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Effect of Water Control on Rice Cultivation in the Red River Delta, Vietnam: A Case Study in the Nhue River Irrigation System

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Abstract

One of the major constraints of agricultural development in the Red river delta is inadequate control of water conditions. The present study aims to clarify the water conditions of agricultural land, analyze their impact on production and labor input, and estimate the effect of the improvement of water control, with emphasis on rice cultivation. Water conditions of agricultural land are closely related to microtopography. Yield and labor input of rice cultivation in the higher and lower areas are affected by insufficient irrigation water supply and inundation, respectively, both in the spring and summer cropping seasons. However, high labor input enables farmers to adopt similar cropping patterns and rice varieties over the whole area, regardless of variation in water conditions. Irrigation and drainage improvement combined with land consolidation are recommended to increase rice yield and reduce labor input, by which 40% to 150% yield increase and 30% to 60% labor saving are expected.

I Introduction

The Red river delta, located in the northern part of Vietnam and covering around 1.5 million ha, has quite different historical and ecological characteristics from other deltas in continental Southeast Asia. Rice cultivation in the Red river delta can be traced back to around three thousand years ago, since when the delta has been one of the agricultural as well as political centers of the region [Sakurai 1987: 245-275]. This contrasts with the rapid expansion of rice cultivation started during the last century in other deltas such as the Mekong delta in southern Vietnam, the Chao Phraya delta in Thailand, and the Irrawaddi delta in Myanmar [Takaya 1987]. Population density has also been higher in the Red river delta, and it now exceeds 1,000 per sq.km. Flash floods in summer and low temperature in winter are the major constraints on rice cultivation, neither of which can be observed in other deltas.

People have tried to overcome these constraints by various measures. Besides improving cultivation techniques, they built high embankments along the major rivers in the upper part of the delta. Some of the embankments exceed 10 m in height. During the French colonial period,

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many canals were constructed or widened for irrigation and drainage by gravity. Since the 1950s, many pumping stations have been constructed for both irrigation and drainage, and the canal network has been improved. As a result, cropping has been intensified and a significant increase in yield achieved. However, inadequate control of water conditions is still reported to cause crop damage [Ministry of Water Resources *et al.* 1993: 17].

Moreover, the changes in national economic policy since the late 1980s are expected to increase non-farm job opportunities for farmers. This, in turn, should draw the attention of both farmers and policy makers to the labor requirement of agriculture, where previously land productivity was the sole target of efforts for water control.

The objectives of the present study are, therefore, as follows. Firstly, having clarified the spatial differences in water conditions of agricultural land, their impact on production and labor requirement of rice cultivation will be analyzed. Finally, the effects of the improvement of water control will be evaluated.

The Nhue river irrigation system, located in the old delta, was chosen for the present study. Its area consists of back swamp enclosed by natural levees of the Red river and the Day river, a tributary of the Red river, and includes areas with severe inundation as well as water shortage. So clear spatial differences in water control within the system were expected [Sakurai 1987: 243-244]. Field survey was conducted from December 1992 to February 1993. Data on hydrological conditions and rice cultivation were collected from related government agencies including village-level authorities and through interviews with farmers [Doan 1993].

II Study Area

1. *Outline*

The Nhue river irrigation system is located southwest of Hanoi (Fig. 1). The Nhue river, which serves as a major irrigation and drainage canal, flows through the center of the area, joining the Day river at the southern end of the system. The land elevation is mostly more than 4 m in the upstream area and around 1 to 3 m in the downstream area. The soil texture changes with topography from sandy loam on the natural levees to clayey loam in the lower parts. The total command area of the system is 107,500 ha, of which around 75% is cultivated.

For cropping, the year is divided into three seasons, summer (approximately from June to October), winter (approximately from October to January), and spring (approximately from February to June). Annual rainfall varies from 1,200 to 2,000 mm, of which more than 70% occurs in summer (Fig. 2). In this season, the water level in the surrounding rivers is much higher than the land surface (Fig. 3), and the lower parts of the area suffer from inundation. The low temperature does not allow rice cultivation in winter, and it also affects rice cultivation in spring, especially at the time of planting. Seedlings and newly transplanted plants often suffer and farmers have to re-prepare or re-transplant seedlings. Water shortage is an another obstacle in spring. Rainfall is less and irrigation is required for rice cultivation, but the river level is still low.

There are two modes of irrigation water intake: by gravity at the head of the Nhue river,

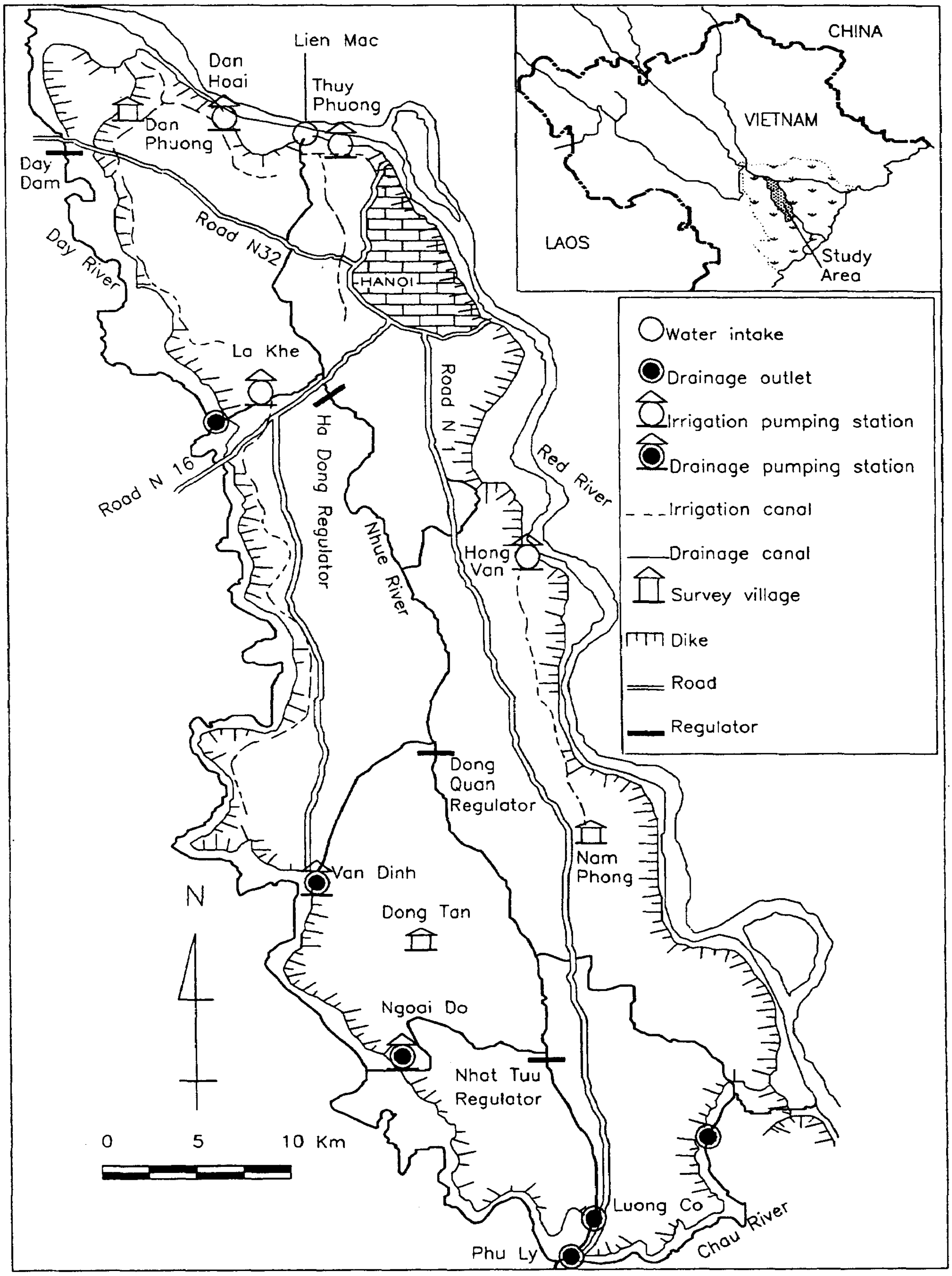

Fig. 1 Irrigation and Drainage System in the Study Area

and by lifting at several pumping stations along the Red river (Fig. 1). In spring, water from the head of the Nhue river is delivered to lower areas by gravity. Higher areas are irrigated by lifting either from the Red river or the Nhue river through low-lift pumping stations. In summer, the Nhue river has to serve as a drainage canal, and the intake at the head is closed in case of heavy rainfall to keep the water level of the Nhue river low. Higher areas are irrigated mostly by lifting, as in spring, and partially by gravity through intakes along the Red river. Lower areas are irrigated mainly by excess water drained from upstream areas.

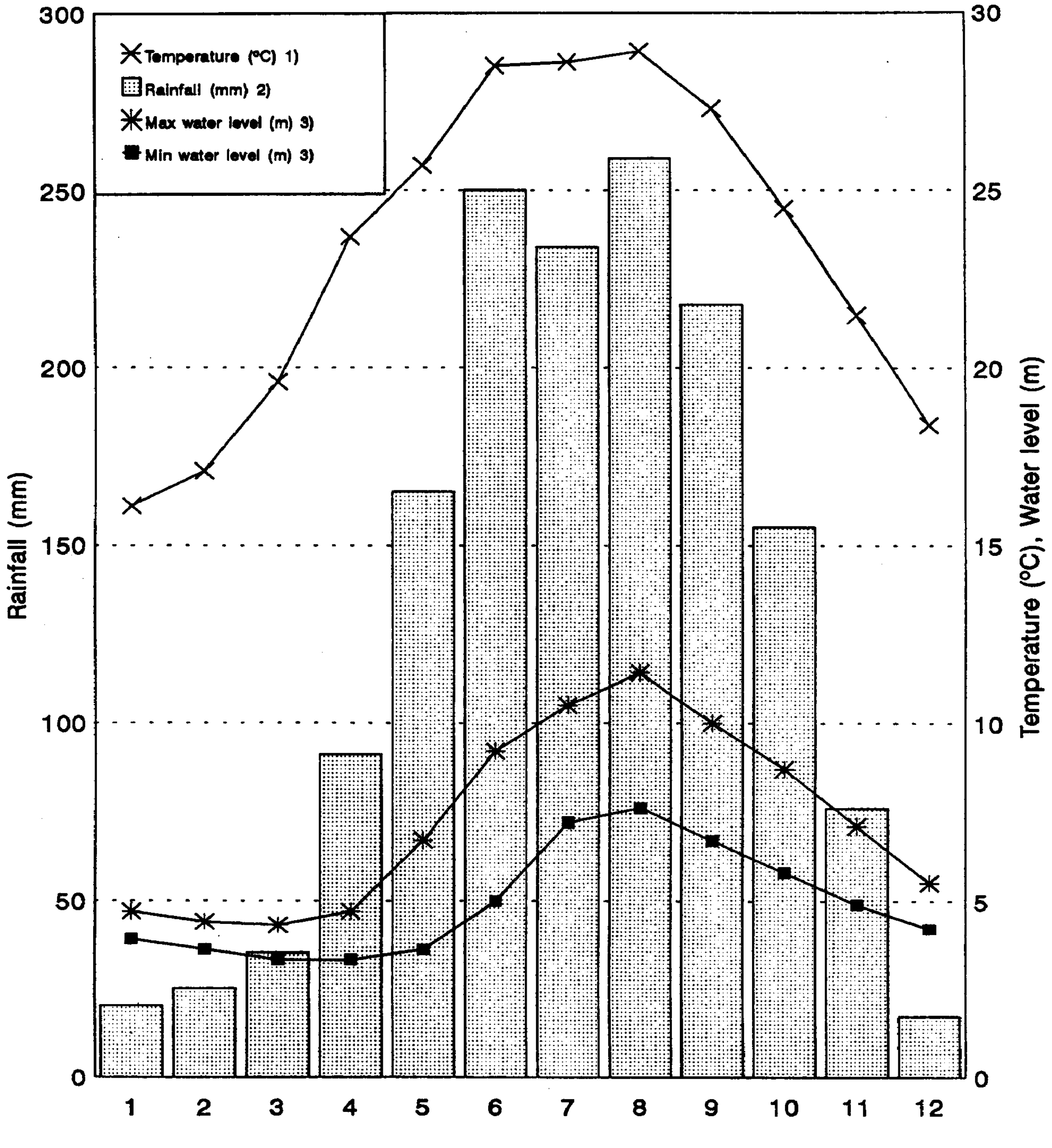

Fig. 2　Seasonal Changes in Climatic and Hydrological Conditions

1) Average of 2 years (1989-1990) at Ha Dong [Ha Son Binh Provincial Government 1991]
2) Average of 35 years (1957-1991) at Ha Dong
3) Water level of the Red river at Lien Mac

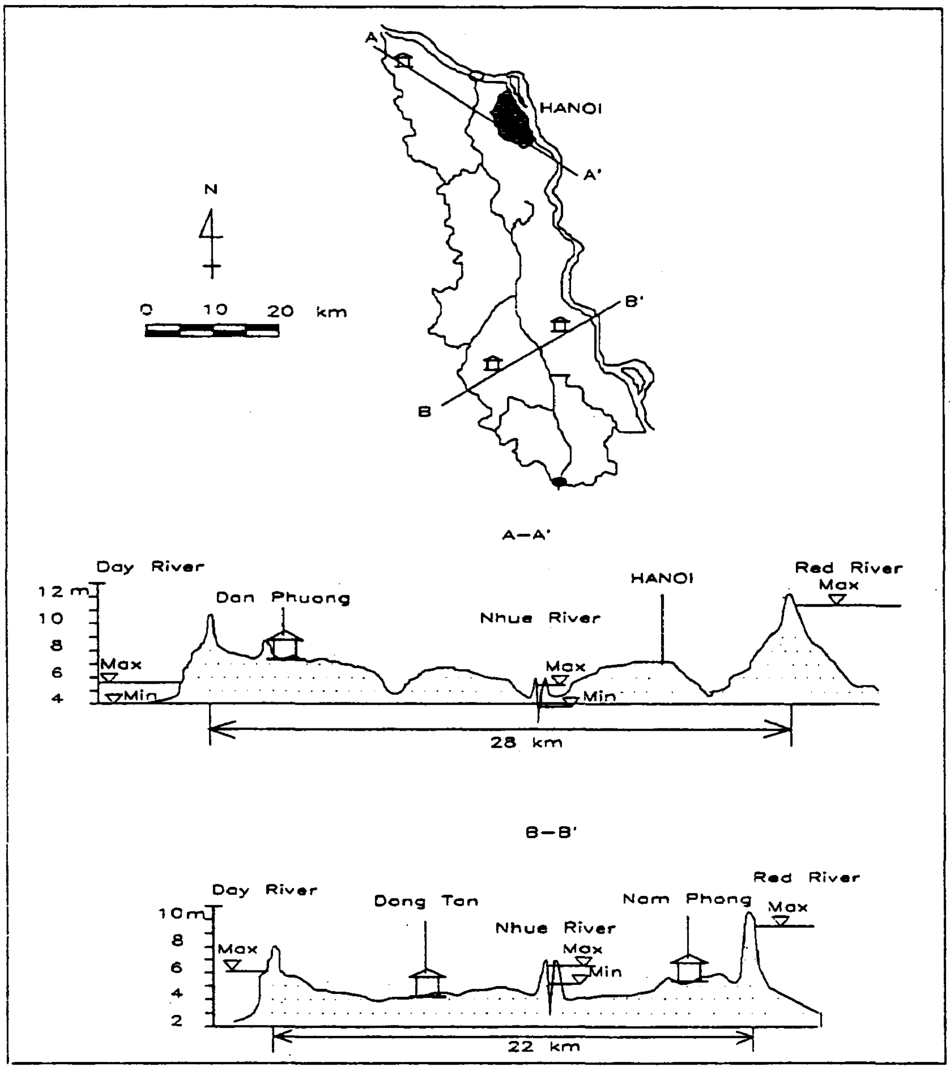

Fig. 3 Locations of the Intensive Survey Villages

For drainage, the whole area is divided into four blocks by embankments and regulators across the Nhue river. Drainage pumping stations to the Day river have been constructed for the two central blocks, while for the furthest upstream and downstream blocks only gravity drainage is possible (Fig. 1). This block-wise drainage plan, however, is not fully effective due to the limited capacity of the pumping stations and the high water level of the Day river. Consequently, some of the excess water in the upstream blocks is still drained to downstream blocks.

Changes in cropping pattern in the study area since the 1930s are summarized in Table 1. Upland crops have been replaced by rice, and single cropping in summer or spring has been replaced mostly by double cropping and partly by triple cropping. However, rice has remained the dominant crop throughout the period.

Table 1 Canges in Cropping Pattern in the Study Area

Cropping Pattern			Area (% on the total command area)					
Summer	Winter	Spring	1932 1)	1961-1963	1967	1971-1972	1986	1990
Paddy	Paddy	Paddy	0	0	1	0	0	0
Paddy	Upland crop	Paddy	0	0	1	1	10	21
Paddy	Upland crop	Upland crop	0	0	3	1	0	0
Paddy	Fallow	Paddy	30	44	65	71	85	75
Paddy	Fallow	Upland crop	0	14	19	18	0	0
Paddy	Fallow	Fallow	19	24	4	4	0	0
Fallow	Fallow	Paddy	51	11	4	3	5	4
Upland crop	Fallow	Fallow	n.a.	7	3	2	0	0
Net area planted (1,000 ha)			94.0	77.4	69.3	68.0	69.1	80.1
Cropping intensity			1.30	1.58	1.93	1.95	2.05	2.18

Note: This table is prepared from Ministry of Water Resource [1974] (up to 1971-1972) and data collected at Ha Tay Provincial Irrigation and Drainage Department (1986 and 1990).
1) Upland crop cultivation is not included in the survey.

The present population of the study area is about 2 million, of which 75% is engaged in agriculture. The average net area cultivated per person is around 0.05 ha.

2. *Intensive-survey Villages*

Three villages were chosen for intensive survey to collect detailed information on water conditions, agricultural production and labor input into rice cultivation. These are Dan Phuong in the upstream area, Nam Phong near the natural levee of the Red river in the downstream area, and Dong Tan in the middle of downstream back swamp (Fig. 3).

Dan Phuong lies 20 km from Hanoi along the road to Son Tay town, and has the best transportation among the three villages. Most fields are irrigated by the Dan Hoai pumping station, which takes water from the Red river, and drain excess water to the Nhue river by gravity, even in summer. Although farms are small (Table 2), farmers grow soybeans and vegetables, and some of them take their produce to Hanoi city by bicycle to sell at a market. Handicrafts such as knitting, embroidery and wood carving, and sweet production also provide important sources of income.

Nam Phong is located about 30 km south of Hanoi along the country's main north-south road. Fields in the village are irrigated by low-lift pumping stations installed along canals taking water from the Nhue river. In summer, drainage also has to be done by pumping to the Nhue river, but in spring most fields can be drained by gravity. Farms are as small as in Dan Phuong. Soybean cultivation, mother-of-pearl work, and contract land preparation using a

Table 2 Overview of Intensive Survey Villages

Village	Overall [1]				Interviewed		
	Population	Number of Households	Total Area Cultivated (ha)	Average Farm Size (ha)	Number of Households	Total Area Cultivated (ha)	Number of Plots
Dan Phuong	7,600	1,410	350	0.25	19	4.44	128
Nam Phong	4,300	960	252	0.26	21	6.01	175
Dong Tan	5,800	1,140	420	0.37	20	5.64	156

1) From interviews with staff of people's committee in each village.

tractor are important sources of income.

Dong Tan is the farthest of the three villages from Hanoi. It lacks a paved road passing through it, and farmers have few sources of income except rice cultivation. Irrigation water is taken from the Nhue river by low-lift pumps or by gravity. In spring, excess water is drained partly by gravity and mostly by pumping. In summer, however, only the higher plots of the village can drain excess water, because the Nhue river is almost full to capacity due to drainage from upstream. The average farm size is around 50% bigger than in the other two villages, and rice is a major source of cash income.

Around 20 farmers from one or two hamlets[1] in each village were selected on the basis of the water conditions of their agricultural land (Table 2). Data on water conditions and agricultural production in each plot cultivated and on agricultural production materials and labor input in each household were collected through interviews with them.

III Paddy Field Classification

1. *Comparison of Villages*

Differences between the villages in cropping pattern, method of rice cultivation and water conditions were preliminary investigated using the data obtained through interviews with farmers.

The crop distribution of the three villages are summarized in Table 3. In all villages, rice cultivation is dominant in both summer and spring. Significant areas are also occupied by soybean in Dan Phuong in summer, and groundnut in Nam Phong and maize in Dan Phuong in spring.

Winter cropping shows significant differences between villages. Rice is not cultivated in any village in this season due to low temperature, and most fields are left fallow particularly in Dong Tan. Sweet potato is cultivated in a few fields in Dong Tan, mainly for home consumption and pig feed, while soybean and maize are popular in the other villages. Overall, fields are

1) The village is the smallest unit of local administration. A village consists of several hamlets.

Table 3 Crop Distribution, by Village

(unit: % on the cultivated area)

Season	Crop	Dan Phuong	Nam Phong	Dong Tan
Summer	Paddy	88	98	100
	Soybean	9	0	0
	Maize	3	1	0
	Vegetables	0	1	0
Winter	Soybean	45	38	0
	Maize	31	2	0
	Sweet potato	1	9	13
	Potato	10	3	1
	Vegetables	2	3	0
	Fallow	11	45	86
Spring	Paddy	83	80	99
	Groundnut	0	13	0
	Maize	10	1	0
	Soybean	4	3	0
	Vegetables	3	3	0
	Fallow	0	0	1
Cropping intensity		2.89	2.55	2.13

Note: These are the average of surveyed farms.

mostly triple cropped in Dan Phuong and double cropped in Dong Tan, with a mixture of triple and double cropping in Nam Phong.

The major differences in cropping pattern between the villages are, therefore, in non-paddy cultivation. These are more popular in the upstream area than the downstream area. This is mainly due to differences in water conditions between villages, as discussed later, and partly due to the better transportation and marketing conditions in the upstream. In the case of vegetables, farmers can transport their produce by bicycle and sell it at a market if they live within 20 to 30 km of Hanoi.

The methods of rice cultivation are similar in the three villages. Transplanting by hand is common all through the study area in both seasons. During the growing period, weeding, fertilizer application, irrigation and drainage are practiced if necessary. All of these operations are done by hand with simple tools. For lifting irrigation and drainage, farmers use a basket with ropes operated by two persons (*gầu sòng*) or a scoop hung on a bamboo tripod operated by one person (*gầu giai*). Harvesting is also done by hand with a sickle.

The only difference observed is in the method of land preparation (Table 4). Plowing and harrowing are first done by a cooperative[2] using a riding tractor in all villages. Some of the bunds between plots are removed to reduce working time for these operations, being rebuilt afterwards along boundary lines fixed by use of string. The land is then leveled and seedlings are transplanted. Some farmers harrow their land again after the cooperative work to make the soil softer, mostly using water buffalo or, in some cases, a hired tractor. Such additional harrowing is more popular in Dong Tan than the other two villages.

Table 4 Method of Land Preparation for Summer and Spring Rice Cultivation

Village	Proportion of Households (%)					Cost of Cooperative Service (*dong*/ha)
	Cooperative Service	Cooperative Service + Machine + Animal	Cooperative Service + Machine	Cooperative Service + Animal	Animal	
Dan Phuong	33	0	0	67	0	350,000
	24	0	0	76	0	440,000
Nam Phong	41	6	24	29	0	310,000
	45	0	20	35	0	310,000
Dong Tan	6	0	0	83	11	110,000
	5	0	0	90	5	250,000

Note: The upper and lower figures are for summer and spring rice cultivation, respectively. Number of households surveyed was 18, 17 and 18 for summer rice and 17, 20 and 20 for spring rice in Dan Phuong, Nam Phong and Dong Tan, respectively.

The cost of cooperative services differs between the villages, being highest in Dan Phuong and lowest in Dong Tan. To some extent, this cost difference reflects a difference in the care taken over the work. It is also remarkable that a few farmers in Dong Tan do not use the cooperative service. This may be due to the poor drainage of their fields.

Information on frequency of inundation and water shortage in individual plots in each village is summarized in Table 5. Damage by inundation was assumed mostly to occur in summer, and damage by water shortage in spring, although the timing of damage was not identified in the interview. It was also not specifically asked whether the damage actually caused a reduction of rice yield. So, damage here is defined as undesirable water conditions which prompted farmers to take countermeasures. These may affect crop growth and may require farmers to input additional labor.

2) A cooperative is a farmers' organization to provide its members with services for agricultural production. Most hamlets have their own cooperative.

Table 5 Distribution of Areas Damaged by Water Shortage and Inundation

(a) Dan Phuong (unit: %)

Frequency during the Last Five Years		Damaged by Water Shortage						Total
		0	1	2	3	4	5	
Damaged by inundation	0	73	3	2	0	0	11	89
	1	6	0	0	0	0	0	6
	2	2	0	0	0	0	0	2
	3	1	0	0	0	0	0	1
	4	0	0	0	0	0	0	0
	5	1	0	0	0	0	1	2
Total		83	3	2	0	0	12	100

(b) Nam Phong (unit: %)

Frequency during the Last Five Years		Damaged by Water Shortage						Total
		0	1	2	3	4	5	
Damaged by inundation	0	48	0	2	1	1	4	56
	1	16	0	0	0	0	0	16
	2	6	9	0	0	0	0	15
	3	7	0	0	0	0	0	7
	4	2	0	0	0	0	0	2
	5	4	0	0	0	0	0	4
Total		83	9	2	1	1	4	100

(c) Dong Tan (unit: %)

Frequency during the Last Five Years		Damaged by Water Shortage						Total
		0	1	2	3	4	5	
Damaged by inundation	0	3	2	2	0	1	4	12
	1	1	0	5	3	0	1	10
	2	3	0	3	0	4	6	16
	3	14	0	2	0	0	1	17
	4	2	2	0	0	1	0	5
	5	25	1	8	1	1	4	40
Total		48	5	20	4	7	16	100

Table 5 shows that more than 70% of the fields in Dan Phuong, about 50% of those in Nam Phong, and only a few fields in Dong Tan were damaged by neither inundation nor water shortage during the last five years. However, each village includes both plots severely damaged by water shortage and others severely damaged by inundation. It is also remarkable that almost half of the fields in Dong Tan were damaged by both inundation and water shortage, while such plots are few in the other villages.

2. *Paddy Field Classification by Water Conditions*

Water conditions overall deteriorate from upstream to downstream, and this is reflected in cropping pattern and method of land preparation. There are, however, many exceptional cases. Therefore, all the surveyed plots are classified into five types based on the frequency of damage by inundation and water shortage, as shown in Table 5, for further analyses on production and labor input of rice cultivation.

Type I plots are those where cultivation was damaged by water shortage once or more during the last five years but not by inundation. These plots are located on the footslopes of natural levees and have relatively sandy soil. They are almost equally distributed among the three villages.

Type II plots are those where cultivation was not damaged by either inundation or water shortage. These plots lie low enough to get sufficient irrigation water and high enough to drain excess water to the Nhue river. They are mostly distributed in Dan Phuong and Nam Phong.

Type III plots are those where cultivation was damaged by inundation in one to three of the last five years but never by water shortage. These plots are located slightly lower than the type II plots and face drainage problems in heavy rainfall years. They are mostly distributed in the downstream villages.

Type IV plots have problems with both irrigation and drainage. Frequencies of damage by inundation and water shortage are respectively one to three years and one or more of the last five years. These plots are located on isolated slightly elevated land in lower areas or at the tail reach of an irrigation canal. Poor drainage of the surrounding lower area is thought to be a major constraint leading to water shortage in these plots. They are mostly distributed in the downstream villages.

Type V plots are located in the lowest areas and face a severe inundation problem, with inundation damage occuring in four or five of the last five years. This type includes plots where cultivation suffered from water shortage and others where it did not. Water shortage in these plots is thought to be caused by a similar situation to that in type IV plots. Type V plots are concentrated in Dong Tan.

IV Rice Production

1. *Cropping Patterns*

Table 6 shows the cropping patterns observed in each type of field. A total of 25 patterns were observed. The dominant cropping pattern in type II plots is rice cultivation in summer and spring followed by non-paddy cultivation in winter; and that in type III, IV and V plots is double cropping of rice followed by winter fallow. This indicates that inundation is not a constraint on rice cultivation in terms of area.

Table 6 Comparison of Cropping Patterns

(unit: %)

Cropping Pattern			Paddy Field Type				
Summer	Winter	Spring	I	II	III	IV	V
Paddy	Vegetable	Paddy	0	2	0	0	0
Paddy	Soybean	Paddy	4	53	15	4	1
Paddy	Maize	Paddy	7	12	3	0	0
Paddy	Potato	Paddy	7	2	0	0	2
Paddy	Sweet potato	Paddy	11	1	3	12	5
Sub-total Paddy	Non-paddy	Paddy	29	70	21	16	8
Paddy	Fallow	Paddy	28	11	78	77	91
Paddy	Vegetable	Vegetable	0	2	0	0	0
Paddy	Potato	Vegetable	0	2	0	0	0
Paddy	Soybean	Soybean	1	1	0	0	0
Paddy	Potato	Soybean	4	2	0	0	0
Paddy	Sweet potato	Soybean	1	1	0	1	0
Paddy	Soybean	Groundnut	0	2	0	4	0
Paddy	Potato	Groundnut	0	1	0	0	0
Paddy	Sweet potato	Groundnut	0	4	0	0	0
Sub-total Paddy	Non-paddy	Non-paddy	6	15	0	5	0
Paddy	Fallow	Vegetable	0	0	0	0	0
Paddy	Fallow	Soybean	1	0	0	0	0
Paddy	Fallow	Groundnut	15	0	0	0	0
Sub-total Paddy	Fallow	Non-paddy	16	0	0	0	0
Vegetable	Vegetable	Vegetable	0	1	1	0	0
Soybean	Maize	Vegetable	2	0	0	0	0
Soybean	Maize	Maize	10	2	0	0	0
Maize	Soybean	Maize	1	0	0	0	0
Maize	Maize	Maize	4	1	0	0	1
Maize	Sweet potato	Maize	2	0	0	0	0
Sub-total Non-paddy	Non-paddy	Non-paddy	19	4	1	0	1
Paddy	Fallow	Fallow	0	0	0	2	0
Soybean	Fallow	Soybean	2	0	0	0	0
Cropping intensity			2.6	2.9	2.2	2.2	2.1

In type I plots, various cropping patterns can be observed. In spring, rice occupies around 60% of the total area and the remainder is occupied by non-paddy such as maize, groundnut, soybean and vegetables. The low proportion of rice cultivation may be partly because of water shortage in this season, especially in case of maize cultivation. Such cash crops, however, seem to be preferred to rice due to their higher prices. This view is supported by the fact that similar crops are also cultivated in type I plots in summer and type II plots in spring, in which seasons sufficient water is available for rice cultivation.

Therefore, no clear effect of water conditions was observed on the area planted with rice, except for a small area of maize cultivation due to water shortage. On the other hand, inadequate drainage may prevent expansion of commercial cultivation of upland crops.

2. *Rice Varieties*

Rice varieties planted in summer and spring are summarized in Table 7. High-yielding varieties such as CR203, A20 and DT10 are dominant in both seasons and in all types of field, but their percentage is lower in type I and type II, where hybrid varieties recently introduced from China are expanding. Farmers report yields around 30 to 50% higher with these hybrids than with high-yielding varieties. Seeds of the hybrid varieties are distributed through the cooperatives each season because these varieties cannot reproduce their own seed. Glutinous rice is also grown in type I plots in summer. It fetches a higher price than non-glutinous rice and is mostly sold for producing cakes and food for traditional occasions.

Table 7 Rice Varieties Planted

(unit: %)

Variety	Paddy Field Type					
	I	II	III	IV	V	Total
Hybrid varieties	13 22	24 7	9 2	4 4	3 4	14 6
High-yielding varieties	73 78	75 89	90 95	96 95	97 96	84 92
Glutinous rice	14 0	1 4	1 3	0 1	0 0	2 2

Note: The upper and lower figures are for summer and spring rice cultivation, respectively.

Type I and type II plots thus show more diversity of rice varieties than other types, which indicates that poor drainage limits the conversion to higher yielding or higher priced varieties. However, the so-called modern varieties are cultivated even in fields severely affected by water shortage or inundation, and no special varieties are adopted to overcome the constraints in water conditions. [3)]

3) A traditional variety of rice tolerant to deep water (*mộc tuyền*) is reported still to be cultivated in the downstream area of the Bac Hung Hai irrigation system, located east of the study area [Vu 1994: 36].

3. *Fertilizer and Insecticide Application*

Data on green manure, chemical fertilizer and insecticide application was collected at the household level. Application levels in each type of paddy field were estimated by multiple regression analysis considering the combination of different types of field in each household. The results of the estimation are shown in Fig. 4.

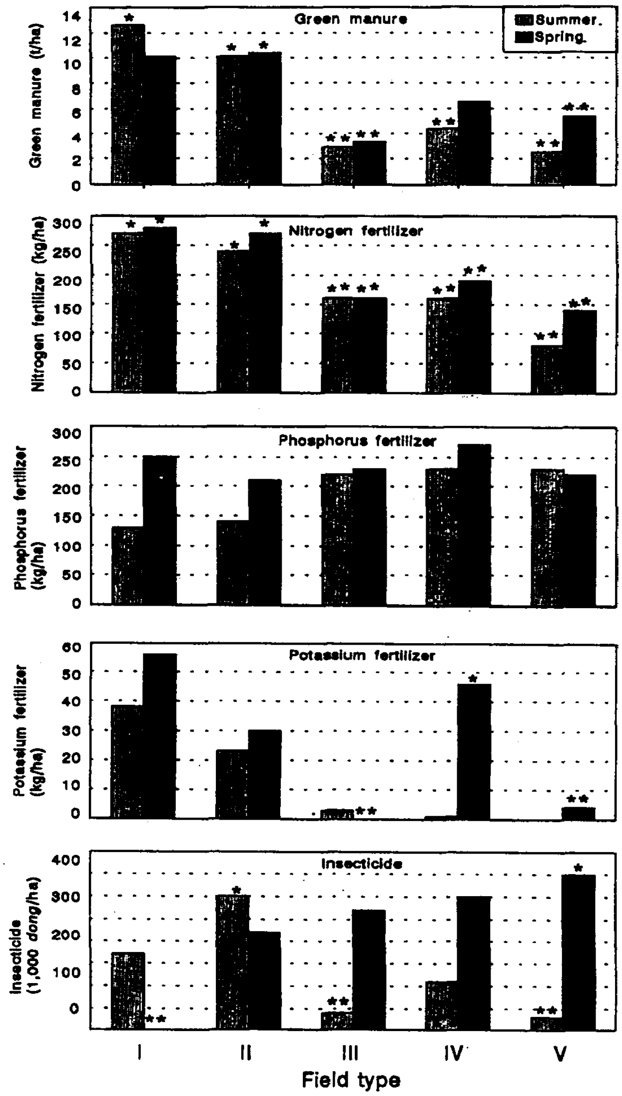

Fig. 4 Fertilizer and Insecticide Application

"＊" and "＊＊" indicate that these values are higher and lower than the mean value of the whole area, respectively, at the significance level of 10%.

Most farmers apply green manure for rice cultivation. They produce it by mixing rice straw, pig dung and water hyacinth. Type I and type II plots show higher application rates than other types in both seasons. Type IV and type V plots show higher application in spring than summer.

All farmers apply nitrogen fertilizer. Urea is most commonly used and costs around 2,000 *dong*/kg (10,000 *dong* ≒ 1 US dollar). Some farmers also apply phosphorus and potassium fertilizer. A popular phosphorus fertilizer called Super Lan costs about 700 *dong*/kg, and a potassium fertilizer called Sunphat Potassium costs 2,500 *dong*/kg. All chemical fertilizers and insecticides are distributed through the cooperatives and are also available at village markets.

Nitrogen fertilizer application shows a similar trend to application of green manure, with higher applications made to the better drained plots. Application levels of phosphorus and potassium fertilizers do not show a clear correlation with paddy field type. This may be partly because farmers are not yet fully aware of the effects of these fertilizers. The economic circumstances of each household are thought to affect the application level of these fertilizers more than the type of paddy field.

Most farmers also apply insecticide. They apply more insecticide to higher plots in summer and to lower plots in spring. The smaller application to lower plots in summer is thought to be due to inundation, which reduces the effect of application. The smaller application to higher plots in spring may be due to the relatively dry conditions, which reduce insect attack.

4. *Rice Yields*

Average yields in each type of paddy field in the spring and summer of 1992 are summarized in Fig. 5. Farmers reported normal rainfall and normal water levels in the Red river in these seasons. The t-test shows significant differences in rice yield between types at the significance level of 5% in both seasons.

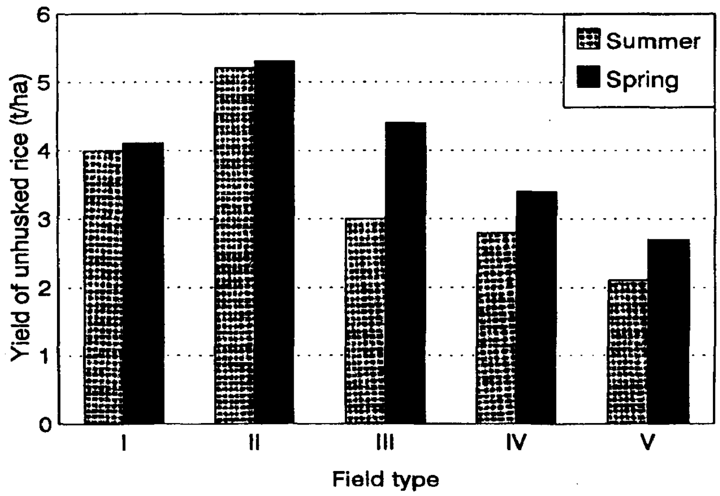

Fig. 5 Rice Yields

Type II shows the highest yield, followed by type I and type III, and type V is the lowest in both seasons.

Type I shows significantly lower yields than type II in both seasons, although almost the same level of green manure and nitrogen fertilizer is applied to both types. The difference may reflect less fertile soil in type I than in type II. At the same time, frequent water shortage is a major reason for the low yields in spring. Moreover, the similar yields in spring and summer indicate that irrigation water supply is not sufficient in type I even in summer.

Type III gives higher yields than type I in spring and lower yields in summer. This relationship clearly reflects the effect of water conditions on yield. In spring, irrigation affects yield more than drainage, while in summer drainage is more influential.

Type IV has significantly lower yields than type III in spring, but similar yields in summer. This indicates that type IV faces water shortage only in spring.

Type V gives lower yields than type III and type IV in both summer and spring. This indicates that inundation and poor drainage adversely affect yields in type V even in spring.

These findings clarify that rice cultivation substantially suffers from water shortage in the higher part and from inundation in the lower part in both seasons, and from inundation in summer and water shortage in spring in the middle part. Water shortage in spring also affects rice cultivation in some fields in the lower part, namely, those located on isolated slightly elevated land or at the tail reach of an irrigation canal.

Rice yields can be increased by improving irrigation and drainage. If it is assumed that the yield reduction caused by inadequate water control and its sequential effects on rice variety selection and fertilizer application in the present type II is not less than 10%, the potential yield with adequate irrigation and drainage would be more than 5.7 t/ha of unhusked rice in both seasons. Such a yield would mean an increase of 40% in type I in both seasons, 30% and 90% in type III in spring and summer, 70% and 100% in type IV in spring and summer, and 110% and 150% in type V in spring and summer. Such yields also assume comparable levels of fertilizer application to the improved type II.

V Labor Input

1. *Input by Cropping Operation*

The labor input into each of the five cropping operations for rice cultivation in each type of plot was estimated from the household data by the same method as that used to estimate fertilizer and insecticide application. The results of the estimation are shown in Fig. 6.

Land preparation is mainly done by a cooperative or by hired labor using a tractor, and cultivators supplement this with their own labor (Table 4). Labor input into this supplementary work is significantly below average in type II plots, but much higher in type V than other types in both seasons. This is because the poor drainage of type V plots makes machine work difficult, resulting in more animal work by cultivators.

Labor input into transplanting is around 60 to 70 man·day/ha, being slightly higher in type I plots than other types. Insufficiently softened sandy soil due to insufficient irrigation water may increase labor input.

Crop care mainly consists of weeding and application of fertilizer and insecticide. Labor input into crop care is highest in type I plots and is higher in spring than summer. A considerable part of the crop care labor in type I plots appears to be spent on weeding, because

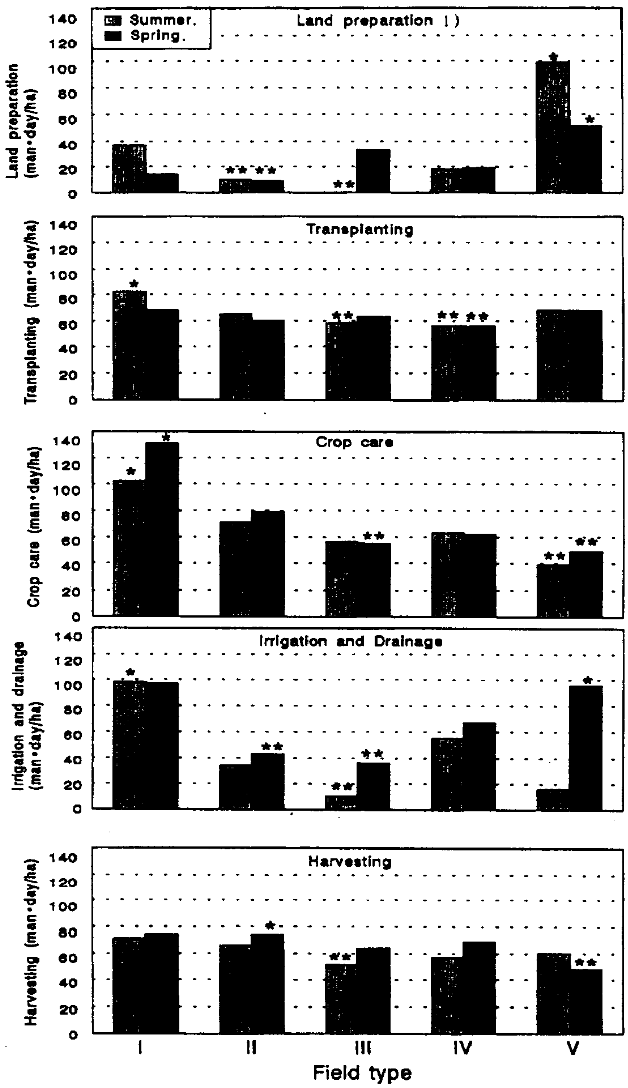

Fig. 6 Labor Input for Cropping Operations

" * " and " ** " indicate that these values are higher and lower than the mean value of the whole area, respectively, at the significance level of 10%.

1) Supplementary work by a cultivator (see Table 4).

labor input into fertilizer and insecticide application in these plots is probably similar to that in type II plots (Fig. 4). Insufficient irrigation water may encourage weed growth and require farmers to spend more labor on weeding.

Scratching the soil surface by a rake and removing weeds open up cracks in the soil which until then were capped by a thin mud layer. This increases the infiltration rate and causes more deep percolation of water. So, farmers in areas of water shortage break soil blocks into small pieces after weeding to reduce infiltration [Vu 1994: 45]. Some farmers build a secondary bund inside a plot along a drainage canal to reduce seepage loss. Labor input into these kinds of work is also included in crop care, and it is increased by insufficient irrigation water supply.

Type V plots show the smallest labor input into crop care in both seasons because of the low application of fertilizer and the deep ponding of water, which controls weed growth.

In summer, labor input into irrigation and drainage is highest in type I plots due to their insufficient irrigation water supply. Most labor is spent on lifting irrigation water. Labor input into drainage in type IV and type V plots is not significantly above average, though these are prone to inundation. This reflects the limited effects of manual lifting for drainage by farmers. In spring, the biggest labor input is into drainage in type V plots. Type I and type IV plots also show big labor inputs into irrigation and both irrigation and drainage, respectively.

Labor input into harvesting is around 50 to 70 man·day/ha, being slightly higher in type II plots because of their higher yields. Labor input is higher in summer than spring only in type V plots, which reflects the heavy work of harvesting under inundated or poorly drained conditions.

Both insufficient irrigation water supply and inundation or poor drainage, therefore, necessitate more labor input. Insufficient irrigation water supply increases labor input into transplanting, weeding, reducing percolation and seepage loss, and lifting irrigation water. Poor drainage increases labor input into supplementary land preparation, lifting excess water for drainage, and harvesting.

2. *Total Labor Input*

Estimated total labor input in each type of paddy field is shown in Fig. 7. The average of all surveyed farmers is 256 and 288 man·day/ha in summer and spring, respectively.

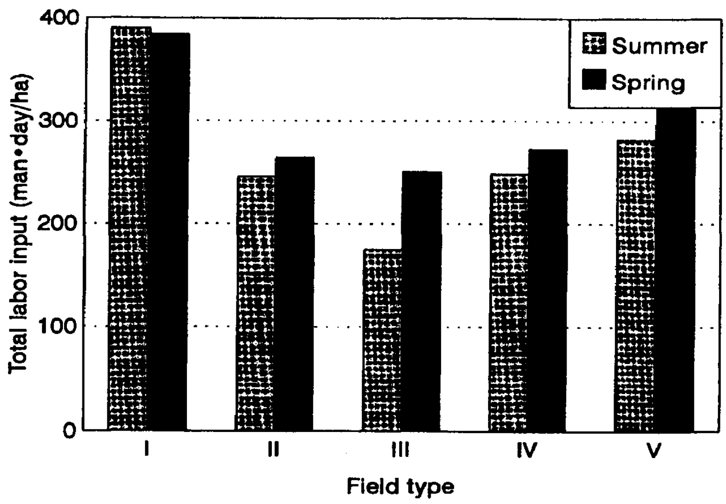

Fig. 7 Total Labor Input

Total labor input in type II and type III plots is smaller than in other types, being around 200 and 250 man·day/ha in summer and spring, respectively. These values are similar to the labor input of rice cultivation in mountain and hilly areas of southern China, and are much higher than those of other parts of Asian countries, which is 40 to 80 man·day/ha in Thailand, 70 to 80 man·day/ha in the Philippines, and 110 to 170 man·day/ha in Indonesia [IRRI 1991:

266-296]. In the other types of fields, where rice cultivation faces problems of water shortage or inundation, labor input is 50 to 100% higher again. These findings clearly show that farmers in the Red river delta spend an extremely high input of labor on rice cultivation, and that inadequate conditions of irrigation and drainage are major factors in this.

Scattering of plots is an another factor that increases labor input. Each farmer cultivates 5 to 10 plots in different locations (Table 8), which increases the time required for travel and transport. Small plot size also reduces working efficiency.

Table 8 Scattering of Cultivated Plots

Village	Distribution of Number of Plots among Households (%)									Average Number of Plots	Average Plot Size (ha)
	4	5	6	7	8	9	10	11	12		
Dan Phuong	21	5	11	26	16	21	0	0	0	6.7	0.035
Nam Phong	5	5	5	14	19	28	14	5	5	8.3	0.034
Dong Tan	15	5	10	10	10	20	25	5	0	7.8	0.036
Overall	13	5	8	17	15	24	13	3	2	7.7	0.035

Labor requirement can be reduced by improving irrigation and drainage conditions. Assuming that not less than 10% and 20% of labor input in the present type III plots in summer and spring, respectively, is the result of inadequate irrigation or drainage, the labor requirement with improved irrigation and drainage condition is estimated to be not more than 160 and 200 man·day/ha in summer and spring, respectively. This means that more than 60%, 35%, and 45% of the present labor input in type I, type IV, and type V plots, respectively, can be saved in summer, and more than 50%, 25%, and 35% in spring. Furthermore, improvement of irrigation and drainage will promote further mechanization to reduce labor requirement for rice cultivation, especially if land consolidation is simultaneously implemented to reduce the number of plots cultivated by each farmer and to increase plot size.

The actual working day for rice cultivation is calculated to be 68 and 77 man·day/household in summer and spring, respectively, as an average for the surveyed farmers. These will be decreased to 42 and 54 man·day/household by the improvement of irrigation and drainage on the assumption mentioned above.

VI Conclusions

The major findings of the present study can be summarized as follows.

1) Agricultural land in the Nhue river irrigation system is classified into five types in terms of water conditions. Type I, type II, type III and type V are located successively from higher to lower areas, i.e., from natural levees to back swamp. Type I suffers from water shortage and type V suffers from inundation in both rice-growing seasons. Type IV plots face both water

shortage and inundation problems because of their microtopography and their location at the tail reach of an irrigation canal.

2) Rice cultivation is not significantly affected by water shortage or inundation in any season in terms of the area cultivated. Rice is planted even in areas suffering from water shortage or inundation. Rice varieties planted show no significant differences between field types, except for the recent expansion of hybrid varieties. On the other hand, inundation and poor drainage prevent the expansion of commercial cultivation of non-paddy crops.

3) Fertilizer application and rice yield are affected by water shortage and poor drainage. Frequent inundation, in particular, discourages farmers from applying fertilizer, resulting in low yields. Yield increase by alleviating water shortage and inundation is estimated to be around 40% and 150%, respectively, in the most significant cases.

4) Labor input into rice cultivation in the study area is much higher than in other Asian countries. It is further increased by insufficient irrigation water and poor drainage, which require farmers to input 150% and 80% more labor in the most severe cases, respectively. Such a high labor input enables farmers to adopt similar cropping patterns and rice varieties over the whole area, regardless of variation in water conditions. The farmers' efforts, however, have limited effect, as is clearly shown by the lower yields in areas of water shortage or inundation.

5) Irrigation and drainage improvement combined with land consolidation are recommended as a measure to increase rice yields, to diversify cropping, and to reduce the labor requirement for rice cultivation. It is estimated that 30% to 40% of the present labor input will be directly saved by the improvement of irrigation and drainage, and more labor saving can be expected by further mechanization of rice cultivation, which will provide farmers with greater opportunity to engage in off-farm and non-farm jobs.

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