and use.

Pollution charges are now being used in Pattaya, Phuket, and the Industrial Estates. In Phuket, charges are far from actual treatment costs, but are below the willingness to pay 2 baht per cubic meter.

5. CONCLUSION

The proper management of water resources in Thailand will require innovation and courage, especially regarding the institutional aspects of water administration; the policy of "open access" is clearly not sustainable. Market-based instruments for the management of water resources are an important option to consider. They provide efficient solutions to allocation problems.

However, in Thai culture, "the market" has a negative connotation. It is viewed as a rather ruthless and uncaring system of distribution, benefiting those with the wealth to purchase what they need, while excluding the poor from participation. When a natural resource such as water is institutionalized as a traded good, people fear that the poor will no longer be able to purchase a basic human necessity. But if one examines carefully the current system of distribution—the "open access" policy—one discovers that in fact this is exactly what is occurring. When conflicts over water occur, it is the wealthy and powerful who are most likely to gain the upper hand and access to the water.

By establishing a market for water, water rights are thus institutionalized. These rights are currently capitalized in the value of the land. In fact, by separating the value of water from land, income distribution could be improved. For example, a farmer would have the right to a given amount (say, a percentage of streamflow) of water each year. In the year when farmers expect the prices of a commodity to be too low, they will have an option to sell their water and release their labor and capital for higher value activities. In an extreme case, the country could decide on using water rights as an income distribution mechanism by granting water rights to the poor only. Therefore, the impact of water rights on income distribution is determined by political and social factors.

One major obstacle to the application of economic instruments in Thailand is the lack of technical knowledge, personnel and supporting legislative framework. Capacity building in this direction is a pre-requisite. As a country advances, many economic instruments such as other variations of emission charges and deposit-refund systems may be used. However, these are second-best solutions and there will still be the need for substantial monitoring and technical resources. Full cost resource pricing which will reduce water demand remains to be the most cost effective way of reducing inefficiency in water use and controlling effluent.

REFERENCES

Christensen, S. R. and Boon-long A. (1993). Institutional Problems in Water Allocation: Challenges for New Legislation, *TDRI Quarterly Review*, Vol. 8, No. 3, pp. 3-8, Bangkok

Panayotou, T. (1993). *Green Markets: The Economics of Sustainable Development*. ICS Press, San Francisco.

Patmasiriwat, D., J.R. DeShazo, A. Boon-Long, H. Vathananukij, and D. Alford. (1995). *Full-Cost Water and Wastewater Pricing: A Case Study of Phuket, Thailand*. Natural Resources and Environment Program, TDRI. Bangkok: August.

Thailand Development Research Institute (TDRI). 1994. *Water Conflicts*. Natural Resources and Environment Program, TDRI, and Queen's University, Canada. Bangkok: October.

Thammasat University (1993). "Proposals Regarding Institutional Framework for Regulating the Chao Phraya" (*draft*). Faculty of Law, Thammasat University. Bangkok.

UNCED (1992). *Thailand Country Report to the United Nations Conference on Environment and Development* (UNCED). Bangkok: June.

Vincent, J. R. (1993). *Reducing Effluent while Raising Affluence: Water Pollution Abatement in Malaysia*. HIID. Cambridge, Massachusetts.

Vincent, J. R. *et al.* (1995). *The Economics of Watershed Management: A Case Study of Mae Taeng*. Natural Resources and Environment Program, TDRI. Bangkok: February.

APPENDIX A[4]

Statistical Models Used for Analysing Reduced Runoff in the Mae Taeng Watershed, Northern Thailand

Stream flow varies greatly from month to month in regions with seasonal climates like northern Thailand. In TDRI's study of the Mae Taeng Watershed in Northern Thailand, regression technique was employed to analyse runoff variation. The explanatory variables were of three types.

Constant terms for each month: These are analogous to the intercept of a line. If no trends are present, they are equivalent to mean stream flow for the month in question during the sample period.

Time trends for each month: The value of the time trend equals 1 for the first year of data, 2 for the second, and so on. These are the most important variables, the ones whose statistical significance would tell whether water yield has changed over time.

Lagged stream flow: This is stream flow from the previous month, (e.g., April stream flow in the case of May, etc). This variable is included to control for possible month-to-month correlations in stream flow. Stream flow is a flow variable. Defining it on a monthly basis creates artificial time units that are not independent. For example, if stream flow is unusually high during April in a given year due to particularly heavy precipitation at the end of that month, it will probably be unusually high in May too, due to the time required for the April precipitation to run off completely and be registered at a downstream guaging station[5].

$$\text{STREAM FLOW}_{it} = \beta 0_i + \beta 1_i \cdot \text{TREND} + \beta 2 \cdot \text{STREAM FLOW}_{i-1,t}$$

Where β's are regression coefficients, i denotes months and t years.

The regression was estimated for monthly runoff data from three stream flow gauging stations. Data were reported by water year beginning April when stream flow begins its annual rise into the wet season, and ending the following March, when stream flow ends its decline during the dry season. For the three stations, from upstream to downstream, the period over which data was analysed is given below.

Station	Catchment Area (km²)	Data Analysed	Missing Data
Ban Muang Kud	1,687	WY1952-1972	March WY1968, March WY1972
Ban Sop Kai	1,636	WY1972-1991	August-October WY1973
Mae Taeng Weir	1,780	WY1975-1993	None

Source: Daily discharge data provided by RID, converted to monthly stream flow. The discharge data from the Mae Taeng weir were expressed in cubic meters per second.

[4] Extracted from Vincent, *et al* (1994), p. 25-29

[5] The length of the lag in streamflow varies throughout the year. Rain that falls at the end of the dry season when the soil is parched will take much longer to affect streamflow than rain that falls at the end of the rainy season when the soil is saturated. This effect is not accounted for in the model.

Regression results are summarized in Table A-1 below.

Table A-1. Regression Results: Trends in Runoff

	Gauging Station		
	Ban Muang Kud	***Ban Sop Kai***	***Mae Taeng Weir***
I. Parameters[1]			
A. Monthly Trends			
1. April	+0.212 (1.09)	-0.302* (2.08)	-0.108 (0.464)
2. May	-0.400 (1.02)	-0.383 (1.42)	-0.283 (0.423)
3. June	-0.473 (0.867)	-0.715 (0.957)	-0.848 (0.566)
4. July	+1.32 (1.38)	-0.652 (0.785)	-1.01 (0.851)
5. August	+1.17 (0.946)	-1.427 (1.15)	-2.05 (1.37)
6. September	-3.59 (1.88)	-1.40 (1.47)	-1.78 (1.27)
7. October	+1.35 (1.11)	-1.50 (1.96)	-1.61 (1.28)
8. November	+0.0976 (0.263)	-1.65 (1.35)	+0.791 (0.753)
9. December	-0.0361 (0.113)	-0.748* (2.42)	-0.535 (1.21)
10. January	-0.265 (1.75)	-0.932* (4.46)	-1.13* (4.38)
11. February	-0.145 (1.60)	-0.564* (3.75)	-0.106 (0.535)
12. March	-0.0683 (0.443)	-0.660* (5.30)	0.0859 (0.555)
B. Lagged Runoff	+0.472* (5.12)	+0.228* (2.68)	+0.294* (4.34)
II. Other Statistics			
A. R^2	0.78	0.77	0.73
B. Durbin-Watson	2.06	2.06	2.13

Notes: 1. Statistics are given in parentheses and are based on standard errors corrected for Heteroskedasticity

** Significant at 5% level*

APPENDIX B[6]

Structure of the agroeconomic model

The model focuses on soy beans and rice, because these are the most important crops in terms of cultivated areas and water use. The model includes five equations: four equations predicting yield and cultivated area for each crop, and a fifth equation that defines total cultivated area as the sum of area in soy beans, area in rice, and area in other crops. Area in other crops is treated as exogenous.

Given the apparently negligible change in crop varieties and farming methods, yield was modeled as a purely biophysical relationship:

Yield equation

1) $Y_1 = b0_i + b1_i \cdot AREA/WATER + b2_i \cdot TREND$

Y is yield, AREA is the total area of all crops, WATER is the amount of water diverted into the system during December-April, and TREND is an annual time trend. The subscript i refers to the crop, soy beans or rice. Hence, there are two of these equations in the model, one for each crop. bβ0, b1, and b2 are parameters that must be estimated for each crop.

In this formulation, yields can change over time for two reasons: changes in irrigation intensity, which is the inverse of AREA/WATER, and exogenous, time-dependent factors, which are represented by TREND. We expect b1 to be negative: for a given area cultivated, a reduction in water should cause yields to fall. Improvements in varieties or farming methods would be expected to cause b2 to be positive. If neither of these two variables is significant, then yields are constant over time and equal to b0.

We tried alternative formulations that included, in addition, the amount of rainfall during December-April and the fertilizer price (no data on amounts of fertilizer applied were available). We found, however, that these additional variables were not statistically significant.

We assumed that farmers decided on the area of each crop to plant by maximizing expected profit, subject to physical and institutional rigidities in changing crop areas from one season to the next. We defined expected profit as:

$$\pi = \mu_S \cdot P_S(-1) \cdot Y_S \cdot A_S + \mu_R \cdot P_R(-1) \cdot Y_R \cdot A_R$$

P_i is farmgate price and A_i is area; μ_i is a parameter that will be explained momentarily. This expression says that total expected profit is the sum of expected profit for soy beans (subscript S) and expected profit for rice (subscript R). Expected profit for each crop is the product of expected revenue — last year's price, $P_i(-1)$, times yield, Y_i, times area, A_i — times a parameter, μ_i, that converts from revenue to profit.

The expression includes last year's price because, as discussed in the previous section, farmers reportedly base their expectations heavily upon it. We included current

[6] Extracted from Vincent *et al.* (1995) p. 44-49

yield rather than last year's yield because we assumed that the RID's estimate of the amount of water that would be available was reasonably accurate; once farmers know this amount, the yield is given by the yield equation (a version of which farmers are assumed to carry in their heads).

It would be better to include data on costs of production directly in the profit expression, instead of using the profit margin parameter μ_i. Unfortunately, aside from agricultural wages and fertilizer prices, no such data are available for the irrigated area.[7] There are no data on labor inputs, amounts of fertilizer applied, and so on. The exclusion of data on the opportunity cost of labor is perhaps the greatest shortcoming of the model. Since the model is intended to be used to analyze changes in variables between alternative scenarios, not to predict their levels under a given scenario, this is less a concern than if the model were intended to serve as a forecasting tool.

Mathematically, the crop areas that maximize the expected profit function are determined by differentiating the function with respect to the crop areas, and solving for the crop areas. This procedure yields:

Crop area equation

$$2) \qquad A_i^* = -Y_i \cdot WATER/\beta 1_i - \frac{\mu_j \cdot P_j(-1) \cdot \beta \beta 1_j}{\mu_i \cdot P_i(-1) \cdot \beta 1_i} \cdot A_j$$

The asterisk superscript (*) on the area variable indicates that it is the *desired* value for area in crop i. Due to physical and institutional rigidities, the farmer might not actually be able to cultivate this area. The inclusion of variables with the subscript j, which denotes the other crop (rice in the case of soy beans, soy beans in the case of rice), indicates that decisions about one crop affect decisions about the other. Assuming that $\beta 1_i$, the coefficient on the inverse of irrigation intensity in the yield function, is negative as expected, the first term of this equation indicates that an increase in water increases the desired area in crop i.

The second term reflects the impacts of changes in areas upon yields, for a given amount of water. This term indicates that:

- If the profit margin for crop j (μ_j) rises relative to the margin for crop i (μ_i), the desired area in crop i decreases.
- If the expected price for crop j (P_j) rises relative to the expected price for crop i (P_i), the desired area in crop i decreases.
- If the area in crop j (A_j) rises, the desired area in crop i decreases. This reflects the constrained amount of water that is available. Not surprisingly, the

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[7] We also explored building the model through the "dual" approach, in which the profit function is specified as including only price terms and terms related to fixed factors of production. This approach yielded poor estimation results, probably due to the lack of information on amounts of inputs used. Hence, we switched to the simpler model described in the text.

strength of this effect depends on the ratio of the area/water coefficients ($\beta 1_i$ and $\beta 1_j$).

These relationships are the ones that one would expect to occur in reality. Because of rigidities, the farmer cannot necessarily achieve the desired crop areas. Actual area is given by:

$$3) \qquad A_i = A_i(-1) + \theta_i \cdot [A_i^* - A_i(-1)]$$

θ_i is an adjustment parameter, which indicates how much the farmer can adjust crop areas from last season's area ($A_i(-1)$) to the desired area (A_i^*). This equation says that actual area is given by last season's area, plus the amount of adjustment. This equation can be rewritten as:

$$A_i = (1-\theta_i) \cdot A_i(-1) + \theta_i \cdot A_i^*$$

If $\theta_i = 0$, no adjustment is possible: crop area is the same from one season to the next ($A_i = A_i(-1)$). On the other hand, if $\theta_i = 1$, adjustment is complete: actual area equals desired area ($A_i = A_i^*$). Given the combination of both rigidities and unused land in the Mae Taeng Irrigation Project, we expect the value of the adjustment parameters to fall between these exu eme values.

The final crop area equation is given by substituting the equation for the desired area into the adjustment equation:

Area equation

$$4) \; A_i = (1-\theta_i) \cdot A_i(-1) + \theta_i \cdot [-Y_i \cdot WATER/\beta 1_i - \frac{\mu_j \cdot P_j(-1) \cdot \beta 1_j}{\mu_i \cdot P_i(-1) \cdot \beta 1_i} \cdot A_j]$$

There are two of these equations in the model, one for each crop.

The fifth equation in the model is the area identity:

Area identity

$$AREA = A_S + A_R + A_M,$$

where A_M is the area in miscellaneous crops.

7.1.3 Estimation and validation of the model

Econometric estimation is required to determine the values of the three parameters in each yield equation ($\beta 0_i$, $\beta 1_i$, $\beta 2_i$) and the two additional parameters in the area equations (μ_i, θ_i). All four yield and area equations must be estimated simultaneously, because they share parameters and because of additional econometric reasons.[8] For statistical reasons, only one of the profit-margin variables (μ_S or μ_R) can be estimated.[9]

The yield and area equations were estimated using data for the period 1979-91. The sample period was short, but this was unavoidable: data on yields and areas were missing for 1975-78, and data on dry-season rice prices were not available before 1974. Because the area equations include lagged values, the actual sample period for the estimation was 1980-91.

The estimation technique was the generalized method of moments, which is a more sophisticated version of the regression techniques employed in the analysis of the stream flow data.[10] Table B-1 summarizes the estimation results. Notable results related to the parameters include:

- All parameters are statistically significant at the 5-percent level except for the coefficient on trend in the yield equation for soy beans.
- All parameters have the expected signs.
- The parameters on the AREA/WATER variable in the yield equations ($\beta 1_i$) are negative. This indicates that a reduction in water for a given area reduces yields. Given the small size of the parameter estimates, however, this effect is small.
- The parameters on the TREND variable in the yield equations ($\beta 2_i$) are positive. This indicates that, aside from effects related to changes in water availability, yields rose over time (though, as just noted, the parameter for soy beans was not significant). The increases were 5.59 kilograms per *rai* per year for soybeans and 15.1 kilograms per *rai* per year for rice.
- The adjustment parameters in the area equations (θ_i) are greater than zero and less than one. They are small: 0.304 in the case of soy beans, and 0.189 in the case of rice. This confirms that crop areas adjust only slowly over time.
- The profit margin variable included in the model, μ_S, is positive and less than one. Because the profit margin for rice could not be estimated, μ_S really represents the ratio of the profit margin for soy beans to the profit margin for rice. The estimated value, 0.937, indicates that the profit margin for soy beans was only 93.7 percent as large as that for rice.

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[8] They include endogenous variables as explanatory variables (for example, yield is on the right-hand side of the area equation), and their error terms are likely to be correlated.

[9] The two parameters do not appear separately in any of the equations; they only appear together, as a ratio.

[10] This is essentially equivalent to three-stage least squares, with the standard errors of the coefficients corrected for first-order serial correlation. We used a constant, lagged prices, the amount of water, and the trend variable as instruments.

Table B-1. Regression Results: Agroeconomic Model

	Crop	
	Soy Beans	**Rice**
I. Parameters[1]		
βϕ (constant)	+451* (11.1)	+625* (5.53)
β 1 (area/water)	-0.322* (9.57)	-0.360* (2.93)
β 2 (trend)	+5.59 (1.54)	+15.1* (3.93)
μ (profit margin)	+0.937* (7.91)	
θ (adjustment)	+0.304* (2.64)	+0.189* (2.70)
II. Other Statistics		
A. Yield Equation		
1. R^2	0.14	0.69
2. Durbin-Watson	2.47	2.00
B. Area Equation		
1. R^2	0.51	0.26
2. Durbin-Watson	1.81	1.43

Notes: 1 Statistics are in parentheses and are based on standard errors corrected for serial correlation

* Significant at 5% level

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shocks to the Bangladesh model. Then, finally, we explore the relationship between food aid and the effects of the Uruguay Round, focussing on the way the domestic policy environment within Bangladesh affects this relationship.

Simulation results

Effects of food aid

Table 7 summarises the simulated effects on the Bangladesh economy of exogenous changes in the level of food aid. The simulations presented are designed to show the relationship between the effects of food aid and the domestic policy environment within Bangladesh with regard to food grain imports.

The experiments reported in Table 7 fall into two sets, 1 and 2. Experiments A1 to C1 simulate the effects of a 10 per cent increase in food aid (in the form of rice and wheat) on the assumption that commercial food imports (other than food aid) are subject to government controls and do not adjust. In experiment A1, rice food aid is increased by 10 per cent. In B1, wheat food aid is increased by 10 per cent and in C1, both forms of food aid are each increased by 10 per cent. The linearity of the underlying model implies that the results of C1 are simply the sum of those obtained from A1 and B1. Experiments A2 through C2 are identical to A1 to C1, respectively, except that they are carried out on the assumption that commercial food imports are tariffied therefore that the quantities of these imports may adjust in response to exogenous changes in food aid.[6]

Table 7

In modelling terms, the difference between experiments in sets 1 and 2 is that in set 1, the quantities of commercial imports of rice and wheat are each exogenously fixed and the domestic prices of these imports are endogenously determined. In set 2, the quantities of these imports are each endogenous and the exogenous levels of the tariffs applying to these two

[6] Linearity of the model also implies that the results of C2 are equal to the sum of those of A2 and B2.