TECHNOLOGICAL CHANGES AND PROFITABILITY OF RICE FARMING UNDER DIFFERENT ECOSYSTEMS IN SUMATRA, INDONESIA: A STUDY OF THREE VILLAGES IN KOMERING IRRIGATION AREA

Siti Jahroh[1] and Akimi Fujimoto[2]

[1] Departemen Agribisnis, Fakultas Ekonomi dan Manajemen IPB
[2] International Bio-Business Studies, Graduate School of Agriculture, Tokyo University of Agriculture-Japan

ABSTRACT

Rice farming in Indonesia has been centered in Java since the colonial period. However, since the contribution of rice production in Java to the total production in the country has decreased, it has become difficult to depend on Java alone in order to achieve rice self-sufficiency. Thus, extensification program outside Java can be one of the solutions.

Based on the questionnaire survey conducted in three villages in Komering Irrigation area in Sumatra, this paper clarified the technological changes in rice farming from rain-fed to irrigated rice field. The future shift of technology from rain-fed to irrigated rice farming will not face many difficulties, since farmers under the rain-fed ecosystem have adopted modern technology, commonly practiced under the irrigated ecosystem, except for direct seeding. By the development of irrigation infrastructure and technology, the productivity has increased and farmers under the newly-irrigated and well-irrigated ecosystems could earn net income double and triple than that of farmers under the rain-fed ecosystem. In addition, because of the stable water supply, farmers were able to diversify their rice fields by cultivating vegetables and raising fish. Thus, land use diversification is needed to be further investigated.

Keywords : rice farming, technological change, profitability, rain-fed ecosystem, newly-irrigated ecosystem, well-irrigated ecosystem.

INTRODUCTION

Rice farming has always been a hot issue in Indonesian political economy and the government has continued its efforts to stabilize the price at an affordable level and to achieve self-sufficiency in the long term. In recent years, the country had to import rice again, especially in order to overcome the rice shortage due to harvest failure caused by natural disasters. Java is the main rice producing island in which its contribution is more than 50% of the total production in the country. However, since its contribution to total production in the country has decreased[3], it is difficult to depend on Java alone for achieving rice self-sufficiency.

Rusastra (1995) found out that wetland rice farming outside Java was less intensive and efficient than in Java, thus in order to increase rice production the emphasis should be put on regions outside Java. Furthermore, in the long-run, food self-sufficiency can be best maintained by improving physical and institutional infrastructures, which have the effect of shifting production function upward. As for the opportunity of land use, according to Puslitbangtanak (2001), which issued the map guidance of agricultural land in Indonesia, there are potential wetland areas of 24.5 million ha in Papua, Sumatra and Kalimantan (Syahyuti, 2004). Therefore, there are great needs and justification for the extensification program to be implemented outside Java, for the increase of rice production for the country, by the development of irrigation system.

In order to support food security program, up to 2009 the government is planning to develop and rehabilitate technical irrigation system to supply water for 7.2 million hectares of lowland rice fields and 1.8 million hectares

[3] For the discussion of the declining rice production in Java, see Irawan et al (2002).

of swampland (Kompas, April 29, 2007). Irrigation infrastructures have been developed in the outer islands, especially under extensification program in which the ecosystem is considered to change from rain-fed to irrigated ecosystems. Some issues over irrigation development to be pointed out include the contribution of irrigation development in increasing farmers' income, the process of technological changes from rain-fed to irrigated rice farming, and profitability of rice farming.

Komering irrigation project is one of the largest irrigation projects in the outer islands. Because this project is still on-going, there are different ecosystems in the irrigation area[4]. Therefore, a typical village under each of the three different ecosystems was selected for this study, namely Rasuan Baru village under the rain-fed area, Tambak Boyo village under the newly-irrigated area, and Karang Sari village under the well-irrigated area. This paper aims to clarify the technological changes and to analyze the profitability of rice farming under the different ecosystems. A questionnaire survey was conducted on 312 farmers from June to October 2005 in Sumatra under three different ecosystems: rain-fed (102 farmers), newly-irrigated (105 farmers) and well-irrigated rice farming (105 farmers).

RICE TECHNOLOGY DEVELOPMENT

The most remarkable technological development in agriculture is well known as the green revolution, especially the outcome of modern varieties, which has increased greatly the wheat and rice production all over the world. In rice farming, modern varieties development can be divided into three stages: First Generation, Second Generation and Third Generation (Estudillo and Otsuka, 2001). First Generation (MV1) were released from mid-1960s to the mid-1970s. These varieties are much higher-yielding than Traditional Varieties (TVs), including IR5 to IR34. The most popular varieties were IR5 and IR20. Second Generation (MV2) released from mid-1970s to mid-1980s enabled improvement of yield stability by incorporating multiple pests and disease resistance, including IR36 to IR62. The most popular varieties in this category were IR36 and IR42. Third Generation (MV3) were released from mid-1980s to the late 1990s. These varieties have better grain quality, but are equally resistant to pests and diseases as MV2, including IR64 to IR74 and PSBRc2 to PSBRc74. The most popular varieties were IR64, IR72, PSBRc10, PSBRc14, and PSBRc28.

The improvement in breeding has been made in order to solve the problems occurring after the implementation of modern varieties became wide-spread. Several studies have addressed the question of whether or not modern varieties (MVs) were less stable than traditional varieties. The results were as follows: the first group agreed that green revolution technology was associated with decreased yield stability, and second group failed to establish a link. However, Traxler et al (1995) conducted an analysis and suggested the reason for the apparent contradiction in previous studies that yield stability decreased with the release of the first generation MVs, but increased with subsequent releases.

Along with the development and wide-spread cultivation of modern varieties which are responsive to fertilizer, the use of fertilizer became intensive. For example, in the Philippines, where MVs were first introduced, fertilizer use in terms of NPK elements accelerated in the beginning of the 1970s. With the wider diffusion of MVs and with the decline

[4] The brief overview of Komering irrigation can be seen in Jahroh and Fujimoto (2005).

in urea price relative to paddy price, fertilizer application had significantly increased in the 1990s (Estudillo and Otsuka, 2001). In Indonesia as well, from the early 1970s until 1999, chemical fertilizers were heavily subsidized, sometimes by as much as 50% of the actual cost. Thus there was rapid growth in fertilizer application during the last three decades (Booth, 2002).

In terms of labor use, there has been a development toward labor-saving technology, mostly by the introduction of machinery such as tractor and threshing machine. In Indonesia, especially West Java, where rice technology is most highly developed, the use of tractors and herbicides had reduced large amount of labor use in land preparation and weeding (Jahroh and Fujimoto, 2003). Besides herbicides, the direct seeding technique, which is a traditional technique in rain-fed ecosystem, has been introduced to wetland rice production, replacing transplanting method, in order to save labor input (Pandey and Velasco, 2005). The shift towards direct seeding occurred during the late 1980s and the mid-1990s, mainly in rapidly growing economies such as Malaysia and Thailand as well as in countries where rapid intensification of the rice production system took place (for example, Vietnam).

In terms of machinery, in the Philippines, in the 1960s large 70 horsepower four-wheel tractors were popular because Central Luzon was rain-fed and the four-wheel heavier tractors were effective in breaking the hard soil. The small two-wheel power tillers replaced the four-wheel tractors when irrigation facilities expanded. In Central Luzon, as early as the 1920s, the big threshing machine called *tilyadora* was used in large haciendas to facilitate the sharing of output between the landlords and share tenants (Hayami and Kikuchi, 1982). The shift to hand threshing might have also been triggered by the improvement in irrigation system in the mid 1970s and the adoption of early maturing varieties of rice. The axial-flow thresher designed by IRRI was released in 1974; the smaller and more portable type came out in 1977.

Byerlee (1992) summarized the technical change in Asia's land-intensive cereals productions system in the following four stages: (1) Pre-Green Revolution; (2) Green Revolution, a technological breakthrough in the form of input-responsive modern varieties; (3) First Post-Green Revolution, emphasizing input intensification; and (4) Second Post-Green Revolution, emphasizing input efficiency.

THE VILLAGES AND FARMERS STUDIED

Villages Studied

Three villages were chosen for the study, Karang Sari village representing a well-irrigated rice field, Tambak Boyo village as a newly-irrigated rice field, and Rasuan Baru village as a rain-fed rice field in the (Table 1). Firstly, in Karang Sari village, there are still some rain-fed rice fields in the village. This is due to the nature of the village wherein a river divides the village area into two distinct ecosystems, irrigated rice fields on one side and rain-fed rice fields on the other side. Karang Sari village is 290 km from Palembang, 95 km from the capital city of OKU district, and 15 km from the capital city of Belitang sub-district. The village consists of 5 hamlets and 14 neighborhoods. The total land area is 1,246 ha, in which agricultural land occupies 850 ha. The well-irrigated rice field totaled to 336 ha, semi-irrigated and rain-fed rice fields to 56 ha and to 270 ha, respectively. The total population is 3,830 persons in 984 households, of which 2,929 persons (76.5%) are engaged in agriculture. There are one KUD (village unit cooperative), 12 Kelompok Tani (farmers groups) and one P3A (water users' organization). The P3A in Karang Sari is well organized and one of the best water users' organizations in the country.

Next, Tambak Boyo village is located 225 km away from the capital city of Palembang, 85 km from capital city of OKU Timur district, and 26 km from the capital city of Buay Madang sub-district. It consists of 3 hamlets and 6 neighborhoods. The total land area was 600 ha, in which the irrigated rice field occupied 353.5 ha. The total population was 2,692 persons or around 659 households, who mostly transmigrated from Java. There are 16 farmers groups, one KUD, and one P3A, but the KUD and P3A did not work well.

Lastly, in Rasuan Baru village, the total land area was 460 ha, in which 250 ha were rain-fed rice fields. The village consisted of 3 hamlets. The total population was 1,020 persons or around 217 households, of which 214 households were engaged in agriculture. The majority of the population were indigenous Komering people, consisting of only around 10% of immigrants from other areas. There were 5 farmers groups, but KUD and P3A did not exist yet.

Table 1. General Conditions of the Three Villages Studied

Item	Rasuan Baru (Rain-fed)	Tambak Boyo (Newly-irrigated)	Karang Sari (Well-irrigated)
Village area (ha)	460	600	1.246
Irrigated rice field (ha)	-	353,5	392
Rain-fed rice field (ha)	250	-	276
Total population (persons)	1.020	2.692	3.830
No. of household	214	659	984
No. of farmers (persons)	217*	n.a.	2.929
No. of hamlet	3	3	5
No. of RT (neighborhood)	-	6	14
Total population (persons)	indigenous	immigrants	immigrants
No. of KUD (village unit cooperative)	-	1(not working)	1
No. of kelompok tani (farmers group)	5	16	12
P3A (Water users' organization)	not exist	not good	good

Source: Village Profile, Interview in Sep. 2004
Note: * refers to no. of households.

In short, it is clear that rice fields-population ratio was higher in the rain-fed area, which is 1.2 ha/person, whereas the irrigated ecosystems were 0.5 and 0.7 ha/person in the newly-irrigated and well-irrigated areas, respectively. This reflects the tendency of people to move to better-conditioned rice fields for better earnings. On the other hand, in terms of institutions, the irrigated areas, where the majority of the population was mostly immigrants, have better institutions than indigenous people in rain-fed area, indicating that the immigrants are more organized and understand the importance of working together within an institution or organization in order to achieve their goals.

Profile of Farmers Studied

A questionnaire survey was conducted from June to October 2005 in the three villages. In Karang Sari village, it was conducted in Hamlet I; covering 105 farmers, in Tambak Boyo village covering 105 farmers in Hamlet I; and in Rasuan Baru village covering 102 farmers in Hamlet I and II. The profile of farmers interviewed is presented in Table 2. Some important points deserve mentioning.

First, the average family size was 3.8 persons in Tambak Boyo and Karang Sari, rather small, indicating the success of family planning program to have only two children in order to control population in the country. On the other hand, it was 4.7 persons in Rasuan Baru village. Second, there were three female headed households in Rasuan Baru and Karang Sari village, while only one in Tambak Boyo village. Although there was only one husband who left the village to work in the city in Karang Sari village, there was a tendency for young people to prefer to work out of the village for better earnings.

Third, the average age of household heads was 37.7, 47.5 and 45.8 years in Rasuan Baru, Tambak Boyo, and Karang Sari respectively, indicating a general trend of aging farmers in the country. Fourth, the majority of farmers completed elementary school, which was the basic formal education until 1994. There were some farmers who graduated from college. Fifth, the average years of rice farming experience were 24.5, 23.8 and 15.8 years in Karang Sari, Tambak Boyo and Rasuan Baru respectively, reflecting that they have been engaged in rice farming since their early twenties. Sixth, the majority of farmers interviewed were ethnic Javanese in Tambak Boyo and Karang Sari, either transmigrated or born in the village. This area was one of the transmigration areas since the colonial period.

Land Resources

The land resources of farmers interviewed can be divided into home yard, irrigated rice field, rain-fed rice field and upland. First, the average owner possessed 0.14 of home yard at the three villages. Second, the farmers operated upland 0.17, 0.09 and 0.13 ha on the average in Rasuan Baru, Tambak Boyo and Karang Sari, respectively. Lastly, the total operated irrigated rice fields were 0.85, 0.57 and 0.77 ha on the average in Rasuan Baru, Tambak Boyo and Karang Sari, respectively. In Karang Sari village, the total operated rice fields consisted of 0.53 ha of irrigated rice fields and 0.24 ha of rain-fed rice fields on the average. In Tambak Boyo village, farmers operated 0.36 ha of irrigated rice fields and 0.21 ha of rain-fed rice fields on the average. It must be noted that although the rice fields in the village were technically irrigated, some rice fields were still depending on rain due to the unstable water supply and thus they were only able to plant rice once a year. Although the operated rice field was larger than the average rice field in Java, the area of irrigated rice field was as small as the average in Java. On the other hand, farmers in Rasuan Baru operated larger rain-fed rice fields of 0.85 ha on the average.

Table 2. Profile of Farmers Interviewed in Rasuan Baru, Tambak Boyo and Karang Sari

Item	Rasuan Baru (RF)			Tambak Boyo (NI)			Karang Sari (WI)		
	Total	Average	SD	Total	Average	SD	Total	Average	SD
No. of farmers (HH)	102			105			105		
Population	484	4,7	1,6	401	3,8	1,3	404	3,8	1,1
Household heads (persons)									
Female	3			1			3		
Male	99			104			102		
Age of household heads (years)		37,7	10,4		47,5	13,0		45,8	13,1
Formal education of HHH (years)		7,4	2,9		6,8	4,0		7,0	2,9
Rice farming experience (years)		15,8	10,9		23,8	13,9		24,5	14,3
Ethnic									
Javanese	3			105			101		
Komering	96			0			2		
Others	3			0			2		
Land Resources (ha)									
Owned home yard	14,28	0,14	0,31	14,30	0,14	0,11	14,28	0,14	0,12
Total operated irrigated rice field				38,16	0,36	0,39	55,02	0,52	0,44
Total operated rain-fed rice field	55,60	0,85	0,58	22,11	0,21	0,30	24,74	0,24	0,50
Total operated rice field	55,60	0,85	0,58	60,27	0,57	0,34	79,76	0,76	0,66
Total operated upland	17,20	0,17	0,49	9,04	0,09	0,42	13,82	0,13	0,50

Source: Survey June-October 2005

TECHNOLOGICAL CHANGES FROM RAIN-FED TO IRRIGATED RICE FARMING

This section examines the technological changes from rain-fed to newly-irrigated, and finally to well-irrigated rice farming in terms of rice cultivation practices, the use of inputs and yield.

Hypothetically, the technological changes are presented in Figure 1. The technology will change from traditional or semi-traditional in the rain-fed rice farming in Rasuan Baru, to early modern in the newly-irrigated rice farming in Tambak Boyo, and finally to modern technology in the well-irrigated rice farming in Karang Sari village. More specifically, the changes are expected as follows. First, the kind of varieties farmers planted will develop from traditional to modern varieties which

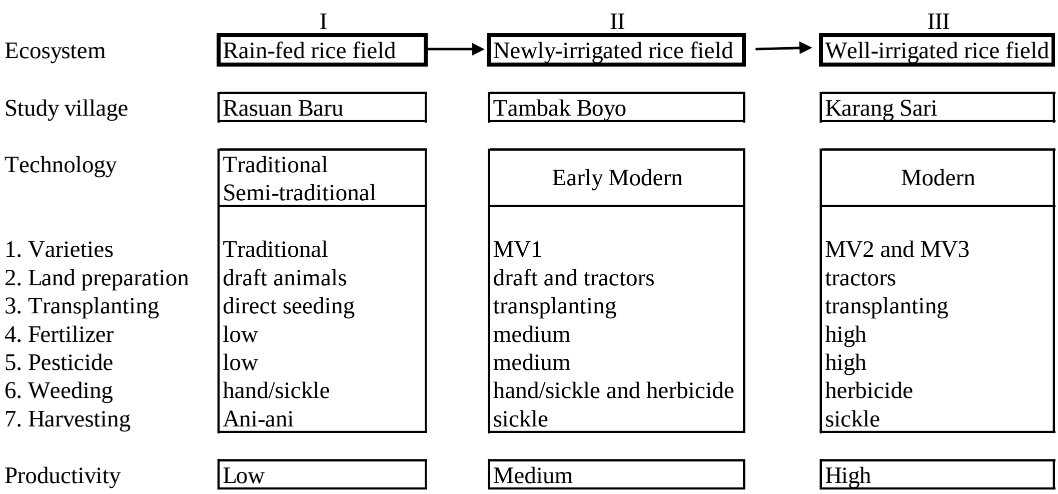

Figure 1. Technological Changes in Hypotheses

specifically can be mentioned as the first generation (MV1), second generation (MV2), and third generation (MV3). Second, in land preparation, farmers will change from using draft animals to tractors. Third, in planting method, farmers who traditionally practiced direct-seeding will adopt the transplanting method. Fourth, fertilizer and pesticide application will increase from low in Rasuan Baru, to medium in Tambak Boyo, and finally to high in Karang Sari. Fifth, in weeding, farmers will change from traditional weeding by hand or sickle to herbicide application. Lastly, in harvesting, under *bawon* system, farmers use ani-ani under the rain-fed ecosystem and will change to sickle under irrigated ecosystem in harvesting their paddy. Overall, by the introduction of tractors and herbicides, the technology will change towards labor-saving technology. Along with the technology improvement, the productivity will increase from low in Rasuan Baru, to medium in Tambak Boyo, and finally to high in Karang Sari.

In order to verify the hypotheses, actual rice cultivation practices, the use of inputs and yield in the three villages will be explained as follows.

Rice Cultivation Practices

Table 3 shows the frequency distribution of farmers by rice cultivation practice under different ecosystems. The interesting points are as follows. First, according to the different water availability, the cropping intensity of the farmers differed significantly. Under the rain-fed ecosystem (Rasuan Baru), farmers were only able to cultivate rice once a year. In Tambak Boyo village where irrigation started operating in 2002, although the water supply was sometimes still unstable, farmers were able to cultivate rice twice a year and some were able to cultivate vegetables in their rice fields. In Karang Sari village where the irrigation system has been developed and managed well, farmers could plant rice twice a year and some farmers raised fish in their rice fields.

Second, most of the rain-fed rice farmers used tractors for land preparation and there were only 5 farmers who used draft animals. This may be due to the fact that the number of indigenous people who raised livestock was smaller than the farmers in the irrigated areas. On the other hand, there were still 27% of farmers in Tambak Boyo and 21% of farmers in Karang Sari, who used draft animals for land preparation. Although the system of contracting hand tractor for land preparation was common in the three villages, the adoption of the hand tractor was slower compared to Java, in that all farmers in a West Java village contracted a tractor for land preparation (Jahroh and Fujimoto, 2003). The farmers in the study villages paid around Rp 240,000 per bau (1 bau = 0.72 ha) for plowing, leveling and puddling. The late adoption may be due to the fact that the contract charge was expensive and some farmers owned and used their own draft animals.

Third, the farmers in the study villages, including rain-fed rice farmers, planted modern varieties, which were either bought or self produced. The most commonly planted variety was Ciliwung. This was obviously one step ahead of the traditional rice farming under the rain-fed ecosystem, where farmers still grew only traditional varieties (von Braun, 2004). However, the percentage of farmers who bought the labeled/certified seed was higher in the rain-fed rice fields than in the irrigated rice fields. Under the rain-fed ecosystem where farmers planted rice once a year, only a few farmers were able to save their rice for the next year's planting season.

On the other hand, the farmers under the irrigated ecosystems usually bought the labeled/certified seed once in every three seasons. The yield of the fourth generation rice was not good and thus the farmers replaced the strain by purchasing the labeled/certified seed. In terms of planting method, all farmers in the irrigated rice fields practiced transplanting. The direct-seeding which was introduced in the late 1980s to mid-1990s for saving-labor technology in the irrigated rice fields (Pandey and Velasco, 2005) was not adopted in the study villages, reflecting the abundance of labor force in the villages and as one of the measures to help each other, and also as one of the sources of income in the rural areas. On the other hand, most of the farmers in the rain-fed rice fields practiced transplanting due to the reason that in direct-seeding practice, they had difficulty in controlling the weeds.

Fourth, regardless of the rice field ecosystems, all farmers applied fertilizer at least twice, which may be due to the planting of fertilizer responsive modern varieties. In terms of pesticide also the trend seemed similar, although there were few farmers who did not apply any pesticide in the irrigated rice fields. It seemed that farmers under the rain-fed ecosystem apply fertilizer and pesticide more frequently.

Fifth, there were some farmers who did not practice weeding under the irrigated ecosystems. Because of the ample availability of water, they kept their rice fields flooded in order to prevent weeds from growing. The well-irrigated rice field in Karang Sari under flooded condition throughout the year also made it difficult for the farmers to cultivate secondary crops in the third season. Thus some of them raised fish in their rice fields instead. More than half of the rain-fed rice farmers applied herbicide first and did weeding by sickle or hand afterward.

Finally, farmers adopted *bawon* system for harvesting, in which harvest workers were paid wages in terms of paddy at a 6:1 rate in general at three villages. There were some farmers who adopted 5:1 share-rate under the rain-fed ecosystem, meaning 5 portions for the owner farmer and 1 portion for the harvesters, while under the irrigated ecosystems, all farmers adopted 6:1 share rate. This may be due to the low yield under the rain-fed ecosystem which leads to the high share-rate, but as the yield increased in irrigated ecosystems the share-rate became lower. However, these sharing rates are considered more favorable for workers, compared to the common rate in West Java of 10:1 (Jahroh and Fujimoto, 2003). There were some farmers who failed to harvest due to natural disasters such as flood and pest attack. This *bawon* system is one of mutual help practices in the rural economy in order to help farmers who had suffered pest damage (Fukui et al., 2002).

In short, the traditional technology under the rain-fed ecosystem is shown in the planting method in that they still practiced direct seeding, which is a traditional technology under the rain-fed ecosystem. However, for other practices, the rain-fed rice farmers had adopted modern technology which is commonly practiced in the irrigated rice fields.

Table 3. Frequency Distribution of Farmers Interviewed by Rice Cultivation Practice in the Three Villages

Item	Rasuan Baru (Rain-fed)		Tambak Boyo (Newly-irrigated)		Karang Sari (Well-irrigated)	
	No.	%	No.	%	No.	%
No. of farmers	101		70		89	
Cropping Pattern						
Rice only	101	100,0	0	0,0	0	0,0
Rice-Rice	0	0,0	38	54,3	61	68,5
Rice-Rice-Fish	0	0,0	2	2,9	28	31,5
Rice-Rice-Vegetables	0	0,0	30	42,9	0	0,0
Land preparation						
Tractor	96	95,0	46	65,7	70	78,7
Draft animals	5	5,0	19	27,1	19	21,3
Tractor and draft animals	0	0,0	5	7,1	0	0,0
Seed						
Labelled/certified	88	87,1	24	34,3	41	46,1
Self-production/from previous harvest	16	15,8	46	65,7	48	53,9
Seedlings	2	2,0	0	0,0	0	0,0
Variety						
Ciliwung	78	77,2	60	85,7	87	97,8
IR64	0	0,0	18	25,7	2	2,2
Ciherang	19	18,8	3	4,3	1	1,1
Others	19	18,8	2	2,9	0	0,0
Planting method						
Transplanting	70	69,3	70	100,0	89	100,0
Direct seeding	32	31,7	0	0,0	0	0,0
Fertilizer						
Nursery	66	65,3	70	100,0	88	98,9
In the field						
Once	99	98,0	70	100,0	89	100,0
Twice	95	94,1	60	85,7	89	100,0
Three times	35	34,7	13	18,6	31	34,8
More than three times	7	6,9	1	1,4	1	1,1
Pesticide						
Nursery	46	45,5	70	100,0	84	94,4
In the field						
Once	94	93,1	70	100,0	87	97,8
Twice	80	79,2	66	94,3	71	79,8
Three times	33	32,7	54	77,1	52	58,4
More than three times	13	12,9	25	35,7	17	19,1
Weeding						
Nursery	3	3,0	0	0,0	0	0,0
In the field						
No weeding	0	0,0	12	17,1	5	5,6
By hand/sickle	0	0,0	3	4,3	15	16,9
Herbicide	33	32,7	52	74,3	41	46,1
Herbicide and by hand/sickle	66	65,3	3	4,3	28	31,5
Harvesting						
Bawon	94	93,1	69	98,6	85	95,5

Source: Survey June-October 2005
Notes:
(1) There were some farmers who planted more than one variety of rice.
(2) There were some farmers who practiced both transplanting and direct-seeding.
(3) There were some farmers who had harvest failure due to flood or pest attack.
(4) There were two farmers in Rasuan Baru who planted rice up to nursery only due to flood.

Yield and Input Use

Table 4 shows the average yield and inputs per ha in the three villages in the rainy season 2004-2005. Between Rasuan Baru and Tambak Boyo villages, the yield was not significantly different, which might be due to the fact that the water supply in Tambak Boyo was still unstable and under adoption process of irrigated technology. In terms of inputs, there were two significant differences, as follows. First, farmers in Tambak Boyo village used much larger amount of fertilizers. Second, in terms of labor input, farmers in Rasuan Baru village used more hired and total labor than in Tambak Boyo.

The yield of Tambak Boyo and Karang Sari villages was significantly different. There were four differences in terms of input use, as follows. First, the amount of seed was significantly different. Although farmers in Karang Sari used lower amount of input, it must be noted that farmers used more labor input in terms of nursery, implying better care of the seedlings and consequently made the seedlings grow stronger in the main field. Second, farmers in Karang Sari applied higher amount of SP36, but lower in terms of other fertilizer input, such as hormone growth. Third, farmers in Karang Sari seemed to use lower amounts of herbicide, due to the low lying environment and water flooding all year-round which may suppress weeds from growing. This condition was also a factor why farmers in Karang Sari were not able to cultivate secondary crops in the third season. Lastly, farmers in Karang Sari seemed more efficient in using their labor inputs, especially family labor.

Table 4. Average Yield and Inputs per ha in the Three Villages the Rainy Season 2004-2005

	Rasuan Baru (RF)		Tambak Boyo (NI)		Karang Sari (WI)	
N	49		49		72	
Yield (kg)	4.916	a	4.948	a	5.740	b
C.V. (%)	23		21		25	
Seed (kg)	86	a	101	a	65	b
Fertilizer						
Urea (kg)	119	a	238	b	249	b
TSP or SP36 (kg)	73	a	149	b	200	c
KCl (kg)	0,8		0		0,3	
Sub total (kg)	193	a	387	b	449	b
Other (Rp)	13.674	a	18.557	a	7.714	a
Total Fertilizer (Rp)	318.483	a	569.524	b	695.208	c
Herbicide (Rp)	33.943	a	22.704	a	13.667	b
Pesticide (Rp)	90.705	a	121.950	a	116.942	a
Labor (hours)						
Water management	0		99	a	156	b
Family labor	246	a	225	a	139	b
Hired labor	775	a	587	b	540	b
Total labor	1.021	a	812	b	679	c

Source: Survey June-October 2005

Notes:

(1) The different letters denote the significant difference at the 5% level.

(2) Exchange labor was included in family labor in Rasuan Baru and Tambak Boyo villages.

(3) Returns per labor hours was 4.8, 5.4 and 6.9 kg/hour in Rasuan Baru, Tambak Boyo and Karang Sari, respectively.

It is observed that although farmers planted the modern variety, different ecosystems resulted in a large yield difference between the well-irrigated (Karang Sari) and rain-fed (Rasuan Baru) rice fields. In addition to the different ecosystems, different amounts of inputs may have been responsible for this yield difference. Only pesticide and a part of fertilizers were not significantly different. Other differences were observed as follows. First, the amount of seed was significantly different, although the amount of seed in the well-irrigated rice field was lower than in the rain-fed rice field, as discussed above, because farmers put more care in to nursery in the well-irrigated rice fields than in the rain-fed rice fields. Second, it is obvious that the well-irrigated rice farmers applied much more fertilizer than the rain-fed rice farmers, and under the better water control in the well-irrigated rice fields, modern varieties responsive to fertilizer resulted in more yield. Third, farmers in the rain-fed rice field used more herbicide than in the well-irrigated rice field. This may be due to the nature of rain-fed where the weeds tended to grow more than under the well-irrigated ecosystem where the irrigation water suppressed the weeds from growing. Finally, the rain-fed rice farmers used more hired labor than the irrigated rice farmers, indicating better care of the field.

Overall, it is clear that yield has increased from the rain-fed to the newly-irrigated, and finally to the well-irrigated ecosystems. The trend of fertilizer and pesticide use showed an increasing trend. In accordance with modern varieties which are responsive to fertilizers, the trend of increasing yield was may be due to the trend of increasing fertilizer. The trend of herbicide use and labor input showed a decreasing trend. It must be noted that returns per labor hours increased from 4.8 kg/hour under the rain-fed ecosystem to 5.4 and 6.9 kg/hour under the newly-irrigated and well-irrigated ecosystems, respectively.

PROFITABILITY OF RICE FARMING

Along with the technology and ecosystem development, the productivity will increase and accordingly will lead to increased profitability and income. This section will examine the production cost and profitability of rice farming of three villages under different ecosystems.

Cost Components of Rice Production

The cost component discussed in this section can be divided into fixed and variable costs. Fixed cost, sometimes called “overhead” or “sunk cost”, represents the total expense that is paid out even when no output is produced; fixed cost is unaffected by any variation in the quantity of output. On the other hand, variable cost represents expenses that vary with the level of output, including raw materials, wages and fuel, and includes all costs that are not fixed (Samuel and Nordhaus, 1995). It is written as:

$$TC = FC + VC$$

Where: TC = Total Cost
FC = Fixed Cost
VC = Variable Cost

Profit is the deduction of total cost from gross return.

In this analysis, production costs were calculated to include not only the cash payment, but also the imputed family labor cost and interest on farm assets in order to assess the profitability of rice farming. Variable costs included seed, fertilizer, pesticide and labor costs. Some farmers purchased seed, while some used their own seeds from the previous harvest. The price of own seeds was assumed at the average price of rice. There were some farmers who purchased seedlings, thus the actual amount paid by them was included. Fertilizer costs included chemical fertilizer and manure which were the total amount applied in the nursery and main fields. Most farmers used manure from their own animals, and there were only two farmers who purchased manure at Rp 5,000 per 50 kg. This price was used to estimate the manure cost. Pesticide costs, including herbicide cost, were the total expenses of pesticides applied in the nursery and main fields paid by farmers. Labor costs consisted of family, exchange and hired labor costs. Exchange labor was found under the rain-fed and newly-irrigated ecosystems. It was estimated in the same manner as family labor, assuming an 8-hour day, regardless of sex, based on the on-going wage rate as Rp 20,000 per day, including meal.

Plowing which was conducted by mechanical and animal undertaken on a contract basis, was included in hired labor cost, while plowing using farmers' own tractors and animals, was included in family labor cost. Under the rain-fed ecosystem, there were some farmers who used water pump to water their rice fields under a contract basis. The interest on variable costs was assumed at 3% for 3 months of rice cultivation.

Fixed costs consisted of irrigation fee, machinery depreciation, interest on capital investment and land charge. Under the irrigated ecosystems, farmers paid an irrigation fee to the irrigation officer in the village at a fixed amount; however, there were some farmers who did not pay. Machinery depreciation was calculated by a straight line method, with the assumption of a 10% salvage value. Interest on capital investment was assumed at 3% for 3 months of rice cultivation. In terms of land charge, in Rasuan Baru (rain-fed ecosystem), it was calculated based on the fixed rent of Rp 1,000,000 per ha which was the common practice in the village. Meanwhile, under the newly-irrigated and well-irrigated ecosystems, land charge was calculated based on share-cropping arrangements common in the village, in which the landlord received 50% of the produce after deducting the harvest laborers' share but he also paid 50% of the chemical fertilizer cost.

Rice Farming in the Rainy Season

Table 5 shows the cost and return of rice production per ha in 2004-2005. In terms of variable costs, the production costs of rice farming in the three ecosystems were not significantly different, amounting to 3.7, 3.8 and 3.4 million rupiahs under the rain-fed, newly-irrigated and well-irrigated ecosystems, respectively. Labor cost occupied the largest proportion of variable costs, followed by fertilizer cost. In terms of fixed costs, land charge occupied the largest proportion of fixed costs due to the assumption of the common fixed rent and share-cropping system practiced among the farmers studied.

As mentioned earlier, the yield of rice farming under the well-irrigated (Karang Sari) ecosystem was higher than the rain-fed (Rasuan Baru) ecosystem, thus the gross return was much higher for well-irrigated rice farming, Rp 6,564,383, compared to Rp 5,229,672 of rain-fed rice farming. However, different methods of calculating land charge was used in this study, in that the fixed rent of Rp 1,000,000 per ha was adopted for the rain-fed ecosystem, while share-cropping was assumed for the well-irrigated ecosystem. That resulted in the profit being almost the same for both well-irrigated and rain-fed rice farming, amounting to Rp 443,904 and Rp 436,403 respectively. In Tambak Boyo as the newly-irrigated rice farming, although the gross return was slightly higher than the rain-fed rice farming, the profit was negative due to the assumption of share-cropping system for the calculation of land charge which occupied the largest proportion of fixed costs.

The R/C ratio of the rain-fed rice farmers was the highest, followed by the well-irrigated and newly-irrigated rice farmers, 1.09, 1.07 and 0.91 respectively, implying that if a rain-fed rice farmer invested Rp 1, he would gain Rp 1.09, while the well-irrigated rice farmers would gain Rp 1.02 from Rp 1 of investment, and on the contrary, the newly-irrigated rice farmers will lose Rp 0.09 from Rp 1 of investment.

However, when the labor cost and land charge were adjusted for family labor and owned land, net income of rice farmers would become much larger. The rice farmers under the well-irrigated, newly-irrigated and rain-fed ecosystems were able to earn Rp 3,204,151, Rp 2,315,604 and Rp 1,761,069 per ha of net income, respectively. The rain-fed rice farmers who were able to cultivate rice only once a year, may earn a net income of Rp 146,756 per month per ha. Since the irrigated rice farmers are able to cultivate rice twice a year, the newly-irrigated and well-irrigated rice farmers may earn a net income of Rp 385,604 and Rp 534,025 per month per ha respectively during the rainy season, more than double that of the rain-fed rice farmers.

Table 5. Average Cost and Return of Rice Production per ha in 2004-2005

Item	Rainy Season					
	Rasuan Baru (RF)		Tambak Boyo (NI)		Karang Sari (WI)	
	Rp/ha	%	Rp/ha	%	Rp/ha	%
N	49		49		72	
Yield (kg/ha)	4.916		4.948		5.740	
Gross Return	5.229.672		5.560.632		6.564.383	
Variable Costs						
Seed	246.190	5,1	396.824	6,5	130.189	2,1
Fertilizer	318.483	6,6	570.422	9,3	698.741	11,4
Pesticide	124.648	2,6	144.654	2,4	130.619	2,1
Labor	2.924.822	61,0	2.601.080	42,6	2.393.415	39,1
Water pump	3.133	0,1	0	0,0	0	0,0
Interest on variable cost (3% for 3 months)	108.518	2,3	111.389	1,8	100.589	1,6
Total Variable Costs	3.725.795	77,7	3.824.369	62,7	3.453.553	56,4
Income above Variable Costs	1.503.876		1.736.263		3.110.830	
Fixed Costs						
Irrigation fee	0	0,0	11.404	0,2	27.861	0,5
Machinery depreciation	44.085	0,9	115.878	1,9	106.102	1,7
Interest on capital investment	23.523	0,5	53.804	0,9	67.260	1,1
Land charge	1.000.000	20,9	2.098.366	34,4	2.465.703	40,3
Total Fixed Costs	1.067.608	22,3	2.279.451	37,3	2.666.926	43,6
Total Costs (Variable + Fixed Costs)	4.793.403	100,0	6.103.820	100,0	6.120.479	100,0
Profit	436.269		(543.188)		443.904	
R/C ratio	1,09		0,91		1,07	

Table 5. Average Cost and Return of Rice Production per ha in 2004-2005 *(continuation)*

Item	Dry Season			
	Tambak Boyo (NI)		Karang Sari (WI)	
	Rp/ha	%	Rp/ha	%
N	37		73	
Yield (kg/ha)	3.688		5.019	
Gross Return	4.422.136		5.801.909	
Variable Costs				
Seed	462.028	8,5	126.129	2,1
Fertilizer	547.391	10,1	750.025	12,4
Pesticide	152.894	2,8	115.669	1,9
Labor	2.338.412	43,2	2.631.857	43,6
Water pump	0	0,0	0	0,0
Interest on variable cost (3% for 3 months)	105.022	1,9	108.710	1,8
Total Variable Costs	3.605.747	66,7	3.732.390	61,8
Income above Variable Costs	816.389		2.069.519	
Fixed Costs				
Irrigation fee	8.550	0,2	28.607	0,5
Machinery depreciation	115.240	2,1	99.994	1,7
Interest on capital investment	56.051	1,0	59.706	1,0
Land charge	1.621.850	30,0	2.114.174	35,0
Total Fixed Costs	1.801.691	33,3	2.302.481	38,2
Total Costs (Variable + Fixed Costs)	5.407.438	100,0	6.034.870	100,0
Profit	(985.302)		(232.961)	
R/C ratio	0,82		0,96	

Source: Survey June-October 2005

Rice Farming in the Dry Season

Farmers who operated rice fields under the newly-irrigated and well-irrigated ecosystems were able to cultivate rice in the dry season (Table 5). It is obvious that the gross return was much lower compared to those in the rainy season. The total variable costs were not significantly different as 3.6 and 3.7 million rupiahs under the newly-irrigated and well-irrigated ecosystems, respectively. In terms of fixed costs, farmers under the well-irrigated ecosystem spent much higher than the newly-irrigated ecosystem, especially for the amount of land charge. Therefore, the total cost of farmers under the well-irrigated ecosystem was higher than that of farmers under the newly-irrigated ecosystem. However, because of much higher gross return of farmers under well-irrigated ecosystem, although the profit was negative, the farmers under the well-irrigated ecosystem were more profitable compared to the newly-irrigated ecosystem with R/C ratio 0.96 and 0.82, respectively.

Table 6. Net Income of Rice Farming per ha Annual and Monthly in 2004-2005 by Categories

Unit: Rp/ha

Item	Rasuan Baru (RF)		Tambak Boyo (NI)		Karang Sari (WI)	
	One Year	per Month	One Year	per Month	One Year	per Month
Farm Size						
Small-scale (less than average)	1.861.961	155.163	3.064.492	255.374	5.789.712	482.476
Large-scale (more than average)	1.571.154	130.930	5.317.958	443.163	5.270.880	439.240
Education						
Lower (less than 6 years)	1.826.945	152.245	3.591.820	299.318	5.378.064	448.172
Higher (more than 6 years)	1.680.222	140.018	3.825.173	318.764	5.920.728	493.394
Age						
Young (less than 45 years)	1.858.138	154.845	3.109.753	259.146	5.729.762	477.480
Old (more than 45 years)	1.518.396	126.533	4.300.081	358.340	5.390.252	449.188
Tenurial Status						
Tenants	1.592.153	132.679	3.233.354	269.446	3.300.011	275.001
Owner farmers	1.868.523	155.710	3.459.646	288.304	5.931.081	494.257
Owner-tenants	1.716.482	143.040	4.827.277	402.273	5.254.019	437.835
Overall	1.761.069	146.756	3.676.923	306.410	5.572.444	464.370

Source: Survey June-October 2005

Net Income from Rice Farming for One Year-round

Table 6 shows the total net income of rice farming for one year-round 2004-2005 in relation to farm size, education, age and tenurial status. Overall, it is clear that farmers under the well-irrigated ecosystem received the highest net income, followed by the newly-irrigated and rain-fed ecosystems. According to monthly net income on a per ha basis, the newly-irrigated rice farmers and well-irrigated rice farmers earned double and triple that of rain-fed rice farmers.

According to farm size, small-scale farmers under the rain-fed and well-irrigated ecosystems received higher net income than large-scale farmers. In contrast, large-scale farmers under the newly-irrigated ecosystem earned higher net income compared to small-scale farmers. In terms of education attainment, farmers with higher education under the irrigated ecosystems gained higher net income than farmers with lower education, while under the rain-fed ecosystem, farmers with lower education received higher net income than farmers with higher education. Young farmers tended to earn higher net income under the rain-fed and well-irrigated ecosystems, while under the newly-irrigated ecosystem old farmers earned higher net income. According to tenurial status, owner farmers earned highest net income under the rain-fed and well-irrigated ecosystems, while under the newly-irrigated ecosystem, owner-tenants gained the highest net income.

CONCLUSION

The traditional nature of rice technology under the rain-fed ecosystem was observed in the practice of direct seeding, while for other practices the farmers had adopted modern technology, commonly practiced in the irrigated rice fields. Thus, the future shift of technology from rain-fed to irrigated rice farming will not face many difficulties. However, since the institutions in the rain-fed village, such as farmers group and cooperative, were not working well, the existing close relationships among farmers can be utilized as an alternative for spreading new technology and exchanging information.

As expected, the average yield under the well-irrigated ecosystem was the highest (5,740 kg/ha), but it was not significantly different under the rain-fed and newly-irrigated ecosystems, 4,916 and 4,948 kg/ha, respectively. This may be due to the short experience in new technology and unstable water supply under the newly-irrigated ecosystem. Modern varieties, which are responsive to inputs, especially fertilizer, resulted in a higher yield under the preferable condition of irrigated ecosystem. In addition, labor input, especially water management in the irrigated rice fields, appeared to contribute to higher yield. It is also noted that farmers of younger age and higher education appeared to obtain a higher yield.

Farmers under the well-irrigated ecosystem produced the highest yield and accordingly the highest net income, followed by farmers under the newly-irrigated ecosystem and rain-fed ecosystem. By the development of irrigation infrastructure and technological practices, the productivity had increased and under the irrigated ecosystems farmers could now cultivate at least twice a year, thus increasing their income in which farmers under the newly-irrigated and well-irrigated ecosystems could earn net income double and triple that of farmers under the rain-fed ecosystem.

Based on the above results, it can be concluded that the development of irrigation infrastructure certainly contributed to the increase in farmers' income. In addition, by the stable water supply, farmers will be able to diversify their rice fields by cultivating vegetables and raising fish, thus the prospects of land use diversification are needed to be investigated.

REFERENCES

Booth, Anne (2002). "The Changing Role of Non-farm Activities in Agricultural Households in Indonesia: Some Insights from the Agricultural Census', *Bulletin of Indonesian Economic Studies*, vol. 38 (2): 179-200.

Byerlee, Derek (1992). "Technical Change, Productivity and Sustainability in Irrigated Cropping Systems of South Asia: Emerging Issues in the post-green revolution era," *Journal of International Development*: Vol.4, 477-496 (1992)

Estudillo, Jonna P. and Keijiro Otsuka (2001). "Has Green Revolution Ended? A Review of

Long-Term Trends in MV Adoption, Rice Yields, and Rice Income in Central Luzon, 1966-99," *Jpn J. Rural Econ*. Vol. 3, pp: 51-56.

Fukui, Seiichi, Slamet Hartono and Noriaki Iwamoto (2002). "Risk and Rice Farming Intensification in Rural Java," *Jpn. J. Rural Econ.* Vol.4, pp.32-43, 2002.

Hayami, Y. and M. Kikuchi (1982). "Asian Village Economy at the Crossroads: An Economic Approach to Institutional Change," Johns Hopkins University Press.

Irawan, Bambang, Nizwar Syafa'at, Rosmijati Sajuti, Sri Wahyuni, Bambang Rahmanto, Adi Setiyanto, and Deri Hidayat (2002), Laporan Akhir: Perumusan Program Peningkatan Produktivitas Padi di Jawa. Kerjasama Biro Perencanaan dan Keuangan, Departemen Pertanian dengan Pusat Penelitian dan Pengembangan Sosial Ekonomi Pertanian, Badan Penelitian dan Pengembangan Pertanian, Departemen Pertanian, Bogor 2002.

Jahroh, Siti and Akimi Fujimoto (2005), "Impacts of Irrigation on Agricultural Performance in Sumatra, Indonesia: A Case Study in Komering Irrigation Project Area", Journal of ISSAAS Vol 11 No 3(Supplement), 2005, pp:221-236.

Jahroh, Siti and Akimi Fujimoto (2003), Two-Decade Changes in Rice Technology and Production Performance in a West Java Village, Journal of ISSAAS Vol. 9, No. 2, Dec 2003: pp:1-11.

Kompas, Minggu 29 April 2007, "Ketahanan Pangan Jadi Prioritas"

Pandey, Sushil and Lourdes Velasco (2005). "Trends in Crop Establishment Methods in Asia and Research Issues," *Rice is Life: Scientific Perspectives for the 21st Century*. http://www.irri.org/publications/wrrc/wrrcpdf/session6-01.pdf

Rusastra, I Wayan (1995) A Profit Function Approach in Estimating Input Demand, Output Supply and Economic Efficiency for Rice Farming in Indonesia. unpublished PhD Dissertation, UPLB, Philippines.

Samuel, Paul A. and William D. Nordhaus (1995). "Economics," International Edition, 15th Edition, McGraw-Hill.

Syahyuti (2004), Kendala Pelaksanaan Landreform di Indonesia: Analisa terhadap Kondisi dan Perkembangan Berbagai Faktor Prasyarat Pelaksanaan Reforma Agraria. Forum Penelitian Agro Economi (FAE) Volume 22, No.2, Desember 2004 pp:89-101

Traxler, Greg, Jose Falck-Zepeda, J.I. Ortiz-Monasterio R. and Ken Sayre (1995). Production Risk and Evolution of Varietal Technology. Amer. J. Agr. Econ. 77 (February 1995), pp: 1-7

Von Braun, Joachim (2004), The Changing Economics and Politics of Rice Implications for Food Security, Globalization, and Environmental Sustainability, World Rice Research Conference November 4, 2004, Tokyo.