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TANK IRRIGATION IN NORTHEASTERN THAILAND: THE RETURNS AND THEIR DISTRIBUTION

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PREFACE

This report is part of the work done by the University of Minnesota and Colorado State University for the U.S. Agency for International Development under the Cooperative Agreement for Economic Planning and Policy Analysis for Irrigation. The studies have been concentrated in Asia and North Africa with special emphasis on South India, Northeastern Thailand, Egypt, and Pakistan. The work in Thailand and India is focusing on small scale irrigation while that in Egypt and Pakistan is concerned with large scale projects.

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TANK IRRIGATION IN NORTHEASTERN THAILAND: THE RETURNS AND THEIR DISTRIBUTION*

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The Northeast region has long been the poorest region in Thailand. It covers 170,218 km^2 and in 1976 had a population of 15.5 million. Approximately 46 million rai[1/] are in agricultural land holdings, out of which 33.6 million rai are in paddy rice and 8.8 million rai are in field crops. Only about 1.6 million rai are irrigated. The semi-arid climate of the Northeast is primarily influenced by two monsoon winds, i.e. the wet southwest monsoon and the dry northeast monsoon. Both droughts and floods are very common. Almost 90 percent of the rainfall occurs during the period of May through October, resulting in the very distinctive difference between the wet and dry seasons. The average annual rainfall of the region during the period 1951-1975 was 1,400 mm., which compares favorably with the rest of the country. However, the rainfall is both unequal in distribution within the region and highly variable from year to year. In addition, soils are low in fertility with some areas of high salinity and others with low water-holding capacity. In short, the natural resource endowments of the region are poor.

Besides the scarcity of water and low quality of soil, the large, rapidly growing and poorly education population makes the situation worse.

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1/ 1 Hectare = 6.25 rai,
1 Acre = 2.53 rai, or
1 Rai = 1600 m^2

While the nationwide compulsory education level has been raised from elementary grade 4 to grade 7, only 75-80 percent of the children in the Northeast are able to complete even the grade 4 level. The rural poor rely mainly on rice for food, protein intake is very low, and malnutrition is common. Potable drinking water is scarce. The doctor per population ratio is 1:50,000 while the national average is 1:9,000.

Even though the Northeast region has about one-third of both the land area and population of Thailand, the region contributes only approximately 17 percent of the nation's Gross Domestic Product (GDP). The average growth rate of real GDP from the Northeast region during 1967-1971 was 5.5 percent while the average growth of the whole kingdom was 7.2 percent. Income per capita in the Northeast during the 1967-1971 period was approximately 48 percent of the whole kingdom average. The average regional growth rate of per capita income during the same period was only 2.8 percent compared to the national average of 4.6 percent.

Rice, mainly glutinous, has long been the major crop grown in the wet season. The combination of low soil fertility and unreliable rainfall causes a relatively low yield for rice. The Northeast average yield during 1973-1977 of 189 kg/rai was the lowest of all four regions. The average yields in the North, Central, and South were 350 kg/rai, 307 kg/rai, and 272 kg/rai, respectively.

Irrigation has always been considered by the Thai's as a prerequisite for improving rice cultivation techniques and rice production. While the Central region has more than 60 percent of the total irrigated area of the nation, the Northeast region has only about 10 percent. Even though upland crops such as cassava have gained popularity, rice is still the major source of income for the majority of the population in the Northeast.

Development Setting

During the first two Plans for National Economic and Social Development (1961-1971), the Royal Thai government placed investment priority on the provision of basic infrastructural services such as highways, irrigation facilities and power systems. This development strategy has contributed significantly to the increase in the national economic growth rate. However, in an evaluation report of the past development plans, it was pointed out that:

> "Although the overall growth rate was satisfactory, the nature of growth led to further income disparities among various income groups and regions of the country. This income disparity can be partly explained by the fact that the past development strategy, emphasizing economic efficiency and overall growth rate of income and production, neglected the distribution of the benefits of growth to the majority of the population. Those who have had access to the economic and social infrastructural facilities that were provided by the Government gained the most, while those in remote areas, which have received little attention from the Government because the national efficiency criteria ruled out such public investments, lost out" (NESDB, p. 5).

Taking the equity problem seriously resulted in adoption of a new set of development objectives and priorities in the Third and Fourth Plans. The Third Plan (1972-1976) emphasized the improvement of the economic structure and the maintenance of economic stability through increased production, along with a reduction of income gaps and inequitable distribution of social services. In both the Third and Fourth Plans, explicit policy measures were included for improving income distribution. Greater emphasis was also given to regional and rural development.

Analysis presented in the Fourth Plan showed that the increasing interregional economic disparities stemmed from two important economic structural problems. First, the production structure of the Central region was more diversified than that of other regions, especially diversification in the industrial sector; while other regions, especially the South and the Northeast depend on a very few agricultural crops. Second, most of the increase in the levels of agriculture and industrial production were in the Central region. In other regions, production expanded slowly and most of the increase in agricultural output was achieved through an expansion of cultivated area rather than an increase in productivity.

There are several poverty-stricken areas in the Northeast, particularly in Mahasarakham, Kalasin and Roi Et provinces. These provinces have a very high population-land ratio and are experiencing considerable out-migration. To improve the income situation, increased effort is aimed at speeding up work on the comprehensive package programs for rural development, small irrigation improvement and job promotion for the local people. Agriculture is considered as the main target for development in the Northeast region.

Problem Statement and Objectives

Both the distribution and the amount of rainfall contribute to the low productivity of agriculture. In order to increase agricultural production and farm income, measures were sought to capture the excess rainfall during the rainy period for use in irrigation during both the wet and dry crop seasons.[2/]

To help provide water for a greater number of farmers and villages the government embarked on a program to construct small reservoirs or tanks. The construction program was started in 1951. However, many tanks were left with only partially completed distribution facilities or none at all. For those which had a complete distribution system, many had no provision for maintenance and the channels became useless due to siltation.

By 1979, there were 544 tanks of all sizes in the Northeast, with a combined total storage capacity of approximately 895 million cubic meters. Besides providing water for humans and animals, they irrigate approximately 137,333 hectares of land (see Table 1).

The emphasis prior to 1955 was on small tanks, with about 86 percent from 0.1 mcm. to 5.0 mcm. in size. After 1955, the emphasis shifted to the bigger tanks. During 1971-1975, no new tanks were built. The construction of new tanks resumed in 1976 with emphasis on construction of very small tanks. About 95 percent of those built from 1976-1979 were less than 1 mcm.

Recently, the government with help from USAID has started to rehabilitate some of the older tanks and at the same time, the government has begun to pay more attention to the economic performance of the tanks. This effort is hampered because very little information exists concerning their economic performance.

[2/] There are two crop seasons in the Northeast. The rainy season is May through October while the dry season is November through March. There is very little rain in the dry season and cropping is dependent on irrigation. Although 90 percent of the rainfall comes in the wet season, there are generally dry spells of 2 to 3 weeks or a severe drought. During these dry periods, irrigation can prevent serious damage to the wet season rice crop.

TABLE 1. Distribution of Tanks Classified by Storage Capacities and Year Construction Started

STORAGE CAPACITY IN MILLION CUBIC METERS

Year Started	Less than 0.01		0.01 - 0.10		0.10 - 1.00		1.00 - 5.00		5.00 - 10.00		10.00 - 20.00		20.00 - 30.00		30.00 +		TOTAL		
	No.	Capacity	No.	Capacity	No.	Capacity	No.	Capacity	No.	Capacity	No.	Capacity	No.	Capacity	No.	Capacity	No.	Capacity	Irrigable Area (Ha)
Before 1955	-	-	4 (3.80)	0.27 (0.14)	46 (44.20)	20.13 (10.39)	44 (42.30)	84.54 (43.66)	8 (7.70)	51.80 (26.75)	2 (1.90)	36.87 (19.04)	-	-	-	-	104 (19.1)	193.61 (21.63)	25,782 (20.95)
1956 - 1960	-	-	2 (8.70)	0.12 (0.16)	6 (26.10)	1.84 (2.44)	9 (39.10)	25.10 (33.31)	4 (17.40)	22.89 (30.37)	2 (8.70)	25.41 (33.72)	-	-	-	-	23 (4.2)	75.36 (8.42)	15,024 (10.93)
1961 - 1965	-	-	-	-	1 (7.70)	0.12 (0.10)	7 (53.80)	21.61 (17.76)	1 (7.70)	6.42 (5.28)	-	-	4 (30.80)	93.53 (76.87)	-	-	13 (2.4)	121.68 (13.95)	16,976. (12.36)
1966 - 1970	-	-	-	-	1 (4.0)	0.94 (0.28)	5 (20.00)	12.84 (3.76)	6 (24.00)	36.48 (10.69)	6 (24.0)	76.02 (22.27)	4 (16.0)	105.04 (30.77)	3 (12.00)	110.25 (32.24)	25 (4.6)	341.37 (38.14)	35,379 (25.76)
1971 - 1975	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0
1976 - 1977	4 (26.7)	n.s.	1 (6.70)	0.06 (0.12)	6 (40.00)	1.79 (3.55)	1 (6.70)	5.0 (9.90)	1 (6.70)	9.6 (19.03)	1 (6.70)	13.0 (25.77)	1 (6.70)	21.0 (41.63)	-	-	15 (2.8)	50.45 (5.64)	6,794 (4.94)
1973 - 1979	92 (25.30)	n.s.	58 (15.9)	3.92 (3.48)	199 (54.70)	77.95 (69.24)	14 (3.8)	23.91 (21.24)	1 (0.30)	6.8 (6.04)	-	-	-	-	-	-	364 (66.90)	112.58 (12.57)	34,378 (25.03)
Total	96 (17.60)	n.s.	65 (11.90)	4.37 (0.49)	259 (47.60)	102.77 (11.48)	80 (14.70)	173.00 (19.33)	21 (3.90)	133.99 (14.97)	11 (2.00)	151.30 (16.90)	9 (1.70)	219.57 (24.53)	3 (0.60)	110.05 (12.30)	544 (100.00)	895.05 (100.00)	137,333 (100.00)

Thus, the primary objectives of this study are to: (1) estimate the economic cost and benefit of the tank projects and (2) determine whether or not the distribution of tank benefits conforms with the government's concern for improving the distribution of income.

Study Area and Sample

Five sample tanks were chosen in the three low income provinces mentioned above. These tanks -- Huai Sathot, Huai Kaeng, Huai Aeng, Nong Ya Ma and Nong Krathum -- range in capacity from 2.5 mcm. to 36.6 mcm. and in irrigated area from 2,500 to 18,000 rai (see Table 2).

Huai Sathot tank is classified as a steep tank because the watershed is surrounded by mountains from which there is rapid runoff. While the rapid runoff results in frequent floods, there is little water in the streams during the dry season. To reduce both flood and drought hazard, RID initiated construction of a tank in 1967 and completed it in 1969. The reported irrigated area for supplemental wet season irrigation is 8,000 rai. However, due to the undulating topography the actual irrigated area was estimated to be only 4,717 rai (RID-IRRI).

Huai Kaeng was constructed in 1966 but one of the main canals was not finished until 1976. The watershed area is also mountainous and even though the area is not as steep as the Huai Sathot area, farmers are faced with similar problems of flood and droughts. The estimate of actual irrigated area for the wet season cultivation is 5,673 rai, whereas the reported figure is 15,000 rai. This tank is a very large tank with a storage capacity of 36.63 mcm.

The watershed area of Huai Aeng's reservoir has an undulating topography with the paddy fields on a slightly sloping plain. Construc-

TABLE 2. General Description of the Five Study Tanks

	Huai Sathot	Huai Kaeng	Huai Aeng	Nong Ya Ma	Nong Krathum
1. Province	Kalasin	Kalasin	Roi-Er	Kalasin	Mahasarakham
2. Construction Period	1967-1969	1966-1976	1963-1964	1953-1956	1958-1959
3. Geography*	Steep (36%)	Steep (20%)	Flat (13%)	Intermediate (n.s.)	Flat (n.s.)
4. Capacity (Mcm)	11.65	36.63	21.89	2.55	2.52
5. Catchment Area (Km^2)	61.00	149.00	147.50	112.50	38.00
6. Surface Area (Rai)	1,093	5,326	4,565	1,029	1,630
7. Depth (m)	12.00	10.00	6.50	4.30	2.85
8. Irrigable Area (Rai)	8,000	15,000	19,000	3,800	2,500
9. Irrigated Area (Rai)	8,000	15,000	18,000	3,800	2,500
10. Construction Cost (Million Baht) (current price)	9.15	25.58	6.92	1.67	1.47
11. Construction Cost (1975 price)	16.18	42.94	14.82	4.02	3.13

*Numbers in the bracket are the coefficient of runoff. The runoff coefficient is high for the steep tank (Huai Sathot) and declines as one approaches the plain area (Huai Aeng). (Sudchookart, Juntharasri, and Early)

SOURCE: Royal Irrigation Department
n.s. = not specified.

tion started in 1963 and was finished in the following year. The actual irrigated area appears to be very close to the reported figure of 18,000 rai.

Nong Ya Ma is a small tank of only 2.55 mcm. storage capacity and a reported irrigated area of 3,800 rai. It is located in an intermediate sloping terrain. It was built in the early period with construction starting in 1953 and completion in 1956.

Nong Krathum is another small tank. It was constructed from 1958-1959 on the flat plain. While the irrigated area reported by the RID's head office is 2,500 rai, records kept at the local office show an irrigated area of only 825 rai.

All five study tanks were constructed to provide supplementary water for wet season rice irrigation, dry season irrigation for a small acreage and water for domestic uses in the dry season. Within the tank command areas, rice occupied most of the irrigated land in the wet season.[3/] Although approximately 90 percent of the command area was left idle in the dry season, there appears to be enough water to irrigate a larger proportion of the area in the dry season.

The field survey was conducted in 1979, and 123 sample farms with irrigation and 63 farms without irrigation (rainfed) were randomly selected for the interviews. The "with irrigation" group of farmers were selected from the lists of members provided by the Water Users Association (WUA) within each tank. The "without irrigation" group was drawn from lists provided by Phuyai Ban (village headmen) of the villages near the project

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3/ The command area is the area that can be irrigated by the project. In most cases the command area is never totally irrigated.

areas. It is important to note that none of these lists of farmers were complete. However, these were the only lists available. A more complete list can be obtained only by conducting a complete farm census in the study areas. From the lists used in this study, only simple random sampling was possible.

Techniques of Analysis

The study employed conventional project appraisal accompanied by sensitivity analysis. The results are summarized in the form of internal rate of return (IRR), benefit-cost ratio (B/C) and net present value (NPV).[4/] While the internal rate of return represents the average rate of return on capital over the project lifetime, the benefit-cost ratio is simply the ratio of discounted total benefits over discounted total costs and the net present value is the discounted benefit minus discounted costs.

Four categories of benefits from the tanks were defined as follows:

1) supplemental water for wet season rice irrigation which will be referred to as wet season benefits (WB),

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[4/] Their mathematical formulas are as follows:

IRR

$$0 = \sum_{t=1}^{n} \frac{B_t - C_t}{(1 + i)^t}$$

NPV

$$NPV = \sum_{t=1}^{n} \frac{B_t - C_t}{(1 + r)^t}$$

B/C

$$\frac{B}{C} = \frac{\sum_{t=1}^{n} \frac{B_t}{(1 + r)^t}}{\sum_{t=1}^{n} \frac{C_t}{(1 + r)^t}}$$

where B_t = project benefit in year t.

C_t = project cost in year t.

i = internal rate of return or that discount rate which makes the NPV zero.

r = discount rate.

n = project lifetime.

2) water for dry season irrigation or dry season benefits (DB),

3) water for human consumption and domestic uses or consumption benefits (CB),

4) water for livestock or livestock benefits (LB),

5) water for fish culture or fishery benefits (FB).

Thus, total benefits (B_t), when appropriately discounted, are:

$$B_t = WB_t + DB_t + CB_t + LB_t + FB_t \tag{1}$$

Wet Season Benefits (WB)

Wet season crop production benefits are measured by the difference in net income between irrigated farms and rainfed or non-irrigated farms. Since most of the irrigated land is planted to rice during the wet season, only the benefits from increased rice production are considered. The present irrigated rice land had three main types of past land uses; i.e., rainfed rice, field crops, and idle land. Without the existing tanks, the first two categories of land use would probably still exist today in the same fashion as before. However, idle land would have been eventually put into cultivation of field crops, depending on the rate of increase of farm population and crop prices. Since the present irrigated rice area is composed of these three different past land use patterns, the benefit estimation has to be different for each past land use. The three different benefit estimations are summarized as follows:

$$WB_t = [(Y_{IR_t} - Y_{NI_t})a_1 + (Y_{IR_t} - Y_{F_t})(a_2 + a_3ut) + (Y_{IR_t} \times a_3)(1 - ut)]Aw_t;$$

$$\text{when } t \leq 10 \tag{2}$$

$$WB_t = [(Y_{IR_t} - Y_{NI_t})a_1 + (Y_{IR_t} - Y_{F_t})(a_2 + a_3)]Aw_t; \text{ when } t > 10 \tag{3}$$

where Y_{IR_t} = average net income per rai from irrigated rice,

Y_{NI_t} = average net income per rai from non-irrigated rice,

Y_{F_t} = weighted average net income per rai from field crops

a_1 = percentage of present irrigated rice area which was under rice production before the construction of the tank,

a_2 = percentage of present irrigated rice area which was under field crops before the construction of the tank,

a_3 = percentage of present irrigated rice area which was left idle before the construction of the tank,

u = rate at which the idle land would have been converted to field crops without the tank,

t = 0, 1, ..., or representative year,

Aw_t = wet season irrigated area in year t.

The first term in equations (2) and (3) simply represents the change in net income due to irrigation of land that was originally rainfed rice land. The second term accounts for the change in net income due to irrigation of land which was originally producing field crops, including idle land (a_3ut) which over time would likely have been converted to field crops. The third term shows the change in net income due to growing irrigated rice on land which would otherwise have been idle. The area of the idle land decreases over time because of the assumption that part of it would have been converted to field crop production. For simplicity, it is assumed that the idle land is decreased by 10 percent each year for 10 years; i.e., $u = .10$. This is a conservative assumption since land, particularly for the tanks constructed in the 1950's, would have stayed idle longer than 10 years. The over-estimation of the opportunity cost of non-irrigated land means an under-estimation of project benefits.

The net income from irrigated rice, Y_{IR}, and non-irrigated, Y_{NI}, is computed from:

$$Y_{IR_t} = (P_{R_t} \times Q_{IR_t}) - X_{IR_t} \tag{4}$$

$$Y_{NI_t} = (P_{R_t} \times Q_{NI_t}) - X_{NI_t} \tag{5}$$

where P_{R_t} = farm price of rice in year t

Q_{IR_t} = yield per rai of irrigated rice in year t

Q_{NI_t} = yield per rai of non-irrigated rice in year t

X_{IR_t} = production cost per rai of irrigated rice

X_{NI_t} = production cost per rai of non-irrigated rice

Since 1955 rice has been subject to a high export tax which is known as the "rice premium". For example, during the period 1961 to 1970, the rice premium was about one-third of the export price. The effect of the rice premium is to reduce domestic rice prices below world prices and, therefore, the farm price does not represent the value of rice for export. Wong (1978) estimates the effects of the rice premium on trade and welfare for Thailand during 1951-1972. He estimates that in a long run equilibrium as much as 50 percent of the rice premium may be passed onto foreigners, while the other 50 percent is passed to the Thai rice farmer.

Based on Wong's estimate the average farm price from our sample farm survey was raised by 50 percent of the average 1961-1976 rice premium rate. The average rice premium rate during the period was approximately 810 Baht per metric ton of milled rice which is about 527 Baht per metric ton of paddy.[5/] The average farm price of paddy in 1978-1979 obtained from the survey was 2.40 Baht per kilogram. Adding 50 percent of the premium raises the paddy price to 2.66 Bh/kg. Both prices, the 2.40 Bh/kg and 2.66 Bh/kg, and an intermediate price, 2.53 Bh/kg, are used to estimate three different levels of net returns.

In each estimate of net returns, only one of the three paddy prices is used for the life of the project. This practice eliminates the year-to-year and long term price fluctuations. Using a constant price is equivalent to inflating past prices and deflating future prices by a price index.

The past paddy yields per rai through crop year 1977-1978, Q_{IR_t} and Q_{NI_t}, are obtained from secondary sources. The RID collected time series data for paddy yield within each irrigation project by the crop cutting method. The RID data probably overestimate yields due to the method of data collection. In the crop cutting survey every square inch of land within one rai was counted as being under production. Yet, within one rai of rice, land will be divided into small parcels by bunds which improve the distribution of water. Therefore, the actual production from one rai of land is likely to be smaller than the estimate obtained from the crop cutting survey. Consequently, it was estimated that the bund area occupied about 10 percent of total planted area, and the annual irrigated yield over time was adjusted down by 10 percent.[6/]

[5/] The conversion rate for converting quantity of paddy into quantity of milled rice is 65 percent. See more detailed discussion in "Rice Production and Consumption Data 1947-1970," by Yuavares Gaesuwan, Ammar Siamwalla, and Delane E. Welsch, Discussion Paper No. 41, Department of Economics, Thammasat University, 1974.

[6/] The non-irrigated paddy yields were based on data for Changwad (province), where all five tanks were located, published by Ministry of Agriculture. The yield data from Ministry of Agriculture was adjusted by Gaesuwan, Siamwalla and Welsch to be consistent with the publication from National Statistics Office.

For the 1978-1979 crop year, the irrigated yield data are derived from the 1979 survey and added to the RID data to provide yields for one more year. The projected future yields on both irrigated and non-irrigated land are estimated by using an average yield from the five year period, 1974-1978. The five year average then becomes the normalized yield which will be used over the remaining life of the project. This assumes that the beneficiary farmers have fully developed their irrigated farming techniques and the present technology of rice production will not change over the rest of project life. The five year average not only captures the yield of current production techniques, but also smooths out the effects on yield of any unusual years.

Cost of production in both the irrigated and rainfed areas includes the cost of hired labor, imputed cost of family labor, the cost of hiring machinery such as tractors, and the cost of purchased inputs such as fertilizer, insecticide, etc. This information was obtained in the farm survey. Since there is no consistent time-series data, the production cost is assumed constant throughout the project life.

In computing net income from field crops, only the two major field crops of the region were included, kenaf and cassava. In the past, kenaf was the most popular field crop in the region due to its high price. Recently its popularity has dropped and cassava has become the dominant field crop. This change was due to two major factors; an increase in relative price of cassava and a problem in the processing of kenaf. After harvesting, kenaf must be soaked. With the scarcity of water in the Northeast, kenaf farmers have difficulty finding water in which to soak their kenaf. The usual practice is to soak it in shallow natural ponds. This causes severe pollution problems and constrains kenaf production.

To take into account the change in area planted to the two field crops, net income per rai from field crops, Y_{F_t}, will be calculated as:

$$Y_{F_t} = [(P_C \times Q_C) - X_C]C_t + [(P_K \times Q_K) - X_K]K_t \qquad (6)$$

$$\text{and } C_t = \frac{A_{C_t}}{A_{C_t} + A_{K_t}} \; ; \; K_t = \frac{A_{K_t}}{A_{C_t} + A_{K_t}} \qquad (7)$$

where P_C, P_K = average cassava price and kenaf price during 1975/1976 - 1979/1980,

Q_C, Q_K = average yield per rai of cassava and kenaf during 1975/1976 - 1979/1980,

A_{C_t}, A_{K_t} = cultivated area of cassava and kenaf in year t,

X_C, X_K = average cost of production per rai of cassava and kenaf in 1978/1979.

C_t and K_t for years prior to 1980 are computed directly from the past data using equation (7). C_t and K_t for 1980 and later years are predicted from equations (8) and (9) using the appropriate time and the 1975-1979 average prices of cassava and kenaf.[7/]

$$C_t + K_t = 1 \qquad (8)$$

$$\text{and } C_t = \underset{(.172)}{-.448^*} + \underset{(.029)}{.061^*T} + \underset{(.433)}{1.054^*} \frac{P_{C_{t-1}}}{P_{K_{t-1}}} + \underset{(.002)}{.0002\,T^2} \qquad (9)$$

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*Indicates that the variables are significant at the 5% level. The numbers in the parentheses are the standard errors.

7/ In equation (9) C_t is estimated as a function of cassava price relative to kenaf price in the previous period and also as a function of time trend (in quadratic form). The statistical fit is quite good as shown by the R^2 of .954. The computed Durbin-Watson statistic of 1.708 suggests no positive autocorrelation.

The coefficient of the price ratio variable is positive, as one would expect. As the price of cassava goes up relative to the price of kenaf, the price ratio increases and, hence, the proportion of land planted to cassava increases. The positive trend coefficient means that, over time, a higher proportion of land is planted to cassava production.

where T = time trend; $T = 1, \ldots, 13$,

$P_{C_{t-1}}$ = cassava price lagged one year,

$P_{K_{t-1}}$ = kenaf price lagged one year.

The irrigation in each tank did not cover the whole irrigable area immediately after the completion of the tank. Each project required an "expansion period" or "developmental period". The irrigated area expanded each year at the beginning of the project and after a length of time the expansion tapered off. For example, the irrigated area for Huai Aeng tank went from 1,093 rai in 1965 to 9,895 in 1970 and 18,000 in 1978 (see Appendix A). Such expansion is related to two primary factors. First, the expansion of water distribution facilities, such as main, secondary, and tertiary canals, depends on the availability of budget and manpower. Second, the beneficiaries need a period to adjust to the water distribution system and to adopt irrigated farming techniques.

Since the five tanks have been in operation for about 10-15 years, each is assumed to have reached its full development and, therefore, the present irrigated area will remain constant. Unfortunately, the RID has only a rough estimate of the area currently being irrigated. Irrigable and irrigated area of most tank projects published by RID are generally estimated by using a rule of thumb, i.e. about 90 percent of total command area. Such across-the-board estimates cause inaccuracies in the estimation of irrigated area. Recently the RID-IRRI research team did a survey of irrigable and irrigated area within Huai Sathot, Huai Kaeng and Huai Aeng.[8/]

8/ RID-IRRI stands for a joint research project between Royal Irrigation Department and International Rice Research Institute.

By using a plane table survey, they estimated the irrigable and irrigated areas for the three tanks. These figures and the RID estimates will be used to provide a sensitivity analysis (see Table 3).

Of the two sets of data the lower irrigated areas reported by the RID-IRRI research team for the three big tanks and the RID local office for Nong Krathum are probably the more accurate. This is based on two factors. First, the RID-IRRI estimates were the results of a survey of each tank command area rather than the RID rule of thumb. Second, the informal conversation with the local RID personnel, the Water User Association and the farmers in the project areas strongly suggest that the lower estimates are more reliable.

Dry Season Benefits (DB)

Without irrigation, crops cannot be grown during the dry season in the Northeastern region. Any cultivation and net income earned from dry season crop production is the result of irrigation. The formula for computing dry season benefit is simple compared to the one for wet season benefits.

$$DB = (Yd_t)Ad_t \tag{10}$$

where Yd_t = net income per rai earned from dry season cultivation in each year t.

Ad_t = area under dry season cultivation in each year t.

Obtaining accurate information to estimate dry season benefits is not simple. As mentioned above, not many farmers in the Northeast grow dry season crops. Those who do, grow on only very small plots. Within

TABLE 3. Two Estimates of Wet Season Irrigable and Irrigated Area (RID's and RID-IRRI's)

	Huai Sathot	Huai Kaeng	Huai Aeng	Nong Krathum
	------------------ Rai ------------------			
RID				
1. Irrigable	8,000	15,000	19,000	2,500
2. Irrigated	8,000	15,000	18,000	2,500
RID-IRRI				
3. Irrigable	9,350	10,246	22,742	2,500
4. Irrigated	4,717	5,673	17,885	825*
(4 ÷ 3) x 100	50.45	55.73	78.64	33.00
(4 ÷ 2) x 100	58.96	37.82	99.36	33.00

*There is no RID-IRRI report in Nong YaMa and Nong Krathum. However, with cooperation from local irrigation office in Mahasarakham province, a list of irrigated farmers in the Nong Krathum area and the size of their irrigated land was obtained. There are 90 farm families which irrigated 825 rai in Nong Krathum project.

each small plot they are, with very few exceptions, growing a combination of crops. Thus, it is very difficult to estimate the dry season irrigated area, cost of production and the income earned from each crop.

From a survey conducted by the Division of Land Policy and Planning in 1976, the average net income from dry season crops was estimated at 1,287 Baht per rai. This figure is the average net income per rai, after deducting cash cost, of various dry season crops. Another study conducted earlier in the same area; i.e. Nong Wai, showed that inexperienced farmers who grow a similar mix of dry season vegetables earned approximately 504 Baht per rai as well as providing excess vegetables for consumption at home (Crump and Suetrong, 1973). If the value of vegetables consumed at home is included and the price increase from 1973 to 1978 is considered, then the net income per rai in both studies seems quite close. Thus, based on these two studies, the dry season benefits are calculated to be 1,478 Baht per rai in 1978 prices.

Since there are no time-series data on area planted in the dry season, information collected in the farm survey was used to estimate dry season cultivated area over time. For dry season, the expansion process was assumed to be slower than for the wet season because more constraints were involved (see Appendix A). Farmers were faced with possible input supply constraints for water and labor as well as wide crop price fluctuations.

Water for Human and Livestock Consumption (CB and LB)

Many villagers have to walk about 2-3 kilometers or more to the nearest water source during the dry season. There are 10 or more wells in each village that provide water of potable quality during the wet season but these wells usually dry up during the long dry season. The small natural ponds and small streams which are used by the water buffalo for cooling and drinking also dry up after the wet season.

The villagers in such places have to walk to the nearest sources and carry the water home in containers often on a simple cart pushed by one or two persons. Children of school age or old family members have to drive the livestock to find water. Irrigation projects of any type provide water for the above needs during the dry period and save time and energy for the villagers near the tanks.

Benefits from these types of domestic uses can be estimated by a number of approaches. For example, the value of water for human consumption could be estimated as follows:[9/]

$$CB = (C_I - C_N)P_C \qquad (11)$$

where C_I = average amount of water consumed per family per period of time in the project area,

C_N = average amount of water consumed per family per period of time in the area without irrigation project,

P_C = price of domestic water from the project.

A similar formula can be applied to estimate benefit of water for livestock. Since no market or market price exists for domestic water, it

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[9/] The formula does not include anything for the consumer surplus gain from a lower price for water. Assuming a linear demand function the consumer surplus would be equal to $P_N - P_C(C_N) + 1/2\ P_N + P_C(C_I - C_N)$ where P_N = price of domestic water before the tank project.

might be indirectly estimated from the opportunity cost of labor and travel time saved from collecting water. An alternative method of estimating benefits would be to ask the villagers how much they would be willing to pay for a more convenient water supply for their home consumption and for their livestock.

According to farmers who lived in the command areas, before the tanks were built, even without the tanks their wells always had some water. Though not many of their wells had water of drinking standard (villagers' standard), they did not experience any serious shortage of water for such purposes. They felt that a tank did provide them with more water for domestic and livestock uses, but such benefits are not as large as it would have been in less fortunate villages.

A survey by the Accelerated Rural Development Office shows that most villagers in the Northeast have to walk between 0-3 kilometers to get water. Assume that, without the tanks, the villagers next to the study tanks had to walk, on the average, 1 km. to get additional water. This takes them about two hours per round trip and, by using a cart, each family makes two trips per week for 17 weeks. The total time is 68 hours or 8.5 man-days per family. Wage rates per day during the dry season, obtained in the survey, were 15 Baht. Therefore, the opportunity cost of labor to collect more water is 127.5 Baht per family per season.

The opportunity cost of school age children to drive livestock to water is based on a cost of 1 Baht per day per family. This is equal to 120 Baht per family per season. The number of families in each tank project is estimated by dividing the total irrigated area (the RID estimate) by the average irrigated area per family.

Fishery Benefits (FB)

Fish production in the tanks is another potentially important benefit. It helps provide additional protein to people with poor diets, and adds extra cash income. The water stored in the tank for irrigation purposes is complementary to fish production but the water released for irrigation can be competitive as it reduces the area for fish production. The fish yield in the tank is calculated as a function of the reservoir surface area; i.e. yield is reduced as the area is reduced. One study suggests that 4,680 Baht per hectare (or about 749 Baht per rai) of surface area is an average return to expect from a small reservoir which does not receive a continuous flow of fresh water (Kloke and Manu, 1975). A Canadian consultant to the Department of Inland Fisheries in 1978 stated that the Kalasin demonstration pond could yield 2,000 Baht per rai of surface area with minimum input (AIT, p. 34).

Villagers who live near the five study tanks or the irrigation canals emanating from them reported catching some fish to supplement their diets. Some lucky days they would catch a lot of fish and sell or trade part of them. Yet there is no evidence of intensive or commercial fish production in the study tanks except that the Department of Inland Fisheries has attempted to increase the fish population by stocking the tanks. The survival rate is a low 20-30 percent. Therefore, the estimate of 749 Baht per rai of surface area appears to be more appropriate than the 2,000 Baht from the demonstration pond. Adjusting the 1975 estimate of 749 Baht per rai by the food price index, the fishery benefit becomes 891 Baht per rai of surface area in 1978 prices.

The surface area of each tank which is used to compute the fishery benefits is derived from the simple average water level in February which is in the middle of the dry season. In his study, Johnson uses the surface area of June 1 for computing the benefit from fish production (Johnson, 1979). However, fish are caught every day during the dry season and fish population is reduced significantly by the end of the dry season. The June surface area is the lowest for the year. Thus, the June water surface area is used as a sensitivity test of the fishery benefits.

Project Costs

Project costs (TC_t) includes construction costs (CC_t), operation costs (OC_t), maintenance costs (MC_t), and the cost of constructing field channels (FC_t). Thus, the total project costs when appropriately discounted are:

$$TC_t = CC_t + MC_t + OC_t + FC_t \qquad (12)$$

Most of the costs have been paid by government. However, the farmers are supposed to be responsible for the cost of digging the farm canals and the cost of cleaning and maintaining the irrigation field canals.

Due to lack of money and know-how, not many farmers have constructed field canals or farm ditches. Those who have, did not keep records on the cost of installation, either in terms of money or labor. Thus, estimates from other studies were used to estimate the cost of field channels. A study by International Bank for Reconstruction and Development (IBRD) in Lam Takhon, Phase II, estimated the cost of having unlined ditches and drains including concrete pipes at 200 Baht/rai (Naguitragool, 1979).

Another study for IBRD in 1973 which considered rehabilitation of three tanks in the Northeast, estimated the cost of field channels at 647 Baht per hectare or 104 Baht/rai (Halcrow, p. 97). The latter figure adjusted by the wholesale price index, becomes 162 Baht/rai which is very close to the 200 Baht estimate when concrete pipes are excluded. The estimates are based on the assumption that a complete system of farm ditches is properly installed. For the present situation, it is more appropriate to assume that only half of the system has been completed. Therefore, the costs of field channels will be assumed to be only 81 Baht/rai of irrigated land.

The farm survey found that most of the beneficiaries only occasionally participated in cleaning and repairing the canals by providing labor. Again, there is no record of how often and how much was spent. Therefore, it is assumed that each year each benefiting family provides one man-day of labor in cleaning and repairing the canals which is valued at 15 Baht per day.

The information on cost paid for by government is also incomplete. Construction cost is available only as total cost. Maintenance costs in the early period for some tanks appears to be missing. There is no information on maintenance cost for several consecutive years in all tanks (see Table 4). In those years in which there is no maintenance cost, the data could be either missing or there was no major maintenance. The large expenditures in 1969, 1976, and 1977 suggest that the RID let these tanks go without maintenance for a number of years before making major repairs. Also, it is right after construction that no maintenance occurs which seems reasonable. Therefore, it is assumed that there was no maintenance

TABLE 4. Construction and Major Maintenance Costs (in Baht), 1956-1980.

Year	Huai Sathot	Huai Kaeng	Huai Aeng	Nong Ya Ma	Nong Krathum
1956				1,670,000	
1957				-	
1958				-	1,469,000
				-	-
1963			7,023,000	-	-
1964			-	-	-
1965			2,365,000	-	-
1966		7,246,336	-	-	-
1967	5,525,794	-	260,000	-	-
1968	2,708,880	2,998,417	-	-	-
1969	-	-	42,500	1,047,500	-
1970	-	-	-	-	-
1971	-	-	129,200	-	-
1972	-	-	-	112,000	-
1973	-	-	-	-	-
1974	38,000	65,700	-	18,300	-
1975	-	16,000	-	-	-
1976	185,000	-	-	81,500	1,364,500
1977	75,940	1,272,400	1,510,000	1,000,000	60,000
1978	-	-	-	-	1,000,000
1979	224,400	305,500	-	76,000	330,000
1980	177,000	804,300	-	-	-

Source: Unpublished data, Royal Irrigation Department, Ministry of Agriculture and Cooperatives.

expenditure except in those years when costs were reported. While the actual cost, adjusted to the 1978 price level, will be used through 1980, the average cost per year in each tank is used as a constant maintenance cost for the remaining years.

For operation and minor maintenance cost, only part of the cost can be obtained from the records since there is no separate account for each small irrigation project. Each local irrigation office has responsibility for all RID small irrigation projects in a specified area. Part of the annual budget for each local office is used to pay the wages and salaries of persons not assigned to a particular project. The share of each project in this common cost is not specified. There are parts of the budget used to pay irrigation personnel who work on particular projects, such as the main-structure caretakers and canal caretakers. These people do both operational and small maintenance jobs. The present salaries and wages paid to people employed to work at a specific tank are increased by 10 percent to account for non-project specific costs. These costs are included as operation and small maintenance costs which are assumed constant over the project life.

Inflation and Discount Rate

All the prices and costs are expressed in constant 1978 prices. This is a common practice in dealing with inflation and price fluctuations in project evaluation (Gittinger, 24, p. 37). By using a constant price, inflation is excluded from the stream of benefits and costs of the projects. Therefore, the discount rate should not include an inflation factor.

Among the multiple market rates of interest, the interest rate on long-term government bonds is almost always the lowest market rate prevailing at any given time. The fact that there are some consumers willing to purchase government bonds implies that their time discount rate must be no higher than the bond rate. In practice, not all persons hold government bonds, and for those who hold the bonds some may have mixed motives in holding them. In his classic article, Baumol concluded that

> "... it seems safe to conclude that at least for some members of the public r percent (his assumed rate on government bonds) is the riskless rate of time preference" (Baumol, 1968).

In Thailand, during the period 1965-1969, interest rate on government bonds was 7 percent, and the rate varied between 7 and 9.5 percent during 1970-1976. The inflation rate during the former period was low, about 1-2 percent while the rate increased significantly during the latter period. The change in the bond rate during the 1970's was probably due to the increase in inflation. In the present study, 7 percent will be used as a lower end of the discount rates. Even though the real discount rate would be 5-6 percent, the slightly higher discount rate is used so that the results will be on the conservative side.

Another alternative discount rate should represent the opportunity cost of capital that has been withdrawn from the private sector. Theoretically, such a rate should be the marginal rate of return on private investment before tax. The lowest lending rate charged by the commercial bank is used as an estimate of the marginal rate of return to investment net of taxes but including an inflation factor. To obtain the appropriate rate of return, the above rate was adjusted by the prevailing business tax and the rate of inflation. The resulting rate is approximately 10 percent which is used as the alternative rate of discount.[10/]

Economic Life (n)

Since one of the studied tanks, Nong Ya Ma, is already 24 years old and still in service, the economic life use in this analysis should not be less than 24 years. At the discount rates employed in the study, any return to an investment beyond 40 years does not significantly change the results. Thus, a 40 year economic lifetime is used for the analysis. However, if the maintenance is not continued throughout the remaining project life, 40 years is too optimistic. Even if the 40 year project life is overly optimistic, it does not significantly alter the outcome of the project evaluation. For example, if the project life is dropped from 40 to 35 years, the results are unchanged. In the Huai Sathot tank, which is an economically marginal tank, the estimated benefit-cost ratio declines from 1.33 to 1.29 (net present value declines from 657,142 Baht to 567,739 Baht) when the project life is cut by 5 years. This assumes a paddy price of 2.53 Baht/kg, a 7 percent discount rate and the low estimate of irrigated area (RID-IRRI).

Net Project Returns

The results are presented under a range of alternative assumptions summarized in Table 5. One of the varied assumptions is the paddy price, which changes from 2.66 Baht/kg to 2.53 Baht/kg to 2.40 Baht/kg, respectively in Tables 6, 7, and 8. June water surface areas are used to estimate fishery

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[10/] In 1973, a World Bank study suggested that the opportunity cost of capital was 10 percent for Thailand (IBRD, 1973).

TABLE 5. Summary of Assumptions

Assumptions	Parameters
I. Paddy farm prices (P_R)	
1. Current farm price (1978)	2.40 Bh/kg
2. Shadow price (adjusted current price for rice premium)	2.66 Bh/kg
3. Intermediate price	2.53 Bh/kg
II. Dry season benefit (DB)	1,478 Bh/rai
III. Human consumption and domestic use benefits (CB)	127.5 Bh/family/year
IV. Livestock water consumption benefits (LB)	120.0 Bh/family/year
V. Fishery benefit (FB)	891 Bh/rai of surface area
VI. Cost of building the farm ditches	81 Bh/rai of irrigated areas
VII. Discount rate (r)	
1. Real social rate of discount (riskless)	7 percent
2. Real opportunity cost of capital	10 percent
VIII. Economic lifetime of the projects (n)	40 years
IX. All values based on 1978 prices	
X. Irrigated area	
Sathot (RID)	8,000 Rai
(RID-IRRI)	4,717 Rai

TABLE 5. Continued

Assumptions	Parameters	
Kaeng (RID)	15,000 Rai	
(RID-IRRI)	5,673 Rai	
Aeng (RID)	18,000 Rai	
(RID-IRRI)	17,885 Rai	
YaMa (RID)	3,800 Rai	
Krathum (RID)	2,500 Rai	
(Local)	825 Rai	
XI. Five year average rice yields		
Sathot	391 Kg/rai	
Kaeng	367 Kg/rai	
Aeng	284 Kg/rai	
YaMa	379 Kg/rai	
Krathum	296 Kg/rai	
XII. Annual operating and minor maintenance cost		
Sathot	158,400 Baht	
Kaeng	237,600 Baht	
Aeng	237,600 Baht	
YaMa	8,327 Baht	
Krathum	5,671 Baht	
XIII. Average surface area	February	June
Sathot	1,125 Rai	625 Rai
Kaeng	3,750 Rai	2,187 Rai
Aeng	2,500 Rai	1,800 Rai
YaMa	594 Rai	470 Rai
Krathum	587 Rai	380 Rai

TABLE 6. Returns on Tank Irrigation Investments (Rice Price = 2.66 Bh/kg)

	RID					RID-IRRI*				
	7%			10%		7%			10%	
ITEM	B/C**	NPV	IRR	B/C	NPV	B/C	NPV	IRR	B/C	NPV
Total Benefit										
Huai Sathot	1.86	17.11	13.10	1.34	6.49	1.39	7.72	10.10	1.01	0.25
Huai Kaeng	3.44	68.06	23.70	2.54	39.64	2.40	38.12	19.10	1.82	20.84
Huai Aeng	2.33	38.18	14.20	1.59	15.77	2.32	37.98	14.20	1.58	15.65
Nong Ya Ma	1.70	4.36	12.40	1.25	1.36	--	--	--	--	--
Nong Krathum	1.99	4.91	18.30	1.60	2.67	1.79	3.81	16.10	1.44	1.93
Agricultural Benefit										
Huai Sathot	1.17	3.39	8.20	0.82	-3.35	0.70	-6.00	4.20	0.49	-9.60
Huai Kaeng	1.76	21.11	11.50	1.20	5.10	0.68	-8.84	4.20	0.46	-13.70
Huai Aeng	1.23	6.60	8.20	0.74	-6.90	1.24	6.85	8.20	0.75	-6.71
Nong Ya Ma	0.41	-3.62	3.10	0.19	-4.51	--	--	--	--	--
Nong Krathum	0.43	-2.83	0	0.32	-3.02	0.19	-3.93	-7.80	0.13	-3.77
Domestic and Fish Benefits***										
Huai Sathot	0.69	-6.28	3.60	0.52	-9.16	0.69	-6.07	3.70	0.52	-8.98
Huai Kaeng	1.69	19.10	14.70	1.33	8.74	1.72	19.63	15.00	1.36	9.17
Huai Aeng	1.10	2.95	8.00	0.85	-4.05	1.10	2.89	8.00	0.85	-4.10
Nong Ya Ma	1.24	1.51	10.30	1.02	0.13	--	--	--	--	--
Nong Krathum	1.55	2.75	14.10	1.28	1.24	1.59	2.88	14.60	1.31	1.35

NOTE: *There are no RID-IRRI figures for Nong Ya Ma and Nong Krathum. For Nong Krathum, the second estimate was provided by the RID's local office.

**The sum of the B/C ratio from the two main groups of benefits (agricultural and domestic) is equal to the B/C for total benefits. However, this is not the case for NPV and IRR because costs would be counted twice.

***Domestic and fish benefits are not subject to paddy price changes and are, therefore, only shown in Table 6 and 9.

TABLE 7. Returns on Tank Irrigation Investments (Rice Price = 2.53 Bh/kg)

ITEM	RID					RID-IRRI*				
	7%			10%		7%			10%	
	B/C	NPV (mill.Bh)	IRR %	B/C	NPV (mill.Bh)	B/C	NPV (mill.Bh)	IRR %	B/C	NPV (mill.Bh)
Total Benefit										
Huai Sathot	1.77	15.34	12.60	1.28	5.32	1.33	6.57	9.70	0.97	-0.52
Huai Kaeng	3.36	65.71	23.30	2.48	38.14	2.36	37.23	18.90	1.80	20.27
Huai Aeng	2.27	36.60	14.00	1.55	14.84	2.22	35.09	13.90	1.53	14.09
Nong Ya Ma	1.64	3.96	12.10	1.20	1.13	--	--	--	--	--
Nong Krathum	1.93	4.65	17.80	1.55	2.49	1.77	3.73	15.90	1.43	1.86
Agricultural Benefit										
Huai Sathot	1.08	1.63	7.60	0.76	-4.51	0.64	-7.14	3.60	0.45	-10.36
Huai Kaeng	1.68	18.76	11.00	1.14	3.60	0.64	-9.72	3.80	0.43	-14.27
Huai Aeng	1.17	4.92	7.90	0.71	-7.90	1.18	5.18	7.90	0.71	-7.70
Nong Ya Ma	0.36	-3.97	2.60	0.15	-4.70	--	--	--	--	--
Nong Krathum	0.40	-3.03	-0.90	0.29	-3.17	0.17	-4.04	-9.00	0.11	-3.85

NOTE: *There are no RID-IRRI figures for Nong Ya Ma and Nong Krathum. For Nong Krathum, the second estimate was provided by the RID's local office.

TABLE 8. Returns on Tank Irrigation Investments (Rice Price = 2.40 Bh/kg)

ITEM	RID					RID-IRRI*				
	7%			10%		7%			10%	
	B/C	NPV	IRR	B/C	NPV	B/C	NPV	IRR	B/C	NPV
		(mill.Bh)	%		(mill.Bh)		(mill.Bh)	%		(mill.Bh)
Total Benefit										
Huai Sathot	1.67	13.38	12.00	1.21	4.03	1.28	5.46	9.20	0.93	-1.25
Huai Kaeng	3.28	63.44	23.00	2.42	36.70	2.33	36.37	18.70	1.78	19.73
Huai Aeng	2.21	34.85	13.80	1.51	13.78	2.20	34.56	13.80	1.51	13.62
Nong Ya Ma	1.58	3.61	11.80	1.17	0.94	--	--	--	--	--
Nong Krathum	1.88	4.40	17.30	1.52	2.31	1.75	3.64	15.80	1.42	1.81
Agricultural Benefit										
Huai Sathot	0.98	-0.33	6.80	0.69	-5.81	0.59	-8.26	2.90	0.41	-11.09
Huai Kaeng	1.59	16.49	10.60	1.08	2.16	0.61	-10.58	3.50	0.41	-14.81
Huai Aeng	1.11	3.25	7.60	0.67	-8.88	1.12	3.52	7.60	0.67	-8.67
Nong Ya Ma	0.30	-4.32	2.00	0.12	-4.89	--	--	--	--	--
Nong Krathum	0.33	-3.34	-2.10	0.24	-3.38	0.15	-4.14	-10.70	0.10	-3.91

NOTE: *There are no RID-IRRI figures for Nong Ya Ma and Nong Krathum. For Nong Krathum, the second estimate was provided by the RID's local office.

benefits in Table 9 while the February surface areas are used in Tables 6 through 8. Each table shows the benefit-cost ratio (B/C), net present value (NPV) and internal rate of return (IRR).

As mentioned above, five major forms of benefit are included in the analysis. For the big tanks (larger than 10 mgm), the government emphasized the benefit from crop cultivation or agricultural benefit; i.e. WB and DB. For the smaller tanks, the emphasis was on increasing the amount of water for human and livestock consumption and for fish production; i.e. CB, LB, and FB, which will be referred to as domestic and fish benefits. Therefore, as expected, agricultural benefits were more important for the three large tanks than they were for the two medium sized tanks. This is particularly true when the higher paddy price and RID irrigated acreages are used. In contrast, domestic and fish benefits are very important for the medium sized tanks.

Results Based on Low Irrigated Area

As indicated above, the RID-IRRI estimates of irrigated areas are probably the most accurate. These estimates are lower than the RID estimates except for Huai Aeng where they are essentially the same. For Huai Sathot and Huai Kaeng, the RID-IRRI estimates are 38 percent and 59 percent of the RID estimates.

Even when the RID-IRRI figures are used to estimate project performance, all five tanks appear acceptable. Only when the rice price is dropped to 2.53 Baht/kg and the 10 percent discount rate is applied does Huai Sathot fail to pass the economic efficiency test; i.e. benefits no longer exceed costs. As long as all benefits are counted the other four tanks

TABLE 9. Returns on Tank Irrigation Investments with Fishery Benefits Based on June Water Surface Areas (Rice Price = 2.66 Bh/kg)

ITEM	RID 7% B/C	RID 7% NPV	RID IRR	RID 10% B/C	RID 10% NPV	RID-IRRI* 7% B/C	RID-IRRI* 7% NPV	RID-IRRI* IRR	RID-IRRI* 10% B/C	RID-IRRI* 10% NPV
		(mill.Bh)	%		(mill.Bh)		(mill.Bh)	%		(mill.Bh)
Total Benefit										
Huai Sathot	1.58	11.62	11.20	1.13	2.55	1.11	2.22	7.90	0.80	-3.70
Huai Kaeng	2.78	49.59	18.40	2.01	26.05	1.72	19.65	13.00	1.29	7.25
Huai Aeng	2.06	30.49	12.70	1.38	10.25	2.05	30.29	12.70	1.38	10.13
Nong Ya Ma	1.44	2.72	10.30	1.03	0.18	--	--	--	--	--
Nong Krathum	1.49	2.46	12.70	1.19	0.87	1.28	1.36	10.40	1.03	0.12
Domestic and Fish Benefits**										
Huai Sathot	0.41	-11.77	-0.30	0.31	-13.10	0.42	-11.57	-0.20	0.31	-12.92
Huai Kaeng	1.02	0.48	7.20	0.81	-4.96	1.04	1.00	7.40	0.82	-4.53
Huai Aeng	0.84	-4.70	5.10	0.64	-9.54	0.83	-4.76	5.10	0.64	-9.58
Nong Ya Ma	1.05	0.29	7.60	0.86	-0.77	--	--	--	--	--
Nong Krathum	1.06	0.32	7.90	0.88	-0.55	1.09	0.45	8.30	0.90	-0.44

NOTE: *There are no RID-IRRI figures for Nong Ya Ma and Nong Krathum. For Nong Krathum, the second estimate was provided by the RID's local office.
**Domestic and fish benefits are not subject to changes in paddy price and are, therefore, only shown in Tables 6 and 9.

pass the economic efficiency test under all assumptions concerning rice price and discount rates. Huai Kaeng has the highest return followed closely by Huai Aeng.

Whether or not the return from Huai Aeng is as high as Huai Kaeng depends on the true irrigated areas in both projects and the paddy price. These results are surprising. An earlier preliminary analysis of Huai Sathot, Huai Kaeng and Huai Aeng showed Huai Aeng with the highest rate of return and Huai Kaeng with the lowest.[11/] There are several reasons for the change in results. First, the preliminary analysis included only the benefit from wet and dry season cultivation and not from domestic water uses and fish production. The benefits from domestic water uses and fish production amounted to over 70 percent of the total benefits for Huai Kaeng. Since it has the largest water surface area of the five tanks, it has the highest total fishery benefits. Excluding domestic and fish benefits substantially reduces the estimated returns for Huai Kaeng. If only agricultural benefits are considered, then this analysis shows the same ranking as the preliminary analysis if the lower irrigated areas are used. A second reason for the difference in the results is the different assumptions related to rice yield. In the preliminary analysis, average yield for the crop year 1978-1979 was used and assumed constant throughout the project life. In the current analysis, a time series of yield data is used for the period before 1978 and a five year average yield, 1974

[11/] Tubpun, Yuavares, Sam Johnson III, and Alan Early, "Economics of Three Tank Irrigation Projects in Northeastern Thailand," paper presented at the Workshop on Irrigation Water Management Research in Northeastern Thailand; Khon Kaen, May 15-16, 1980.

to 1978, is used to compute future benefits. The adjusted rice yield data for 1974 to 1977 are significantly higher than the survey yield from 1978-1979 for Huai Sathot and Huai Kaeng but lower for Huai Aeng. This difference helps explain why the performance of Huai Aeng as compared to Huai Kaeng is reversed.

When only agricultural benefits are counted, the benefits from all tanks but Huai Aeng drop below costs. Even Huai Aeng shows a negative NPV when the discount rate is raised to 10 percent or the rice price is dropped to 2.53 Baht/kg. This points out the importance of domestic water uses and fish production benefits. Without these benefits, none of the tanks should probably have been built since costs would have exceeded benefits.

Benefits from water for domestic water uses and fish production account for 47-77 percent of total benefits in the three big tanks and 76-93 percent of the total benefits in the smaller tanks. In all tanks, the biggest percentage of domestic and fish benefits come from fish production, i.e. 85, 93, 85, 87, and 88 percent in Huai Sathot, Huai Kaeng, Huai Aeng, Nong Ya Ma, and Nong Krathum, respectively.

As discussed earlier, the estimate of fish benefits is based solely on estimates of two measures; i.e. yield per unit of water surface area and water surface areas. If the estimate of either figure or both is incorrect, then there will be a significant error in the estimate of project profitability. When the water surface area in June is used instead of the area in February, the fish benefits drop significantly. The drop ranges from 21 to 44 percent (44 percent in Huai Sathot, 42 percent in Huai Kaeng, 28 percent in Huai Aeng, 21 percent in Nong Ya Ma and 35 percent in Nong Krathum). This decline can also be interpreted as a situation where the water surface areas stay the same but fish yields per rai are reduced by the above percentages. Even though the reductions in fish benefits have caused a considerable decline in total benefit, the results in Table 9 show no change in the sign of the NPV except for Huai Sathot.

Results Based on High Irrigated Area

When the irrigated areas reported by RID are used, the returns to all tanks except Huai Aeng improve. Huai Kaeng tank has the highest performance and Nong Ya Ma has the lowest. There are many factors that account for the high profitability in Huai Kaeng project. The large irrigated area and high paddy yield accompanied by the lowest cost of paddy production per rai are responsible for the relatively large wet season benefits. High benefits from human and livestock water consumption are based on the high estimated number of families in the project area which, in turn, depends partly on the size of irrigated area. For Nong Ya Ma, the major factor causing a relatively poor performance is no dry season cultivation in the project area.

If only agricultural benefits are considered, the B/C ratio drops significantly (approximately 40-50 percent in the large tanks and about 75-80 percent in small tanks), but Huai Kaeng tank still has the highest return. For Huai Sathot and Huai Aeng, benefits exceeding costs when the discount rate is 7 percent and the paddy price is 2.53 Bh/kg, but costs become larger than benefits with a 10 percent discount rate. Farmers in Huai Sathot have a higher paddy yield and, therefore, are hurt more by the lower paddy price. The lower agricultural benefit in Huai Sathot and Huai Aeng can be explained by their high cost of paddy production. While it costs farmers in Huai Kaeng 1.45 Baht to produce a kilogram of paddy, it costs farmers in Huai Sathot and Huai Aeng 1.62 Bh/kg and 1.90 Bh/kg, respectively. Labor costs and the opportunity cost of land seem to be the major factors causing the high production cost in Huai Sathot. In Huai Aeng the high cost of labor and chemical inputs such as fertilizer, insecticides, etc. are the two major reasons for high production costs. Lower soil fertility may explain partly why farmers in Huai Aeng apply more fertilizer than farmers in other tanks. The larger amount of labor used and, hence, the higher labor cost may be explained by the need for more labor to apply the chemical inputs. High labor cost in Huai Sathot may relate directly to higher yield as more labor is needed for harvesting, transporting, and threshing the paddy.

For the medium sized tanks, Nong Ya Ma and Nong Krathum, agricultural benefits account for only 10 percent to 24 percent of the total benefit. They are not economically feasible with only agricultural benefits even when the discount rate is 7 percent. The costs of paddy production are quite high; i.e. 1.66 Bh/kg in Nong Ya Ma and 1.96 Bh/kg in Nong Krathum. Labor cost is high in both areas. Even with a high rate of fertilizer application, compared to other projects, yields are still low in Nong Krathum. Low soil fertility seems to be responsible for the low yields and high fertilizer use. In 1978-1979, most farmers in the Nong Krathum lost all their crop due to flooding while the crops in the other four tanks were only reduced. Another major reason for low agricultural benefit in these two medium sized tanks is the low adoption of dry season cultivation.

The farmers reported no dry season crops at all in Nong Ya Ma and only a little in Nong Krathum. Farmers in Nong Krathum had not planted dry season crops before 1978-1979. They did grow rice and some other crops in 1978-1979 because they lost all their rice crop in the wet season. This may be a one-time effort to offset losses and is not likely to be sustained in the future.

Considering the full range of sensitivity analysis, the five projects pass the economic efficiency test. Of the large tanks, Huai Sathot is the marginal project with its relative high product costs and small irrigated area. Huai Kaeng and Huai Aeng have the highest returns. The domestic and fish benefits are very important for both tanks. The returns to Huai Kaeng tends to be higher than that for Huai Aeng. Yet Huai Aeng is much less sensitive to changes in the assumptions.

Income Distribution by Farm Size[12/]

Although the tank projects pass the economic efficiency test, questions still remain concerning their impact on income distribution. To determine the project's impact on income distribution, farmers are classified into three groups based on the area planted to rice. These three groups are compared to test the hypothesis that farmers with large areas of rice benefit more than farmers with a small area of rice. Farmers with large holdings generally have more wealth, education and higher social status. These farmers are also likely to have closer con-

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[12/] What has been calculated is the distribution of project benefit among farm size groups. However, the distribution within groups was not considered due to the lack of data.

tacts with irrigation personnel in order to obtain information and express their water requirements. Furthermore, the farmers with large holdings may be able to bring pressure on irrigation officials leading to the relocation of the watercourse outlets nearer to their farms (Wade, 1975).

The range of medium size farms is approximately the mean ± 0.5 standard deviation. The average area planted to rice in the sample farm survey is 21.5 rai with a 15 rai standard deviation. Thus, the small farms are less than 15 rai while the medium sized farms are 15-30 rai and the large farms are over 30 rai.[13/]

We will follow Kalter's and Stevens' (1971) suggestions and consider income distribution changed if the net benefits from the tank projects are non-proportional to the income distribution projected to occur without the project. The income distribution is adversely effected by the project if project benefits going to large farms are proportionally more than their share of current income or population. When small farms get a share of project benefit greater than their proportion of income or population, income distribution is positively effected.

Since Thai farmers do not have to pay back the government project cost, the no reimbursement model is used to estimate changes in the distribution of income. In other words, only the direct and indirect costs to the farmer will be included as costs in the analysis. The benefit estimates

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[13/] Instead of the widely used ± one standard deviation, the ± 0.5 standard deviation is used because the standard deviation is high compared to the mean. A mean ± one standard deviation would result in too wide a range for the medium size group and too small a range for the small and the large farm groups.

are also simplified for the wet season crop production. Non-irrigated rice production is used as the only opportunity cost for the tank irrigated land. This provides a slightly lower estimate of project benefits than the procedure used in the previous section. The modified procedure for estimating wet season benefits is as follows:

$$WB_{jt} = [Y_{IR_{jt}} - Y_{NI_{jt}}] A_{W_{jt}} \tag{13}$$

$$\text{where } Y_{IR_{jt}} = (P_{R_t} \times Q_{IR_{jt}}) - X_{IR_{jt}} \tag{14}$$

$$Y_{NI_{jt}} = (P_{R_t} \times Q_{NI_{jt}}) - X_{NI_{jt}} \tag{15}$$

where WB_{jt} = average wet season benefit per family in group j

$Y_{IR_{jt}}$ = average net income per rai from irrigated rice received by farmers in group j

$Y_{NI_{jt}}$ = average net income per rai from non-irrigated rice received by farmers in group j outside the project area

$A_{W_{kt}}$ = average quantity of irrigated rice land per family in group j

$Q_{IR_{jt}}$ = yield per rai of irrigated rice by farm families in group j

$Q_{NI_{jt}}$ = yield per rai of non-irrigated rice by farm families in group j

$X_{IR_{jt}}$ = production cost per rai of irrigated rice to farm families in group j

$X_{NI_{jt}}$ = production cost per rai of non-irrigated rice to farm families in group j

P_{R_t} = farm price of rice

In addition to the wet season and dry season benefits, additional benefits from human consumption, livestock consumption and fish production were estimated on an average per family basis. Each family was assumed to receive these benefits equally. The total benefits per farm family in the three groups are:

$$B_{jt} = WB_{jt} + DB_{jt} + \overline{CB} + \overline{LB} + \overline{FB} \tag{16}$$

where DB_{jt} = average dry season benefits per irrigated farm family in group j

$\overline{CB}$ = average benefit per family from water for human consumption

$\overline{LB}$ = average benefit per family from water for livestock consumption

$\overline{FB}$ = average benefit per family from fish catching

The average yield in each project area from the 1978-1979 survey is quite different from the annual yields estimated by RID. In order to correct for the problems of unusually low yields in 1978-1979, yields reported by each individual farmer are adjusted by a constant factor and then held constant over the project life. In each tank, the adjustment factor is the percentage difference between the 1978-1979 survey yields and the nine year average, 1969-1977, of the adjusted yield from the RID annual surveys.

On the cost side, project costs which have been paid from general government funds are shared by all taxpayers. Farmers, in general, are exempt from direct income tax, but they pay a 5 Baht per rai per year land tax. Rice farmers indirectly pay part of the rice export tax (the rice premium) in the form of lower farm price of rice received per unit of rice sold. Therefore, the more rice a farmer has sold, the more he has paid for the premium. As discussed earlier, Wong estimated that rice farmers bear about 50 percent of the total rice premium. Therefore, the share of each rice farmer in rice premium can be estimated by:

$$RT_{jt} = (.5)\ \overline{RT} \cdot SQ_{jt} \tag{17}$$

where RT_{jt} = the burden of rice premium per family in class j in the project area

$\overline{\overline{RT}}$ = average over time of rice premium rate

SQ_{jt} = average amount of rice sold per family in group j

Besides land tax and rice premium, the farmers are also responsible for constructing farm ditches and are also assumed to contribute one man-day per year in maintaining and cleaning the irrigation canals. The cost of farm ditch construction is 81 Baht per rai. In addition, each irrigated farm family is entitled to become a member of the Water User Association (WUA) and pay a one-time membership fee. Therefore, the cost of the project to a farm family in a particular group can be estimated as follows:

$$C_{jt} = RT_{jt} + LT_t + MC_t + FC_j + \overline{\overline{MF}} \qquad (18)$$

where LT_t = land tax

MC_t = opportunity cost of time in cleaning and maintaining the irrigation canals

FC_j = farm ditch construction costs occur only once at the beginning of the project. For each family, it is equal to 81 Baht times the number of rai in the average irrigated farm size in each group j,

$\overline{\overline{MF}}$ = one-time payment of membership fee to the Water User Association.

These estimates of project costs to farmers are on the high side. The land tax and the income from the rice premium are used to support a range of government programs and not just tank irrigation. Therefore, only a part of these payments can be attributed to the tank project. This makes our estimates of the impacts on income distribution rather conservative.

Due to the small sample size in each project area, the analysis of income distribution is done by combining the sample farms from four tanks. The sample from Nong Krathum is excluded because the farmer sampled reported heavy flood damage to the 1978-1979 crop. The distribution of benefits might not be the same if the analysis had been conducted for individual tanks. However, the average results may be more useful since the four tanks represent a range of differences in size, topography, location, soil fertility, and water use efficiency.

The above model provides an estimate of the average distribution of benefits and costs per family in each farm size. The distribution of the net benefit per rai in each group can be derived by simply dividing the per family results by the average irrigated farm size of each group. By the same token, the net benefit distributed to each group as a whole is estimated by multiplying the net benefit per family by the number of families in the corresponding group.[14/]

14/ However, the number of families that belong to each group is not known. The population list that was used for drawing the survey samples was not complete. Therefore, the number of families in each group had to be estimated. First, from the combined samples of the four tanks, the percentage of total irrigated land in the samples which belonged to each size group was computed. Second, these percentages were multiplied by the irrigated area reported by RID-IRRI. This provides the share of irrigated land that belonged to each group. Finally, the number of families in a group was then estimated by dividing the share of irrigated land in each group by its corresponding average irrigated farm size.

Results

The average sizes of paddy land holding inside and outside the projects are quite close for all three size groups in the sample survey (see Table 10). Within the project areas, the proportion of the cultivated rice land which was irrigated was 81, 75, and 61 percent for the small, medium, and large farms, respectively.

Part A of Table 11 presents the estimate of the present value of total net benefits (NPV) from the project accruing to each size group. Part B shows the present value of average net benefits per farm (NPV/farm) in each size group. Part C exhibits the present value of average net benefits on a per rai (NPV/rai) basis by size group.

In terms of benefits and costs accruing to farmers, the small and medium sized farms obtained the largest share of net benefits. While the medium sized farms have the highest NPV, the small farm group has the highest B/C ratio. If only the agricultural benefit (WB + DB) are included there is dramatic drop in benefits to all three groups. However, benefits still remain high for the medium and small farm groups.

The medium farm size also has the highest NPV/farm, but is followed closely by the small farms (Part B, Tables 11 and 12). The large farm group is a distant third in terms of NPV/farm even though its absolute area irrigated was higher than the other size groups. Finally, the NPV/rai are highest in the small farm group and decline as farm size increases (Part C, Tables 11 and 12).

The above analysis shows the absolute amount of benefits going to each class. Another comparison would be between the distribution of project benefits and the distribution of income for the respondents out-

TABLE 10. Average Paddy Land Holding per Farm Within and Outside the Project Irrigated Areas

	Within			Outside		
	Small	Medium	Large	Small	Medium	Large
Number of farms sampled	40	43	25	19	29	15
	-------	rai	------	------	rai	-------
Average paddy land	9.1	21.6	41.4	10.0	21.1	45.3
Irrigated	7.4	16.1	26.0	--	--	--
Non-irrigated	1.7	5.5	15.4	10.0	21.1	45.3

SOURCE: Field survey in 1979.

TABLE 11. Distribution of Project Net Benefits by Farm Size (All Benefits Included)

Farm Size Classes	Net Present Value (7%)	Net Present Value (10%)	Benefit Cost Ratio (7%)	Benefit Cost Ratio (10%)
A. Net Benefit Distribution by Classes				
Farm size*	--- million baht ----			
Small	37.93	27.10	16.57	15.53
Medium	46.12	32.84	8.80	8.28
Large	14.16	9.92	3.72	3.49
TOTAL	98.21	69.86		
B. Net Benefit per Farm by Classes				
	------- baht -------			
Small	48,374	34,563		
Medium	54,714	38,953		
Large	28,893	20,249		
C. Net Benefit per Rai by Classes				
	------- baht -------			
Small	6,515	4,655		
Medium	3,409	2,427		
Large	1,113	780		

*Small - less than 15 rai,
Medium - 15 to 30 rai,
Large - greater than 30 rai.

TABLE 12. Distribution of Project Net Benefits by Farm Size (Agricultural Benefits Only)

	Net Present Value		Benefit Cost Ratio	
Farm Size Classes	(7%)	(10%)	(7%)	(10%)
A. Net Benefit Distribution by Classes				
Farm Size*	--- million baht ---			
Small	16.17	11.49	7.63	7.16
Medium	23.62	16.69	5.00	4.70
Large	1.69	0.97	1.32	1.24
TOTAL	41.48	29.15		
B. Net Benefit Distribution per Farm by Classes				
	------- baht -------			
Small	20,626	14,657		
Medium	28,023	19,805		
Large	3,453	1,973		
C. Net Benefit Distribution per Rai by Classes				
	------- baht -------			
Small	2,778	1,974		
Medium	1,746	1,234		
Large	133	76		

* Small - less than 15 rai,
Medium - 15 to 30 rai,
Large - greater than 30 rai.

side the projects. Outside the project areas, 30 percent of the farmers are in the small farm group and they received about 23 percent of total rice farm income (see Table 13). The medium size farmers account for 46 percent of the farm families but earned only approximately 33 percent of total rice farm income. Only 24 percent of the farm families are in the large farm group, but they obtained about 44 percent of the rice farm income.

In comparison, the distribution of project benefits among the irrigated farms is more equal. The small farms accounted for 37 percent of the families and 39 percent of project benefits. The medium sized farms had 40 percent of the farms and 47 percent of the benefits. This leaves the large farms with 23 percent of farm families but only 14 percent of the project benefits.[15/]

The factors which caused such a distribution of benefits relate primarily to the wet season and dry season irrigation benefit. For wet season benefit, the major factor which favors small and medium sized farm groups is the higher paddy yields (Table 14). The larger the farm size, the lower the yield. There is, however, an offsetting factor. The smaller the farm size, the higher the cost of production per rai, especially the cost of family labor. These trends are consistent for farms both inside and outside of the project areas. Thus, the small irrigated farms gain the highest average net income per rai while the medium size irrigated farms

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15/ The medium and small farmers have a higher share of the benefits than their share of the population. Yet, the analysis did not cover all sources of income and one cannot conclude that the total income distribution in the project is more equal than that outside.

TABLE 13. Percentage Distribution of Project Net Benefits and Population by Farm Size

	Percentage Distribution in Irrigated Area		Percentage Distribution in Non-irrigated Area	
Farm Size (rai)	Benefit	Population	Income	Population
A. All Benefits Included				
Farm Size*		----- percent -----		
Small	39	37	23	30
Medium	47	40	33	46
Large	14	23	44	24
	100	100	100	100
B. Agricultural Benefits Only (percent)				
Small	39			
Medium	57			
Large	4			
	100			

* Small - less than 15 rai,
Medium - 15 to 30 rai,
Large - greater than 30 rai.

TABLE 14. Income and Cost of Production for Wet Season Paddy by Farm Size, 1979

Farm Size Class	Family Labor Cost	Total Cost of Production	Yield	Net Income
	(Baht/Rai)	(Baht/Rai)	(Kgs/Rai)	(Baht/Rai)
		With Irrigation		
Small	456.8	718.0	405	253.0
Medium	301.5	561.9	302	162.9
Large	227.5	484.5	261	141.9
		Without Irrigation		
Small	345.3	551.8	324	225.8
Medium	227.9	396.0	204	93.7
Large	132.2	273.5	169	132.1

have the highest increase in total net income over the corresponding group of rainfed farmers.

Another factor favoring small farmers is dry season cropping. On the average, about 15 percent of the irrigated land in the small farm group is under dry season cultivation while only 7 percent and 2 percent of the irrigated land in the medium and large farm groups, respectively, is used in the dry season.

Conclusions and Recommendations

Conclusions

On the basis of total benefits, all five tanks are economically acceptable investments. Under various assumptions, the real internal rates of return on individual tank investments ranged from 23.7 percent to 7.9 percent. Huai Kaeng and Huai Aeng show satisfactory performance under all sensitivity tests. Performance of Huai Sathot was sensitive to the size of actual area irrigated and the discount rate. Nong Krathum was sensitive to the size of water surface area (used in the estimation of fish benefits). Nong Ya Ma was sensitive to the discount rate and the size of water surface area.

Benefits from domestic water uses and fish production are very important in all tanks but particularly in the small tank where they make up over 75 percent of total benefits. More than 80 percent for the total domestic and fish benefits is due to fish production.

Among three different farm sizes, the results show that as a class the middle size farms (15-30 rai) have the highest share of benefits. The small size farms (less than 15 rai) have the next highest, and the largest farms (more than 30 rai) had the lowest share. Benefits per rai are the highest in the small farm group and declines as farm size increases.

Inside the project areas, the percentage of farmers in each farm size group was compared with the percentage share of total project net benefit. Outside the project areas, the percentage of farmers in each group was compared with the percentage share of total income earned from paddy production. The distribution of project benefits among the irrigated farms was found to be more equally divided than distribution of income among the non-irrigated farms outside the project area.

There are two major factors which caused such a distribution of benefits. First, small and medium sized farms have higher paddy yield than the large farms. The higher yields on the smaller farms is the result of more intensive farming. Farmers with a small farm use much higher quantities of labor and other inputs. Second, small farmers use their land more intensively in the dry season than the other two groups.

In conclusion, the water which was made available by these tanks not only helped to increase income and the well-being of people in the areas but also helped to improve income distribution among regions. Furthermore, inside the project area, the distribution of net project benefits from the tanks is in favor of small and medium-size farms. This pattern of distribution conforms with the Thai government objective of improving income distribution.

Recommendations

For the tank studies, if the irrigable and irrigated areas estimated by the RID-IRRI research are accurate, a high priority should be given to increasing the irrigated areas in Huai Sathot and Huai Kaeng.

Rehabilitation and modernization of both tanks so that a larger area can be irrigated has a high potential for providing a good return on investment. In addition, water distribution rules need to be developed before expanding the irrigated areas. Rules need to specify how water will be distributed during periods of water shortage. Procedures should also be established for determining the times for opening and closing the reservoir outlets. The larger the irrigated area, the more complicated become the distribution and management problems.

The potential for increasing the irrigated area appears to be much lower in Huai Aeng, Nong Ya Ma and Nong Krathum. To increase agricultural benefit in these tanks, more emphasis will need to be placed on increasing paddy yields. The low fertility of soil and inefficient water allocation appear to be major constraints in such an effort. If these prove to be the major constraints, then the tank rehabilitation should focus on improving the distribution systems and on developing rules for allocating the water.

For all five tanks a careful study of dry season cropping is imperative. Profitable cropping alternative should be developed for alternative dry season conditions including different levels of water and labor availability and different crop prices. Water distribution and marketing problems should be carefully investigated in determining the profitable dry season cropping alternatives.

Judging from the magnitude of the benefits from domestic water uses and fish production these aspects of the projects should receive more attention. This is particularly true of fish production. Added research is needed to determine the likely range of fishery and domestic water use benefits.

The difference between the RID estimates of area irrigated and the RID-IRRI estimates emphasize the need for a consistent system of data collection. RID needs to establish a system for collecting data concerning the performance of the tank irrigation projects. This would include data by season on water available, water delivered, area irrigated, farmers served, crops grown, yields by location in the command area, etc. RID badly needs this type of information to make decisions concerning tank management, rehabilitation, and new construction.

Finally, RID needs to develop a common procedure for evaluating irrigation tank projects. This means adopting one of the set evaluation procedures applied in this paper and using it consistently across all projects. If a common evaluation procedure is adopted and data is collected concerning tank performance, then RID will have a basis for making better decisions concerning future tank investments.

APPENDIX A

TABLE 1A. Tank Irrigated Area since Completion of the Tanks Based on RID Report

	Huai Sathot		Huai Kaeng		Huai Aeng	
Year	Wet Season	Dry Season	Wet Season	Dry Season	Wet Season	Dry Season
	---------------------- Rai ----------------------					
1965					1,093	–
1966					1,442	–
1967			2,344	–	1,615	–
1968			2,344	–	6,165	–
1969	3,227	–	2,344	–	6,836	–
1970	3,227	–	2,344	–	9,895	–
1971	3,227	–	2,344	–	10,193	–
1972	3,762	–	2,344	–	10,566	–
1973	4,129	–	6,328	–	12,000	51
1974	5,926	41	8,484	–	15,415	154
1975	7,045	41	11,157	–	16,857	617
1976	7,137	122	12,282	360	17,453	1,208
1977	7,889	326	15,000	675	17,453	1,414
1978	8,000	448	15,000	1,035	18,000	1,800

TABLE 1A. Continued

	Nong Ya Ma		Nong Krathum	
Year	Wet Season	Dry Season	Wet Season	Dry Season
1957	550	-		
1958	550	-		
1959	550	-	938	-
1960	1,099	-	1,279	-
1961	1,099	-	1,506	-
1962	1,099	-	1,506	-
1963	1,099	-	1,705	-
1964	1,099	-	1,705	-
1965	1,404	-	1,705	-
1966	1,450	-	1,705	-
1967	2,579	-	1,705	-
1968	3,647	-	1,875	-
1969	3,647	-	1,875	-
1970	3,800	-	1,960	-
1971	3,800	-	1,960	-
1972	3,800	-	1,960	-
1973	3,800	-	2,472	-
1974	3,800	-	2,472	-
1975	3,800	-	2,472	-
1976	3,800	-	2,472	-
1977	3,800	-	2,500	-
1978	3,800	-	2,500	170
1979	3,800	-	2,500	170

TABLE 2A. Tank Irrigated Area since Completion of the Tanks Based on RID-IRRI Survey a/

Year	Huai Sathot		Huai Kaeng		Huai Aeng	
	Wet Season	Dry Season	Wet Season	Dry Season	Wet Season	Dry Season
	Rai					
1965					1,086	-
1966					1,433	-
1967			887	-	1,604	-
1968			887	-	6,126	-
1969	1,903	-	887	-	6,793	-
1970	1,903	-	887	-	9,831	-
1971	1,903	-	887	-	10,128	-
1972	2,218	-	887	-	10,498	-
1973	2,434	-	2,393	-	11,931	51
1974	3,494	24	3,208	-	15,317	153
1975	4,154	24	4,219	-	16,749	613
1976	4,209	72	4,645	135	17,341	1,201
1977	4,652	192	5,673	253	17,341	1,406
1978	4,717	264	5,673	388	17,885	1,789

SOURCE: RID-IRRI field survey in 1979.

NOTE:

a/ See footnote in TABLE 4.8.

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