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The Three Decades of Green Revolution in a Philippine Village*

Yujiro Hayami† and Masao Kikuchi‡

Using the longitudinal data on one rice village in the Philippines that were collected from recurrent household surveys in the past three decades, changes in agricultural productivity and production structure corresponding to the development and diffusion of modern high-yielding varieties of rice were fully documented. The micro village history shows how quickly the potential of new rice technology was exploited within about a decade and half since the release of IR8, the first modern rice variety from the International Rice Research Institute, and was exhausted thereafter.

Keywords: new rice technology, modern inputs, total factor productivity.

1. Introduction

Successful development and diffusion of modern high-yielding varieties of rice and wheat in tropical Asia—popularly called the "Green Revolution"—resulted in a quantum leap in food production far exceeding the speed of population growth in the region during the 1970s and 80s. Correspondingly, Malthusian pessimism was replaced by optimism and complacency on the prospect of food supply in Asia. More recently, however, a serious concern has been expressed on the exhaustion of production potential opened up by the release of modern varieties (MV) from the International Rice Research Institute (IRRI) in the late 1960s (Pingali, Hossain and Gerpacio [10]).

Development and diffusion of short-statured, fertilizer-responsive MVs, which were the core of the Green Revolution, are considered a process of international technology transfer from temperate to tropical Asia through adaptive research (Hayami and Ruttan [8]). It is well known that the semi-dwarf MVs from IRRI were developed using improved varieties in Japan and Taiwan as a proto type (Yoshida [12]). It was the transfer of technology through the transfer of a plant type concept.

In general, to the extent that a technology transfer is successfully implemented, the productivity of recipient economies will rise rapidly by reducing the gap of their technology relative to an international technology frontier. However as their technology will approach the international frontier, the room for further productivity gain will be reduced. It is naturally expected that the production potential of Green Revolution technology in tropical Asia will eventually be exhausted unless the international technology frontier will be raised. The tendency of the steam of Green Revolution technology to run out has been more clearly visible in well-irrigated areas where MV adoption was completed earlier than in less favorable areas where MV adoption was late to start (Hayami and Otsuka [7]).

This paper aims to present a concrete illustration of how the Green Revolution emerged and its steam run off through the case study of one village in the Philippines. This village is located in the East Coast of Laguna de Bay, the largest lake in the Philippines, lying in the south of Manila (Fig. 1). Henceforth, this village is called "East Laguna Village." The lowland belt along the lake coast within the province of Laguna recorded the earliest and the most complete adoption of MV among rice-producing areas of not only in the Philippines

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* This paper was prepared during the authors' visit to the International Rice Research Institute under the IRRI-Japan Shuttle project. Its materials will be incorporated into a more comprehensive treatment of the study village (Hayami and Kikuchi [6]).

† Aoyama-Gakuin University, ‡ Chiba University.

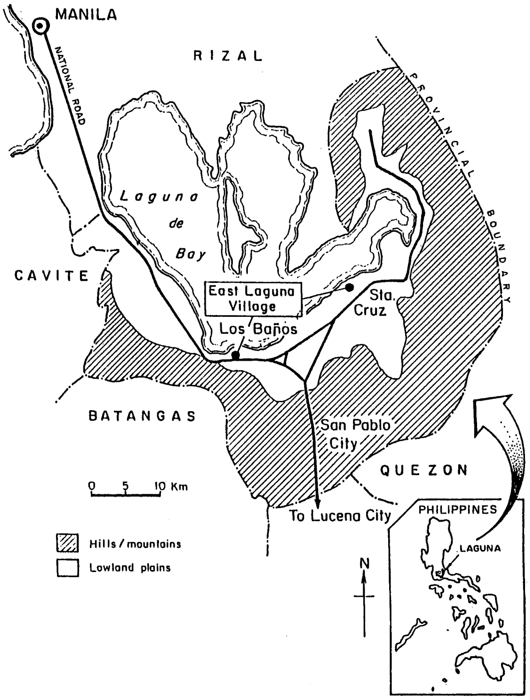

Figure 1. Map of the Province of Laguna, Philippines

but also throughout tropical Asia, because of the location of IRRI in Los Banos within this province. The process of emergence and exploitation of new rice technology can be most clearly observed through the case study in this "heartland of the Green Revolution."

Our analysis on East Laguna Village is based mainly on household surveys conducted eleven times during the three decades from 1966 to 1997. The first survey in 1966 (the year in which IR8 was released) was conducted by Umehara [11] and in the next 10 surveys were organized by ourselves in association with the IRRI Social Sciences Division. Those recurrent surveys were conducted for monitoring economic and social changes in the rural sector in their total complexity including farm production, non-farm activities, level of living, income distribution and village community structures. In this paper we only cover the aspect of agricultural production. It is exclusively focused on the impacts of new rice technology on the productivity of rice farming, while not touching upon the impacts on income distribution and poverty incidence. Those who might be interested in those aspects that are not dealt with in this paper are advised to read the forthcoming final report of this village study (Hayami and Kikuchi [6]).

2. Laguna in the Green Revolution

Before proceeding to the case of East Laguna Village, it will be useful to identify the position of Laguna Province with respect to the diffusion of modern rice technology in the Philippines.

Laguna's lead in MV adoption in the Philippines is clearly shown in the upper diagram in Fig. 2. MV planted area has already exceeded 90 percent of total rice harvested area in Laguna by the mid-1970s, whereas that level of diffusion was reached by the Philippines as a whole only in the 1990 s. The early start of MV diffusion in Laguna was, of course, facilitated by the location within this province of IRRI and a large agricultural education-extension-research complex of the University of the Philippines at Los Banos (UPLB). Although Philippine government strongly promoted the propagation of MV through its network of extension services throughout the nation, the advantage of farmers in Laguna in their access to information on this technology was incomparable. From the beginning of its development, Laguna farmers were well exposed to new rice technology either by visiting IRRI directly or through observation on and interaction with various on-farm research activities over the province by the staff of IRRI and UPLB.

Yet, easy access to the major research center alone does not explain the almost complete adoption of MV in Laguna within only about a decade since 1966. It was the well-developed irrigation infrastructure that made MV diffusion in Laguna so rapid and complete. It is well known that MVs' high-yielding capacity can only poorly exerted without adequate water control (Barker and Herdt [1], Hayami and Ruttan [8]). In this regard, Laguna Province was in an exceptionally favored position. As shown in the middle diagram of Fig. 2 nearly 80 percent of rice area in the province was already irrigated in the 1960s when the ratio was only about 40 percent in the Philippines. Even in Central Luzon known as "the rice bowl of the Philippines," the irrigation ratio in the 1960s was about 60 percent.

On the basis of early irrigation development

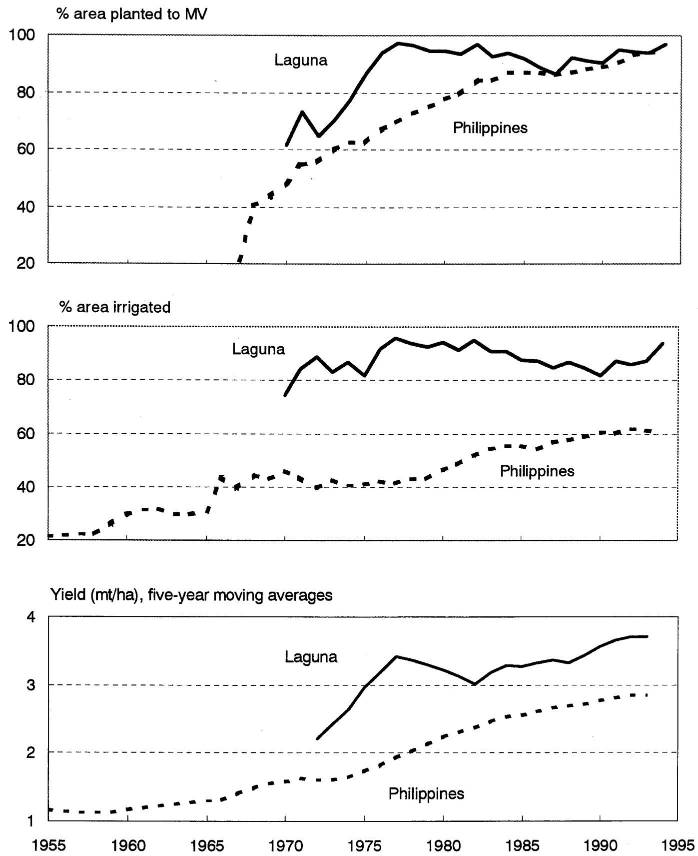

Figure 2. Area planted to MV, irrigated area, and average rice yield per hectare in the Philippines and Laguna, 1955-94
Source: Bureau of Agricultural Statistics, Rice and Corn Survey, various issues.

and MV adoption, Laguna experienced a major spurt of rice yield increase ahead of other areas in the Philippines in the first decade of the Green Revolution (the bottom diagram of Fig. 2). However, as both the irrigation ratio and the MV adoption ratio reached near 100 percent, average rice yield in Laguna began to stagnate already in the late 1970s. Meanwhile, as irrigation development and MV diffusion continued in other regions, the margin of Laguna's yield over the national average was progressively closed.

Such characteristics of Laguna Province in the adoption of MV technology should be kept in mind when the case of East Laguna Village is examined.

3. Diffusion of Modern Varieties

The process of MV diffusion in East Laguna Village is shown in Table 1 and the upper diagram of Fig. 3. Indeed, farmers in this village were fast and uniform in MV adoption. In 1966 all the farmers grew traditional varieties (TV). Only a decade later, as much as 97 percent of them adopted MV in wet season and 98 percent in dry season in 1976. This speed of MV adoption in East Laguna Village was even faster than in Laguna Province, as observed in Fig. 2.

According to Umehara [11], who surveyed the village in the dry season of 1966/67, only one farmer tried IR8 in a small plot. Next year, Governor San Luis of Laguna Province distributed one kg of the new seeds each to officers in all the *barangays* (villages) in his jurisdiction.

Table 1. Changes in rice varieties planted in East Laguna Village, 1966-1996

	Wet season							Dry season					
	1966	1976	1979	1982	1987	1992	1996	1976	1979	1982	1987	1992	1996
Rate of adoption	...... % of farmer adopters												
Traditional	100	3	2					2			2		
MV_1 [a]		97	6	3				98	4	2			
MV_2 [b]			92	97	9	9			96	98	18	17	
MV_3 [c]					91	91	100				80	83	100
Top variety	na	IR26	IR42	IR50	IR64	IR64	RC20	IR26	IR36	IR50	IR64	IR64	RC14
Rate of adoption	na	75	36	68	65	26	20	67	46	79	65	28	57
Yield	...... tons/ha												
Traditional	1.9	1.1	3.3					2.0			4.6		
MV_1 [a]		2.8	3.0	3.7				3.2	3.8	2.8			
MV_2 [b]			3.2	3.9	3.7	2.8			4.0	3.6	5.2	3.1	
MV_3 [c]					4.2	3.1	4.0				4.1	4.0	5.3

a) IR5-IR34 and C4 series. b) IR36-IR62. c) IR64-IR74 and RC varieties.

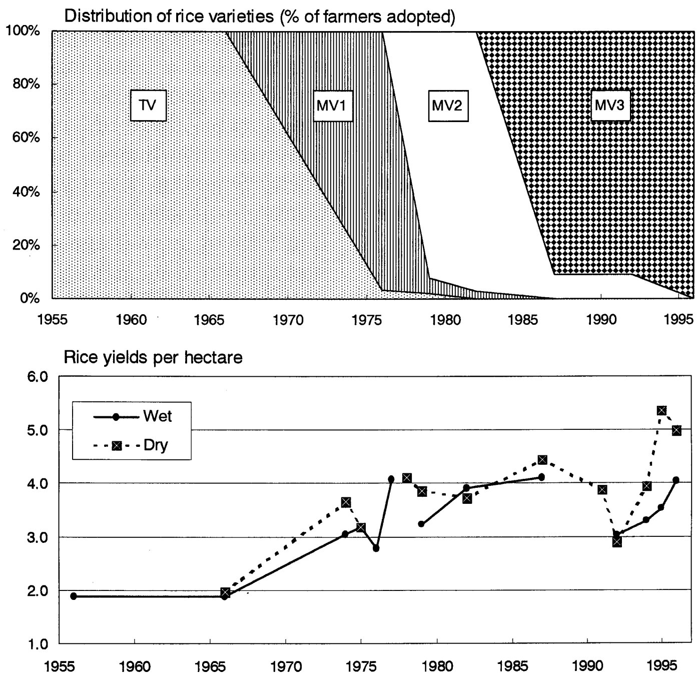

Figure 3. Distribution of rice varieties adopted by farmers and average rice yield per hectare harvested, East Laguna Village, 1956-1996

The seeds received by a *captain* (village headman) and seven council members in East Laguna Village were planted and yielded almost twice as much the yields of traditional varieties. Harvested paddy of the new variety was given to other villagers in exchange of ordinary paddy they grew. Subsequently, IR8 has been remembered by the name "San Luis variety."

Another route of diffusion was on-farm demonstration experiments conducted by the Bureau of Agricultural Extension. Since before MV development, when the Bureau had found new technologies worth propagating to farmers, its local offices had been directed to organize demonstration farming under a contract with farmer cooperators; a cooperator agrees to perform farm tasks on his field according to the instruction of extension technicians with such inputs as fertilizers and chemicals paid by the office and, upon harvest, outputs become his possession. According to this scheme the planting of IR8 and subsequent modern varieties was demonstrated on farms nearby East Laguna Village. Paddy produced from those demonstration plots was sold to other farmers in cash or exchange of paddy from old varieties.

Many other channels were also developed. For example, IRRI researchers who tried to conduct on-farm experiments found it instrumental for obtaining farmers' cooperation to give them a small pack of new seeds. Also, there were cases in which IRRI's local staff members of farm origin multiplied the new seeds in their or parents' farms for distribution to relatives and neighbours.

Quantitative data are not available to identify the MV diffusion process in East Laguna Village before 1976. According to the memory of several veteran farmers, however, the rate of MV adoption as measured by percentage of adopters reached nearly one third by 1970 and held back somewhat for the next couple of years due to the outbreak of tungro virus disease; it then returned to a level of one third in 1973 and rose to about one half in 1974, before our 1976 survey recorded the near complete adoption.

Modern varieties diffused in this initial period (MV_1)—IR series from IR5 to IR34 as well as C4 series developed by rice breeders in UP LB — were susceptible to pests, especially brown planthoppers and tungro virus disease. As pest resistant varieties (MV_2) such as IR36 were developed, farmers very quickly shifted to them, with the adoption rate of MV_2 reaching 92 percent in wet season and 96 percent in dry season by 1979. From the mid-1980s on, farmers shifted to MV_3, such as IR64 and subsequent RC series, characterized by better grain quality and improved pest resistance. By 1996 the adoption rate of MV_3 reached 100 percent in both wet and dry seasons.

In Table 1 the adoption rates for the three MV categories are compared with their average yields. It is hazardous to make an inference based on single-year yield data subject to weather and other environmental variations. Yet, it appears clear that yield margins of MV_1 and MV_2 over TV were much larger than those of MV_3 over MV_1 and MV_2. This indicates that the potential of yield growth opened up in the late 1960s had largely been exhausted by around 1980 when the diffusion of MV_2 was completed. Subsequent varietal improvement had no significant contribution to yield growth, while some improvements were done in such aspects as grain quality and pest resistance to reduce application of chemicals.

4. Rice Yield Trends

How did rice yields change corresponding to the MV diffusion? The data of rice yields in East Laguna Village collected from our periodic surveys from 1974-96 are assembled in Table 2 (columns 1-3). Considering the critical importance of observing pre-Green Revolution situations as a benchmark for comparison, we try to extrapolate our village data by the sample survey data on rice farms in Laguna Province conducted periodically by IRRI's Social Sciences Division, titled *Laguna Survey*. Concrete procedures of extrapolation to 1965 and 1966 of our village data are as follow: For wet season the *Laguna Survey* data are available for 1966, 1975, 1978 and 1981 while our village data are available annually from 1974 to 1982 except for 1978, 1980 and 1982; for estimation of the village yield data in 1966, we first took the ratio of the 1974-82 village average to the 1975-81 *Laguna Survey* average and then multiplied this ratio to the 1966 *Laguna Survey* data. Similarly, for dry season, the Laguna Survey data are available for 1965, 1982 and 1988 while the village data are available for 1978, 1979, 1982 and 1987; the ratio of the village average for 1982 and 1987 to the Laguna Survey average for 1982 and 1988 was multiplied to the 1965 *Laguna Survey* data. The wet season yield in 1956 is assumed the same as that of 1966 based on veteran farmers' recollection.

Similar to the yield data in Table 1, the data in Table 2 are subject to intrinsic weakness in identifying systematic trends in output and productivity due to technological progress, because single-year data for specific survey years are subject to large annual fluctuations due to changes in environmental conditions

Table 2. Average rice yields per hectare by season and total/per capita rice production in East Laguna Village, 1956-1996

	Yield per hectare per season			Output per year	
	Wet	Dry [a]	Average [b]	Village total	Per capita
Average yield		... tons / ha ...		... tons ...	
1956 [c]	1.9	No crop	1.9	136	0.53
1966 [d]	1.9	2.0 [e]	1.9	401	1.00
1974	3.0	3.7 [f]	3.4	704	1.28
1975	3.2	3.2	3.2	676	1.14
1976	2.8	na			
1977	4.1	na			
1978	na	4.1			
1979	3.2	3.9	3.5	636	0.90
1982	3.9	3.7 [g]	3.8	610	0.82
1987	4.1	4.4 [h]	4.3	761	0.93
1991	na	3.9			
1992	3.0	2.9	3.0	550	0.56
1994	3.3	3.9	3.6	702	0.66
1995	3.5	5.3	4.4	958	0.84
1996	4.0	5.0	4.5	na	na
Growth rate [f]			... % / year ...		
1956-82	3.1 **		3.1 **	6.1 *	1.9
1966-82	4.4 *	4.3 **	4.2 **	2.6	-1.4
1977-96	-0.3	0.7	0.6	1.3	-1.6
1977-92	-1.0	-1.1	-1.1	-0.6	-3.1
1956-96 [g]	**1.6 ****		**1.9 ****	**3.4 ***	**-0.2**
1966-96 [g]	**1.30 ***	**1.8 ****	**1.8 ****	**1.5 ***	**-1.9 ****

a) Unless otherwise noted, recorded for the year the dry season begins, e.g., 1996 for 1996/97 dry season. b) Weighted average using harvested areas as weights. c) Assumed to be the same as in 1966. d) Estimated by multiplying to the *Laguna Survey* data for 1966 the ratio of 1974-82 village average to 1975-81 *Laguna Survey* average for wet season, and by multiplying to the Laguna Survey for 1965 the ratio of 1982-87 village average to 1982-88 *Laguna Survey* average for dry season. e) Recorded for the year the dry season ends. f) Estimated from semi-log time trend regressions: ** significant at 5-percent level; * significant at 10-percent level. g) For village total and per-capita rice output, up to 1995 instead of 1996.

such as weather and pest infestation. For example, a major yield decline in 1976 was resulted from the severe outbreak of brown planthopper and tungro virus disease. Another major drop in 1992 and 1994 was due to water supply cut from the national irrigation system. On the other hand, a sudden boost in dry season yield in 1995-96 was brought about by farmers' purchase of irrigation pumps in response to deterioration in surface irrigation from the national system.

Despite the major influences of such environmental shocks, the impacts of new rice technology over time are unmistakable from a comparison between changes in average rice yield and distribution in rice varieties, as plotted in Fig. 3. First, starting from a pre-MV level of about two tons per hectare, average rice yield in wet season rose rapidly over a decade and a half between the late 1960s and the early 1980s to reach a level of about four tons per hectare, corresponding to the diffusion of MV_1 and MV_2, and thereafter became largely stagnant. Essentially a similar growth pattern was observed for dry-season yields. A rise in dry season yield to a five-ton level in 1995-1996 corresponded to the diffusion of private irrigation pumps but it is yet to be seen if this level will sustain in the future.

Recognizing major data limitations, Fig. 3 is unmistakable to show that a kink in the rice yield trend in this village occurred some time in the late 1970s to the early 1980s. Regression estimates of the average yield growth rates for both 1956-82 and 1966-82 were positive and statistically significant, while those for 1977-96 and 1977-92 were all not significantly different from zero (lower part of Table 2). The deceleration in rice yield trends in 10 to 15 years after the advent of the Green Revolution is clearly reflected in our survey data on East Laguna Villages.

5. Purchased Inputs for Rice Production

How were the modernization of agricultural production, as epitomized by MV adoption, associated with purchased inputs from market? Unfortunately, data are not available to ascertain the pattern of input changes in this village in the early phase of the Green Revolution because our survey began to cover the side of farm production inputs only from 1976 onwards. The 1965-66 levels are estimated by applying the same method as applied to the rice yield, except that the years for which input data are available for the village are limited to 1976 and 1982 for wet season and to 1979 and 1987 for dry season.

1) Fertilizers and chemicals

As is commonly called "seed-fertilizer technology," the new rice technology that supported major boosts in rice yields in tropical Asia during the first decade of the Green Revolution was characterized, above all, by association of MV diffusion with increased application of fertilizers and chemicals.

This characteristic is clearly reflected in changes in current inputs in East Laguna Village (Table 3). In 1966, the level of fertilizer input was very low at only 13 kg of nitrogen (N) per hectare and 15 kg of all plant nutrients (nitrogen-N, phosphate-P, potash-K) added together; this was almost one-tenth the level prevailed in Japan in the same period. Starting from such a low level, average fertilizer input in this village increased in the first decade of

Table 3. Current inputs in rice production, East Laguna Village, 1965-1995

	Fertilizer		Insecticide	Herbicide
	N	NPK total		
	kg/ha	kg/ha	liter/ha	liter/ha
Input level:				
Wet season				
1966 [a]	13	15	0.1	0.4
1976	58	67	2.6	0.9
1982	80	91	1.6	1.5
1987	92	103	1.9	1.5
1995	88	111	1.1	1.3
Dry season				
1965 [b]	15	20	0.1	0.5
1979	63	84	1.3	1.3
1987	94	109	2.0	1.6
1995	106	132	1.0	1.5
Growth rate (%/year):				
Wet season				
1966-76	16	16	36	10
1976-82	5	4	-7	7
1982-87	3	3	3	0
1987-95	-1	1	-7	-1
Dry Season				
1965-79	11	11	18	6
1979-87	5	3	5	3
1987-95	2	2	-8	-2

a) Estimated by multiplying to the *Laguna Survey* data for 1966 the ratio of 1976-82 village averages to 1975-81 *Laguna Survey* averages. b) Estimated by multiplying to the *Laguna Survey* data for 1965 the ratio of 1979-87 village averages to 1982-88 *Laguna Survey* averages.

Table 4. Farmers' purchase prices of inputs relative to their sale price of rice (paddy), East Laguna Village, 1966-1996

	Real price in rice equivalent			Real price index (1966=100)		
	Labor wage	Tractor rental	Nitrogen	Labor wage	Tractor rental	Nitrogen
	kg/day	kg/day	kg/kg	... 1966=100 ...		
1966	9.6	50	3.2	100	100	100
1974	8.5	51	3.0	88	103	94
1976	9.8	61	3.7	101	123	117
1980	11.4	72	3.5	118	144	110
1983	15.0	121	4.1	155	242	129
1987	13.2	88	2.1	137	176	67
1992	18.3	75	2.7	190	151	84
1994	21.4	78	2.6	223	156	83
1995	17.8	63	1.9	185	125	61

Green Revolution (1966 to 1976) by more than four folds or as fast as 16 percent per year.

It is important to recognize that during this decade the price of nitrogen did not decline but increased slightly relative to the price of rice (Table 4). Therefore, the dramatic increase in the application of fertilizer in the first decade of Green Revolution is explained solely by a shift from traditional varieties (TV) characterized by low fertilizer responsiveness to highly fertilizer-responsive MV.

After the first decade, however, the increase in fertilizer input decelerated sharply, and virtually no significant increase was recorded after nitrogen input reached a level of about 90 kg per hectare in the 1980s. The pattern of rapid rise and stagnation in fertilizer input paralleled the pattern of rice yield growth (Table 2), both reflecting the process of exploitation and exhaustion of new production potential opened up by the transfer of a new rice plant type to tropical Asia through adaptive research.

Even more dramatic were changes in the use of pesticides. The rate of increase in pesticide application from 1966 to 1976 was more than twice faster than that of fertilizer (Table 3). This extraordinary increase was induced, to a large extent, by farmers' fear of brown planthopper and tungro virus disease which caused a major loss to the crop of early IR-varieties (MV_1). However, as IR36 and other varieties resistant to brown planthopper (MV_2) were developed in the mid-1970s, pesticide application began to decline. This trend continued to be strengthened with the development and diffusion of MV_3. Increasingly both farmers and scientists recognized that a pay-off to increased pesticide dosage is low or even negative as it causes environmental degradation such as reduction in the population of natural enemies to pests (Pingali, Hossain and Gerpacio [10], chs. 5 and 11), not to talk about external diseconomies such as water contamination and human health hazard. As the result, a major decline in the application of pesticides was recorded for 1987-95.

It is well known that the thinner leaf cover of short-stalked MV together with increased fertilizer application invigorates the growth of weed as compared with the case of TV. Despite the increased need of weeding, the use of herbicides increased much slower than the input of fertilizers for the first decade of MV diffusion. This was mainly because this need was covered primarily by increased labor for weeding under the condition of stable wage rates relative to the price of rice during this period (Table 4). Later, as the real wage rate increased corresponding to increases in non-farm employment opportunities, the application of herbicides increased much faster than fertilizer input. It is a puzzle, however, that the input of herbicides dropped slightly from 1987 to 1995 despite a major increase in the real wage rate. This anomaly might be explained by the shift in the herbicide used by farmers from 2-4D to more effective butachlor.

2) Use of productive capital assets

In the use of capital assets for rice production, the first major change was a shift from carabao (water buffalo) to hand tractor (power tiller) for land preparation (Table 5). Although carabaos continued to be used for

Table 5. Use of capital services in rice production, East Laguna Village, 1965-1995

(% of farmers adopted)

	Carabao	Tractor	Thresher	Irrigation pump
Wet season				
1966 [a]	93 (10.3) [b]	39 (1.2) [c]	-	-
1976	78 (0.9)	100 (5.0)	-	-
1982	73 (1.6)	98 (3.5)	30	-
1987	96 (2.1)	98 (2.9)	92	-
1995	66 (0.5)	98 (3.6)	100	69
Dry season				
1965 [a]	100 (9.3)	35 (1.4)	-	-
1979	94 (1.2)	100 (5.6)	33	-
1987	98 (2.1)	98 (3.2)	80	4
1995	64 (0.7)	95 (3.4)	100	83

a) Estimates same as Table 3. b) Numbers of carabao-service days per hectare in parentheses.
c) Numbers of tractor-service days per hectare in parentheses.

supplementary tasks such as cultivation in the edge of a field, tractors had almost completely dominated carabaos as the source of power for land preparation by the mid-1970s. However, this shift was not a result of MV technology. It began much earlier than MV diffusion, as evident from the fact that already in 1966 nearly 40 percent of farmers used tractors. Several factors underlay the early adoption of hand tractors. First, tractors with floating wheels could operate more efficiently in deep water fields adjacent to Laguna de Bay where even carabaos often got stuck. Second, the increased speed of land preparation by tractors was also advantageous with a shift from single to double cropping for planting dry-season crop soon after wet-season harvest in order to avoid water shortage in late dry months (Umehara [11]). It is also said that the use of tractor was induced by increased scarcity of grazing land as the result of expansion of rice cultivation frontiers as well as frequent incidence of animal theft. Another underlying factor might be duty-free imports of tractors and application of subsidized credits to tractor purchase under a World Bank loan in the 1950s under the slogan of "agricultural modernization" (Barker et al. [2]).

A dramatic development that took place in this village during the second decade of the Green Revolution from 1976 to 1987 was the introduction of portable threshing machines. The use of axial-flow threshers designed by IRRI spreaded very rapidly and completely replaced hand threshing. This technological innovation induced major changes in labor contract relations. Traditionally, the same laborer who cut rice plants by a sickle threshed the crop by beating the harvested plants on a bamboo stand or a wooden plate, and he received a certain share of output for both the tasks. With the use of mechanical thresher, the task of threshing was separately contracted out to a machine owner who provided a custom service of machine threshing with operators for a fee also paid in a percentage of threshed paddy. This custom service operation was initially practiced by large farmers. However, it was found in 1995 that three landless agricultural laborers were also operating this business with the machines they purchased. Another dramatic change occurred in more recent years was the introduction of irrigation pumps as a response to serious deterioration in the service of the national irrigation system to this village in the 1990s. In 1987 only two farmers owned pumps. The number increased to 13 in 1995 and further jumped up to 28 next year.

A highly conspicuous aspect in this village (as well as surrounding villages) was active rental markets for animals and machines. It has been argued that markets are difficult to develop for the rental of draft animals and agricultural machines for the danger of damage likely to be caused by reckless use of animals and machines by renters (Binswanger and Rosenzweig [3]). In this village, also, the rental of animal or machine alone was seldom practiced. But, the market of custom services with operation handled by an owner or his

Table 6. Dependency on hired capital services in rice production, East Laguna Village, 1965-1995

(%)

	Carabao	Hand tractor	Thresher	Irrigation pump
Wet season				
1966 [b]	20	75	-	-
1976	58	31	-	-
1982	61	44	68	-
1987	75	68	94	-
1995	82	49	78	9
Dry season				
1965 [b]	17	71 [c]	-	-
1979	61	32	na	-
1987	63	64	90	-
1995	90	51	78	11

a) Percent of area received hired services.
b) Estimates same as for Table 3.
c) Estimated from the 1966 wet estimate by applying the ratio between wet and dry in the *Laguna Survey*.

employees were pervasive, as evident from the very high dependency of hired capital services in the operation of farm tasks using animals and machines (Table 6). The major role of custom service operation in the diffusion of portable threshers was explained before. Its role was also large in tractorisation, especially in the early period when the purchase of tractors was limited to large farmers; this was reflected in a very high percentage of the rice area that received tractor custom services in 1966 before the percentage declined according to subsequent tractor purchases by smaller farmers. Because of this active market for capital services, even small farmers whose operational sizes were economically too small to purchase large high-cost machineries, such as tractor and thresher, were not excluded from the use of modern mechanical technologies. Investments in these productive assets by large farmers yielded significant cash incomes to them as they were used for custom services.

In the case of irrigation pump, the custom service has not yet been so well developed with the ratio of dependency on hired services remaining only nine percent in 1995 wet season and 11 percent in dry season (Table 6).

6. Labor Use in Rice Production

How did the use of labor change in the process of Green Revolution?

During the first decade of MV diffusion, average labor input as measured by the number of days of work (workdays) applied to rice production per hectare increased by more than 15 percent from the wet season total of 89 days in 1966 to 105 days in 1976 (Table 7).

By task, a significant reduction was recorded for land preparation due to progress of tractorisation. Labor input in crop establishment including seedbed preparation and transplanting remained about the same. In this village, after its fields were converted from rainfed to irrigated conditions, the so-called *dapog* method was introduced. In this method a seedbed was prepared on a dry clay or concrete floor covered by banana leaves on which seeds are densely placed for germination (in some cases mixed with husks of paddy); young seedlings in about 10 days after seeding

Table 7. Use of labor in rice production, East Laguna Village, 1965-1995

(days/ha)

	Total	Land preparation	Crop establishment	Weeding	Harvesting & threshing	Others
Wet season						
1966 [a]	89	28	10	13	32	6
1976	105	19	10	32	38	7
1982	80	16	10	18	29	7
1987	68	12	11	14	24	7
1995	73	12	10	15	27	9
Dry season						
1965 [a]	75	27	9	5	27	7
1979	72	18	10	17	22	5
1987	69	12	11	15	24	7
1995	76	11	9	14	26	16

a) Estimates same as for Table 3.

were rolled up like a carpet and brought to fields for transplanting. Compared with traditional seedbed preparation in a watered paddy-field (*punla*) in which seedlings are grown for about a month before transplanting, the *dapog* method saves significant labor in both seedbed preparation and transplanting, though it requires twice as much seeds and, more critically, good water control in the transplanted fields so that young seedlings will not be drowned by flood or killed by drought. This method had already been adopted by the majority of farmers in this village before 1966 (Umehara [11]). Not much change in labor input for crop establishment was experienced after then. Only a modest gain was recorded in harvesting and threshing corresponding to yield increases, because traditional hand harvesting and threshing continued during the first decade.

A major increase in labor input occurred for weeding with the spread of straight-row planting and rotary weeders. A slight increase was also recorded in "others," reflecting an increased labor use for water control, fertilizer and chemical application associated with MV technology. The increase in those tasks outweighed the decrease in labor input for land preparation. In other words, the labor absorptive capacity of rice production enhanced by MV technology was able to more than offset the decrease resulted from labor-saving technologies such as tractorisation, at least for the first decade of Green Revolution. Underlying this process was the stability of labor wage rates relative to the price of output (Table 4).

However, as the wage rate rose relative to the price of output after the late 1970s, the power of labor-saving technology began to outweigh the labor-absorptive effect of MV technology. Increasingly, manual weeding with the use of rotary weeders was replaced by herbicides, and threshing with hand beating was replaced by threshing machines. A reversal in this declining trend in labor intensity was observed in both seasons from 1987 to 1997. This was due primarily to increased labor use for the operation of irrigation pumps that farmers introduced in order to counteract deterioration in the service of the gravity irrigation system.

Throughout the three decades since the advent of Green Revolution, dependency on hired labor in rice production continued to increase (Table 8). Dependency on hired labor in irrigated rice farming in the Philippines as well as many other Southeast Asian economies had traditionally been much higher than in North East Asia, such as Japan (Hayami [5]). The dependency rose further during the past three decades.

Before 1972 when land reform programs covered this village, most farmers were sharecroppers. The common form of land tenure contract then prevailed was to share both output and the cost of inputs including hired labor 50 : 50 between a landlord and a tenant. However, not all the labor costs were shared. It was customary that payments to transplanting and harvesting labor are shared equally. Dependency on hired labor for transplanting and harvesting at the seasonal peaks of labor de-

Table 8. Dependency on hired labor in rice production, East Laguna Village, 1965-1995

(%)

	Total	Land preparation	Crop establishment	Weeding	Harvesting & threshing	Others
Wet season						
1966 [a]	49	20	78	16	90	20
1976	71	53	83	71	90	23
1982	70	47	77	69	89	32
1987	83	70	81	93	98	37
1995	84	78	85	86	98	42
Dry season						
1965 [a]	56	20	75	21	93	11
1979	70	57	85	71	86	19
1987	83	71	83	93	97	39
1995	78	79	86	83	95	40

a) Estimates same as for Table 3.

mand was traditionally high even before the introduction of MV.

On the other hand, land preparation with the use of carabao, crop care activities, such as weeding, fertilizer and chemical application, and water control had supposedly been performed by tenants. Concurrent with MV diffusion, dependency on hired labor in land preparation rose as many small farmers who owned no tractor became dependent on custom services of tractors operated by large farmers.

A major increase in the employment of hired labor was associated with the diffusion of *gama* contract in the first decade of MV diffusion in which weeding and harvesting on a plot were performed by a same laborer for receiving a share of harvested crop from this plot (Hayami and Kikuchi [4], ch. 4 and 5). However, despite significant declines in the incidence of this contract from the 1980s, the use of hired labor continued to increase under the daily wage contract (*upahan*). Similarly, the use of daily wage laborers for such tasks as fertilizer and chemical application also increased. Thus, in the past three decades farmers continued to substitute hired labor for family labor in rice production.

Underlying this substitution process were major increases in farmers' incomes. After they were converted from sharecroppers to leasehold tenants or amortizing owners with rents and amortization charges fixed by land reform laws, they were able to capture all the yield gains from new rice technology. As their incomes increased, disutility of labor would have risen to reduce their own work. More importantly, as their children received better education, they seldom return home to succeed parents in farming. Under the land reform laws that dictate deprivation of land reform beneficiaries' titles on farm land upon renting it to someone else, they had no option but to continue farming under their own

Table 9. Indices of real inputs in rice production per hectare, East Laguna Village, 1965-1995

(1966=100)

	Current input [a]	Capital [b]	Labor	Total input: Include current input	Total input: Exclude current input
Index					
Wet					
1966	100	100	100	100	100
1976	389	145	117	157	113
1982	418	152	90	155	104
1987	498	164	76	166	101
1995	458	237	82	173	115
Dry					
1965	100	100	100	100	100
1979	324	182	96	133	109
1987	461	156	92	147	104
1995	437	353	101	174	138
Growth rate (%/year)					
Wet					
1966-82	9.3	2.6	-0.7	2.8	0.2
1982-95	0.7	3.5	-0.7	0.8	0.8
1966-95	**5.4**	**3.0**	**-0.7**	**1.9**	**0.5**
Dry					
1965-79	8.8	4.4	-0.3	2.1	0.6
1979-95	1.9	4.2	0.3	1.7	1.5
1965-95	**5.0**	**4.3**	**0.0**	**1.9**	**1.1**

a) Aggregate of seed, fertiliser (deflated by the price of nitrogen), pesticide (deflated by the price of Brodan) and herbicide (deflated by the price of 2-4D). b) Include services of carabao, tractor, thresher and irrigation pump. c) Edgeworth indices for respective intervals using factor shares in Table 10 as weights for aggregation are chain-linked.

management while relying more on hired labor (Hayami, Quisumbing and Adriano [9]). Through this process, employment and income from new rice technology spilled over to landless agricultural laborers who received no direct benefit from land reform programs.

7. Factor Inputs, Factor Shares and Total Factor Productivity

A broader perspective on the nature of technological change in East Laguna Village may be obtained by aggregating inputs used for rice production per hectare. In Table 9, inputs are aggregated into three categories: (i) current input including seeds, fertilizers and chemicals, (ii) capital including services of draft animals and farm machineries and (iii) labor in workdays. These three categories of inputs are further aggregated into total input using as weights factor shares estimated in Table 10. Both current and capital inputs are converted into real terms through deflation by item in each category.

For the entire three decades current input increased more than four times and capital input increased two to three times, whereas labor decreased by about 20 percent in wet season but stayed nearly constant in dry season. Consequently, the index of total input including current input increased much faster than the aggregate of capital and labor alone. However, the patterns of input movements were very different between the earlier period (1966-82 for wet and 1965-79 for dry seasons) and the later period (1982-95 for wet and 1979-95 for dry seasons). In the first period the rate of increase in current input was nearly three times higher than that of capital. In the second period, however, the rate for current input dropped precipitously, whereas the growth of capital input accelerated and exceeded the rate of increase in current input over a wide margin. These movements reflect the process in which the major momentum of technological progress in this village shifted from increasing yield per hectare based on MV adoption and fertilizer application to substituting labor by machineries.

Table 10. Factor shares in rice production per hectare, East Laguna Village, 1966-1995

(%)

	Factor shares in output				
	Total	Current inputs	Capital	Labor	Residual
Wet season					
1966	100	8	10	36	46
1976	100	24	12	31	33
1982	100	18	17	30	35
1987	100	14	13	26	47
1995	100	14	15	35	36
Dry season					
1965	100	7	10	39	44
1979	100	15	13	27	45
1987	100	13	12	26	49
1995	100	11	16	30	43

This change in the nature of technological progress is also reflected in movements in factor shares in Table 10. These shares are the shares of nominal input costs in the current value of rice output per hectare. The residual after subtracting all the input costs from output value per hectare is supposed to measure returns to land and operators' entrepreneurship. As such, it is likely that an increase in the share of one input category reflects a bias in technological change to increase the use of this input category relative to other categories. Relative increases in the share of current input in the earlier period and in the share of capital in the later period are, therefore, consistent with the hypothesis on the bias of technological progress toward using more current input in the former and toward using more capital in the latter.

Overall, what would have been the rate of technological progress in East Laguna Village? As its crude measure, total factor productivity (TFP) is calculated by taking the ratio of total output to total input in Table 11. Two kinds of TFP are calculated—one taking the ratio of rice output to total input including all the three categories of inputs and another the ratio of value added (output minus current input cost) to total input including only capital and labor. Since the cost of current inputs such as fertilizer is paid out to the non-farm sector, TFP in value-added terms is appropriate to analyze the productivity of factors owned by farm operators. Because current input was the fastest to increase among the three input categories, total input including current input grew faster so that TFP in output terms grew slower than TFP in value added terms. In order to avoid the influences of environmental factors, such as weather and

Table 11. Estimates of total factor productivity (TFP) in rice production per hectar, East Laguna Village, 1965-1995 survey years

(1966=100)

	Output terms			Value-added terms		
	Output	Total input [a]	TFP	Value added	Total input [b]	TFP
Index						
Wet						
1966	100	100	100	100	100	100
1976	175 [c]	157	112	144 [c]	113	128
1982	189 [d]	155	122	168 [d]	104	162
1987	218	166	131	203	101	201
1995	201 [e]	173	116	187 [e]	115	163
Dry						
1965	100	100	100	100	100	100
1979	198 [f]	133	149	181 [f]	109	166
1987	226	147	153	211	104	203
1995	263 [g]	174	151	251 [g]	138	182
Growth rate (%/year)						
Wet						
1966-82	4.1	2.8	1.2	3.3	0.2	3.1
1982-95	0.5	0.8	-0.4	0.8	0.8	0.0
1966-95	**2.4**	**1.9**	**0.5**	**2.2**	**0.5**	**1.7**
Dry						
1965-79	5.0	2.1	2.9	4.3	0.6	3.7
1979-95	1.8	1.7	0.1	2.1	1.5	0.6
1965-95	**3.3**	**1.9**	**1.4**	**3.1**	**1.1**	**2.0**

a) Including current input. b) Excluding current input. c) Average for 1974-1977. d) Average for 1979 and 1982. e) Average for 1995 and 1996. f) Average for 1978, 1979 and 1982. g) Average for 1995 and 1996.

pest incidence, several years' averages are used for output and value added, where data are available (see footnotes to Table 11). Yet, our observations are too small to eliminate those influences, with the result that major differences arose in the estimates of TFP between wet and dry seasons as well as between output and value-added terms.

Nevertheless, all the estimates are unanimous to show that a significant deceleration occurred sometime around 1980. The TFP growth rates in output terms decreased from 1.2 percent per year in 1966-82 to −0.4 percent in 1982-95 for wet season and 2.9 to 0.1 percent for dry season. Meanwhile, the rates in value-added terms also decreased from 3.1 percent in 1966-82 to zero percent in 1982-95 for wet season, and from 3.7 to 0.6 percent for dry season. These estimates are consistent with the hypothesis that a major advance in technology (defined as an increase in output for given inputs) in East Laguna Village was limited mainly within one to two decades since the advent of the Green Revolution. It is also indicated that significant mechanization in more recent years represented a substitution of capital for labor along a fixed production surface in response to relative price changes rather than technological progress or an upward shift in the production frontier.

8. Conclusion

In this paper we have traced changes in rice yields, inputs and productivity for the past three decades in a village located in a well-irrigated area in the Philippines, which was the earliest in the adaption of MV leading to the Green Revolution in tropical Asia. Despite major data limitations, the experience of this village that we have observed is unambiguous at the point that the production potential opened up by the Green Revolution was able to support rapid increases in rice output and productivity for about one decade and a half and that the potential was largely exhausted as it was rapidly exploited. This village experience has been reiterated in many well-irrigated areas where MV adoption was completed earlier. Stagnation in rice yields due to exhaustion of the potential is yet to occur in less favourable areas where MV adoption was late to start. Before this process will be reiterated in the laggard areas, it is necessary for the sake of global food security to strengthen the capacity of research and development for elevating the international frontier of agricultural production technology. Investment requirement for raising the technology frontier at a sufficient speed is likely to be much larger than that for closing the technology gap between temperate and tropical Asia existed in the eve of the Green Revolution. Yet, unless the world community will meet this requirement, serious food insecurity will become an inevitable consequence in the twenty first century.

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