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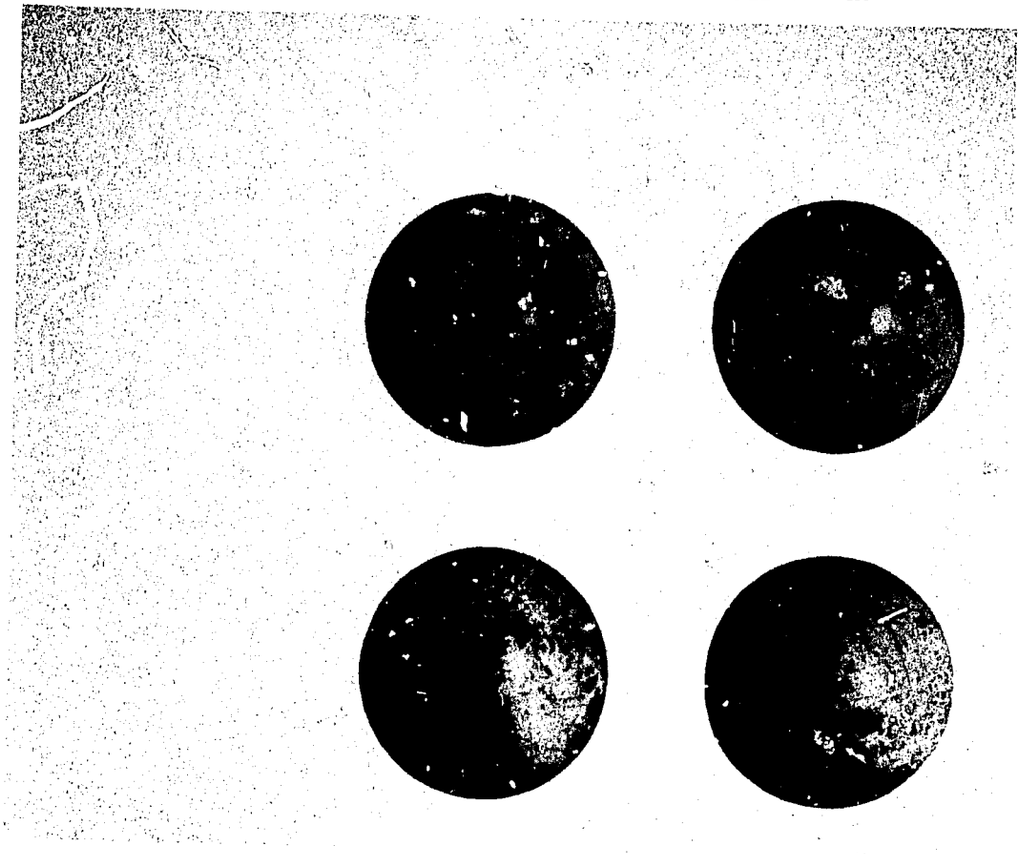

Economic Evaluation of Water Control in the Greater Chao Phya Project of Thailand

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NEW YORK STATE COLLEGE OF AGRICULTURE AND LIFE SCIENCES
A STATUTORY COLLEGE OF THE STATE UNIVERSITY
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Economic Evaluation of Water Control in the Greater Chao Phya Project of Thailand*

Leslie E. Small†

The Greater Chao Phya project is the largest water control project in Thailand, encompassing a total of 910,000 hectares. First proposed early in the 20th century, the project became a reality during the 1950s and early 1960s. It was originally constructed to "stabilize" wet-season rice production by reducing the frequency and severity of damage caused by excessive flooding or drought. With the subsequent construction of two upstream storage dams (Bhumiphol and Sirikit), the government hoped to increase production during the dry season. In recent years, disappointment with the rate of expansion of dry-season production has led to criticisms of the project.

Objectives of the Study

In spite of the controversy surrounding the project, no systematic investigation of the costs and benefits has been made. The first objective of the study, therefore, was to estimate the rate of return to the existing investment in water control facilities in the project area. Since the system is designed primarily to increase agricultural production, the evaluation was confined to an analysis of the effects of the project on the area planted to crops (mainly rice) and on average yields.

A number of proposals for improvements in the system have been offered in recent years. Some of these proposed changes would require large additional investments. A second objective of the study was to identify alternative approaches for improving the system and to evaluate these alternatives to provide some basis for ranking them with respect to potential gains in relation to costs.

* The research summarized in this article was undertaken as a joint project between the Department of Agricultural Economics of the New York State College of Agriculture and Life Sciences at Cornell University and the Faculty of Economics and Business Administration at Kasetsart University in Bangkok.

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Project Area

The analysis is based on that part of the Greater Chao Phya project which is served by the network of distribution canals which are fed by the Chao Phya diversion dam at Chainat. This area (hereafter referred to as the project area[1]) covers approximately 660,000 hectares, of which roughly 600,000 hectares are planted to rice during the wet season. The southern portion of the Greater Chao Phya project (consisting of about 250,000 hectares in the West Bank and Chiangrak-Khlong Dan tracts) was built before 1950. Since this area does not benefit directly from the dam at Chainat, it has been excluded from the study.

Although rice is the only significant crop grown, the project area is not a homogeneous agricultural region. In some places rice is transplanted on fields where rainfall is the only source of water. In other places, floating varieties of rice are planted by broadcasting the seed on fields that flood to a depth of 2 to 3 meters. To identify and measure the total effects of the water control system, it was first necessary to deal with the problems caused by this heterogeneity of agricultural conditions. The project area was therefore divided into six "agronomic" regions, each of which is relatively homogeneous in terms of major agricultural characteristics. The boundaries of the regions are shown in figure 1. Information on wet-season rice production in each of the regions is presented in table 1. The distinguishing characteristics of each region are as follows:

[1] The project area is made up of the following 16 sub-projects: Pholathep, Tha Boi, Sam Chuk, Sam Chuk Extension, Pho Phraya, Boromathai, Channasut, Yang Mani, Phak Hai, Maharat, Noi-Maharat Extension, Manorom, Chong Khae, Khok Krathiam, Roeng Rang, and Nakhon Luang.

Table 1. **Agronomic regions of project area**

Agronomic regions	Total rice area	Percent rice area broadcast	Avg. percent rice area harvested	Avg. yield 1965-1969 (harv. area)
	hectares			**kg/ha**
NW	109,000	35	99	2,470
WT	40,000	6	97	2,240
WTT	83,000	47	97	2,190
SE	152,000	99	95	2,170
CB	149,000	92	90	1,860
ET	64,000	16	97	1,940

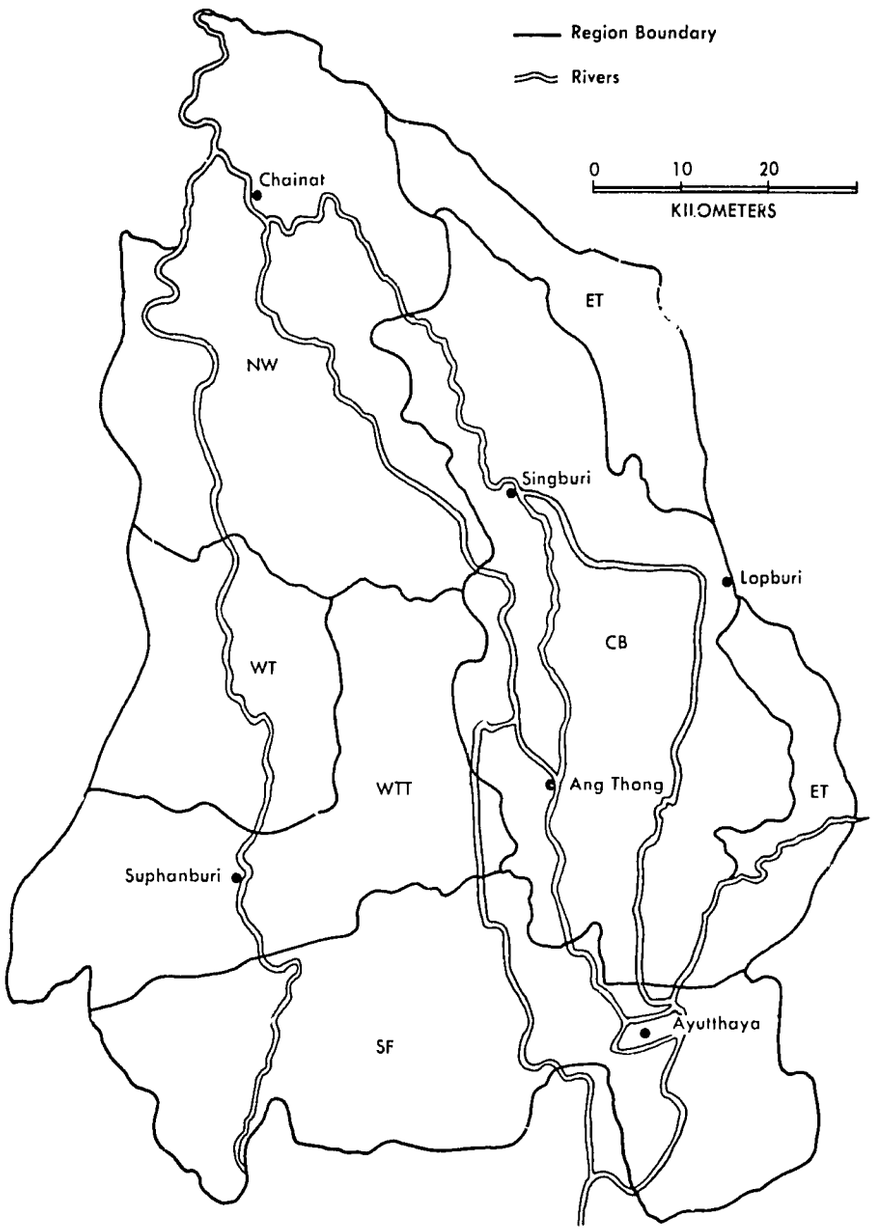

Figure 1. **Agronomic regions of the project area.**

1. ***Northwest mixed transplant–broadcast rice region (NW).*** This region has a complex pattern of higher land, where transplanted rice is grown, and lower areas where the seed is broadcast. Average yields are the highest of all the agronomic regions.

2. ***Western transplanted rice region (WT).*** Being a relatively high area with little flooding, the rice here is almost entirely transplanted. Dry-season cropping is more important than in other regions.

3. ***Western transplanted rice transitional region (WTT).*** This is a heterogeneous region in which there is a gradual transition from the characteristics of the WT region to those of the CB and SF regions.

4. ***Southern floating rice region (SF).*** Floating varieties of rice are grown throughout this area because deep flooding occurs every year. Average yields are the lowest of all the agronomic regions.

5. ***Central broadcast rice region (CB).*** Consisting of the Chao Phya River and its flood plain, most of the region is flooded deeply every year. Rice, often of the floating varieties, is planted by broadcasting throughout most of the area. Yields show large fluctuations from year to year.

6. ***Eastern transplanted rice region (ET).*** This region consists of those parts of the terrace along the eastern edge of the Central Plain that are included in the Greater Chao Phya project. Most of the rice grown on this terrace is transplanted.

Returns to Past Investments in Water Control

Benefits from water control facilities have been mainly in the form of increased rice production in the wet season, although some increase in dry-season production of rice and other crops has occurred as well. Because weather conditions cause year-to-year fluctuations in both yields and the area planted, it was difficult to isolate the effects of the project from seasonal factors and underlying trends that would have persisted in the absence of the project; however, an attempt was made to measure separately the effects of the project on:

1. the area damaged by either excessive flooding or inadequate water,
2. the proportion of the area transplanted rather than broadcast,
3. average yields and the variability of yields from year to year, and
4. the area planted to rice and other crops in the dry season.

The estimated increment in total production attributable to water control structures was then converted into value units based on past

and projected prices. Subsequently, estimates were made of the costs associated with constructing and maintaining the water control facilities and of the increments in farm costs attributable to changes in production practices or the area planted as a result of better water control. Finally, rates of return to total costs were calculated using conventional benefit/cost procedures.

Reduction in damaged area

One of the major purposes in constructing the Greater Chao Phya project was to reduce the frequency and severity of crop failures caused by unfavorable weather conditions. Because variations in weather conditions result in large annual fluctuations in the amount of damaged area, an attempt was made to separate the effects of any random differences in weather conditions from the effects of the water control system. Regression techniques were used for this purpose, with the effects of the water control system represented by a zero–one dummy variable. Observations for years before the system was in operation (1955-1961) were assigned a value of zero, while observations for the years 1962-1969 were given a value of one. This procedure made it possible to estimate statistically the realtionships existing before and after the system was completed. The weather variables included in the analysis were derived from rainfall observations in the area and from water flow measurements on the Chao Phya River.

The analysis indicated that since the project was completed, the proportion of the planted area that is left unharvested has decreased. However, this change is not attributable to differences in weather between the before and after periods. The decrease in unharvested area has been concentrated in those regions that do not flood deeply (the NW, WT, WTT, and ET agronomic regions). Little or no decrease in the extent of damage has occurred in the nearly 50 percent of the project area that is deeply flooded each year (the CB and SF regions). For the entire project area, the average portion damaged annually is estimated to have decreased by approximately 17,000 hectares. Consequently, the average annual production is estimated to have increased by about 38,000 tons of paddy, which is equivalent to 3.3 percent of total production in the project area (table 2).

Increase in area transplanted

The relationship between the method of planting and yields is a complex one. Experiments have demonstrated that under certain management conditions the method of planting has no significant effect on yields. Under farm conditions, however, there is an observable relationship between the method of planting and yields.

Table 2. **Components of the estimated average annual increase in wet-season rice production attributable to water control facilities**

Source of increase	Est. avg. ann. increase (1000 metric T)	Total % production*
Reduction in damaged area	37.6	3.3
Increase in area transplanted	23.2	2.0
Net increase in yield†	106.7	9.3
Total increment	167.5	14.6

* Based on average annual production (1965–1969) of 1,150,000 metric tons.

† Computed as a residual after taking account of changes due to weather, increased use of fertilizer, pesticides and herbicides, and improved management.

In localities that are subject to deep flooding or rapidly rising waters, transplanting is likely to lead to a complete crop failure. Under such conditions, farmers consider broadcasting to be the only feasible planting method. On the other hand, in areas where transplanted rice is not threatened with destruction from deep flooding, farmers generally prefer to transplant, since they expect higher yields than if they broadcast. The reason for the expected higher yields appears to lie in the improved management conditions (especially for water and weed control) that the farmer is able to achieve in conjunction with transplanting.

The percentage of the project area planted by the broadcast method declined from 78 percent before construction of the project to 62 percent in 1969. This represents a shift from broadcast to transplanted rice of about 96,000 hectares. Part of this shift might be attributed to the increased availability of labor (from population growth) rather than to the improvement in water control facilities. To test this hypothesis, districts lying outside the project area were examined. Although population there had grown, no changes in water control had been introduced. There was no significant decrease in the proportion of the area planted by the broadcast method in these districts. Furthermore, in those districts within the project area where farmers have the option of choosing between broadcasting and transplanting, no significant relationship was found between the population density and the proportion of the area planted by the broadcast method. This evidence supports the conclusion that the change in the size of the area transplanted was due almost entirely to the improvement in water control.

No completely satisfactory method exists for estimating the increase in production that resulted from this change in the planting method. In most of the data on production, no distinction is made

between broadcast and transplanted rice. Furthermore, there is no guarantee that the average difference in yield between transplanted and broadcast rice reflects the difference actually obtained on land where the method of planting has changed. But in the absence of any better information, the average yield differentials, as estimated from the limited data available, were used to calculate the effect on total production. On the basis of these calculations, the shift from broadcasting to transplanting is estimated to have increased average annual production by about 23,000 tons (table 2).

Net increase in wet-season rice yields

Improvements in water conditions unquestionably have led to higher average yields in the project area, but the magnitude of the increase is extremely difficult to measure. The procedure followed in attempting to estimate the net effect of the project was to use time series data to determine trends and to adjust yield estimates before and after the implementation of the scheme for differences due to weather.[2] From these figures, deductions were made to reflect changes in input use that did not appear to be related to improvements in water control. Deductions were also made for the effects of the water control project on damaged area and on the planting method. Thus this third effect attributed to the project is, in fact, a residual not accounted for by other variables that could be expected to increase yields in the absence of improved water control facilities.

Regression techniques were used to estimate the change in yields in each of the agronomic regions between 1955–1961 and 1962–1969, after allowing for any differences in weather conditions in the two periods. The production effect of increased fertilizer use was subtracted from total production in the project area, since a comparison of the growth rates of fertilizer used in the project area with those outside provided no evidence that increased fertilizer use was attributable to better water control. A similar procedure was followed for the use of pesticides and herbicides, although use of these chemicals is so limited that their effect on production is nearly negligible. Examination of the data from an area not included in the project but with similar soils and climate showed that yields have risen partly because of improved management techniques. The magnitude of this effect was also estimated and subtracted from yield increases in the project area. Finally, the increase in average yields that was implied by the change in the

[2] Time series data used were from the Ministry of Agriculture and based on reports from village leaders. Although the system by which these data are generated has deficiencies, detailed investigation indicated that they can be be used to analyze trends in yields and are more reliable for this type of analysis than any available alternative data. For a fuller discussion of these points, see Small (4:155-168).

method of planting rice and by the decrease in damaged area was subtracted, leaving a residual increase in yields that was attributed to improvements in the water control system.

The estimated net increase in five of the six regions ranged from about 190 to 310 kilograms of paddy per hectare. In the SF region no improvement could be detected. For the entire project area, the rise in the average annual production resulting from this net increase in yields was estimated to be 107,000 tons of paddy, or about two-thirds of the total increment of approximately 168,000 tons in wet-season production that was attributable to the water control system (table 2).

Changes in dry-season production

Analysis of the data on dry-season crop production indicates that the water control system has been an important factor in the production of only three crops: rice, sugarcane, and watermelons. Production of crops such as vegetables and perennials has not increased significantly. For field crops such as mung beans and peanuts, the results of regression analysis indicate that production is related mainly to the amount of rainfall that occurs during the dry season.

Although some dry-season rice has been irrigated by large pumps belonging to the Ministry of Interior, there has been a pronounced enlargement of the area for dry-season rice that is produced with water from the Greater Chao Phya project. Partly because new, high-yielding rice varieties became available, production rose sharply between 1970 and 1971. In 1971, the area of dry-season rice that was dependent upon the water control system was estimated to be 9800 hectares. Most of this production took place in the WT agronomic region.

The water control system also supports the production of about 2400 hectares of sugarcane, located in the northeast corner of the WT region, near the sugar mill at Sam Chuk. Because sugarcane occupies the land throughout the year, it replaces wet-season rice, making the net increase in the value of production much smaller than the value of the sugarcane crop. Dry-season watermelon production in the area near Sam Chuk has increased markedly in recent years. The planted area rose from virtually zero in 1964 to 1600 hectares in 1969 and to 4500 hectares in 1970. This high level of production glutted the market, with a consequent sharp fall in prices. As a result, the planted area dropped to about 800 hectares in 1971.

Increased costs associated with changes in production

Both the wet-season and the dry-season production effects that have been reviewed involve changes in input use as well as changes in output. These changes were estimated from budgets based on farm

management data obtained from several previous studies. Most of the changes involved the increased use of family labor, especially for transplanting and harvesting the rice. It was therefore necessary to impute a value to family labor in order to calculate the incremental effect of the water control project on costs of production.

Additional labor was valued at its opportunity cost. In the wet season, additional labor is required during the periods of peak demand, when the opportunity cost is certainly positive. But because rice is virtually the only crop planted in the wet season, the opportunity cost of this marginal labor is the rice production that would have occurred had this labor been available for other tasks, such as more timely transplanting. Thus, the rice not produced is the real cost of such labor and since this is already reflected in the total production figure, it would be incorrect to make an additional adjustment by imputing some positive monetary value to this additional labor.[3]

In the dry season a different situation prevails, since alternative opportunities for productive use of labor are limited. Considered from the point of view of society as a whole, the opportunity cost of labor in the dry season is close to zero. For this reason no charge for either family or hired labor was included as a cost of production for dry-season crops.

Valuing net production effects

Having estimated both the gross production effects of the water control system and the changes in the cost of production associated with these incremental changes, the net benefits of the system can be determined once the product prices are known. The only difficulty involves the appropriate price to use for paddy. Because of an export tax known as the "rice premium", the price that farmers have received for paddy is much lower than the value of paddy to Thailand. It is therefore necessary to adjust the paddy price upward to reflect the fact that increased paddy production has resulted in additional government revenue. If there were no marketing costs, the appropriate price to use would be one reflecting the full value of the exported rice. Since 1 ton of paddy yields about 670 kilograms of milled rice, this would give an adjusted paddy price of 67 percent of the average export price of milled rice. In fact, of course, there are costs associated with transforming the product from paddy on individual farms to milled rice loaded on ships. These costs were first estimated (5) and then deducted from the export price. On the basis of these calculations, the minimum appropriate price to reflect the real value of

[3] This assumes that the water control system has not appreciably reduced the emigration of labor from the project area.

paddy is 54 percent of the average export price of milled rice. Using this figure, the average adjusted price of paddy for the period from 1962 to 1970 was calculated to be slightly over $.07 per kilogram. The 1970 figure was $.06, while the figure for 1971 was estimated to be close to $.05 per kilogram.[4]

Public costs

Total costs attributable to the project include those associated with construction as well as operation and maintenance. Information on these costs was obtained from the Royal Irrigation Department. The construction costs, which were incurred over a period of many years, were adjusted to current value, using a 5 percent interest rate.

Returns to public investment in the project

With estimates of both the net production benefits and the costs of the water control system, it is possible to calculate various measures of returns to the public funds invested. Two of the commonly used measures are the benefit–cost ratio and the internal rate of return. Both measures involve discounting to permit comparison of the costs and benefits at a common point in time. For the benefit–cost measure, the analyst must select the discount rate to be used. The calculation indicates the ratio of the discounted annual benefits to the sum of the construction costs plus the discounted annual operation and maintenance costs. The higher the discount rate selected, the lower will be the benefit–cost ratio. Because it is often difficult to determine the appropriate discount rate to use, an alternative approach is to calculate the discount rate at which the benefit–cost ratio would have a value of 1.0. This rate is called the internal rate of return.

Using various assumptions, a number of internal rates of return were calculated. In general these ranged from 4 to 9 percent. The calculations that are probably the most realistic are based on the use of a 25-year period analysis (1962-1986), and on a paddy price of $.07 per kilogram for 1962–1970 and of $.06 per kilogram for 1971–1986. Wet-season benefits were assumed to be at their average 1962–1969 level throughout the period of analysis, while dry-season benefits were assumed to begin in 1969 at their 1971 level, and to remain constant throughout the remainder of the period. Under these assumptions the estimated internal rates of return range from 6 to 9 percent, depending on the method used to allocate the cost of the Bhumiphol storage dam. The low estimate of 6 percent results from allocating 25 percent of

[4] The conversion from Thai to U.S. currency is based on the exchange rate of 20 *baht* to the dollar.

the cost of the dam to irrigation, which is the procedure used by the U.S. Bureau of Reclamation. But because the dam has been operated primarily for power, it could be argued that it is not appropriate to attribute such a large share of the cost of this dam to the water control system. If none of the cost of the dam is allocated to the system, the estimated rate of return is 9 percent. Lengthening the period of analysis to 45 years increases the estimated rate of return by about one percentage point, while lowering the assumed value of paddy for the period 1971–1986 to $.05 per kilogram causes the rate of return to decline about one percentage point. If it is assumed that dry-season benefits will double in 1974 and then double again in 1979, the estimated rate of return increases by about one percentage point.

These figures suggest that, while the Greater Chao Phya project has provided an important element of stability in rice production in the project area, the overall returns to the investment in water control have been modest.[5] Returns are relatively low, not because the existing system failed to achieve its potential, but because the system, as it was designed and built, had a limited capability for supporting changes in techniques of production.

Alternatives for the Future of the Greater Chao Phya Project

Although the existing system has largely achieved its potential for increasing production, further gains could be realized from new investments that might transform the water control system into one capable of supporting "modern" agricultural technology. The most important aspect of this technology involves the use of new high-yielding varieties of rice with associated increases in the use of fertilizer and chemicals to control pests. With better water control these varieties could be grown successfully in both the wet and the dry seasons. At the present time, however, water control in the wet season is generally not adequate for the use of these varieties, and the capacity of the system to support additional production in the dry season is severely limited. These problems have led to a number of proposals for improvements in the system.

Three broad types of alternative approaches to the improvement of water control were considered: (1) investment to improve conditions for wet-season production, mainly by providing additional drainage; (2) investment to promote dry-season rice production by improving the distribution system; and (3) investment to promote dry-season production of "upland" crops (crops other than rice). While each of these alternatives could be analyzed independently, it is somewhat

[5] Note again that only the crop production benefits of the system have been considered. Although small by comparison, other benefits such as improved water transportation have also accrued.

more realistic to consider their effects if they are undertaken sequentially. In each case, the marginal costs and benefits associated with the sequential development of the alternative are considered. The sum of the marginal costs (or of the marginal benefits) for each of the three alternatives is thus equal to the total cost (or the total benefits) of implementing the third alternative.

Even if no additional government investment were to be made, some increase in production in both the wet and dry season would occur. In the wet season a modest expansion in the use of the high-yielding rice varieties and their complementary technology would probably take place. Based on data from a recent study conducted in the WT region (1), it is estimated that in the four agronomic regions with relatively shallow water conditions (NW, WT, WTT, and ET), about 15 percent of the transplanted area could be profitably planted to the new varieties of rice without further improvement in water control. The total area involved would thus be 32,000 hectares, which is 5 percent of the entire project area. Assuming, again on the basis of recent survey data (1), that the average yield of the new varieties would be 30 percent higher than the average for the traditional varieties, the total increase in wet-season production would amount to approximately 21,000 tons of paddy per year.

In the dry season, production expansion would be limited by the capability of the system to deliver water by gravity. Considering the current level of production in the WT region, it is estimated that in the NW, WT, WTT, and ET regions, dry-season rice production could expand to cover two-thirds of the area that can presently receive water by gravity in the dry season. This implies a total planted area of 32,000 hectares of dry-season rice. Assuming that only high-yielding varieties are grown in the dry season, with an average yield of 2.8 tons per hectare, dry-season production would amount to approximately 90,000 tons of paddy. This is an increase of about 62,000 tons over current dry-season production. Taking account of both wet- and dry-season production, the total increase, even without any further investment in water control, could thus amount to as much as 84,000 tons of paddy per year.

Alternative 1

Better drainage is the main requirement for improved conditions for wet-season rice production (alternative 1). Improved drainage does not appear to be feasible for most of the CB and SF regions, since it is impossible to discharge the excess water that annually floods these areas. In the remaining four agronomic regions, additional drainage facilities would make possible a further expansion of the area

planted to the high-yielding rice varieties, although very little information is available for estimating the magnitude of this expansion. Presumably, areas that were transplanted before the water control system was constructed would have the most favorable conditions for the new varieties after improved drainage facilities are provided. By assuming that these varieties could be grown on all of the land originally transplanted, it can be estimated that under this alternative approximately 128,000 hectares, or about 20 percent of the project area, would be planted to the new varieties. This is an increase of 96,000 hectares, which would yield an increment in production of 64,000 tons of paddy per year. No further increase in dry-season production has been assumed, although it is possible that an improved drainage system would facilitate the production of dry-season rice in some parts of the project area as well. After subtracting the increase in costs associated with the additional wet-season production, the net benefits of alternative 1 are estimated to be $8.70 per hectare at a paddy price of $.05 per kilogram, or $10.90 per hectare at a price of $.06 per kilogram of paddy. Capitalized at 10 percent, the value of these net benefits would be $87 and $109 per hectare, respectively (table 3).

Table 3. **Comparison of additional costs and returns for alternative approaches to improvement in water control***

Item	Increase in costs or returns from implementation of:		
	alternative 1	altern. 2 following altern. 1	altern. 3 following altern. 2
	($ per ha developed)†		
1. Net cash returns at paddy price of $.05 per kg			
wet season	$ 8.70	$ 0	$ 13.20
dry season	0	13.50	4.60
total	8.70	13.50	17.80
capitalized (10%) value of total	87.00	135.00	178.00
2. Net cash returns at paddy price of $.06 per kg			
wet season	$ 10.90	$ 0	$ 16.09
dry season	0	17.50	5.90
total	10.90	17.50	21.90
capitalized (10%) value of total	109.00	175.00	210.00
3. Construction cost	55-118	23.00	187.00

* Alternative 1: Investment to improve wet-season conditions.
Alternative 2: Investment to promote dry-season rice production.
Alternative 3: Investment to promote dry-season upland crop production.

† Assuming total area of NW, WT, WTT, and ET regions (296,000 ha) is developed.

Using information from a recent engineering study (3), the drainage facilities required under this alternative are estimated to cost approximately $55 per hectare. Increased drainage, however, would result in more flooding in the lower reaches of the Chao Phya River, including the Bangkok-Thonburi area. To prevent this, an additional expenditure of not more than $63 per hectare (of land benefiting from the drainage) would be required to raise the height of the proposed flood control dikes surrounding the city of Bangkok (3). The total cost for alternative 1 is thus estimated to be between $55 and $118 per hectare. Under the assumptions used, modest net returns could therefore be expected from an investment in additional drainage that would enable farmers to increase wet-season production.

Alternative 2

To increase the production of rice in the dry season (alternative 2), it is necessary to improve the distribution of water by augmenting the existing canal system and to avoid the inundation of low-lying areas by the construction of additional drainage facilities. Because of deep flooding in the CB and SF regions in the wet season (which would destroy any structures built for dry-season water distribution), it is assumed that implementation of this alternative would be limited to the four remaining agronomic regions. If the improvements in drainage are assumed to be identical with those considered under alternative 1, the wet-season effects of these two alternatives would be the same. The difference between these alternatives thus centers on the production increase in the dry season, and on the costs of the improved delivery system. Considering the limited amount of water that will be available even after the Sirikit storage dam is completed in 1972 or 1973, it is estimated that under alternative 2 only 25 percent of the area could be planted to dry-season rice. This implies a total dry-season planted area of 74,000 hectares, or about 42,000 hectares more than under alternative 1, and results in an estimated increase in production of about 120,000 tons of paddy per year. Capitalized at 10 percent, the value of the estimated increase in net benefits would be $135 per hectare at a paddy price of $.05 per kilogram, or $175 per hectare at a price of $.06 per kilogram (table 3). Since the cost of the improved delivery system is estimated to be only about $23 per hectare (3), it is obvious that the marginal returns associated with adding alternative 2 to the proposed first alternative are very high.

Alternative 3

Proposals to increase dry-season upland crop production (alternative 3) have received the greatest attention from policy makers. This

emphasis on upland crop production reflects a long-standing effort to promote agricultural diversification as well as a more recent concern about the long-term prospects for rice exports. Four pilot projects have been established in the NW agronomic regions to gain information and experience regarding upland crops. All of these projects involve land levelling plus the construction of additional facilities to deliver irrigation water to individual farms and to remove excess water from them.

In spite of the fact that the physical improvements made in the pilot areas were designed to promote upland crops, a large proportion of the increase has been in the production of rice. A major reason for this is the nature of the soils in the project area, which are mostly heavy clays that are difficult to manage for upland crops. On the basis of a recent land suitability study (2), it is estimated that only 11 percent of the cultivated land in the NW, WT, WTT, and ET regions is either best suited for upland crops or equally suited for rice and upland crops. Another 17 percent is considered marginally suited for upland crops, but best suited for rice. The remaining 72 percent is classified as suitable only for rice. Experience to date has shown that even on many of the soils classified as suitable for irrigated upland crops, it is difficult to produce such crops profitably. To grow upland crops on these soils requires exceptional water management skills. In addition, upland crops require more labor per hectare, particularly for weeding, than does rice. Under existing conditions, a family with the equivalent of three adult workers can cultivate only 0.8 to 0.9 hectare of upland crops, whereas the same family could probably handle 1.5 hectares of rice. A third reason for the predominance of rice in the pilot areas is that the returns from upland crop production in recent years have been relatively low. This is partly attributable to low yields related to the unfavorable soil conditions, and partly due to other technical production problems that are as yet unsolved. Given the magnitude of the returns, it is estimated that even at a paddy price of $.04 per kilogram, a farmer could expect to earn as much or more from about 1.2 hectares of rice as he could from the production of 0.8 to 0.9 hectare of upland crops.

Although the purpose of the improvements in water control undertaken in alternative 3 is the promotion of upland crops, it seems more realistic, considering past experience, to base the analysis on what is likely to happen to rice production. Considering the labor constraint on the production of upland crops and the magnitude of the returns involved, the benefits of rice production are probably at least as great as those that might be derived from producing upland crops.

With additional investment in improved water distribution facilities and land levelling, some increase in wet-season yields could be

expected. Using data from the pilot projects, it is estimated that yields of the traditional varieties would rise by about 350 kilograms of paddy per hectare, whereas those of the new varieties would be about 20 percent higher than that. Production could also be expected to increase in the dry season. On the basis of experience in the pilot projects, it is estimated that the average yields of rice in the dry season would be at least 3300 kilograms per hectare, which is 500 more than those assumed in measuring benefits under alternative 2. Although the more efficient use of water that would presumably result from land levelling might make possible a larger planted area than is available with alternative 2, there is no satisfactory basis for estimating the magnitude of the increase. If the planted area were the same as in the previous plan, the capitalized value of the marginal net benefits from alternative 4 would be $178 per hectare at a paddy price of $.05 per kilogram, or $187 per hectare at a price of $.06 per kilogram of paddy. If, as seems likely from experience in the pilot projects, the average dry-season yields are higher than 3300 kilograms, or if the area planted in the dry season is larger than for alternative 2, then the increase in benefits would be even greater.

The marginal cost involved in the development of alternative 3 is estimated to be approximately $187 per hectare, most of which is for land levelling. There is, however, some evidence that the cost of land levelling might be reduced by as much as $34 per hectare where the land is prepared only for rice production. A comparison of these costs with the estimated net benefits demonstrates that, while favorable returns may be possible from the sequential implementation of alternative 3, the anticipated rate of return is considerably lower than for alternative 2.

Development strategies

Although the estimates presented for each of the three alternatives are necessarily crude, it is possible that favorable returns could be obtained from all three policies involving additional investment. The immediate implementation of alternative 3 throughout the project area would be the preferred strategy from an efficiency standpoint. But because funds are limited, it would be unrealistic to expect simultaneous implementation over the entire area. Instead, implementation of alternative 3 would result in bringing benefits to some areas but not to others. Such a strategy would therefore result in considerable inequities among farmers within the project area.

The preferred strategy from the standpoint of equity would be the sequential development of the three alternatives. Under this strategy, drainage facilities would be constructed first (alternative 1) and followed by investments made to increase dry-season rice production

(alternative 2). Finally the land levelling would be done and the water distribution improved, as proposed under alternative 3. But because the analysis indicates that the highest *average* returns are likely to be associated with alternative 2, this strategy would be economically inefficient.

A compromise strategy would be to implement the second alternative as rapidly as possible throughout the area, and then follow with investments in water distribution and land levelling (alternative 3). This compromise would result in relatively minor efficiency losses as compared with the most efficient strategy and in relatively minor equity losses as compared with the most equitable approach.

Summary and Implications

The study revealed that while the large-scale water control facilities in the upper part of the Chao Phya project of Thailand have resulted in a substantial increase in farm incomes, the rate of return to the public investment in these facilities has been modest, ranging in the neighborhood of 6 to 9 percent. The gains, which have been concentrated in those parts of the area that do not normally experience deep flooding, have been achieved mainly by reducing the risk of wet-season crop losses associated with both inadequate water and excessive flooding. Better water control in these areas has also made it possible to increase the area of rice transplanted rather than broadcast, which, under the water management conditions prevalent in the area, has led to somewhat higher yields. In addition, some increase in dry-season production, especially of rice, has occurred as a result of the project. Thus far, the project has had little effect on the production of upland crops in the dry season, a matter of some disappointment to government officials.

Deep flooding still occurs annually throughout approximately half of the area studied. Farmers in these areas have received few benefits from the water control facilities. Very large expenditures would be required to completely control the massive amounts of water that move through the river system during the wet season, making it economically impractical to attempt to prevent the annual flooding of these areas. Farmers in these areas are thus unlikely to gain substantially from further improvements in the water control facilities.

Better water control helps to create an environment in which the benefits of improvements in agricultural technology can be realized, but thus far, the existence of water control facilities in the upper region of the Greater Chao Phya project has not led to spectacular changes in technology. The major difficulty appears to be that the crucial element of the new technology in rice production — the high-yielding varieties — requires better drainage than generally exists in

the area studied. This suggests that high priority should be given to improved drainage; however, the construction of drainage canals, while improving the situation in some areas, may cause increased flooding in others. This problem substantially reduces the net benefits that can be expected from an investment to improve drainage.

The foregoing discussion suggests that the new rice technology has increased the relative advantage of rice areas that do not have drainage problems. Thus the Chao Phya area of Thailand, which has traditionally had a comparative advantage in the production of rice, may have lost part of this advantage by the development of a technology that is not readily applicable to the area. This also suggests that the Chao Phya area would reap large benefits from a breakthrough in current efforts to develop high-yielding varieties that would thrive under conditions of poor drainage and moderate depths of standing water. Such a development would again increase the comparative advantage of this major rice-producing area of Thailand, and would greatly reduce the importance of large investments to improve drainage.

The capabilities of the water control system to support dry-season production have rather consistently been overestimated. Recent experience in pilot projects demonstrates that the original investment in water control facilities may have been only from one-third to one-half of the total investment required to provide the degree of water control necessary for the widespread production of crops in the dry season. The study suggests that the required investment in improved drainage and distribution, and possibly also in land levelling, could yield favorable returns. But the argument sometimes put forward, that the original investment has created the potential for a large increase in production should a very small investment be added, is unrealistic.

Both the Thai government and international agencies have emphasized improving the water control system for the purpose of supporting the production of dry-season crops other than rice. But the technical problems associated with this type of production have generally been underestimated. And while some very useful research on the technical production problems of dry-season cropping has been undertaken in recent years, enough problems remain to make the returns to the production of many dry-season crops low and uncertain. Furthermore, the characteristics of the soils and the labor requirements suggest that any increase in dry-season production is more likely to be in the form of rice than in upland crops. Returns to resources invested primarily to increase the output of upland crops in the Chao Phya region are likely to be low.

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