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An Economic Analysis of Traditional Water Management Institutions in Northern Thailand

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Abstract

The problem of water management in Thailand has become an issue because water resources are predicted to be insufficient for future agricultural development. In exploring relevant water management methods, an investigation of people's irrigation systems is instructive.

The objective of this article is to make an economic analysis of traditional water management institutions in Northern Thailand on the basis of a field survey. The results of the analysis are as follows.

1) The rules for maintenance of traditional irrigation systems are consistent with the individual farmer's self-motivation in a labor-surplus economy.

2) The relative scarcity of water resources in the process of agricultural development has induced a change in the traditional water management institution to alleviate the scarcity.

3) The new institution (so-called strict rotation system) has generally relieved the congestion of water utilization, but some farmers whose fields lie far from the main canal still suffer losses from the congestion.

I Introduction

In his discussion of water management in Thailand, Nakajima [1984] pointed out that easily exploitable water resources in Thailand have been exhausted, so that the marginal cost of large-scale irrigation projects has increased considerably. Also, existing facilities have not been fully utilized. Therefore, small-scale irrigation projects were considered to have a priority over large ones, as Rijik and van der Meer [1984] observed. Under these circumstances, the further agricultural development of Thailand will require the efficient use of scarce resources by farmers themselves (Suraresks [1980] etc.). This viewpoint is shared by all scholars interested in irrigation problems in Asian developing countries.[1)]

Research has been already carried out on traditional irrigation systems in Northern Thailand.[2)] Sektheera and Thodey [1974], Suraresks [1980] and Ayudhaya [1983] have elucidated the actual conditions of these irrigation systems and investigated the roles of government and people's organizations in water

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1) Coward Jr. [1980: Part II] contains a bibliography of important literature related to this subject.

2) I define the irrigation system as a concept incorporating physical equipment and human organization.

management. From the anthropological point of view, Moerman [1968], Potter [1976], Tanabe [1976] and others have investigated the relationship between the tightness of social structure and traditional irrigation institutions.

This article takes a different approach from these previous studies. It looks at the practical concern of creating appropriate irrigation organizations that will enhance the operational effectiveness of irrigation systems. In this regard, more emphasis is put on the dynamic changes within an irrigation system in the process of economic development. This is because the most appropriate water management system will be affected by economic conditions. In this way the relevancy of the induced institutional change hypothesis to irrigation institutions will be investigated.[3]

This article has two objectives. The first is to identify the conditions for intensive agriculture in the Chiang Mai Valley and to observe the changes of traditional irrigation systems there. The second is to carry out an economic analysis of traditional irrigation systems in Northern Thailand. For the latter purpose, two subjects are examined. One is the effectiveness of institutional changes in attacking the problem of scarce water resources caused by intensive production. The other is the economics of traditional regulations for weir repair and canal maintenance.

In treating the first subject, the theory of quasi-collective goods [Kuchiki 1978][4] is applied to building a theoretical model of irrigation equipment, which is regarded as public goods. In addition, the difference of productivity between the farmers who suffered a loss from the congestion of irrigation use and those who did not is examined by use of a production function analysis. After estimating labor market conditions with this estimated production function, the consistency of the individual farmer's self-motivation with the regulations is examined with regard to the second subject.

The results of this study are as follows. 1) The findings support the hypothesis that the rules for maintenance of traditional irrigation systems are compatible with the individual farmer's self-motivation in a labor-surplus economy. 2) The relative scarcity of water resources in the process of agricultural development has induced changes in the traditional water management institutions to alleviate the scarcity. 3) The new institutions (so-called strict rotation systems) have relieved the congestion of water utilization to some extent, but some farmers whose paddy fields lie far from the main canal still suffer loss from the congestion.

II Agriculture and People's Irrigation Systems in the Village

II–1. Agriculture, Geographical Conditions and Climate in the Village

The author conducted a field survey in Mubaan (village) 8, Tambon Ban Kat, Amphoe (district) San Pa Tong, Changwat (province) Chiang Mai from December 1984 to January

3) For "induced institutional change hypothesis", see Hayami and Ruttan [1971], Binswanger and Ruttan [1978] etc.

4) According to Kuchiki, the number of users of quasi-collective production goods is limited and they have to pay an extra charge for use if the demand for them exceeds the permitted quantity, because of external diseconomy or increasing cost of public service.

1985. According to the village headman (Pau Liang) and his assistants, the population of M8 is 947, the total number of households 270, and the number of farm households 206 as of January 14, 1985.

M8 is located in the valley of the Wang River (Mae Nam Wang) and lies 30 km southwest of Chiang Mai City. The basin has a floor of semi-recent alluvials and merges with low terraces, then with middle terraces toward the sideslopes of the river. This area reportedly began to be exploited at least 180 years ago.[5)] The irrigation systems in the Wang River basin are not managed by the government but by the farmers themselves. These systems have been maintained by the farmers for more than 100 years and allow the practice of triple cropping even today.

In San Pa Tong district, rain normally starts in late April and falls heavily in July [Suraresks 1980]. The rainy season in the Chiang Mai Valley continues from early July to the middle of October, and is shorter than in Central Thailand [Sawat 1973: 89-90]. The amount of annual rainfall from April to June is rather unstable. This is an important factor which has a crucial effect on the growth of dry-season rice after transplanting [Kaida 1978; Watabe 1967]. In order to grow rice, farmers must depend on the traditional gravity irrigation systems because of the instability and shortage of rainfall.[6)]

Farmers divert water by constructing traditional weirs at appropriate locations in the main canal and laterals from natural streams. These are made of locally available materials: bamboo stakes, logs, leaves and stones.

The Wang River basin contains several tens of these gravity irrigation systems of weirs canal constructed by methods that have been handed down through many generations.[7)] Irrigated areas in these irrigation systems range from 400 rai to 18,000 rai. Two of the larger weirs are made of concrete.

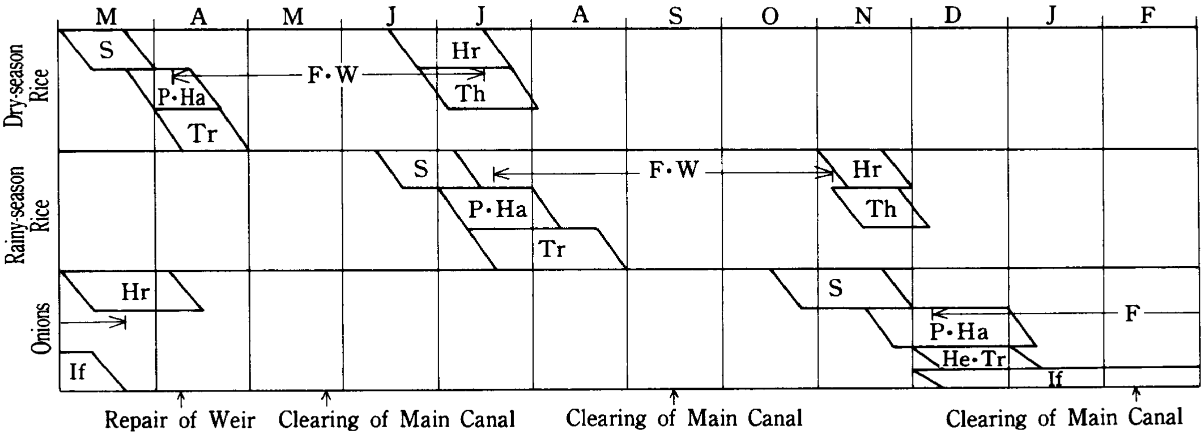
The farmers in the surveyed village practice triple cropping, typically with rainy-season rice, onions, and dry-season rice, by making use of water diverted from Wang River through two weirs (Huay Phung weir and Khung Khong weir).

In the rainy season, they usually grow glutinous rice (San Pa Tong variety, a medium-maturing rice with a growth period of 140-150 days; or RD6, an early-maturing rice with a growth period of 120-130 days). The rainy-season rice cropping usually starts in the nursery plot in the middle of June. Ploughing and harrowing are done after the heavy June rains. All the farmers use power tillers. One or one-and-a-half months after seeding, seedlings are transplanted to the paddy field. Most farmers do not need to weed in the rainy season, but some do because of poor field conditions. These latter farmers apply herbicides just after transplanting and cut weeds 1-2 months after that. Fertilizer is applied 2-4 times beginning one to two weeks after transplanting. Harvesting is usually done in October, after which the rice is dried in the paddy field for several days before being threshed in a big bamboo basket (***ku***). During

5) This information was from an interview with the headman of Khung Khong weir group.

6) See Kaida [1978]. The village headman told us that without the weir, even rainy-season rice could not be grown.

7) This information is from Lumpaopong *et al.* [1984].



S: Seeding,　P: Ploughing,　Ha: Harrowing,　Tr: Transplanting,　F: Fertilizer Application,
W: Weeding, Hr: Harvesting, Th: Threshing, If: Furrow Irrigation, He: Herbicide Application

Fig. 1 Seasonal Sequence of Farming Operations in the Surveyed Village (1983–1984)

this period, each farmer takes care to keep a depth of three inches of water in his fields.

Before the harvesting of the rainy-season rice, a seedbed has to be prepared and onion seed planted. After the rice harvest, a series of operations including making ridges, herbicide application, and straw mulching is carried out. Forty to fifty days after sowing, nursery plants are transplanted into the fields, where they are watered by furrow irrigation during the period from late March to early April.

In the dry season, non-glutinous rice (RD7, an early-maturing rice with a growth period of 120–130 days) is grown for the market. Because they must finish harvesting before transplanting the rainy-season rice, farmers start the dry-rice seedlings in March. Ploughing and harrowing are done from late March to mid-April, then transplanting is started. Irrigation, fertilizer application and weeding after transplanting are done in the same way as in the rainy season. Around the middle of June harvesting of the dry-season rice begins. Harvested rice is threshed with a threshing machine as soon as possible, lest it should get wet in the rain. In this way, the farmers in M8 have practiced very intensive multiple cropping for many years; but during the period of getting the paddy covered with water after transplanting (from April to mid-June), water shortage is often a problem.

Interviews were conducted with 70 farm

Table 1 Average Farm Household Income by Source (1984): 70 Farm Households

	Rice	Onions	Other Crops	Livestock	Capital Income	Non-agricultural	Farm Household Income (Total)
Total Income by Source(B)	468,595.5	773,710	113,026	129,804	32,149	253,495	1,770,779.5
%	26.5	43.7	6.4	7.3	1.8	14.3	100.0
Average Income by Source(B)	6,694	11,053	1,615	1,854	459	3,621	25,297

Table 2 The Distribution of Farm Households by Tenure Status

Tenure Status	Farm Households No.	Farm Households %
Landlord	1	1.4
Landlord-tenant	1	1.4
Owner	28	40.0
Owner-tenant	17	24.3
Tenant	23	32.9
Total	70	100.0

Table 3 The Distribution of Agricultural Land

Scale (rai)	Owned Area No.	Owned Area %	Cultivated Area No.	Cultivated Area %
T=0	24	34.3	1	1.4
0<T≤2	23	32.9	10	14.3
2<T≤4	11	15.7	19	27.1
4<T≤6	3	4.3	13	18.6
6<T≤8	5	7.1	18	25.7
8<T≤10	2	2.9	4	5.7
10<T	2	2.9	5	7.1
Total	70	100.1	70	99.9
Average Area (rai)	2.46		5.51	

households introduced by the village headman. Their reported sources of farm household income are as follows. Paddy growing (26.5%), onion growing (43.7%), other agricultural income (14.3%). Rice and onions thus account for 70% of farm household income (see Table 1).

The average area of agricultural land owned per household is 2.46 rai, and that of cultivated land is 5.51 rai. Inequality of land distribution is small. The percentages of owner farmers, owner-tenant farmers and pure tenant farmers are respectively 40%, 24.3%, 32.9% (see Tables 2 and 3). The dominant tenancy form is share-tenancy (*na pa*), which accounts for 80% of total tenancy contracts. In all cases, land rent is not paid for onion cropping (see Table 4).

Table 4 Tenancy Form and Land Rent

Tenancy Form		Land Rent	No.	%
Fixed Rent	No Rent	r=0	2(1)	4.0
	In Kind (*Gin ka hua*)	r≤B500	1(1)	12.0
	In Cash (*Chao lan na*)	B500<r≤B1000	3(1)	
		B1000<r≤B2000	1	
		B2000<r	1	
Share-tenancy (*Na pa*)		Rainy-season Rice — Onion — Dry-season Rice		
		30% — 0 — 0	1	78.0
		45 — 0 — 25%	5	
		50 — 0 — 0	6	
		50 — 0 — 25	9	
		50 — 0 — 33	13	
		50 — 0 — 50	5(1)	
		50 — 0 — B2500/7rai	1	6.0
		50 — 0 — B3000/5rai	1(1)	
		50 — 0 — B1500/5rai	1	
		Total	50(9)	100.0

Note. The figures in parentheses refer to tenancy contracts between relatives.

Table 5 indicates that 72.6% of family labor is taken up by growing rice and onions. This implies that employment opportunities for farmers are limited to agricultural production and that the demand for labor from off-farm sources is limited.

Finally, it is important to point out the labor market situation. In M8, there are several kinds of job opportunities outside farming such as shopkeeping, daily wage labor, agricultural wage labor, trading and

Table 5 Employment Structure of Farm Households (1984): 70 Farm Households

	Agricultural (Rice, Onion)	Non-agricultural						Total
		Agr. Wage Labor	Daily Wage Labor	Permanent Hired Labor	Shop-keeping	Trading	Others	
Working Days (man. day)	12,644	774	1,046	436	1,163	905	447	17,415
%	72.6	4.4	6.0	2.5	6.7	5.2	2.6	100.0

permanent hired labor etc. Among these, the daily income from shopkeeping varies widely from one household to another (ranging from B30 to B200). On the other hand, the wages for hired agricultural labor are B30/day for rice harvesting and transplanting, and B50/day for ploughing and harrowing paddy fields making ridges for onions. While the wage differential between different jobs is large, a single wage rate seems to apply for each job. Moreover, the monthly wage for permanent hired labor, which ranges from B700 to B1500, is equal to that of agricultural wage labor in terms of a daily wage. This suggests that the market wage rate for farmers is given.

II–2. Agricultural Development and Irrigation Systems

Farmers in M8 utilize two weirs to divert water for their fields into canals. One of them, Huay Phung weir, is constructed of large wooden logs piled on top of each other and held in position by bamboo stakes. Branches, earth and sand are dumped on top. The main canal heads above the weir and runs along the mountain foot, and from this farmers draw water directly into their paddy fields by gravity. The area irrigated by this irrigation system is 480 rai. One hundred and fifty farm households in five villages utilize this system, of which 130 belong to M8.

Khung Khong weir was reconstructed in concrete two years ago with financial support from the Royal Irrigation Department, and no longer has to be rebuilt year after year. The main canal from this weir runs through the center of the terrace plain, and contains seven small weirs (*tae*) to divert water to laterals and control water flow. The irrigated area is 8,000 rai, and the number of users is 1,147.

The Huay Phung irrigation system is not equipped to control water flow, and the slope of the river at the location of the weir is steeper than that of Khung Khong. Therefore, water flow into the Huay Phung main canal is more unstable during the water shortage season.

Huay Phung weir, being made of wood, must be repaired every year, and the canal is cleaned three times a year, but the concrete Khung Khong weir need not be repaired, and the main canal is cleaned and repaired only twice a year.

These projects are done with communal labor. The users of the irrigation systems are obliged to do the work themselves because they cannot make use of market mechanisms for the purpose of maintaining collective production goods.

The Huay Phung weir is usually repaired in the middle of April. At that time the headman of the irrigation organization (*huana fai*)[8)]

8) In case of the Huay Phung weir group, the

assigns the dates, and his assistant informs the member farmers at least five days in advance so that they can collect logs and bamboo in the state forest. It takes three days to finish driving in the bamboo stakes and cleaning the weir.

In 1984, the main canal was cleaned on one day each in the middle of February (before making nursery plots for dry-season rice), late May (before making nursery plots for rainy-season rice), and late September (before making nursery plots for onions).

Table 6 shows the guidelines for the obligations member farmers in collective work, which aim to ensure that all collective work is carried out in a timely and efficient manner. In the case of the Huay Phung users' organization, if a farmer refuses to bring building materials, he will be forced to stop drawing water from the canal. If he does not join communal work in cleaning the weir and main canal, he has to pay B50/day fine. The assistant monitors the members' compliance in order to enforce these regulations.[9] The fine for Khung Khong members is B100/time.

The number of farmers who fail to meet their duties is negligible. This seems to be closely related to the importance of agricultural production and the small inequality of land distribution.

Farmers in the Chiang Mai Valley have been agriculturally innovative, probably in response to the fragmentation of agricultural land due to population pressure. In M8, two important technological changes have taken place in the past decade. As a consequence, traditional irrigation institutions have also been forced to change.

The first technological change was the introduction of a rice-soybean double-cropping system. Although this system was widely adopted by farmers in M8 about 10 years ago, water shortage did not become a problem until about five years ago.

The second technological innovation was the adoption of the triple-cropping system with rainy-season rice, onions, and dry-season rice, which became widespread about five years ago. Since this time, water shortage after transplanting the dry-season rice crop has become acute.[10] To cope with this problem, in the second year of triple cropping farmers adopted

Table 6 Work Duties and Fines

	Repair of Weir					Cleaning of Canal	Fine
	Log	Bamboo Stake			Labor		
		Large	Middle	Small			
Huay Phung	1/2 rai	3/rai	10/rai	20/rai	3 days	1 day × 3 times	B50/day
Khung Khong	—	—	—	—	—	1 day × 2 times	B100/time

headman is elected by vote every four years. The present headman of M8 has held this position for 10 years.

9) Among the farm households who belong to both weir groups, five are exempted from their duties because the working period overlaps. They paid six tang (one tang = 10 kg) per rai of paddy rice to the headman in compensation. (Their total cultivated area amounts to 30 rai.)

10) This is also due to recent deforestation, which has reduced the capacity of natural vegetation to retain water and has caused river beds to rise because of increased sedimentation.

a rotation method of drawing water based on the headman's instructions. In previous years, the decision when to draw water had been left to individuals. Users along the main canal were divided into three groups, upstream, middle stream and lower stream, and the users in each group could draw water from canal at any time on three out of every nine days. This did not solve the problem, however, because some users in the middle stream group had paddy fields located far from the canal and could not secure sufficient water within three days.[11]

The headman therefore reintroduced a stricter rotation of water allocation, which had been used three years previously. Under this arrangement, the members in the middle stream group who still suffered a shortage were further divided into two groups, one of 10 members and one of 20. Water was distributed to the former group for one day and to the latter for two days. Moreover, rotational water allocation to individual group members was enforced, with the assistant monitoring to avoid conflict. The headman reported that these arrangements had alleviated the problem.[12]

This kind of problem has not yet arisen with the users of the Khung Khong irrigation system.

III Theoretical Framework

In this article, the theory of the subjective equilibrium of a farm household is applied in the building of a theoretical framework for economic analysis.

We consider a rural economy in which the prices of products, market labor, land, machinery and current input are fixed in competitive markets, but the market price of irrigation services is not determined. There are n homogeneous farm households which make collective use of an irrigation system. The utility function of each farm household is twice differentiable by income (Y) and (L) and is quasi-concave. We define income as

$$Y = q + w\cdot(L - l_1 - l_2) + p\cdot f + r\cdot(\bar{t} - t) + i\cdot(\bar{k} - k) - \pi\cdot(\delta - l_2).$$

Agricultural product is taken as a numeraire and notations are defined as follows.

- q : agricultural gross income.
- l_1 : family labor in farming.
- l_2 : family labor in communal work for maintenance of irrigation equipment.
- L : total family labor input.
- w : market wage rate.
- p : price of current input.
- t : cultivated area.
- $\bar{t}$: owned area.
- f : current input.
- r : land rent.
- k : capital stock used.
- $\bar{k}$: capital stock owned.
- i : rental rate of capital stock.
- δ : duty work assigned to the household.
- π : fine per unit of labor.

Output q is a quasi-concave function and twice differentiable at l_1, f, t, k and m (each user's amount of use of irrigation equipment). It is important to note the following two points. 1) Family labor supplied for communal work has no impact on the production of each farm because the amount of labor allocated is

11) According to an interview with the assistant, while it is possible to soak 10 rai of paddy field near the canal within one hour, it takes half a day to soak five rai far from the canal.

12) Some farmers still complained privately about water shortage.

negligible compared with the total labor supplied. 2) The total water available to the users is limited and the number of users is finite. Thus, we can regard irrigation facilities as quasi-collective goods [Kuchiki 1978].

The sixth term of the income equation indicates that if each farm household supplies less labor than required, such that $l_2 < \delta$, the fine for punishment is imposed on the difference $(\delta - l_2)$. This definition supports the assumption that if any member neglects his labor obligation, he will always be detected and fined because of the perfect monitoring of the assistant.[13]

Moreover, three constraints are assumed. The labor market is held to be characterized by excess supply and competitive, so that, following Arrow [1959], the market demand for labor is assumed to be limited to $\bar{l} \cdot (L - l_1 - l_2 \leq \bar{l})$. Each member is not required to work more than δ so that l_2 does not exceed $\delta \cdot (l_2 \leq \delta)$. Finally, if the total potential demand for irrigation facilities (nm) exceeds its total permitted quantity (M), the amount available to each member will be restricted to only M/n of irrigation facilities.

Under these assumptions, each farm household maximizes its utility over l_1, f, t, k, m, l_2 and L, subject to $L - l_1 - l_2 - \bar{l} \leq 0$, $l_2 - \delta \leq 0$ and $m - M/n \leq 0$. In terms of the Lagrangean multipliers,

$$Q = U \cdot (Y, L) - \lambda_1 \cdot (L - l_1 - l_2 - \bar{l}) + \lambda_2 \cdot (\delta - l_2) + \lambda_3 \cdot (M/n - m).$$

(λ_1, λ_2, λ_3 are the Lagrangean multipliers.)

13) I believe there are only a few who do not pay the fine even if they are detected. This is because even rational, selfish farmers may choose to cooperate rather than act as free riders if they are in a community with intimate social interactions among its members [Taylor 1976], and this is the case in M8.

Concerning the two cases used in the following analysis, the Kuhn-Tucker conditions with respect to irrigation facilities and labor are reduced to:

if $\lambda_1 > 0$, $\lambda_2 > 0$, $\lambda_3 = 0$

$$\frac{\partial q}{\partial m} = 0 \cdots ①, \quad \frac{\partial q}{\partial l_1} = w - \frac{\lambda_1}{\partial U/\partial Y} \cdots ②,$$

$$\pi - w = \frac{-\lambda_1 + \lambda_2}{\partial U/\partial Y} \cdots ③,$$

$$w = -\frac{\partial U/\partial L}{\partial U/\partial Y} + \frac{\lambda_1}{\partial U/\partial Y} \cdots ④,$$

if $\lambda_1 > 0$, $\lambda_2 > 0$, $\lambda_3 > 0$

$$\frac{\partial q}{\partial m} = \frac{\lambda_3}{\partial U/\partial Y} \cdots ①',$$

and equations ②, ③, ④.

In the former case, a farmer does not suffer losses from congestion in use of irrigation facilities. Therefore, as shown in Fig. 2, he uses the equipment up to the point B where the marginal value productivity equals zero. On the other hand, in the latter case, a farmer suffers opportunity losses (the shaded area in Fig. 2) because he cannot use more than M/n owing to congestion. (A is equilibrium point.) If we assume that homogeneous farmers do not use the facilities at the same time, but that the time allocation of water distribution among users

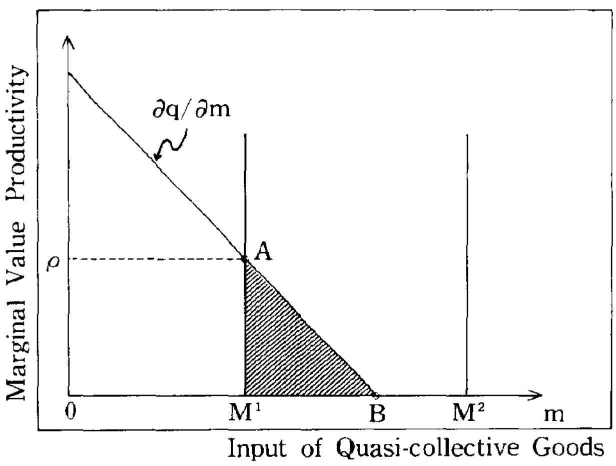


Fig. 2

(rotation method) can be efficiently arranged, the congestion problem can be solved.

With regard to labor, I assume that the market wage rate is given for any farmer, but that employment opportunity is limited ($\lambda_1>0$). In this case, a sufficient condition for the enforcement of labor supply on communal work ($\lambda_2>0$) is to set the fine for non-contribution of labor at a higher level than the marginal cost of labor, which may be lower than market wage rate.[14)]

As shown in Fig. 3, if the fine is set at π^1, the curve indicating the marginal cost of labor intersects AB at the point B and a part of labor obligation ($\bar{B}\bar{D}$) is ignored. But if the fine is set at higher level, π^2 or π^3, then marginal labor cost intersects $\partial q/\partial l$ at point C, and the family labor input is in equilibrium at C. That is to say, the obligation is perfectly enforced, simultaneously satisfying the subjective equilibrium of the farm household.

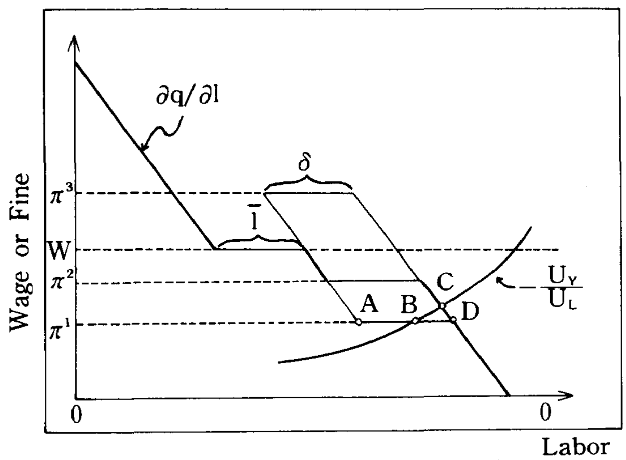


Fig. 3

14) From ③, ④, $\pi=-\frac{\partial U/\partial L}{\partial U/\partial Y}+\frac{\lambda_2}{\partial U/\partial Y}$.

Therefore if $\pi>-\frac{\partial U/\partial L}{\partial U/\partial Y}$, $\lambda_2>0$.

IV Production Function Analysis

IV-1. Formulation of Production Function and Data

The following Cobb-Douglas type production function can be specified.[15)]

$$\ln Y = B+\alpha_1\ln L+\alpha_2\ln F+\alpha_3\ln K+\alpha_4\ln T +\beta D_1+\gamma D_2+U \cdots ①$$

$$\ln Y = B+\alpha_1'\ln L+\alpha_2'\ln F+\alpha_3'\ln K+\alpha_4'\ln T +\beta' D_1+\delta D_3+U' \cdots ②$$

Notations of the variables in these functions are as follows.

Y: gross revenue from dry-season rice crop, L: labor input, F: current input, K: machine (flow term), T: land.

D_1, D_2 and D_3 are dummy variables, where

D_1 = 1 if the member is a tenant farmer with share contract (42 farm households); 0 if not (17 farm households)

D_2 = 1 if the strict rotation rule is enforced (19 farm households); 0 if not (50 farm households)

D_3 = 1 if he belongs to Huay Phung weir group (44 farm households); 0 if he belongs to Khung Khong weir group (25 farm households).

Dummy variables D_1 were applied in the equations to test the hypothesis that share-tenancy leads to inferior production. This is because, despite much research, the arguments continue (see Ohtsuka [1985]). The other two dummy variables are applied to overcome the difficulty of data collection on each user's

15) An estimate was also made by applying three dummy variables. As a result, the coefficient of determination, t statistics and F statistics are lower than the type of equation shown here.

demand on irrigation facilities. If the members of each group suffer losses from congestion in use of irrigation facilities, the parameter of dummy variables is significantly different from zero. α_1, α_2, α_3, α_4, β, γ and δ are parameters and U is the disturbance term.

The sample size is 69, and the data used for estimation of the production function were as follows. (All items relate to the 1984 dry-season rice crop.)

Gross revenue (Y): gross revenue.

Labor (L): total labor.

Current input (F): total expense for chemical fertilizer and herbicide.

Machine (K): 1/2 × depreciation value, calculated from the formula (purchase price/10 durable years).[16]

Land (T): cultivated area in dry-season rice crop.

Table 7 Estimates of Agricultural Production Function (Dry-season Rice): n=69

Explanatory Variables	Estimated Coefficients	
	Equation 1	Equation 2
Constant Term (B)	5.428 (4.543)*	5.477 (6.352)*
Labor (L)	0.028 (0.238)	0.003 (0.027)
Machine (K)	0.283 (2.376)**	0.292 (2.400)**
Current Input (F)	0.102 (1.093)	0.114 (1.194)
Land (T)	0.558 (4.090)*	0.515 (3.657)*
Dummy Variables		
Share-tenancy	0.032 (0.327)	0.069 (0.642)
Strict Rotation	−0.219 (−2.332)**	
Weir Group		−0.143 (−1.608)
Coefficient of Determination[1]	0.670	0.695
F Ratio	27.661*	26.053*

Note 1) Adjusted for the degree of freedom.
2) T statistics are in parentheses. * Statistically significant at 1% significant level. **Statistically significant at 5% significant level.

IV–2. Examination of Estimated Results

The results of the estimation are shown in Table 7. The estimated coefficient of dummy variables D_2, which distinguish the strict rotation group members from the others, is significantly different from zero. This result implies that members who were obliged to follow a strict rotation rule still suffered a loss owing to congestion. On the other hand, the coefficient of dummy variables D_3, which distinguish the members of Huay Phung weir group from those of Khung Khong weir group, does not differ significantly at the 10% level.[17] This significance level might seem to be too large to conclude that the hypothesis can be rejected that a productivity gap exists between the two groups. For further classification another statistical test of the efficiency of both systems should be applied. An appropriate procedure is to compare the yield per rai of the Khung Khong members with that of the Huay Phung members who do not belong to the strict rotation group.

By testing the significance of the dry-season yield gap between the two groups, we see that the null hypothesis that the yield of each group member is homogeneous cannot be rejected even at a 20% significance level (see Table 8). This confirms that the loose rotation rule contrib-

16) If an agricultural machine was co-owned, the purchase price was divided by the number of owners.

17) Farm households which belongs to both weir groups were arbitrarily assigned to the group of whichever weir they drew more water from.

uted to some extent in dissolving congestion of water use among members of the Huay Phung weir group and allowed more efficient use of quasi-public goods, i.e., irrigation facilities.

The possibility of inferior field conditions of the farmers forced to follow the strict rotation rule may be discounted, because no significant difference was found in the rainy-season yield between these two groups (see Table 8). This supports the conclusion that it is not inferior field conditions but water shortage in the dry season which caused the farmers' losses.

With regard to both estimates, the adjusted coefficient of determination and F ratio show them to be statistically significant. The estimated coefficient of labor and t statistics in both equations are so low that the hypothesis cannot be rejected that the coefficient of labor is zero. This hypothesis means that marginal cost of labor and marginal value productivity of labor are zero and supports the intuitive proposition of labor abundance mentioned in an earlier section.[18)]

From this analysis, we can conclude that the fine is set at a higher level than the marginal cost of labor. As a result, the present supply of labor and building materials is consistent with each individual farmer's personal motivation.

Table 8 Comparison of Yields between Users' Groups

	Dry-season Rice Crop		Rainy-season Rice Crop	
	Huay Phung, Non-strict Regulation (n=25)	Khung Khong (n=25)	Huay Phung, Strict (n=19)	Others (n=50)
Average Yield (tang/rai)	76	79	71	74
F Ratio	$1.54 < F(24, 24 : 0.05)$		$1.48 < F(49, 18 : 0.05)$	
T Statistics	$0.58 < T(48 : 0.2)$		$0.57 < T(67 : 0.2)$	

V Conclusion

The results of the analysis in the previous section indicate that the irrigation institution has been modified in order to save a resource that had grown more scarce in the process of agricultural development, and that the communal work custom can be explained from an economic point of view.[19)]

This implies that changes in traditional irrigation institutions can be considered as a communal adjustment aimed at the efficient use of resources under a non-market economic system, and that such communal institutions can be a method of resolving market-failure problems.

18) I also calculated another type of production function from the data of yearly total products and total input. These results also support the hypothesis. (Coefficient of labor is 0.1714, t statistics is 0.926.)

19) The formation of Japanese agricultural irrigation institutions during the Tokugawa era and the recent process of change have been discussed from the viewpoint of social norms in the rural community [Tamaki *et al.* 1984]. But this alone does not explain why such traditional institutions have been maintained for more than 100 years. In reexamining the Japanese experience, economic analysis will be useful and the case study in Northern Thailand is suggestive.
On the relation between farm management and irrigation institutions, case studies have been conducted in Nagata [1971], Yamauchi *et al.* [1961] etc.

One assumption made in this study was that if the members failed to meet their duties, they would be forced to pay fines. But the members might not be kept to the rule if the cost of its enforcement is too great for the leaders. Furthermore, the introduction of the rotation system was not agreed upon through bargaining and negotiation; the headman and his assistant played an important role in making the rule and enforcing it. Even if they have the potential to do so, they might not necessarily be able to work out an arrangement for the optimum supply of collective goods, as Olson [1965: 177] has stated. Their efforts to produce an institution which supplies an optimum quantity of collective goods also involve a large transaction cost.

In order to construct a more comprehensive framework for analysis, it should be investigated why these transaction costs are so low that the leaders can operate the institution well.

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