THE ECONOMIC RETURNS TO INDONESIAN RICE AND SOYBEAN RESEARCH

An AARD/ISNAR Report*

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ACRONYMS AND ABBREVIATIONS

AARD	Agency for Agricultural Research and Development
ARSSP	Agricultural and Rural Sector Support Program
AVRDC	Asian Vegetable Research and Development Agency
AP3I	Indonesian Estate Crops Research and Development Association
BARIF	Banjarbaru Research Institute for Food Crops
BIMAS	*Bimbingan Massal* (Intensification and Credit or "Mass Guidance" Programs)
BORIF	Bogor Research Institute for Food Crops
BPLPP	*Badan Pendidikan, Latihan dan Penyeluhan Pertanian* or (AAETE) Agency for Agricultural Extension, Training and Education
CARP	Center for Agricultural Research Programming
CRIFC	Central Research Institute for Food Crops
DFCE	Directorate of Food Crops Extension
DGFC	Directorate General for Food Crops
IPM	Integrated pest management
IRRI	International Rice Research Institute
ISNAR	International Service for National Agricultural Research
MARIF	Malang Research Institute for Food Crops
MORIF	Maros Research Institute for Food Crops
SARIF	Sukarami Research Institute for Food Crops
SURIF	Sukamandi Research Institute for Food Crops
USAID	United States Agency for International Development

EXECUTIVE SUMMARY

THE ECONOMIC RETURNS TO INDONESIAN RICE AND SOYBEAN RESEARCH

1. Since 1969 rice production grew at an annual average rate of 4.66% but slowed to 3.49% per annum in the post-1985 period. About 70% of the longer-run growth was due to increased yields and 30% to an increase in harvested area. Over 90% of Indonesia's rice is grown in lowland (largely Javanese) production systems where yields are presently double those found in upland (i.e., rainfed) environments.

2. At 6.22% per annum the rate of growth in soybean output has been 1.3-fold higher than that for rice. In contrast with rice, only one-third of this growth is attributable to increased yields. About 62% is due to an expansion in the area harvested, with much of this growth taking place in the provinces of Aceh, Lampung, and, to a lesser but still significant extent, in West Nusatenggara, West Java, North Sumatra, and North and South Sulawesi.

Research Inputs

3. In real terms total research expenditures by the Agency for Agricultural Research and Development (AARD) grew at an annual average rate of 7.8% since 1975 while the Agency's professional staff (net of trainees) grew by 10.1% per annum. Indonesia currently spends 0.28 cents of every dollar of agricultural output on agricultural research. Less-developed countries as a group spend 1.5-times that amount while public spending on agricultural research by more-developed countries is seven-fold higher. AARD has become increasingly reliant on foreign-sourced (i.e., loan and grant) funds. In 1975, 26.1% of AARD's expenditures were foreign sourced compared with 55.1% in 1990 and 74.4% in 1991.

4. The commodity orientation of AARD's research portfolio has changed in substantive ways over the past 15 years. Expenditures on food crops now account for about 14% of AARD's total expenditures, down from their 19.2% share in the mid-1970s. In relative terms, estate crops research has dropped quite dramatically from 32.2% to 19.8% of AARD's expenditures over the corresponding period.

5. Within the food crops program, AARD has increasingly shifted its focus away from rice research. Since 1975, expenditures on rice and soybean research grew at an annual rate of 6.6% and 13.3% respectively. Research intensities (i.e., research spending relative to the value of output) grew by 5.3% per annum in the case of soybeans but actually shrunk by 0.4% annually in the case of rice. AARD now spends two dollars on rice research for every one dollar spent on soybeans, compared with a ratio of 5.9 dollars to one in 1975.

Research Outputs

6. Research by AARD on rice has ranged across many disciplines and generated a significant number of valuable findings and innovations. Rice research output that is most clearly identified and readily quantified is the breeding and selection of new varieties. In the 18 years since 1974, AARD bred and released 48 new varieties. Of these varieties, 28 were bred for lowland growing conditions and the remainder were targeted to upland agroecological zones or tidal swamps. In addition, over the same period, AARD selected and released 14 new varieties from a large number of imported breeding lines, and also facilitated the importation of 22 new varieties bred by IRRI.

7. Other significant rice research outputs include the identification of sulphur deficiency in South

Sulawesi, the development of a minimum tillage (or *gogo rancah)* farming system, the serrated sickle, and an integrated pest management program to control tungro virus in South Sulawesi.

8. Soybean breeding research also has been very successful. A total of 19 new varieties have been released since the creation of AARD. Sixteen of these varieties were bred by the Agency. The other three were either selected by AARD or imported directly.

Research Use

9. Of all the research outputs generated by AARD, adoption of new rice varieties is the only one that can be documented with some precision. From a base of zero in 1974, the area under varieties bred and/or selected by AARD grew to 46% of the total area sown to rice by 1986. The most notable feature in the case of rice is the importance of the lowland varieties bred by AARD. The first of these varieties was released in 1976, and from 1974 to 1985 the area planted to this category of varieties grew from two percent to 34% of total area under rice.

10. During the 1980s, rice production was dominated by successive "waves" of superior varieties. Initially an imported variety, IR36, which was locally released in 1977, displaced a combination of *Lokal* varieties, early IRRI cultivars such as IR5 and IR8, and modern varieties bred in Indonesia such as Pelita I-1 and I-2. The next superior variety was Cisadane, which was released in 1980. By 1985 Cisadane accounted for 24% of all area sown to rice. In 1986 the imported IRRI variety IR64 was released, and by the late 1980s was rapidly taking over from IR36 and Cisadane as the dominant variety.

11. Available data on adoption of soybeans are less comprehensive. It is clear though from BPS statistics for the 1988 and 1989 wet and dry seasons as well as from other less official data, that Wilis, a variety bred by AARD and released in 1983, has been the soybean success story of the 1980s. By 1989 this one variety accounted for 45% of the total area sown to soybeans in all of Indonesia. It is possible that another breeding line imported by AARD and released as the variety Tidar may assume an equally dominant position in the 1990s.

Research Impacts

Returns to research in the aggregate

12. Productivity gains in the rice and soybean subsectors have been substantial over the past decade and a half. Measured total factor productivity for rice grew by 3.1% per year over the 1974 to 1989 period, although it slowed considerably in more recent years to average only 0.33% per annum since 1984. Total factor productivity gains for soybeans averaged 3.56% per annum over the longer run and 5.04% since 1984. There were large inter-regional differences in total factor productivity growth with Sumatra showing the smallest gains in this respect for both commodities.

13. Production function estimates of the growth-promoting effects of AARD's past investments in research suggest that its marginal internal rate of return in the case of rice ranges from 80% to 116% and was around 48% for soybeans.

14. Econometric estimates of the joint rice and soybean cost function indicates that the rate of technological progress averaged around 3% annually since 1974 although it declined over time; a finding that is in keeping with the TFP results reported above. Technical change appeared to be input using for labor and fertilizer, and input saving for land, seed, pesticides, and "other" inputs.

Returns to rice breeding research

15. Most of the adoption of Cisadane was achieved by displacing some combination of Pelita I-1 and IR36. During the 1980s, 90% of total area planted to Cisadane was grown in Java. Pelita I-1 and Cisadane

are both rated as having "good" taste, and both take approximately the same number of days to reach maturity. Based on the results of 35 paired yield trials on Java, where both Pelita I-1 and Cisadane were grown at the same location in the same season, the latter outyielded the former by 33% on average.

While Cisadane is rated as having "good" taste, IR36 is rated as having "poor" taste. On the other hand, Cisadane takes approximately 140 days to reach maturity, while IR36 takes only 115 days. On Java, there were 53 yield trials where IR36 and Cisadane were both grown at the same location and in the same season. For these trials Cisadane outyielded IR36 by 27%.

16. It is estimated that the adoption of Cisadane on Java alone has yielded a 92% rate of return on the total investment in rice research by AARD *plus* the total investment in associated extension services. At a discount rate of 15% this is equivalent to a benefit:cost ratio of 16.4.

17. The rate of return estimate outlined above is extremely conservative because it ignores any benefits of adoption of Cisadane outside of Java, benefits of adoption of other varieties bred by AARD, benefits of speedier adoption of varieties selected by AARD from imported lines as well as imported varieties per se, and benefits of all other AARD rice research.

Returns to soybean breeding research

18. There is a lack of evidence about the varieties that Wilis displaced during its rapid diffusion, but most available clues suggest that Orba was the most important variety at the time of Wilis introduction. In 1988, 92% of the total area under cultivation to Wilis was on Java. For 1989 the corresponding value was 83%.

19. Based on 33 experimental yield trials on Java, Wilis outyielded Orba by 7%. The number of paired trials in which both varieties were grown on the same location in the same season was quite limited. For Indonesia in total there were 12 such trials and again Wilis outyielded Orba by 7%.

20. It is estimated that the adoption of Wilis alone yielded a 43% rate of return on the total investment in soybean research by AARD plus the investment in associated extension services. At a discount rate of 15%, this is equivalent to a benefit:cost ratio of 4.3. But once again these estimates are extremely conservative because they ignore adoption of other soybean varieties bred by AARD and the benefits of other AARD research on soybeans.

1. INTRODUCTION

The widespread uptake of new technologies has been a significant feature of contemporary agricultural development in Indonesia. And government pricing, marketing, and input supply policies as well as public investment in the generation and extension of new agricultural technologies have all played a substantial role in this regard. But at this stage in the country's economic development, the future orientation of Indonesia's public policy stance toward agriculture is coming under closer scrutiny by both the domestic policy making and international donor communities alike.

After several decades of sustained and broadly based economic growth the agricultural sector now accounts for one fifth of gross domestic product (GDP), compared with a third of GDP just two decades ago. Over the corresponding period the agricultural labor force has shrunk from 72% to a still sizable 50% of the total labor force. As industrialization and off-farm employment opportunities continue to develop, the demand for marketable surpluses of cash crops will increase. With a smaller share of the population relying directly on agriculture for its livelihood -- and presuming the level of purchased inputs used in agriculture as well as the post-harvest inputs used in processing primary agricultural outputs continue to rise -- the value-added in agriculture will increasingly move off-farm. As this trend continues claims on the government purse coming from sectors other than agriculture (such as health, education, and urban development) are bound to intensify. Certainly the efficacy of attempts to maintain national self-sufficiency in rice and the role of market forces versus more overt, publicly directed efforts to intensify agricultural (and in particular rice) production systems are being reevaluated. So to are the substantial transfers to agriculture that have been achieved through input subsidy programs, with fertilizer subsidies in particular having already been reduced substantially in more recent years. All of these changes are likely to lead to marked shifts in the structure of demand for technology services that must clearly be addressed by those policymakers charged with overseeing the country's technology generation and transfer systems.

Quantifying the economic effects of Indonesia's past investments in rice and soybean research is a potentially informative way of looking back to the future. The primary objective of this study is to assess the economic rate of return to the rice and soybean research program of Indonesia's Agency for Agricultural Research and Development (AARD). There were several reasons for choosing to evaluate these aspects of AARD's research program. Both commodities are important to Indonesia in production, consumption, trade and research terms. Rice is the staple food crop for Indonesia and in 1989 accounted for 61% of the total area harvested for food crops. In terms of value of production, soybeans constitute the fifth most important food crop in the country and the exceptionally rapid growth in the area sown to this crop over recent years makes it worthy of attention. Research on these commodities presently accounts for a combined share of about 15% of AARD's (including estate crops) budget. Moreover, the Agency has researched both commodities since its inception in 1974 (in fact Indonesian research on these crops predates AARD by a good number of years) and it has produced a range of new technologies that have had sufficient time to run their course with regard to their adoptability by farmers.

But measuring the benefits due to AARD's research on rice and soybeans poses several challenges. As noted earlier, a good deal of locally sponsored research on both commodities took place before 1974, so care needs to be taken when measuring the impacts of research and interpreting the results of our analysis to ensure that only AARD-related research benefits (and, where appropriate, research costs) are included. For rice in particular, there has also been a substantial amount of technology spillin from foreign sources (especially with regard to new germplasm from the International Rice Research Institute (IRRI) located in the Philippines) that also needs to be identified and taken into account.

Finally, care must be taken to partition out the productivity consequences of research-induced technical changes from other sources of output growth such as the changing mix and/or increased use of inputs like fertilizers, pesticides, and rural infrastructural (e.g., irrigation) services. Typically, the data at our disposal are *mutatis mutandis* (everything changing) time series and/or cross-sections data from which we need to isolate the impacts of research (and extension) in a *ceteris paribus* (everything else constant) evaluation. This presents particular problems in Indonesia where, over the post-1974 period being evaluated, substantial changes in input use have taken place, heavily influenced by public pricing, marketing and infrastructural development policies. For this reason we supplemented our estimates of the aggregate productivity and growth-enhancing effects of research with a number of case studies in which the development of particular new technologies could be linked explicitly to AARD's research program and the economic consequences of these technologies (ceteris paribus) were measured.

2. PRODUCTION PATTERNS AND TRENDS

About 60% of rice production in Indonesia takes place in the three provinces of West Java, East Java, and Central Java (table 2.1). West Java alone accounted for about 23% of the country's annual rice production since 1969. The four Sumatra provinces (Lampung and North, West, and South Sumatra) as well as South Sulawesi are mid-sized producers, on average supplying around three to seven percent of total national rice production. All other provinces are residual suppliers. Soybean production in Indonesia is heavily concentrated in the provinces of East and Central Java (table 2.2). Aceh, Lampung, West Nusatenggara, and West Java are also important producers.

Detailed area harvested, production, and yield data are presented in a set of appendix tables. In order to develop appropriate summary statistics the rice and soybean data for the 1969-89 period were divided into four sub-periods (1969-74, 1975-79, 1980-84, and 1985-89) and two regions, Java and Off-Java.[1] Rice production is also decomposed into its lowland and upland components. The mean levels of production, as well as the rate of growth and variability of production are then computed and compared in the two regions over the various periods.

Rice

Over 90% of Indonesia's rice output is grown in lowland production systems. Table 2.3 shows that Indonesia experienced a steady rate of growth in rice production since 1969, with the period 1980 to 1984 experiencing the highest rate (5.3% per annum in lowland Java and 6.5% in lowland Off-Java). The rapid growth of rice production in Indonesia over the past two decades is primarily due to growth in yields per harvested hectare, which, as we demonstrate below, comes largely from the increased use of modern inputs and infrastructural services, technological advances, and changes in the institutional environment facing agriculture. For example, during the period 1980 to 1984, of the 5.3% annual production growth in lowland Java, 4.5% is directly associated with the growth in yields and only 0.8% is due to the growth in the area harvested. This pattern is even more pronounced in the upland production areas.

It is important to clarify the relationship between production growth and output variability and develop an understanding as to what extent the variability in production is due to changes in area harvested versus yields. Production variability in this study is measured by the coefficient of variation (CV). The CV is computed as

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[1]The grouping of provinces into Java and Off-Java is detailed in appendix table A2.4.

Table: 2.1 *Rice Production by Province*

	1969-71 average		1987-89 average	
Province[a]	Production[b]	Share of national total	Production[b]	Share of national total
	(tons)	%	*(tons)*	%
West Java	3,019,102	23.1	6,603,184	23.0
East Java	2,396,939	18.4	5,339,656	18.6
Central Java	2,316,708	17.8	5,00,7193	17.5
South Sulawesi	801,557	6.1	1,974,380	6.9
North Sumatra	961,149	7.4	1,665,254	5.8
West Sumatra	423,695	3.2	1,030,104	3.6
South Sumatra	379,835	2.9	869,268	3.0
Lampung	223,605	1.7	857,590	3.0
Aceh	400,796	3.1	722,145	2.5
West Nusa Tenggara	240,947	1.8	696,693	2.4
South Kalimantan	236,907	1.8	615,576	2.1
Bali	298,464	2.3	562,220	2.0
West Kalimantan	213,071	1.6	443,657	1.5
DI Yogyakarta	197,225	1.5	413,065	1.4
Jambi	167,195	1.3	334,647	1.2
Central Sulawesi	79,007	0.6	240,765	0.8
Riau	164,166	1.3	235,527	0.8
North Sulawesi	90,277	0.7	215,608	0.8
East Nusa Tenggara	94,464	0.7	194,737	0.7
Bengkulu	113,344	0.9	176,081	0.6
Central Kalimantan	84,468	0.6	167,907	0.6
East Kalimantan	70,604	0.5	141,291	0.5
S. E. Sulawesi	46,224	0.4	92,185	0.3
East Timor	0	0.0	27,144	0.1
DKI Jakarta	15,996	0.1	26,418	0.1
Irian Jaya	609	0.0	13,435	0.0
Maluku	5,973	0.0	12,943	0.0
Indonesia	1,304,2326	100.0	28,678,672	100.0

Source: Adapted from BPS, *Statistik Indonesia* (various issues).

[a]Provinces ranked in decending order by their 1987-89 share of the national total.
[b]Measured in milled-rice (*beras*) equivalent terms. The data were reported in "dry unhusked paddy before milling" (*gabah kering*) units and converted to milled rice units by multiplying by 0.68.

Table: 2.2 *Soybean Production by Province*

Province[a]	1969-71 average		1987-89 average	
	Production[b]	Share of national total	Production[b]	Share of national total
	(tons)	%	*(tons)*	%
East Java	289,870	62.0	441,023	35.4
Central Java	85,497	18.3	167,100	13.4
Aceh	1,209	0.3	107,500	8.6
Lampung	7,806	1.7	105,924	8.5
West Nusa Tenggara	27,397	5.9	104,653	8.4
West Java	17,583	3.8	63,305	5.1
DI Yogyakarta	14,328	3.1	60,254	4.8
South Sulawesi	4,458	1.0	34,846	2.8
North Sulawesi	247	0.1	27,560	2.2
North Sumatra	6,742	1.4	27,354	2.2
Bali	8,408	1.8	25,487	2.0
South Sumatra	615	0.1	16,770	1.3
West Sumatra	704	0.2	14,825	1.2
Irian Jaya	30	0.0	6,520	0.5
Central Sulawesi	573	0.1	6,345	0.5
S. E. Sulawesi	53	0.0	5,786	0.5
Jambi	243	0.1	5,764	0.5
Riau	44	0.0	5,690	0.5
South Kalimantan	331	0.1	3,417	0.3
East Kalimantan	109	0.0	3,278	0.3
Bengkulu	135	0.0	3,037	0.2
Central Kalimantan	1	0.0	2,889	0.2
West Kalimantan	496	0.1	2,176	0.2
East Nusa Tenggara	160	0.0	1,305	0.1
Maluku	441	0.1	1,164	0.1
East Timor	0	0.0	110	0.0
DKI Jakarta	0	0.0	0	0.0
Indonesia	467,478	100.0	1,244,083	100.0

Source: Adapted from BPS, *Statistik Indonesia* various issues.

[a]Provinces ranked in descending order by their 1987-89 share of the national total.
[b]Measured in dry shelled (*biji kering*) form.

Table 2.3: *Regional Rice Production Indices*

		Java									Indonesia	
	Sumatra	DKI Jakarta	West Java	Central Java	DI Yogyakarta	East Java	Total	Bali & Nusatenggara[a]	Kalimantan	Sulawesi	Index	Actual[b]
						(1980 = 100)						*('000 tons)*
1969	71.13	51.83	64.78	56.31	55.47	58.20	59.93	53.90	50.39	54.07	60.77	12,252,711
1970	74.14	27.88	65.26	68.55	59.31	56.45	62.98	58.97	58.03	70.22	65.19	13,145,058
1971	74.89	33.88	71.94	72.51	68.96	58.37	67.40	60.68	55.57	70.91	68.09	13,729,209
1972	75.52	38.96	68.60	67.04	66.62	58.73	64.74	60.99	58.67	53.72	65.40	13,187,647
1973	81.42	32.65	77.64	73.31	71.57	61.62	70.80	73.51	65.02	68.37	72.47	14,612,860
1974	82.60	40.75	79.26	77.37	86.75	68.96	75.37	80.01	70.81	62.96	75.79	15,281,693
1975	81.36	32.59	80.80	74.39	87.18	67.29	74.52	76.32	69.23	70.72	75.34	15,190,682
1976	86.50	49.75	83.38	71.80	78.86	72.67	76.34	80.12	74.80	78.59	78.58	15,844,639
1977	88.65	74.04	76.66	73.67	71.51	73.16	74.52	77.24	83.46	85.74	78.74	15,876,050
1978	90.78	75.83	87.32	86.84	89.36	79.72	84.68	86.32	90.07	93.43	86.91	17,524,668
1979	95.31	76.11	88.91	79.90	85.61	85.88	85.25	87.94	98.45	93.28	88.67	17,879,011
1980	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	20,163,227
1981	107.16	84.67	110.50	111.26	116.20	112.55	111.45	113.16	110.41	109.71	110.53	22,286,440
1982	116.50	79.25	112.69	111.50	115.93	115.37	113.22	117.60	109.31	105.42	113.26	22,836,900
1983	126.45	53.10	117.83	117.82	121.89	116.93	117.41	118.73	104.22	124.68	119.06	24,006,112
1984	132.00	55.89	129.31	133.32	135.31	124.24	128.66	122.18	109.34	137.95	128.61	25,932,783
1985	134.97	60.45	136.83	134.62	126.30	124.27	131.51	121.33	112.88	144.83	131.64	26,542,403
1986	139.04	66.43	137.82	135.69	128.07	125.90	132.78	122.78	116.07	151.49	133.98	27,014,197
1987	144.81	61.78	140.46	136.52	123.67	124.14	133.24	127.64	117.51	144.46	135.16	27,253,173
1988	153.99	62.15	144.64	139.17	126.44	126.09	136.20	132.18	123.88	159.36	140.52	28,332,983
1989	158.84	63.66	156.66	150.91	134.72	135.20	147.05	145.64	129.49	182.32	151.02	30,449,859
1989 Actual[b]	*6,133,709*	*26,895*	*702,5202*	*5,313,855*	*433,817*	*5,619,160*	*18,418,929*	*1,595,693*	*1,433,294*	*2,868,233*		*30,449,859*

Table 2.3: *Regional Rice Production Indices*

	Sumatra	Java: DKI Jakarta	Java: West Java	Java: Central Java	Java: DI Yogyakarta	Java: East Java	Java: Total	Bali & Nusatenggara[a]	Kalimantan	Sulawesi	Indonesia: Index	Indonesia: Actual[b]
Annual growth rate												
	%	%	%	%	%	%	%	%	%	%	%	%
1969-74	3.03	-4.70	4.12	6.56	9.36	3.45	4.69	8.22	7.04	3.09	4.52	4.52
1975-79	4.04	23.62	2.42	1.80	-0.46	6.29	3.42	3.61	9.20	7.17	4.16	4.16
1980-84	7.19	-13.54	6.64	7.45	7.85	5.58	6.50	5.14	2.26	8.37	6.49	6.49
1985-89	4.16	1.30	3.44	2.90	1.63	2.13	2.83	4.67	3.49	5.92	3.49	3.49
1969-89	*4.10*	*1.03*	*4.51*	*5.05*	*4.54*	*4.30*	*4.59*	*5.10*	*4.83*	*6.27*	*4.66*	*4.66*

Source: Compiled from BPS *Statistik Indonesia* (various issues).

[a]Bali and Nusatenggara includes East Timor.
[b]Measured in milled-rice equivalents.

the ratio of the standard deviation to the mean in table 2.4.

In general, the variation of rice production in lowland areas is much lower than in upland areas over the past two decades. Comparing across provinces, Java appears to have a much higher output variability than the Off-Java region. For example, for lowland rice the average CV of production is about 2.7% in Java, compared with 1.9% in Off-Java. While the production variation in the lowlands is due primarily to variations in area harvested, production variation in the upland region is caused by both area and yield variations. In other words, rice yields in the lowland areas are much more stable than in the upland. In addition, rice yields in the lowlands are about 50% higher than that in the upland areas, reflecting relative advantages of rice production (due, in part, to more favorable agroecological conditions as well as infrastructure, e.g., irrigation services) in the former.

Soybean

About 60% of soybean production in Indonesia comes from Java. Table 2.5 shows that soybean production increased more rapidly than rice production during the past 10 years. This no doubt reflects, to some degree, the government's increasing emphasis on policies designed to encourage secondary food crop production.

Unlike rice, the rise of soybean production over the recent past was not the result of higher yields, but was due mainly to increases in the area harvested. For example, the rate of growth in production for the Off-Java region over the past decade has averaged 12% per annum, of which 10% is due to the increase in area harvested. In a similar vein, the CV for production on Java is 17% over the 1980-84 period while that of area harvested is 15% (accounting for more than 80% of the total CV of production).

Following Bohrnstedt and Goldberger (1969), the means and variance of rice and soybean production were decomposed into several components defined in table 2.6. The methodology is described in appendix 3. The purpose of this exercise is to identify broad sources of production variabilities -- for example, the extent to which the variation caused by the effects of inputs, weather, and policy variations occurs *within* provinces versus the covariance of these factors *across* provinces.

These results show that over 73% of the variation in rice production and 85% of the variation in soybean production in Indonesia are accounted for by the covariances of production across provinces. The high interregional correlation in crop production may be due to the uniform government policies or high level of

Table 2.4: *Comparison of Growth Rate and Variability of Rice and Soybean Production In Indonesia, 1969-89*

	Lowland rice						Upland rice						Soybean					
	Java[a]			Off-Java[b]			Java[a]			Off-Java[b]			Java[a]			Off-Java[b]		
	Mean	G.rate	C.V.	Mean	G.rate	C.V.	Mean	G.rate	C.V.	Mean	G.rate	C.V.	Mean	G.rate	C.V.	Mean	G.rate	C.V.
Area Harvested									*('000 ha)*									
1969-74	4108	2.2	2.1	2778	2.1	2.9	331	-3.7	4.9	1012	-5.4	1.9	573	3.3	6.1	115	13.7	5.7
1975-79	4322	0.6	3.1	3106	2.7	0.9	253	-2.5	9.4	911	0.9	1.8	566	2.3	8.8	146	1.2	8.8
1980-84	4632	0.8	3.5	3452	2.5	1.7	281	7.7	8.1	895	-1.9	1.7	559	-2.1	15.0	171	10.5	14.5
1985-89	4959	0.2	1.9	3977	2.6	0.8	334	1.7	3.8	811	0.6	4.3	653	2.1	8.6	470	9.5	13.4
Production									*('000 tons)*									
1969-74	11915	4.3	3.0	6669	4.6	3.7	402	-0.3	7.1	1162	-2.8	5.3	428	4.3	6.7	81	18.0	14.4
1975-79	14202	3.8	3.4	8485	5.5	0.9	361	-0.5	11.3	1163	2.2	1.9	469	5.3	9.1	117	1.3	10.1
1980-84	20498	5.3	2.3	11516	6.5	0.9	529	14.3	9.3	1347	2.7	2.6	495	-2.4	17.0	142	10.9	16.2
1985-89	24316	2.4	2.3	14578	4.3	2.1	765	4.3	3.7	1398	5.3	4.1	701	6.2	5.4	465	12.4	16.1
Yield									*(tons/ha)*									
1969-74	2.9	2.1	1.8	2.4	2.5	1.9	1.2	3.4	4.9	1.1	2.6	5.9	0.8	1.0	3.2	0.7	4.3	10.3
1975-79	3.3	3.2	1.5	2.7	2.8	1.1	1.4	2.0	2.1	1.3	1.3	2.8	0.8	3.0	1.5	0.8	0.1	2.3
1980-84	4.4	4.5	1.7	3.3	4.0	1.1	1.9	6.6	1.7	1.5	4.6	3.0	0.9	-0.3	3.1	0.8	0.4	2.8
1985-89	4.9	2.2	0.7	3.7	1.7	1.2	2.3	2.6	1.3	1.7	4.7	0.7	1.1	4.1	3.5	1.0	2.9	3.5

Note: The data were detrended prior to computing the coefficient of variation (C.V.). The detrending method is described in appendix 3.

[a]Java includes the provinces of Jakarta, West Java, Central Java, Yogyatarta and East Java.
[b]Off-Java includes all other provinces as detailed in appendix table A2.4.

Table 2.5: *Regional Soybean Production Indices*

	Sumatra	Java					Bali and Nusatenggara[a]	Kalimantan	Sulawesi	Indonesia	
		West Java	Central Java	DI Yogyakarta	East Java	Total				Index	Actual[b]
				(1980 = 100)							*('000 tons)*
1969	33.11	78.80	51.81	43.68	69.24	64.48	49.27	28.65	29.88	59.58	388,907
1970	37.40	82.01	93.22	36.55	82.39	81.20	87.67	32.15	28.59	76.27	497,883
1971	35.14	112.73	110.32	35.05	82.37	85.45	85.45	41.79	16.61	78.99	515,644
1972	53.38	105.81	85.96	54.97	85.95	84.49	82.41	70.99	13.52	79.39	518,229
1973	96.29	118.38	124.54	52.39	73.19	83.13	94.38	72.99	25.76	82.88	541,040
1974	142.23	143.56	117.91	65.09	77.17	86.48	104.59	89.49	35.41	90.27	589,239
1975	107.23	108.39	108.50	56.82	85.19	88.47	122.41	77.19	31.87	90.36	589,831
1976	95.87	107.86	76.15	55.48	77.52	76.81	115.87	90.11	40.51	79.93	521,777
1977	91.48	75.74	103.15	66.97	74.08	79.16	87.12	95.55	60.46	80.09	522,821
1978	88.89	110.35	118.56	67.66	92.28	96.20	97.17	93.03	61.33	94.46	616,599
1979	121.92	90.74	134.47	84.34	97.14	103.10	109.32	103.36	79.19	104.15	679,825
1980	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	652,762
1981	112.27	108.69	140.12	108.27	101.53	109.60	100.29	60.26	79.09	107.82	703,811
1982	97.73	84.36	64.85	75.21	78.97	76.22	100.71	69.67	82.55	79.88	521,394
1983	120.69	106.19	99.20	69.32	68.12	75.50	87.34	129.93	134.08	82.13	536,103
1984	202.48	271.59	139.27	125.01	87.71	106.84	128.96	199.38	155.02	117.87	769,384
1985	322.11	211.88	139.47	110.11	99.84	112.18	144.38	226.02	174.30	133.24	869,718
1986	610.84	433.09	178.31	161.76	105.48	135.24	236.60	500.80	344.25	187.93	1,226,727
1987	598.50	270.62	135.37	142.55	111.78	124.23	223.09	409.31	377.18	177.85	1,160,963
1988	583.36	344.43	165.12	168.54	120.63	140.63	270.43	451.79	403.66	194.62	1,270,417
1989	550.24	369.79	198.60	173.67	123.62	150.37	319.95	426.46	283.16	199.29	1,300,868
1989 Actual[b]	*273,385*	*71,310*	*199,478*	*64,759*	*459,382*	*794,929*	*155,225*	*11,685*	*65,644*		*1,300,868*

Table 2.5: *Regional Soybean Production Indices*

		Java								Indonesia	
	Sumatra	West Java	Central Java	DI Yogyakarta	East Java	Total	Bali and Nusatenggara[a]	Kalimantan	Sulawesi	Index	Actual[b]
Annual growth rate											
	%	%	%	%	%	%	%	%	%	%	%
1969-74	33.85	12.75	17.88	8.31	2.19	6.05	16.25	25.58	3.46	8.66	8.66
1975-79	3.26	-4.35	5.51	10.38	3.34	3.90	-2.79	7.57	25.55	3.61	3.61
1980-84	19.29	28.37	8.63	5.74	-3.23	1.67	6.57	18.83	11.58	4.20	4.20
1985-89	14.32	14.94	9.24	12.07	5.49	7.60	22.01	17.20	12.90	10.59	10.59
1969-89	*15.09*	*8.04*	*6.95*	*7.15*	*2.94*	*4.33*	*9.81*	*14.46*	*11.90*	*6.22*	*6.22*

Source: Compiled from BPS *Statistik Indonesia* (various issues).

[a]Bali and Nusatenggara includes East Timor.
[b]Measured in dry-shelled equivalents.

Table 2.6: *Decomposition of Variability of Rice and Soybean Production in Indonesia, 1969-1989*

	Lowland rice		Upland rice		Soybean	
	('000 tons)	*%*	*('000 tons)*	*%*	*('000 tons)*	*%*
Mean Decomposition	27589	100.0	1771	100.0	714	100.0
Interaction between E(area) & E(yield)	27577	100.0	1777	100.3	688	96.4
Covariance of Area & Yield	12	0.0	-6	-0.3	26	3.6
Variability Decomposition	2452400	100.0	22861	100.0	23855	100.0
Variability Within Provinces	616966	25.2	6700	29.3	10000	41.9
Variability Across Provinces	1841611	75.1	16583	72.5	19705	82.6
Others	-6177	-0.3	-422	-1.8	-5850	-24.5

Note: Data for rice includes 26 provinces (East Timor is excluded) and data for soybeans includes 25 provinces (East Timor, Central Kalimantan, and Jakarta are excluded).

weather covariance among the regions.[2] This result reinforces the view that an attempt to estimate an Indonesian agricultural production model using national aggregate data, without explicitly accounting for these high covariances across provinces, could well lead to biased results.

[2]Due to the scope of this study, we did not explicitly compute the contribution of individual factors such as input, weather, policy and so on to the observed variation.

3. AGRICULTURAL RESEARCH

3.1 Research Inputs

3.1.1 Personnel and expenditure trends

Prior to AARD's establishment by Presidential decree in 1974, Indonesia's agricultural research efforts were institutionally fragmented. Public sector research was performed by a number of institutes each administered by its respective Directorate General within the Ministry of Agriculture. By consolidating the planning, coordination and management of these agricultural research institutes within AARD, the government sought a more integrated and efficient deployment of the country's scarce research resources. Since that time AARD's professional staff grew at an annual average rate of 12.3%, with a corresponding 7.8% rate of growth in real research expenditures (table 3.1). By 1991 AARD employed around 2,170 professional staff (net of trainees) and 7,800 support staff. At 3.6 support staff per professional this represents a marked change in the personnel structure of AARD since 1975 when the corresponding ratio was 11.4.

Indeed AARD has invested heavily in developing its human capital base. In 1975 there were only 276 professional staff working for AARD (net of trainees), seven of whom held a PhD degree and 26 an MSc degree. AARD embarked on an intensive training program that saw at least 20% of the Agency's professional staff away on training for each of the years 1979 to 1985. By 1991 the proportion of professional staff away on training had dropped to 6.5% but by that time there were 194 researchers with PhDs and 548 with MSc degrees.[3] A similar pattern of professional enhancement evolved within CRIFC that, if anything, saw even more impressive results. Following a rapid period of growth between the formation of the Central Research Institute for Agriculture (CRIA) in 1970/71 up to 1982, when it had been become the Central Research Institute for Food Crops (CRIFC), total staff numbers stabilised at between 2,850 and 3,100. Personnel data for 1990 indicate a total CRIFC staff of 2,953 of whom 2,026 were official GoI employees (*pegawai tetap*), representing some 20% of AARD's total *pegawai* complement (table 3.1). However, with 75 PhDs and 199 MSc/Ir staff, CRIFC account for a disproportionately large 39% and 36% of the respective AARD totals. Starting with just two PhD research staff in 1971, the almost 19% average annual rate of growth to reach a total of 75 PhDs in 1990 is a remarkable testimony to the determination of AARD/CRIFC senior management, supported by the donor community, to improve indigenous food crop research capacity.

[3] In 1991 *AP3I* (estate crops) employed an additional 330 professional staff of whom 37 held a PhD and 87 an MSc degree.

Table 3.1: *Quantitative Development of Indonesian Agricultural Research, 1975-91*

	1975-79	1980-84	1985-89	1990	1991
Professional personnel[a]		*(full-time equivalents)*			
AARD (net of estates)	449	968	1,600	1,979	1,991
CRIFC	-	-	387	621	621
AP3I	96	138	233	330	330
Total professional staff	544	1,106	1,834	2,309	2,321
Total professional staff net of trainees	-	830	1,599	2,125	2,169
Support staff[a]					
Total support staff	4,407	5,423	6,160	7,877	7,879
Total support staff net of trainees	-	5,395	6,106	7,777	7,827
Research expenditures[b]		*(millions 1980 PPP dollars)*			
AARD (net of estates)	60.8	91.2	128.2	138.2	-
CRIFC	16.7	18.2	23.2	43.0	-
AP3I	22.5	17.5	25.1	34.0	-
Total	83.4	108.6	153.3	172.0	-
Foreign-sourced expenditure share[c]	%	%	%	%	%
AARD (net of estates)	36.6	38.9	57.0	66.7	81.5
Rice	21.6	36.9	53.6	57.2	54.9
Soybean	16.0	39.5	63.6	62.9	-
AP3I	2.2	8.9	34.8	7.8	-
Total	25.6	34.0	53.6	55.1	74.4

Source: Constructed by authors using published and unpublished AARD and CRIFC data as described in Pardey et al. (forthcoming). The nominal rice and soybean data were taken from table 3.2.

[a]Because of incomplete data these personnel series include only official (*pegawai tetap*) AARD staff and exclude honorary (i.e., non-GOI or *honorer*) staff. In 1991 there were a total of 8,784 AARD (net of estates) staff of whom 6,175 were classified as official staff. Around 98% of the honorary staff were trained to no more than a diploma (*sarjana muda*) level and are principally in the support staff category. Professional staff include those holding a Ph.D., MSc, or a *sarjana/ingeneur/doctorandus* or their equivalents (i.e., *S3, S2* and *S1* degrees respectively). Support staff include those with training to the diploma, high school, middle school or elementary school level (i.e., *SO, SMTA, SMTP* and *SD* respectively). To construct the series net of trainees it was assumed that a PhD took four years to complete, an MSc two years, and an *S1* or *S0* three years each.

[b]Research expenditures include "expenditures" from routine, development and technical assistance loans and grant monies. In this instance, the technical assistance monies for CRIFC and *AP3I* include only those funds administered directly by these respective agencies. Nominal expenditure data were first deflated to 1980 rupiah using the Indonesian implicit GDP deflator and then converted to 1980 purchasing power parity (PPP) dollars using the PPP from Summers and Heston (1991), which in 1980 was 289.36 rupiah per international dollar.

[c]Foreign-sourced funds are taken here to be technical assistance loans and grants monies *excluding* ARSSP funds. Rice and soybean data were taken from table 3.2.

While AARD's total research expenditures grew by 7.8% per annum since 1975, the *AP3I* (estate crops) component of AARD increased its real spending by only 4.8% per annum (compared with 9.1% per annum for the rest of AARD). As a consequence, *AP3I* accounted for 19.8% of AARD's total expenditures in 1991 compared with nearly a third of the Agency's expenditures in 1975.

In line with the more rapid increase in numbers of research personnel compared with real expenditures, spending per scientist levels declined markedly. The 1990 average of 81,000 (1980) purchasing power parity (PPP)[4] dollars per scientist is less than half the corresponding 1975 figure. This is consistent with the substantial decline in the number of support staff per scientist noted earlier as well as a fall in the share of annual expenditures being committed to both physical and human capital development. This same pattern of expenditures was observed for the US land-grant system during its first two decades of development (Pardey, Roseboom and Anderson 1991). In spite of this decline, researchers working for the estate crops institutes within AARD continue to enjoy substantially higher levels of per capita support than their colleagues in the remainder of the system. In 1990, *AP3I* scientists worked with 103,000 (1980) PPP dollars per capita, which is nearly 48% higher than the average of 69,800 PPP dollars per scientist for those working in the other institutes within AARD. In any event, contemporary spending per scientist estimates for AARD are significantly higher than the corresponding South Asia and Southeast Asia averages (Pardey, Roseboom and Anderson 1991).

One of the striking aspects of AARD's development over the past one and a half decades is the increasing share of expenditures coming from foreign-sourced (loan and grant) funds. In 1975 the Agency got 26% of its funding from foreign sources. This share grew by 6.8% per annum so that by 1990 the foreign-sourced component was 55% and in 1991 it jumped to 74%. For most years (other than the five year period beginning in 1985) *AP3I* institutes received less than 10% of their funding from foreign sources with a large share (generally in excess of 50%) coming from local, privately and publicly owned estate corporations (*PTP/PNP*).

CRIFC's total budget, while growing in nominal terms at just over 21% per year since 1975, has significantly declined as a share of AARD's total budget. In the mid-1970s CRIFC expenditures represented

[4]PPPs are synthetic exchange rates that attempt to get a broader measure of relative currency values than indicated by official or market exchange rates. While market exchange rates are based only on a basket of traded goods and services, PPPs compare the relative cost of a detailed basket of traded and nontraded goods and services which includes the land, labor and facilities components that make up a large share of national research budgets. They have the major advantage that they are not particularly sensitive to policy shifts in exchange rates or sudden swings in international financial transactions. See Pardey, Craig, and Roseboom (1992) for more details.

about 28% of the AARD (net of estate crops) total[5], but by the end of the 1980s had declined to around 15%[6]. However, this aggregate picture masks some important underlying trends. While CRIFC's routine budget has remained consistently around 30% of AARD's, its development budget has shown considerable fluctuation -- between extremes of over 50% (1979/80) to around 21% (1991/92) of AARD's development total. Furthermore, CRIFC's technical assistance budget, although increasing from around one million (nominal) US dollars in 1975 to around four million dollars in 1989, has fallen significantly as a share of AARD's technical assistance monies; from around 27% in the mid-1970s to average 10-12% in recent years. The dominance of technical assistance in CRIFC's total budget, around 65% to 75% in recent years, combined with the increasing share of AARD's technical assistance monies directed to the nonfood crop sectors, has led to a decline in CRIFC's share of AARD's overall budget. To some extent it could be argued that CRIFC's success in developing rice technologies, in particular, has provided AARD with the opportunity to diversify its research portfolio. Given the high levels of funding originally directed to support the rice research program, relatively modest proportionate decreases in rice research expenditures can release significant amounts of research resources for other less strategic crops. Having said this, caution is urged elsewhere in this report not to overestimate the extent to which current (not to mention future) rice production constraints have been overcome -- particularly those related to biotic stress resistance.

It is informative to compare the evolution of technical assistance funding with that of technical assistance personnel at CRIFC during the lifetime of AARD. Although CRIFC has relied increasingly on technical assistance funds -- they accounted for about 30% of CRIFC's budget in the mid-1970s but had risen to around 70% by the late 1980s -- the reliance on technical assistance personnel has been decreasing. In 1975 around 20 expatriate technical assistance personnel, nearly all with PhDs, were working at CRIFC in collaborative projects with IRRI, a Japanese funded research project that focused primarily on rice, and a Dutch-funded crop ecology project. In the late 1980s, and with many more (but mostly small) projects, some 13 PhD

[5] AARD expenditures are quoted net of estate crop expenditures in the remainder of this section

[6] A significant exception to this trend occurred in 1989/90 when technical assistance and development budget increases pushed CRIFC's total budget to around 31% of the AARD total for that year.

level expatriate staff were engaged in CRIFC's technical assistance activities[7]. While local staff accounted for just 17% (i.e., 4 local, 20 expatriate) PhD-level researchers in 1975 they now constitute around 85% (i.e., 75 local, 13 expatriate) of this total, having reached parity (i.e., 20 local and 20 expatriate) in 1982.

Rice and Soybean Research Expenditures

An estimate of AARD's expenditures on rice and soybean was obtained by identifying the respective share of CRIFC's routine and development expenditures going to each of these two commodities plus the share of CRIFC and other relevant AARD technical assistance (i.e., loan and grant) monies that support the rice and soybean research programs. Estimation details are set out in appendix 2 and the results are summarised in table 3.2.

An important principle underlying the estimation procedures for both commodities was that expenditures should include not only the direct commodity specific research costs, for example, desk, field, and laboratory costs, but also an appropriate share of the capital, administrative and other research and overhead costs which must be incurred by any research system to properly sustain its research programs. Thus, commodity specific research costs were considered to have two components;

i. commodity specific direct research costs

ii. commodity share of the general (non-commodity) research, research development, infrastructure and operational overhead costs

This generated expenditure estimates that are considerably higher than those often cited, as only the first of these cost categories has usually been included in previous compilations. Our approach ensures that the sum of research cost allocations to all CRIFC's mandated commodities equals the total of all CRIFC's expenditures (routine, development and loan/grant) *plus* some allowance for any food crop research support received directly from AARD loan/grant projects. As can be seen in appendix 2 the combined rice and soybean cost allocations presently account for about 70% of CRIFC's total budget (down from 80% in 1975). The remaining 30% of the budget is allocable to CRIFC's other mandated crops, for example, corn, cassava, and peanuts. These changes point to some major shifts in priorities. Rice, though still dominating the overall commodity portfolio, has seen its share of CRIFC's budget reduced from around two-thirds to just under one-half. By contrast, and in a complementary way, soybean's share has increased from about 12% to around 22%. Since the decreased

[7] This excludes researchers at CGPRT (ESCAP) who, although collaborating with CRIFC, operate autonomously with an Asia-Pacific focus. Also excluded here are AARP technical assistance personnel. Despite this project's substantial support of food crops research it is an AARD not a CRIFC project. Estimates of the contributions to rice and soybean research for special cases such as these are discussed in appendix 2.

Table: 3.2 *Summary of Rice and Soybean Research and Development Expenditures in Indonesia, 1971-92 ('000 nominal rupiah)*

	Rice						Soybean					
	Routine and Development[a]		TA loans and grants[b]	Total			Routine and Development[a]		TA loans and grants[b]	Total		
	Amount	% CRIFC		Actual	% of AARD (excl. estates)	% of AARD (incl. estates)	Amount	% CRIFC		Actual	% of AARD (excl. estates)	% of AARD (incl. estates)
		%			%	%		%			%	%
1971	603,607	67	653,813	657,420	--	--	107,251	12	3,504	110,755	--	--
1972	697,680	67	210,846	908,526	--	--	127,100	12	14,661	141,761	--	--
1973	807,403	67	223,398	1,030,801	--	--	150,771	12	15,548	166,319	--	--
1974	935,681	67	265,539	1,201,220	--	--	179,409	13	23,099	202,508	--	--
1975	1,077,623	67	265,599	1,343,222	31.5	21.3	215,714	13	23,111	238,825	5.6	3.8
1976	1,090,229	57	341,418	1,431,647	24.0	16.5	210,900	11	40,123	251,023	4.2	2.9
1977	1,697,723	77	298,484	1,996,207	17.7	13.2	332,845	15	40,123	372,968	3.3	2.5
1978	1,698,465	66	606,983	2,305,448	18.2	13.8	387,026	15	76,416	463,442	3.7	2.8
1979	1,985,545	69	589,547	2,575,092	17.7	13.3	448,083	16	165,280	613,363	4.2	3.2
1980	2,135,575	64	830,956	2,966,531	18.8	14.3	503,077	15	232,960	736,037	4.7	3.5
1981	2,669,759	59	1,965,222	4,634,981	16.8	14.0	633,124	14	487,994	1,121,118	4.1	3.4
1982	3,159,893	58	1,862,340	5,022,233	14.9	12.6	711,864	13	465,325	1,177,189	3.5	3.0
1983	3,276,074	56	1,821,129	5,097,203	13.7	11.6	755,336	13	468,829	1,224,165	3.3	2.8
1984	3,658,806	56	2,596,755	6,255,561	11.8	10.3	984,195	15	796,940	1,781,135	3.4	2.9
1985	3,300,179	57	3,375,081	6,675,260	15.8	12.5	856,380	15	1,014,369	1,870,749	4.4	3.5
1986	3,449,680	58	3,751,799	7,201,479	14.0	11.3	944,921	16	1,343,918	2,288,839	4.4	3.6
1987	3,377,232	60	3,880,569	7,257,801	10.6	8.9	800,350	14	2,194,069	2,994,419	4.4	3.7
1988	3,412,286	57	4,838,086	8,250,372	10.3	8.8	945,404	16	2,574,795	3,520,199	4.4	3.8
1989	4,824,286	54	5,523,621	10,347,907	10.9	9.4	2,044,501	23	3,054,185	5,098,686	5.3	4.6
1990	4,783,288	52	6,394,436	11,177,724	12.4	10.0	2,080,652	23	3,527,877	5,608,529	6.2	5.0
1991	3,747,021	43	4,569,233	8,316,254	--	--	1,895,457	22	--	1,895,457	--	--
1992	4,664,689	39	--	--	--	--	3,491,718	29	--	--	--	--

Source: Compiled by authors from unpublished AARD and CRIFC data files (see appendix 2).
[a]Includes ARSSP-sourced funds for the years 1988-92.
[b]Includes components of some AARD projects e.g. AARP I/II.

share going to rice has not been completely offset by the increased share going to soybean, it is apparent that soybean is not the only benefactor from rice's decline, but we made no attempt to investigate this further.

While table 3.2 indicates estimated expenditures in nominal units these were deflated for inclusion in the production function analysis reported in section 4.2. Table 3.3 reports two constant-priced US dollar series for each commodity, the details of which are given briefly in the notes to this table and in more detail in Pardey et al. (forthcoming). The production function results were relatively insensitive to the choice of one constant priced series or another.

3.1.2 Agricultural research intensities

Ratios of agricultural research intensity (ARI) that express expenditures on public-sector agricultural research as a proportion of agricultural product are commonly used to measure the support to NARSs. In 1975 Indonesia spent only 0.16 cents on agricultural research for every dollar of agricultural output (table 3.4). While this grew by 4.3% per annum to reach 0.28 cents in the dollar by the late 1980s, the less-developed countries as a group spent 1.5-times that amount in the mid-1980s while the more-developed countries spending levels where seven-fold higher.

It is noteworthy for this study that over the longer term, the rate of increase in the value of rice production outpaced the growth in rice research expenditures so that the intensity ratio for rice actually declined by an average of 0.4% per annum. By contrast the intensity ratio for soybeans grew at an average annual rate of 5.3% per annum since 1975.

3.1.3. Research Orientation

One of the more important policy and management dimensions of a NARS is its overall commodity orientation. In thinking about this issue, the congruence rule has been used widely as a crude procedure for research resource allocations. By this method research is funded in proportion to the value of production. To do this, funds are allocated so as to equate research intensities -- research investment per value of output in gross or value-added terms -- across areas. Implementing this approach has minimal, but still non-negligible, requirements for information. It will maximize the total economic benefits for society to be gained from a portfolio or research investments when, among other things, all projects or programs are subject to the same per unit research (or knowledge) production function. Unfortunately, the full set of conditions necessary for this to be true are unlikely to be fulfilled. Some production problems are harder to solve than others and the rate of uptake of new research findings or technologies can vary markedly across commodities.

Table: 3.3 *Deflated Rice and Soybean Research Expenditures in Indonesia, 1960-89*

	Rice		Soybean	
	Series 1	Series 2	Series 1	Series 2
		(constant 1980 rupiah)		
1960	3,857,785	1,390,552	2,268,716	816,553
1961	3,917,528	1,486,201	1,949,935	738,250
1962	3,968,194	1,584,025	1,692,274	673,697
1963	4,011,008	1,684,325	1,483,151	620,622
1964	4,046,922	1,787,262	1,312,826	577,210
1965	4,075,971	1,892,569	1,173,688	541,999
1966	4,099,136	2,000,435	1,059,940	513,907
1967	4,126,241	2,115,396	967,792	492,457
1968	4,150,886	2,234,224	893,099	476,743
1969	4,174,541	2,357,504	833,268	466,419
1970	4,204,272	2,488,708	786,779	461,547
1971	3,859,736	2,509,089	649,183	420,662
1972	5,041,547	3,333,137	790,790	517,879
1973	4,719,372	3,197,505	768,950	514,854
1974	4,012,937	2,838,385	680,120	474,710
1975	4,260,776	2,889,184	765,877	513,072
1976	4,138,135	2,738,219	728,895	479,949
1977	5,237,214	3,479,071	984,039	649,730
1978	3,227,517	3,703,619	649,248	743,756
1979	2,973,035	3,162,130	708,274	753,318
1980	2,966,531	2,966,531	736,037	736,037
1981	4,592,388	4,448,276	1,110,614	1,075,986
1982	4,747,167	4,462,717	1,112,510	1,046,317
1983	4,396,110	3,970,191	1,055,898	953,924
1984	4,675,929	4,451,130	1,333,601	1,268,995
1985	4,834,171	4,508,536	1,357,146	1,265,336
1986	3,724,771	4,744,483	1,197,324	1,513,545
1987	3,663,500	4,236,307	1,600,815	1,775,968
1988	4,125,138	4,545,667	1,839,039	1,967,291
1989	4,864,776	5,274,345	2,447,258	2,616,230

Source: Constructed by authors from published and unpublished AARD and CRIFC data.

Note: The nominal routine, development and technical assistance (loans and grants) series from table 3.2 were deflated in two ways. Routine expenditures were partitioned in to a salary and an "other" component. The other part was deflated by a local, general wholesale price index. The salaries part was deflated with the Indonesian R&D salaries index described in Pardey et al. (forthcoming) to give the "Series 1" figures and the local consumer price index to give the "Series 2" figures. Development expenditures were partitioned into three classes -- salaries; land, equipment and construction; maintenance, travel and other. The salaries part was deflated by the Indonesian R&D salaries index and the CPI, to give series 1 and 2 respectively, the land, equipment and construction expenditures were deflated by the Indonesian wholesale price index for buildings, while the general wholesale price index was used to deflate the maintenance, travel and other expenditures.

Technical assistance expenditures were divided into a "salary" and an "other" component with fixed weights of 0.33 and 0.67 respectively. The salaries component was deflated by the US wholesale price index (actually producer price index), to reflect the predominantly expatriate salary nature of this component, while the general wholesale price index was used to deflate the remainder. The nominal routine and development aggregate and the nominal technical assistance series were econometrically backcast for the 1960-70 period (using a double log regression on the 1971-89 data with t and t^2 as regressors) and deflated with econometrically backcast deflators to form the constant priced series for these earlier years. This short-cut approach, which the lack of available data made necessary, at least preserves the substantial differences in the rates of growth in local- versus foreign-sourced expenditures.

Table 3.4: *Agricultural Research Intensity Ratios, Weighted Averages, 1961-90*

Region/income group[a]	1961-65	1966-70	1971-75	1976-80	1981-85	1986-89	1990
Region	%	%	%	%	%	%	%
Indonesia							
AARD (incl. estates)	-	-	0.157[c]	0.213	0.258	0.273	0.283[d]
Rice	-	-	0.101[c]	0.101	0.112	0.106	0.096
Soybean	-	-	0.370[c]	0.433	0.656	0.631	0.803
China	0.42	0.32	0.40	0.48	0.40	0.39[e]	-
South Asia (6)[b]	0.11	0.13	0.17	0.27	0.28	-	-
Southeast Asia (7)	0.21	0.31	0.32	0.31	0.38	-	-
Pacific (2)	0.43	0.50	0.72	1.16	1.30	-	-
Less-Developed Countries (92)	0.24	0.29	0.34	0.41	0.41	-	-
More-Developed Countries (18)	0.96	1.29	1.41	1.60	2.03	-	-
Total (110)	*0.48*	*0.60*	*0.65*	*0.72*	*0.76*	-	-
Income							
Low (30)	0.22	0.21	0.27	0.36	0.35	-	-
Lower-middle (28)	0.24	0.33	0.35	0.39	0.40	-	-
Middle (18)	0.25	0.44	0.46	0.49	0.57	-	-
Higher-middle (18)	0.27	0.38	0.44	0.52	0.55	-	-
Higher (16)	1.08	1.44	1.57	1.78	2.23	-	-
Total (110)	*0.48*	*0.60*	*0.65*	*0.72*	*0.76*	-	-

Source: Indonesian estimates calculated by authors, China data from Fan and Pardey (1992) and Roe and Pardey (1991) for the remainder.

Note: Agricultural research intensity ratios, as defined here, measure agricultural research expenditures as a percentage of AgGDP. Rice and soybean intensities represent commodity-specific research expenditures as a share of gross value of output. Averages are weighted by the respective country's share of aggregate AgGDP.

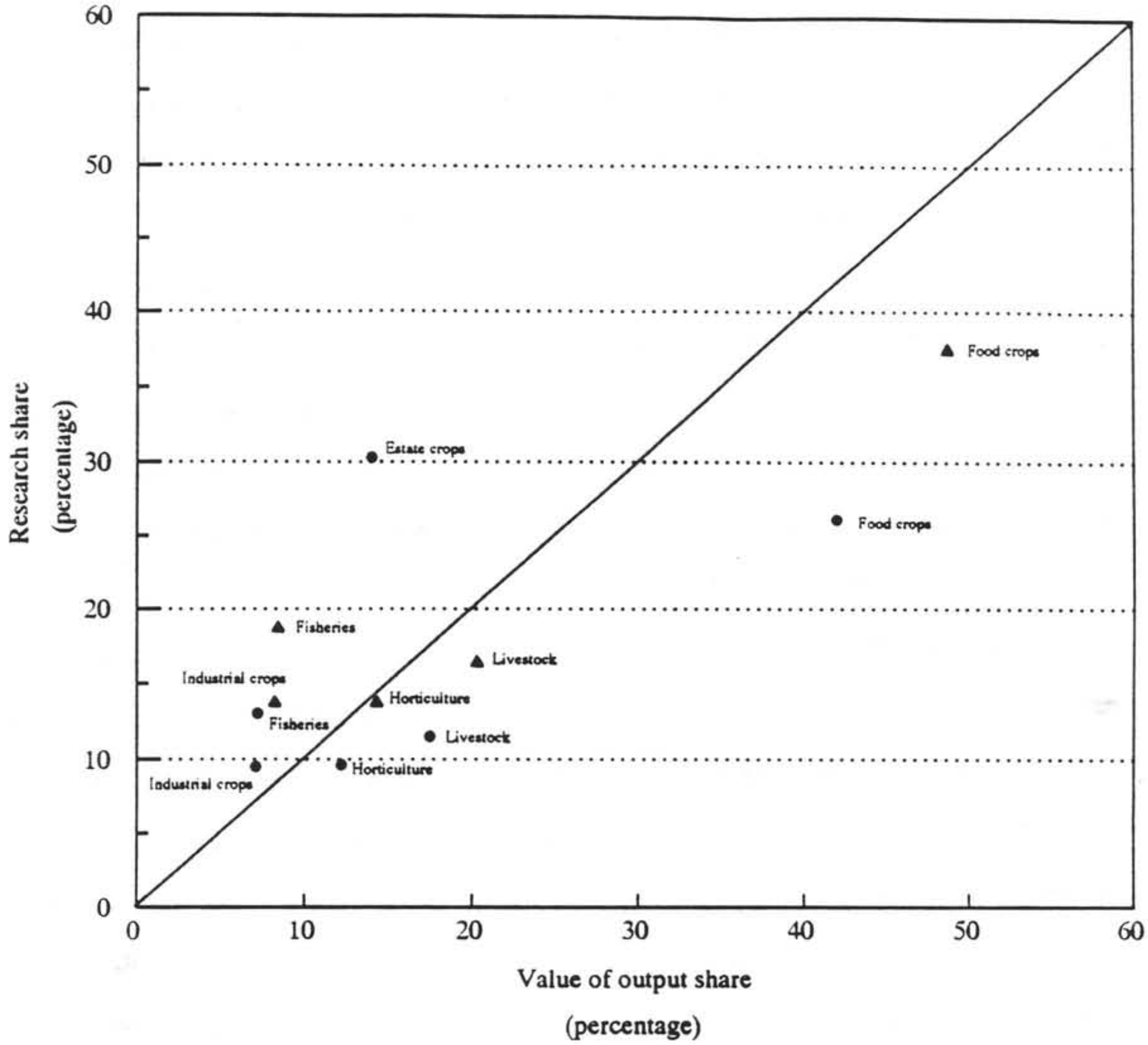
[a]Countries assigned to income classes based on 1971-75 per capita GDP averages where *Low* represents <$600; *Lower-middle*, $600-1500; *Middle*, $1500-3000; *Upper-middle*, $4000-6000; and *High* >$6000.
[b]Bracketed figures represents number of countries in regional and income group totals.
[c]1975 data. [d]1989 data. [e]1986-88 average.

Indeed congruence ratios -- which normalize research expenditures on *contemporaneous* output measures -- also gloss over the dynamics between research expenditures and output. Research usually leads to an increase in the stock of knowledge or an improvement in technology, which in turn generates a stream of benefits that continues until the new technology or knowledge is superseded or becomes obsolete. But for research to realize its growth-promoting impact takes some time, given the lags in the research process itself and the further lags in the uptake of new ideas and new technologies. In this way *current* output levels in part reflect the successes (or failures) of *past* research investments. Whether present research expenditures will have a similar impact on future levels of output is one of the central questions to be addressed when contemplating a research investment decision and it is an issue on which congruence ratios, ipso facto, shed no light. Moreover, other factors such as income- and population-driven shifts in demand can alter future research benefits streams, thereby having a direct bearing on research investment decisions. A more explicit analysis of the (expected) flows of benefits and costs from alternative projects and programs would be required if these factors were to be included in a more complete assessment of the priorities a system places on its various commodity programs. These concerns notwithstanding, the congruence rule is a useful point of reference when reviewing a system's investment strategy.

Congruence ratios for various commodity aggregates (both including and excluding estate crops) are presented graphically in figure 3.1, and for individual commodity programs in appendix figures A3.1 and A3.2. If the share of AARD's research expenditures going to specific commodity programs were congruent with the commodity's corresponding share of the value of output then it would have a congruence ratio of one and lie along the 45^0 line. Considering the totality of AARD's research program (i.e., including estate crops) then livestock, horticulture crops, and especially food crops, receive less than their congruent share of research expenditures while industrial crops, fisheries and especially estate crops receive more than their congruent share. Excluding estates crops from the calculation causes the congruence ratio for rice, livestock, and especially horticulture to converge toward one, indicating a more equal correspondence between research spending and the value of output. The individual commodity data shows that the aggregate food crops results are heavily influenced by the less than congruent share of resources going to rice and cassava research, with soybean and corn both receiving a higher than congruent share of the available research resources.

Compounding the difficulties of selecting an appropriate commodity focus within a research program are decisions concerning the appropriate technology focus of each commodity program. Those decisions must be based on a broad range of considerations including the capacity of the research system, the commodity specific production, storage, processing or marketing constraints to be addressed, and the demands and capabilities of target adoption groups.

Figure 3.1: *Congruence between research and value of production for AARD institutes (including and excluding AP3I), 1990*



Legend : **Including estate crops ● ; excluding estate crops ▲**

As a prerequisite to analysing expected impacts of AARD's current research, a parallel AARD/ISNAR research priority setting (ex ante) study has elicited information from AARD scientists and research managers on the technology focus of their on-going (1990) commodity program (table 3.5). It was estimated that for both rice and soybean, CRIFC's research was predominantly production oriented (90%) with the expectation that a greater focus on post-harvest technologies for soybean (in particular, processing technologies) would be made in the forseeable future. However, these 1990 proportions are probably a good indication of those prevailing over the period of our rate-of-return (ex post) analysis.

Table 3.5: *Research Technology Orientation, 1990*

Research institutes/ programs	Post-harvest	Production	Production: Genetic improvement	Production: Pest and disease	Production: Soil, crop, livestock, management
	%	%	%	%	%
CRIFC	10	90	39	27	34
Rice	10	90	39	33	28
Irrigated	-	-	22	44	34
Rainfed	-	-	39	39	22
Swamp	-	-	56	17	27
Soybean	10	90	20	30	50
CRIH	34	66	33	36	31
CRIAS	22	78	16	29	56
CRIIC	19	81	52	22	25
AP3I	30	70	58	10	31

Source: Elicited from AARD scientists and reported in Pardey et al. (forthcoming).

Note: CRIFC includes rice, soybean, corn, and cassava research; CRIHC includes onion, cabbage, mango, red chilli, citrus, banana, and potato research; CRIAS includes beef, dairy, sheep, goat, pig, chicken, and duck research; CRIIC includes coconut and clove research; AP3I includes oil palm, cocoa, tea, coffee, and rubber research.

Within the production research domain three major groups of technologies were identified by CRIFC scientists; genetic improvement, pest and disease control, and soil/water/crop management. Based on the estimates of CRIFC scientists a clear distinction emerges between the technology orientation of rice and soybean research. Whereas rice research is dominated by the interlinked development of improved varieties as well as pest and disease resistance or control technologies, soybean research focuses more on developing crop management technologies. Since the rice program predominates in CRIFC's activities, so the overall balance of CRIFC's technology targeting across all commodities is marked by the high focus on plant breeding and more recently biotechnology research (39%), followed by plant management and cropping systems (34%), and finally chemical and biological pest and disease control (27%). Although not quantified, there was a general feeling that greater emphasis was placed on plant breeding, particularly for rice, in the early years of CRIFC research.

Research, if successful, gives rise to an emerging piece of technology that may be developed to the point of dissemination for potential adoption. This development and transfer process consumes both resources and time. As described in the previous section, estimates were made of the annual costs associated with the rice and soybean research programs. But it is also necessary to obtain realistic estimates of the technology gestation periods (i.e., the research and development lags) in order that appropriately timed benefit streams can be generated. Clearly economic benefits cannot be realized until a technology is adopted, and the availability for adoption depends, in turn, on the research and development lag from the time of initial research investments. The AARD/ISNAR 'ex ante' study elicited R&D lags by commodity and technology from CRIFC scientists and, using the technology focus weights set out in table 3.5, these have been converted into overall R&D lags for rice (3.6 years) and soybean (3.2 years). The rice lags are, as shown in table 3.6, an aggregate over both technology type and rice ecotypes (irrigated, rainfed, and swamp). Although these R&D lags relate to the current stock of research knowledge and the current research programs they were used as representative over the whole period of our rate-of-return analysis.

3.1.4 Agricultural extension

Although the focus of this study is to assess returns to investment in specific components of AARD's research program, it is impossible to do this without accounting for the role, costs, and impacts of agricultural extension. To complement our estimates of the marginal benefits accruing to farmers from the adoption of AARD technologies it is necessary to estimate the total costs of developing *and* delivering those technologies to the farm level. The primary responsibility for "packaging, delivering and marketing" AARD technologies lies with the the MoA's extension services.

Institutional responsibility for extension within MoA has been somewhat fragmented although recent organisational changes -- in support of a decentralisation drive to improve the local responsiveness of extension -- have sought to address this problem. Extension support is delivered through three agencies; the Directorate of Food Crops Extension (DFCE, in DGFC), the Agency for Agricultural Education, Training and Extension (AAETE or *Badan Pendidikan, Latihan dan Penyeluhan Pertanian, BPLPP*), and *BIMAS*. These agencies work together to deliver new technologies, provide implementation advice, and offer production incentives including subsidised inputs and credit facilities.

At the field level technologies are delivered by field extension workers (*PPL*) who each work, through close cooperation with contact farmers (*kontak tani*), with 16 farmer groups. Each farmer group comprises around 100 farmers of whom 10 to 20 are generally recognised as progressive (e.g., early adopters). Given their importance as peer group role models the *kontak tani* are almost exclusively drawn from the progressive farmer (*petani maju*) subgroup. In this way each *PPL* has access to around 1600 farm households. At the sub-district level (*kecamatan* or *kecamatan* group) several *PPL*s operate from a rural extension centre (REC or *Balai Penyeluhan Pertanian, BPP*) under the coordination of an extension program officer (*PPM* or *PPUP*). At the

Table 3.6: *Research and Development Lags in Indonesia, 1990*

Research institute/ program	Commodity orientation	Technology orientation			
		Genetic improvement	Pest and disease	Soil, crop, livestock management	Weighted average[a]
			(years)		
CRIFC	Foodcrops	5	3	4	4.0
Rice		5	3	3	3.6
Irrigated		5	3	2	2.9
Rainfed		6	3	3	4.0
Swamp		5	3	3	4.0
Soybean		4	3	3	3.2
CRIH	Horticultural crops	8	6	6	6.5
CRIAS	Livestock	7	4	3	4.1
CRIIC	Industrial crops	22	7	6	14.8
AP3I	Estate crops	21	6	6	14.7

Source: Elicited from AARD scientists and reported in Pardey et al. (forthcoming).

Note: CRIFC includes rice, soybean, corn, and cassava research; CRIHC includes onion, cabbage, mango, red chilli, citrus, banana, and potato research; CRIAS includes beef, dairy, sheep, goat, pig, chicken, and duck research; CRIIC includes coconut and clove research; AP3I includes oil palm, cocoa, tea, coffee, and rubber research.

[a]Weighted by the share of research resources going to the respective technology components of each commodity program.

district level (*kabupaten*) is the main linkage to both the extension support services of DFCE through extension specialists (*PPS*) and the district level *BIMAS* representation, both normally stationed at the district food crops office (*DINAS Tanaman Pangan, Tingkat II*). The *PPS* serve primarily as technical consultants to the *BPPs*.

Although extension rhetoric defines its role through four means of advancing agricultural production; intensification, extensification, diversification and rehabilitation, by far the major emphasis is support of the rice intensification program through a series of technology and credit packages e.g., *BIMAS, INMAS, INSUS* and *SUPRA INSUS*. However, extension and credit support for other food crop commodities, particularly soybean, are available and some broader measure of diversification to such commodities as small ruminants and prawns has also been introduced.

To highlight the relevance of the research-extension linkage to this study we may consider the case of the *INSUS* (special intensification program) initiated in 1979 and the introduction of Cisadane -- the HYV given special attention in the rice research benefit case study described elsewhere in this report. The *INSUS* program introduced in 1979 brought two major innovations -- the newly released brown plant hopper resistant rice HYVs from AARD's own research program, e.g., Cisadane, and the promotion of group farming approaches. While AARD's technologies significantly increased yield potentials, the "social engineering" activities instigated under the auspices of the *INSUS* program gave access to subsidized inputs while also encouraging labour and equipment pooling, introducing integrated plant protection strategies as well as improved irrigation water management practices. By so doing, this program also sought to accelerate the rate of adoption of these new technologies and increase ceiling levels of adoption with the overall effect of moving average industry level yields closer to the experimental yield potentials of Cisadane. Thus, although the production gains made under *INSUS* were unambiguous, there are obviously differences in the perception of AARD and the extension services as to what was the primary motor of these gains. This example serves to illustrate one of the major analytical challenges of a rate of return (ex post) study -- attempting to correctly identify and ascribe the causal agents of productivity advances. Indeed this challenge was one of the major reasons for using a detailed case study approach for the cost-benefit analysis. The rice case study (section 5) documents evidence of significant (about 27%) research station yield gains for Cisadane over the next best existing variety. On the basis of other authoritative research, the case study assumes an on-farm yield gain of only 13.5%, that is, a 50% yield relativity between experimental and on-farm yields. This is corroborated by DFCE who report average yield relativities of 50% for rice and 52% for soybean (Sukaryo 1989). Given the production gains in the early 1980s attributed to the combination of *INSUS* strategies and AARD's HYVs, primarily Cisadane, it is possible that rice farmers were able to realise more than half the potential (experimental) yield gains. However, this was not investigated further and remains as a conservative assumption in the cost-benefit analysis.

It remained to estimate the cost shares of extension activities for rice and soybean in order to add them to research and development costs. On the (again conservative) assumption that extension efforts were focused exclusively on food crops (in fact, 90% of *PPLs* in 1974 and 75% of *PPLs* in 1989 were associated with food crops) we opted to allocate total extension costs to rice and soybean using the same proportionate cost shares for extension as had been derived for CRIFC's rice and soybean research expenditures. The time series of those shares are given in table 3.2.

Routine, development and technical assistance expenditures for 1989-90 were obtained for the extension activities of all the relevant agencies, i.e., DGFE, *BIMAS* and *BPLPP*, and an aggregate time series of *PPL* staff development was used to backcast these budget figures to 1974-75 (table 3.7).

Table 3.7: *Extension Cost Estimates*

Year	Rice	Soybean
	(millions of nominal rupiah)	
1975	44	8
1976	34	6
1977	49	9
1978	562	113
1979	752	179
1980	1,064	264
1981	1,354	327
1982	1,636	383
1983	1,763	423
1984	2,118	603
1985	2,881	807
1986	5,348	1,700
1987	6,490	2,678
1988	6,655	2,840
1989	7,366	3,629
1990	10,195	5,115

Note: 1989/90 total extension expenditures backcast using a time series based on the number of field extension officers (PPL). Costs over extension activitiees of DFCE (DGFC), *BPLPP*, and *BIMAS*. Base data provided by CARP, AARD.

3.2 Research Outputs: Rice

All of the new technologies produced by AARD research are too numerous to describe in detail in this report. They are documented in a number of publications, including AARD (1978, 1981a, 1981b and 1988), International Rice Research Institute (1984), and Nestel (1985).

Extensive consultations were held with AARD scientists to identify the sub-set of research results that are commonly regarded as being the most successful in terms of achievement of objectives. The description below of this sub-set is based on a variety of sources, including records of interviews with AARD scientists, the references cited above, and other miscellaneous publications.

3.2.1 Plant breeding research

All experts seem to agree that the varietal improvement program has been one of, and arguably, the most important sources of the sustained increase in rice yields and production. Part of the increase in rice production has been due to an increase in the area under the crop. But more important has been the increase in yields from 1,529 kg. of milled rice per hectare in 1969 to 2,913 kg. per hectare in 1989. Farmers have achieved these yield increases because, among other things, they have been willing to adopt modern technology that has to a large extent been developed and/or tested by AARD, supported by government intensification programs, and disseminated through the extension system.

As shown above, 70% of the increase in rice production is due to higher yields, and only 30% to growth in area harvested. Much of the increase in yields can be attributed to improved varieties and more effective use of fertiliser. For instance, in a review of attempts by various authors to estimate the contribution of different factors to the growth in rice production in recent years, the World Bank (1982) concluded that for the period between 1968 and 1982, improvements in the quality of irrigation was the most important single source of yield improvements, but nearly 7% was due solely to improved varieties and a further 5% could be attributed solely to fertiliser. However, 75% of the yield increase was judged to be due to the interaction or joint effects of fertiliser, irrigation and HYV's. Given the widely recognised impact of the HYV's on water and nutrient productivity, much of the increase in fertiliser and irrigation use can be treated as being induced by adoption of the HYV's, so a major part of this interaction effect can be traced either directly or indirectly to the varietal improvement program. Moreover, because the major impact of the HYV's was not really felt until the late 1970s when they became widely diffused, the above estimates of the contribution of HYV's to growth in rice yields undoubtedly understates their importance over the longer run. Not only has the overall area planted to the modern varieties of rice expanded sharply over time, but as is demonstrated below, the importance of Indonesian varieties developed by AARD since 1974 increased dramatically during the 1980s. Subsequent studies, such as an unpublished USAID, Jakarta study covering the period 1976-81, attributes 13.5% of the growth in yield during this period to new varieties.

Whatever the true contribution of HYV's to on-farm yield increases, it is an oversimplification to attribute all of the progress to the plant breeding program per se. First of all, the development of new varieties is a complex scientific process involving input from several disciplines. Secondly, the technological package of which new varieties forms a part, must be adaptable to field conditions and implemented on a large scale if they are significantly to affect national production. Consequently, considerable scientific expertise is needed to determine the optimal agronomic practices for each HYV if the true genetic potential embodied in the variety is to be even partly realised in practice. Nevertheless, the starting point is the varietal improvement program, so a brief description of the aims and objectives of AARD's rice breeding program follows.

The earlier history of varietal development and adoption in Indonesia is reviewed in Bernsten, Siwi, and Beachell (1981). In more recent years, a principal factor influencing the introduction and diffusion of the new varieties has been their resistance to the brown planthopper (BPH). This pest was first recorded in Indonesia in 1854 but did not become a serious problem until the early 1970s when more intensive methods of production (heavier fertilization, elimination of fallow) created favourable conditions for its spread[8]. As all varieties grown in Indonesia before 1975 were susceptible, new sources of resistance had to be found. This was done, but the process had to continue because new biotypes developed.

Biotype 2 appeared in the mid-1970s. Biotype 3 was noted in North Sumatra in 1983. To date, the successive waves of BPH biotypes have tended to limit the use of the early modern varieties. The result has been successive waves of more resistant modern varieties.

One of AARD's research strategies has been to develop high-yielding, intermediate amylose, and pest and disease-resistant varieties suitable for wetland (both irrigated and rainfed) rice (*padi sawah*); rainfed, high elevation, non-irrigated upland rice (*padi gogo);* and tidal swamp rice (*padi sawah pasang surut).*

For irrigated lowlands, which make up about 53% of the rice area, the research strategy has been to develop varieties with strong seedling vigor, moderately high tillering ability, erect leaves, intermediate to short height (100-130 cm), resistance to lodging, 90-135 days maturity, intermediate threshability and responsiveness to 90-135 kg/ha of nitrogen. Since increased disease and pest problems have developed with intensified production, high priority is placed on developing resistance to bacterial leaf blight, grassy stunt, rice ragged stunt, tungro virus and brown planthopper.

The strategy for the rainfed lowlands, which cover about 26% of the total rice land, is similar. But there are some important differences. Because the water supply is unreliable, weed problems are usually greater. Hence, varieties with moderately erect leaves and intermediate height are needed to shade out the weeds. Also, risks associated with uncertainty of water supply imply the need for varieties responsive to lower fertiliser rates (60-90 kg/ha of nitrogen), and drought and submergence tolerance. For dry seeded environments, early seedling vigour, early maturity, drought and submergence tolerance are especially important.

Non-irrigated upland rice amounts to 17% of the land planted in rice. Most of this area lies in Sumatra (42%), followed by Java, Bali and Kalimantan. The research strategy is similar to that for rainfed environments, except that varieties are needed with slightly drooping leaves to compete against weeds, responsive to 45-90 kg/ha of nitrogen, and resistant to blast disease. For the intensive cropping systems being developed, very early (90-105 days) varieties of moderate height (110-120 cm) that respond to nitrogenous fertilisers are required.

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[8]IRRI (1984 p.65) estimated Indonesian-wide production losses from BPH (and grassy stunt and ragged stunt, two viruses transmitted by BPH) to be 0.37% in 1972 increasing to 5.52% in 1977.

Indonesia has extensive areas of tidal swamp that can be developed for rice cultivation. Presently, only about 4% of the rice is in tidal swamp areas. About 55% of this is located in Kalimantan and 41% in Sumatra. Research strategy for this environment calls for developing varieties tolerant to low pH and acid sulphate soils, as well as submergence, drought, and salinity tolerance.

Nevertheless, pests and diseases remain a continual problem, particularly BPH of which three biotypes have evolved. However, varieties resistant to each of these have been produced. Tungro virus is also a problem and has caused losses in IR36 and Cisadane, two widely planted varieties, although varieties with a higher level of tolerance are now being released.

Not many varieties of upland rice have been developed so far, since many promising lines are susceptible to blast. It is necessary that new varieties with resistance to different races of blast be systematically released and five such varieties were put out in 1983 and 1984. Several new varieties perform well under tidal swamp conditions; one from Thailand was released in 1981, a locally derived one in 1983 and another in 1984. All this reflects a dynamic rice breeding program constantly trying to keep abreast, if not one step ahead, of the problems.

Table 3.8 lists all rice varieties released since the inception of AARD in 1974, as well as most varieties released prior to that time. These varieties are grouped into one of six categories as follows: ***Pre-AARD*** - All varieties available to growers prior to 1974; ***AARD-ll+lh*** -- All "lowland" rice varieties bred by AARD; ***AARD-d+s*** -- All other rice varieties bred by AARD; ***ATOM*** -- Varieties bred by the Indonesian Agency for Atomic Energy; ***SELIMP*** -- Breeding lines imported by AARD, and released after further evaluation by AARD; and ***IRRI*** -- All imported varieties released in Indonesia from 1974 onwards. This classification arrangement was designed to facilitate the evaluation of the impact of plant breeding research by AARD on rice productivity growth. Clearly AARD had no role in the development of varieties in the pre-AARD category, but should be credited in full for varieties in the next two categories[9]. While there has been a degree of collaboration and cooperation between AARD and the Indonesian Agency for Atomic Energy in their respective rice breeding programs, a conservative evaluation approach dictates that any contribution which AARD might have made to the development of varieties in the fourth category should not be recognised in estimating rates of return to AARD research per se.

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[9]Like many other agencies, AARD has participated in various cooperative varietal improvement programs such as the Genetic Evaluation and Utilisation (GEU) program and the International Rice Testing Program (IRTP). In doing so, it has both received benefits from breeding work in other institutions and provided benefits to these institutions. Because the cost of the Indonesian component of these programs has been included as part of AARD's cost in this study, and because the benefits from participation are mutual and reciprocal, it is logically consistent to apportion 100% of AARD bred and released varieties to AARD research.

Table 3.8: *Rice Varieties Released in Indonesia, 1943-91*

Variety	Year of release	Agroecological suitability	Days to maturity	Yield range[a]	Taste	Planthopper & leafhopper resistance[b]
			(days)	*(t/ha)*		
Pre-AARD						
Bengawan	1943	Lowland/low elevation	155	3-5	good	-
Sigadis	1953	Lowland/low elevation	145	3-5	good	-
Ramaja	1954	Lowland/low elevation	155	4-0	good	-
Jelita	1955	Lowland/low elevation	155	4-0	good	-
Dara	1960	Lowland/low elevation	140	3-0	good	-
Genjah Lampung	1960	Dryland	145	3-4	good	-
Seratus Malam	1960	Dryland	120	3-4	good	-
Syntha	1963	Lowland/low elevation	145	3-5	good	-
Kartuna	1963	Dryland	105	3-4	good	-
Dewi Tara	1964	Lowland/low elevation	148	4-0	good	-
Arimbi	1965	Lowland/low elevation	150	4-0	good	-
Bathara	1965	Lowland/low elevation	148	4-5	good	-
PB-5[c]	1967	Lowland/low elevation	145	4-6	poor	-
PB-8[c]	1967	Lowland/low elevation	130	4-6	poor	-
IR-22		Lowland/low elevation			poor	
Dewi Ratih	1969	Lowland/low elevation	140	4-6	good	-
Siampat/C4-63[d]	1969	Lowland/low elevation	125	4-7	good	-
Pelita I-1[e]	1971	Lowland/low elevation	135	5-8	good	-
Pelita I-2[e]	1971	Lowland/low elevation	135	5-8	good	-
AARD "lowland"						
Gemar	1976	Lowland/high elevation	140	4-7	mod.	-
Adil	1976	Lowland/high elevation	140	5-8	poor	-
Makmur	1976	Lowland/high elevation	140	5-8	poor	-
Brantas	1978	Lowland/low elevation	130	4-7	poor	BPH 1
Serayu	1978	Lowland/low elevation	130	4-7	poor	BPH 1
Citarum	1978	Lowland/low elevation	130	4-7	good	BPH 1
Cisadane[f]	1980	Lowland/low elevation	140	4-7	good	BPH 1,2; GLH
Cimandiri	1980	Lowland/low elevation	140	4-7	good	BPH 1,2; GLH
Ayung	1980	Lowland/low elevation	140	5-7	gluten	BPH 1,2
Cipunegara	1981	Lowland/low elevation	130	5-8	good	BPH 1,2
Krueng Aceh	1981	Lowland/low elevation	130	5-8	good	BPH 1,2
Batang Agam	1981	Lowland/high elevation	150	5-8	mod.	-
Sadang	1983	Lowland/low elevation	125	5-8	good	BPH 1,2; WBPH
Porong	1983	Lowland/low elevation	110	5-8	good	BPH 1,2; GLH
Bogowonto	1983	Lowland/low elevation	115	5-8	good	BPH 1,2; GLH
Batang Ombilin	1984	Lowland/high elevation	140	4-7	poor	BPH 1
Cikapundung	1984	Lowland/low elevation	115	5-8	good	BPH 1,2
Cisokan	1985	Lowland/low elevation	115	5-8	poor	BPH 1,2
Progo	1985	Lowland/low elevation	120	5-8	poor	BPH 1,2
Cimanuk	1985	Lowland/low elevation	117	5-8	poor	BPH 1,2; GLH
Bahbutong	1985	Lowland/low elevation	120	4-7	good	BPH 1,2,3
Tuntang	1985	Lowland/low elevation	120	5-8	poor	BPH 1,2
Batang Pane	1985	Lowland/low elevation	120	5-8	good	BPH 1,2
Cisanggarum	1985	Lowland/low elevation	130	5-8	good	BPH 1,2
Ciliwung	1987	Lowland/low elevation	121	5-8	good	BPH 1,2; GLH
Lusi	1989	Lowland/low elevation	135	5-8	gluten	BPH 1,2
Way Seputih	1989	Lowland/low elevation	125	5-8	good	BPH 1,2
Walanai	1989	Lowland/low elevation	125	5-8	mod.	BPH 1,2

Table 3.8: *Rice Varieties Released in Indonesia, 1943-91*

Variety	Year of release	Agroecological suitability	Days to maturity	Yield range[a]	Taste	Planthopper & leafhopper resistance[b]
			(days)	*(t/ha)*		
AARD "dryland" & swamp						
Gata	1976	Dryland	115	3-4	poor	-
Gati	1976	Dryland	105	3-4	poor	-
Barito	1981	Lowland/tidal swamp	140	5-7	mod.	BPH 1
Sentani	1983	Dryland	115	3-4	good	BPH 1
Tondano	1983	Dryland	115	3-4	mod.	BPH 1
Singkarak	1983	Dryland	115	3-7	mod.	BPH 1,2,3
Mahakam	1983	Lowland/tidal swamp	140	4-7	poor	-
Kapuas	1984	Lowland/tidal swamp	125	4-7	good	BPH 1,2
Ranau	1984	Dryland	105	3-4	mod.	-
Arias[g]	1984	Dryland	135	3-4	mod.	-
Maninjau	1985	Dryland	115	3-4	good	BPH 2
Danau Atas	1988	Dryland	115	3-4	poor	BPH 1,2,3
Batur	1988	Dryland	123	4-7	good	BPH 1,2
Poso	1989	Dryland	120	4-7	mod.	BPH 1,2
Musi	1988	Lowland/tidal swamp	140	4-7	poor	BPH 2
Laut Tawar	1989	Dryland	110	3-4	mod.	BPH 1,2
Danau Tempe	1991	Dryland	135	3-5	poor	-
Cenranae	1991	Dryland	115	4.5-5.5	poor	BPH 1,2; GLH
Lariang	1991	Dryland	115	4.5-5.5	mod.	BPH 1,2; GLH
Lematang	1991	Lowland/tidal swamp	130	5-6	poor	BPH 1,2,3
Atomic energy agency						
Atomita 1	1982	Lowland/low elevation	125	5-8	good	BPH 1; GLH
Atomita 2	1983	Lowland/low elevation	125	5-8	good	BPH 1; GLH
Atomita -3/4	1991	Lowland/low elevation	120	5-7	good	BPH 1,2
Selected imports						
Asahan	1978	Lowland/low elevation	125	4-7	good	BPH 1,2
Semeru	1980	Lowland/low elevation	120	4-7	poor	BPH 1,2
Bahbolon	1983	Lowland/low elevation	125	5-8	poor	BPH 1,2,3; WBPH; GLH
Kelara	1983	Lowland/low elevation	105	5-8	poor	BPH 1,2,3
Citanduy	1983	Lowland/low elevation	120	5-8	mod.	BPH 1,2
Tajum	1985	Lowland/low elevation	125	4-7	good	BPH 1
Nagara	1986	Lowland/tidal swamp	170	3-4	mod.	-
Alabio	1986	Lowland/tidal swamp	170	3-4	good	-
Tapus	1986	Lowland/tidal swamp	140	3-4	mod.	-
Dodokan	1987	Lowland/low elevation	105	4-7	mod.	BPH 1,2
Jangkok	1987	Lowland/low elevation	100	4-7	mod.	BPH 1,2
Batang Sumani	1989	Lowland/high elevation	140	5-8	mod.	-
Sei Lilin	1991	Lowland/tidal swamp	125	5-6	poor	BPH 2,3
Barumun	1991	Lowland/low elevation	130	5-6	good	BPH 1,2,3

Table 3.8: *Rice Varieties Released in Indonesia, 1943-91*

Variety	Year of release	Agroecological suitability	Days to maturity	Yield range[a]	Taste	Planthopper & leafhopper resistance[b]
			(days)	*(t/ha)*		
Introduced[c]						
PB-20	1974	Lowland/low elevation	120	4-7	mod.	-
PB-26	1975	Lowland/low elevation	125	5-8	poor	BPH; GLH
PB-28	1975	Lowland/low elevation	110	4-7	poor	BPH; GLH
PB-29	1975	Lowland/low elevation			poor	
PB-30	1975	Lowland/low elevation	110	4-7	poor	BPH; GLH
PB-34	1976	Lowland/low elevation	130	4-7	poor	BPH; GLH
PB-32	1977	Lowland/low elevation	140	4-7	mod.	BPH 1,2
PB-36	1977	Lowland/low elevation	115	5-8	poor	BPH 1,2; GLH
PB-38	1978	Lowland/low elevation	125	5-8	poor	BPH 1,2; GLH
PB-42	1980	Lowland/low elevation	135	5-8	poor	BPH 1,2
PB-50	1981	Lowland/low elevation	105	5-8	poor	BPH 1,2
PB-52	1981	Lowland/low elevation	115	5-8	poor	BPH 1,2
PB-54	1981	Lowland/low elevation	125	5-8	poor	BPH 1,2
PB-56	1983	Lowland/low elevation	115	5-8	poor	BPH 1,2
IR-46	1983	Lowland/low elevation	130	5-8	poor	BPH 1,3
IR-48	1986	Lowland/low elevation	135	5-8	poor	BPH 1,2
IR-64	1986	Lowland/low elevation	115	5-8	good	BPH 1,2; GLH
IR-65	1986	Lowland/low elevation	110	5-8	gluten	BPH 1,2; GLH
IR-66	1986	Lowland/low elevation	115	5-8	mod.	BPH 1,2; GLH
IR-70	1989	Lowland/low elevation	130	5-8	poor	BPH 1,2
IR-72	1989	Lowland/low elevation	120	5-8	poor	BPH 1,2
C-22[d]	1989	Dryland	135	3-4	poor	-
IR-74	1991		115	4-6	good	BPH 1,2; GLH; WBPH

Source: CRIFC (1991) and personal communication with CRIFC scientists.

Note: Pre-AARD varieties include all varieties available to growers prior to 1974 irrespective of source. AARD "lowland" (i.e., *padi sawah*) varieties include rice varieties bred by AARD that are grown on bunded or floodable rice land (i.e., *sawah*) whether it be of low (< 500m) or high (> 500m) elevation. AARD "dryland and swamp" varieties (i.e., *padi gogo* and *padi sawah pasang surut* varieties respectively) include rice varieties bred by AARD that are grown in nonbunded land that is dependent on rainfall (*telegan*) and those varieties grown in tidal or swamp conditions. Atomic energy agency varieties are those bred by the Indonesian Agency for Atomic Energy. Selected imports include all imported lines that were not released by the breeding institution (e.g., IRRI) but were released by AARD after evaluation in variety trials which indicated they were suited to Indonesian conditions. Introduced varieties include all varieties bred and released by IRRI or by the Republic of the Philippines and also released in Indonesia from 1974 onwards.

[a]Given in "dry unhusked paddy before milling" (*gabah kering giling*) units

[b]BPH 1,2,3 = brown planthopper biotypes 1,2, and 3 (biotype 3 is also known as North Sumatra planthopper); GLH = green leafhopper; and WBPH = white-backed planthopper. Bernsten, Siwi and Beachell (1981) further classify these tolerance levels into resistant, moderately resistent, moderately susceptible and susceptible for a number of the pre-1980 varieties.

[c]Designating varieties with a "PB" was a nomenclature used by Indonesia for IRRI varieties to mean *Peta Baru* or "new Peta" in the case of PB5, PB8 and PB20 and *Padi Baru* or "new rice" for the varieties that followed. Peta is a tall variety produced by Indonesian-Dutch breeders from crossing Tinja with Latisail (a variety from Bengal). Dalrymple (1986) described the genealogy of these and other IRRI varieties in some detail. This naming practice was dropped in 1983, whereafter all IRRI varieties were designated by their IRRI names.

[d]Introduced from the Bureau of Plant Industry, Philippines.

[e]Pelita I-1 and I-2 represent selections from a cross between IR5 and Syntha.

[f]The parentage of Cisadane is Pelita I-1 and P2388 (a cross between IR789 and IR2157).

[g]Represents a purified land race.

Appropriate treatment of the varieties in the fifth and sixth categories is not so easily determined. As part of its participation in cooperative schemes such the Genetic Evaluation and Utilisation (GEU) program and the International Rice Testing Program (IRTP), AARD regularly imports varieties bred by other institutions, most notably IRRI, as well as breeding lines which for various reasons are not released as a variety by the breeding institution. Both types of imported material may be included in so called nurseries distributed to about 50 countries as part of the IRTP. Indonesia has received about 20 such nurseries each year since 1976, and subjects them to extensive screening and evaluation in a combination of yield trials, observational trials, and stress screening trials for susceptibility to pests and diseases, low temperatures, drought, salinity/alkalinity, and other soil deficiencies or toxicities.

As a direct outcome of this process, AARD has released many imported varieties under its varietal certification program as being suited to Indonesian conditions. An appreciable number of imported breeder lines have also been released as Indonesian varieties even though they did not gain certification in the country where they were bred.

The international diffusion of improved rice varieties is quite well documented (Dalrymple 1986), and includes not only cases that were not supported by in-country evaluation programs of the type described above, but also includes smuggling in the face of determined attempts to prevent such international transfers. Consequently, there can be little doubt that in the absence of AARD, Indonesian farmers would have still adopted imported IRRI varieties, and most likely sooner or later would have discovered and started using other beneficial rice breeding lines as well.

However, diffusion of imported varieties, and particularly of imported lines not released as varieties, would have been slower without the extra knowledge about performance potential generated by the evaluation program. Just how much slower can not be objectively estimated, but without the government's ability to fast track customs and quarantine clearances, private attempts to import IRRI varieties would almost certainly have lagged behind actual importation rates by at least one year. For varieties in the SELIMP category, diffusion rates would have been considerably slower as private farmers would not have had ready or timely access to foreign bred breeding lines. Furthermore, without AARD's evaluation program, farmers (or *BIMAS*) would have been faced with the costs of conducting their own trials, and/or with the production losses from ill-advised varietal choices.

Arguably the most conservative assumption that could be made without totally ignoring the contribution made by AARD is to assume, as we do here, that diffusion of imported varieties would have been delayed on average by one year. At best, diffusion of SELIMP varieties in the absence of AARD's rice varietal evaluation program would have been delayed by two or more years on average, and at worst might not have been available to Indonesian farmers within the time frame of this study.

3.2.2 Farming systems

Intensification of cropping systems

A key to the dramatic growth in production in the agricultural sector generally has been the increase in cropping intensity. In the more richly endowed farming areas, three crops are now grown where only two were grown previously. In some dryland areas, two crops are being grown instead of only one, while in other dryland areas, yield of the second crop has increased dramatically. The necessary foundation for these productivity gains has been the development of rice and *palawija* cultivars with shorter growing periods, and improved irrigation also has been an important factor in many cases. But realisation of the potential embodied in these changes has required the development of new cropping systems. The farming systems research carried out by AARD is highly location specific because such cropping systems need to be adapted to a host of site specific agroecological conditions as well as to farm specific factor endowments.

As an example of this type of research, a joint AARD-IRRI program has shown how cropping systems could be intensified through use of earlier maturing crop varieties, use of *gogo rancah* (direct seeding of rice on aerobic soil, followed by flooding as the rains increase) in partially irrigated and rainfed areas, and reduction in turn-around time. Component research developed more appropriate fertiliser rates and methods of application, insect control measures and weed management.

Profitable "lowland rice - lowland rice - legume" rotations have been successfully developed for fully irrigated areas as well as for seven to nine months irrigation categories. In the areas that receive only five months or no irrigation, a combination of *gogo rancah* rice and lowland rice in the pattern "*gogo rancah* - lowland rice - cowpea" has permitted the production of three crops in one year, where previously only one crop was grown.

3.2.3 Pest Management

Tungro virus control in south sulawesi

Tungro virus disease of rice has been a serious problem in rice production in South Sulawesi for many years, but there was a major outbreak in 1973 when resistance of common varieties such as Pelita I-1, IR5, and C4-63 broke down in spectacular fashion. To solve this problem, an integrated pest management scheme based on research demonstrating that the principal vector is greenleaf hopper (GLH) was developed in 1983. In essence it is an ecologically based system of pest control that has the following four components:

- scheduling time of transplanting of the crop in those months when the vector population is low (based on research demonstrating that the incidence of tungro is related to the level of infestation of GLH, which varies seasonally according to rainfall patterns),

- synchronising crop planting in each area so that all rice is planted, and reaches maturity at approximately the same time,

- rotation of cultivars with different degrees of resistance to the leafhopper vector,

- selective application of insecticide to reduce vector density in tungro affected fields.

Implementation of these practices by incorporation into extension packages has both reduced the incidence of tungro and the use of insecticide.

National Integrated Pest Management Program

The work of AARD entomologists in monitoring the population dynamics of brown planthopper from the mid-1970s facilitated the timely prediction of outbreaks of this pest in problem areas. More basic research also contributed to the stock of fundamental knowledge about the biology and ecology of this pest which provided the scientific basis for the National Integrated Pest Management Program implemented by Presidential decree in 1986. The decree initially banned fifty-seven insecticides, mostly organophosphates. In subsequent years, all subsidies on pesticides were eliminated and an ambitious training program in how to control pest populations without excessive use of herbicides was set up for pest observers, field extension workers, and farmers.

3.2.4 Soil fertility and fertiliser efficiency

Sulphur deficiency in South Sulawesi

Similar symptoms to those found in tungro virus outbreaks led to research which identified a sulphur deficiency as the cause when tungro was not a problem. Subsequently, a series of soil fertility studies were carried out in South Sulawesi to investigate sulphur requirements of lowland rice. The first study found that rice yields responded to applications of ammonium sulphate in lieu of urea, which was the previous type of nitrogenous fertiliser used. Later experiments revealed a yield response to sulphur which was widely distributed over the province, and covers different soils and parent materials. Ammonium sulphate, gypsum, potassium sulphate, and elemental sulphur were found to all be equally effective as sources of sulphur for rice. The INSUS package of recommendations on type of fertiliser to use was changed in 1978 on the basis of this research.

Reduced phosphorus applications in central java

Long term fertility trials have revealed a diminished response to high application rates of phosphate fertilisers due to a build up in soil phosphorus. This finding has led to recommendations to farmers to reduce fertiliser application rates.

3.2.5 Harvest and post-harvest technology

Serrated sickle

Serrated sickles were probably first developed in Taiwan, but over time various designs have become available from a range of sources. Relative to older designs, serrated sickles reduce grain harvest loss due to shattering, but this advantage must be set against extra harvest labour requirements because serrated sickles are slower to use. The Sukamandi Research Centre conducted some field evaluation trials of a range of different designs in the mid-1980s to test performance under typical farming conditions. This study identified one sickle as having the best field performance. Because the research was initiated at the request of the government, it now recommends that farmers participating in the revolving credit system use this superior serrated sickle.

3.3 Research Outputs: Soybean

3.3.1 Plant breeding research

Twenty-one soybean varieties have been released for cultivation in Indonesia since 1918, and table 3.9 sets out background information on these varieties. Many of the early varieties were imported from overseas. Breeding work was intensified at Bogor by AARD in the early 1970s and resulted in the release of some 10 improved varieties with early maturity, medium seed size and tolerance to rust.

Unlike the situation for rice, almost all of the soybean varieties released in Indonesia since 1974 were bred by AARD, and of the few that were not, the only imported variety was Tambora which was bred and first released as a variety in Thailand. A few other varieties, such as Dempo and Tidar, were selections made by AARD from imported breeding lines. It is noteworthy though that the line imported from the Asian Vegetable Research and Development Centre (AVRDC) in Taiwan which gave rise to Tidar was itself a mutant of a variety grown in Indonesia from the early part of this century.

Prominent objectives of the breeding program included higher yield, shorter maturation period, and grain quality. The principal breeder, Sumarno (1983) has emphasized the need for early maturing, small seed size and semideterminate types to be planted after lowland rice in the existing cropping systems and determinate types for upland inter cropping systems. With the exception of resistance to rust, pest and disease control did not dominate breeding strategies in the same way as they did for rice. It is also pertinent to point out that breeding for grain quality is a more complex matter than for rice because of the greater degree of post-harvest processing of soybean into a wide variety of quite distinctive end uses.

Table 3.9: *Soybean Varieties Released in Indonesia, 1918-91*

Variety	Year of release	Agroecological suitability	Days to maturity	Yield range[a]	Rust tolerance
			(days)	*(t/ha)*	
Pre-AARD					
Otau	1918		95	1.1-1.5	-
No. 27	1919		100	1.1-1.5	-
No. 29	1924		105	1.2-1.6	mod. susceptible
Ringgit	1935		90	1.2-1.6	susceptible
Sumbing	1937		85	1.0-1.5	susceptible
Merapi	1938		85	1.0-1.5	-
Shakti	1965		85	1.2-1.6	mod. susceptible
Davros	1965		85	1.2-1.6	susceptible
AARD					
Orba	1974		85	1.5-2.5	tolerant
Galunggung	1981	Dryland/upland	85	1.5-2.5	mod. susceptible
Lokon	1982	Dryland/upland/irrigated wetland	76	1.1-2.0	mod. susceptible
Guntur	1982	Irrigated/wetland	78	1.1-2.0	mod. susceptible
Wilis[b]	1983	Dryland/upland/irrigated wetland	88	1.5-2.5	tolerant
Kerinci	1985	Dryland/upland/irrigated wetland	87	1.5-2.5	tolerant
Merbabu	1986	Irrigated wetland	90	1.5-2.5	tolerant
Raung	1986	Dryland/upland/irrigated wetland	85	1.5-2.5	tolerant
Rinjani	1989	Irrigated wetland	88	1.5-2.5	tolerant
Petek	1989		80	1.0-1.5	-
Lompobatang	1989	Irrigated wetland	86	1.5-2.5	tolerant
Lumajang Bewok[c]	1989		80	1.2-1.7	tolerant
Lawu	1991		74	1.2-1.7	-
Dieng	1991		78	1.2-1.7	tolerant
Jayawijaya	1991		87	1.2-1.7	tolerant
Tennger	1991		79	1.0-1.7	-
Selected Imports					
Dempo	1984	Dryland/upland	90	1.5-2.5	resistant
Tidar	1987	Dryland/upland/irrigated wetland	75	1.4-2.0	tolerant
Introduced					
Tambora	1989		85	1.5-2.0	tolerant

Source: CRIFC (1991) and personal communication with CRIFC scientists. Agroecological suitability taken from Subandi and Manwan (1990).

[a]Given in dry-shelled (*biji kering*) units.
[b]Moderately resistant to virus diseases.
[c]Represents a purified land race.

Average yields for most varieties released prior to 1984 were of the order of 1.5 tons/ha, while later releases yielded 1.6 to 1.8 tons/ha. However, the variety Wilis released in 1983 matures in 88 days, has excellent yielding ability, and is tolerant to rust and moderately resistant to virus, while Tidar, which was released four years later, matures in 75 days, has good yielding ability, and tolerance to both rust and bean fly. Under favourable environments, yields of up to 3 tons/ha (three-fold higher than the current national average) have been recorded from some experimental plots for some varieties. The soybean breeding program of AARD demonstrates that a lot can be accomplished with relatively few resources. For most of the period covered by this study, total expenditure on soybean research averaged about 20% of that on rice research. Furthermore, while no over time breakdown of expenditure by type of research within each program was available, the above ratio almost certainly overstates the size of the soybean breeding program relative to that of the rice breeding effort[10].

3.3.2 Agronomic research

AARD research has identified a range of ways to improve yields of soybean, or reduce costs, by modifying cultural practices. For instance, it was found that yield was not significantly affected by tillage or no-tillage when soybean is planted on wetland following rice. Obviously adopting no-tillage saves costs and also allows earlier planting which often is critical to intensified land use.

Another finding was that when soybean is grown on wetland previously planted to rice so that it received high rates of NPK fertilisers, savings could be made in fertiliser applications on the soybean crop. A yield increasing innovation developed by AARD involved mulching the Lokon variety with two tons per hectare of rice straw plus three separate irrigations at planting, 14 days, and 30 days after planting.

It has also been shown that soybean responds to liming on acid soils. Deep plowing and liming on acid podzolic soils can increase grain yield due to better root growth and utilization of soil moisture. Applying phosphate and potassium fertilisers on podzolic soils also may increase yield if soils contain less than 18 ppm phosphorus, whereas with soils containing a higher value of phosphorus soybean crops show little or no response to P application.

Mulching in the dry season on acid podzolic soils also increased soybean yield by up to 40% due to better soil moisture conservation. Soybeans on wetland during the early dry season responded well to improved drainage. Yields of up to 2.62 tons/ha, or an increase of 138%, were obtained with drainage. However, for the late dry season crop the problem is often that of water deficit rather than drainage. The wet culture system with soybean has been found beneficial in stabilizing growth and yield in experiment station trials.

Other research on inoculation has revealed that use of commercially available rhizobium inoculants on soils previously planted to soybean does not consistently increase yields, and that cost savings could be realised by discontinuing this practice. However, in newly opened areas, rhizobium inoculation is needed to obtain high yields.

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[10]Estimates for 1990 presented in table ?? indicate that the rice program commits about 39% of its expenditures to genetic improvement activities, nearly double the share going to breeding within the soybean program.

3.3.3 Pest and Disease Control

The general occurrence of soybean pests and their ecology has been studied for some time. Control measures for most of the pests have been worked out and recommended for different areas. Because of lack of success in breeding resistant varieties to many of the pests and diseases of soybeans, studies on integrated pest management for specific areas and cropping systems have been emphasized.

Several common insects, such as species of Agromyza sp., Spodoptera sp., Plusia sp., Etiella sp., and Nezara sp. can reduce grain yields by as much as 70%. Preventive measures developed by AARD and recommended for endemic areas involve seed treatment, and periodic insecticide applications linked to the earliest insect stage of the pest.

3.4 Research Use: Rice

3.4.1 Overview

To an unusual degree, adoption of new technologies by Indonesian farmers is influenced by the government's extension programs. The key reason for the influential role of the extension effort has been the series of production intensification programs, such as *BIMAS*, *INMAS*, *INSUS*, and so on, which were briefly described in section 3.1.4. All of these programs combine recommended technology packages with the supply of government subsidised inputs and technical advice. While AARD does not have responsibility for extension, the existence of effective linkages between it and the extension agencies which design the production intensification programs, recommended technology packages incorporate many research outputs. These linkages are fostered by a communications unit in each research coordinating centre of AARD. These units assist in the organization of training courses for extension workers, technical meetings, seminars and publication of technical bulletins and papers dealing with all aspects of agricultural production. To further strengthen the linkages, extension subject matter specialists (*PPS*'s) belonging to the five Directorates General have access to selected research institutes, stations and farms as home bases. *PPS*'s have the opportunity to interact directly with multidisciplinary research teams working at the research institutes and stations. Regularly structured consultations between research institute staff and provincial agricultural officers provide the opportunity for a two-way flow of information on research results and current problems and needs in the area.

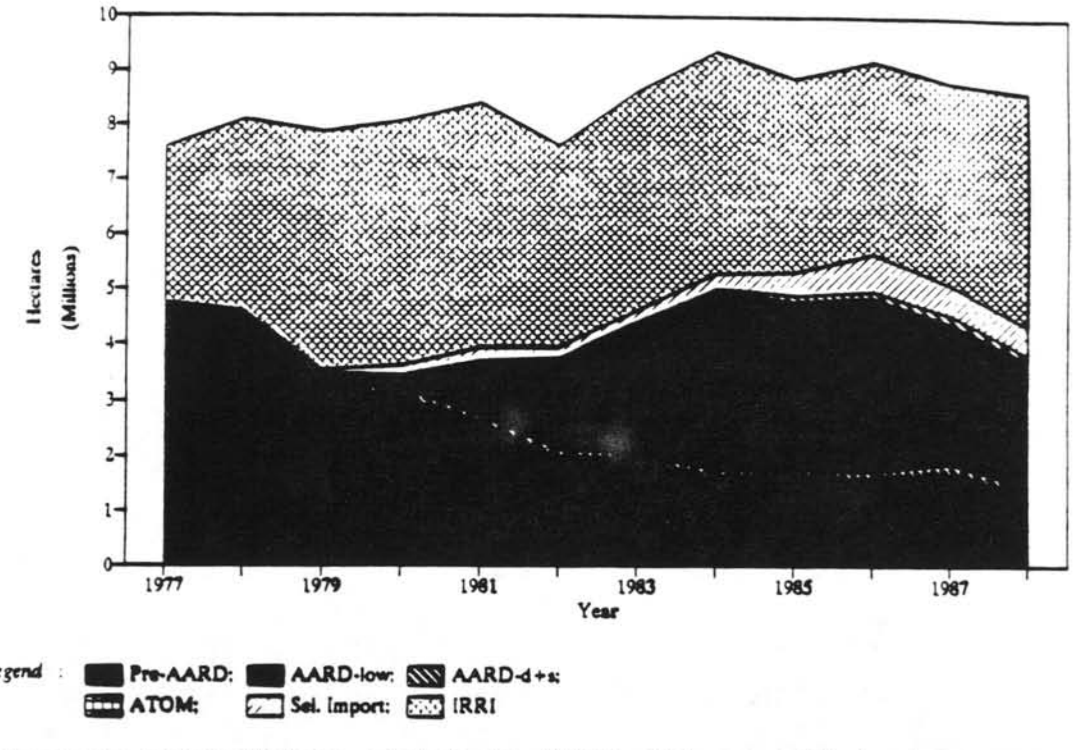
3.4.2 Technology adoption practices

New rice cultivars

In contrast to most research outputs, adoption of rice varieties is well documented. Beginning in the 1975/76 wet season, surveys have been conducted annually by the Sub-Directorate of Seed Production, formerly under the Directorate of Plant Protection (*Direktorat Perlindungan Tanaman Pangan*) but now under the Directorate of Crop Production (*Direktorat Bina Produksi*) within the Directorate Generale of Food Crops, to enumerate areas under cultivation (i.e., planted areas) to all significant rice varieties[11]. In this study, these data were collated and organised so that the contribution made by AARD rice breeding research could be identified and quantified.

An overview of the changing pattern of adoption of rice varieties from different sources is presented in figure 3.2. For the combination of wet and dry seasons for all of Indonesia, this diagram illustrates area by breeding source for each of the six sources of rice varieties defined above. The most notable feature is the rise

Figure 3.2: *Rice varieties by area; combined seasons, Indonesia*



in importance of the lowland rice varieties bred by AARD, which accounted for less than one percent of total area prior to 1979, but then expanded to over one-third of the area sown for three years in the mid-1980s, before falling back to about 25% by the end of the decade. Those breeding lines imported by AARD and released as Indonesian varieties (SELIMP) followed a similar pattern, albeit to a much lesser extent (i.e., maximum of 8% of area planted). Also notable is the corresponding decline in the importance of the Pre-AARD varieties from a dominant position (75% of total area) in the late 1970s to one of secondary importance (<20%

[11]For earlier years back to the 1971-72 wet season, data were collected by *BIMAS* authorities.

of total area) by the end of the 1980s. Throughout most of the period, imported varieties, mainly from IRRI, accounted for almost half of the total area, but this apparent stability conceals considerable change in the composition of varieties within this category. Varieties bred by AARD for dryland or swamp conditions, as well as varieties bred by the Indonesian Agency for Atomic Energy also grew in importance during the period under consideration, but essentially were inconsequential in the overall picture.

Figures 3.3 and 3.4 for all of Indonesia for the wet and dry season respectively show that, in general, seasonal influences are relatively unimportant at this highly aggregated level. The most obvious difference between the seasons is in the relatively greater importance in the wet season of the Pre-AARD varieties at the beginning of the period, and in the much faster decline in area of this category of varieties over the following one and a half decades. By contrast, in the dry season IRRI varieties persisted in their relative importance throughout the period (up to 60% of total area), and there is a suggestion that AARD varieties were declining more rapidly by the end of the period.

Figure 3.3: *Rice varieties by area; wet season, Indonesia*

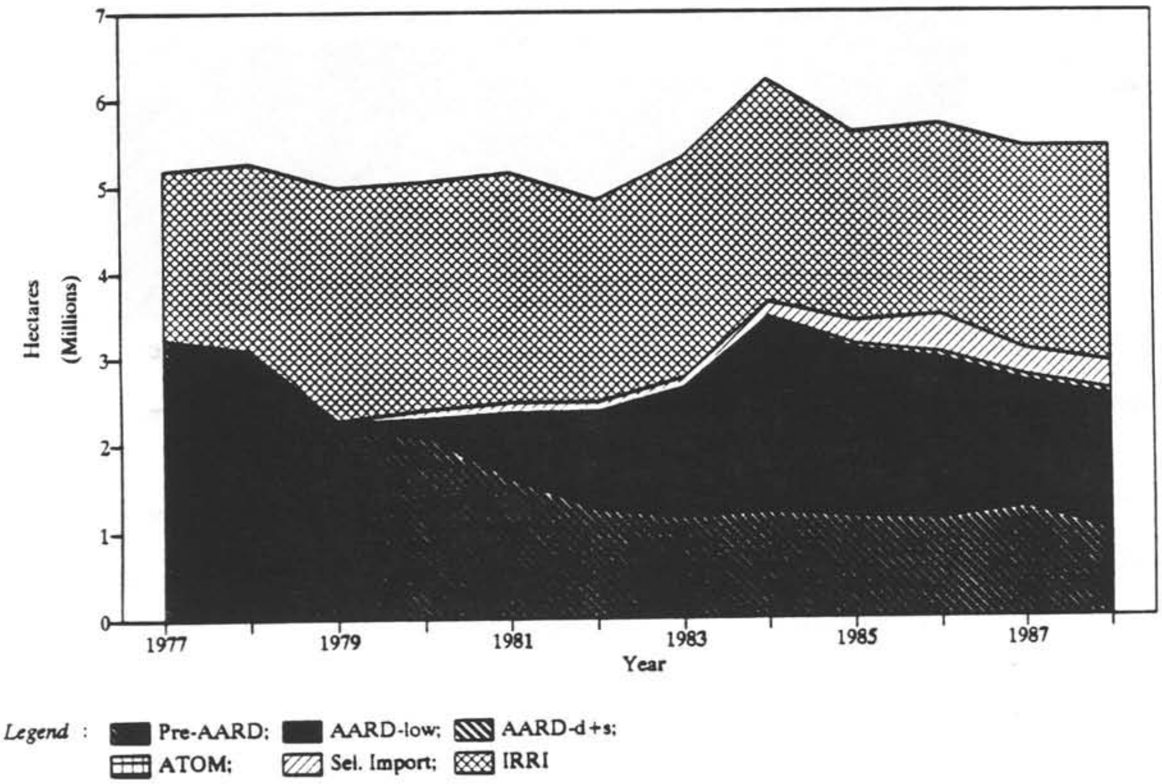
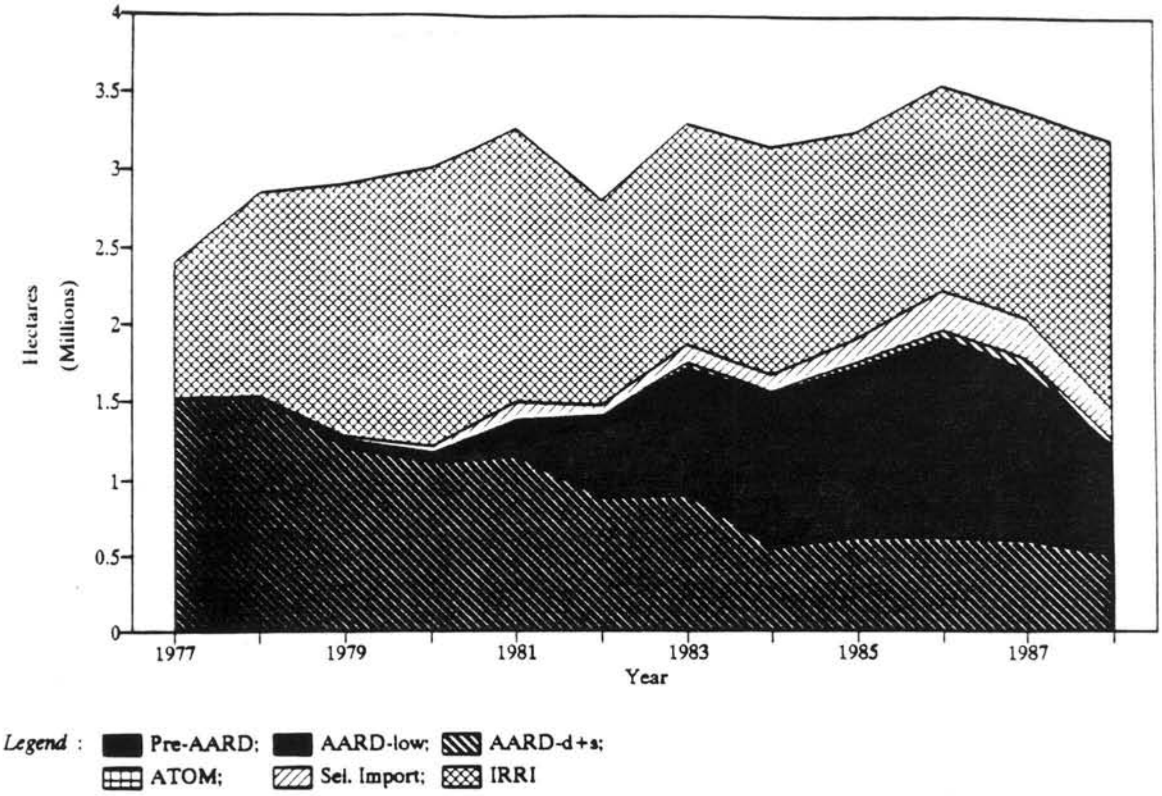


Figure 3.4: *Rice varieties by area: dry season, Indonesia*

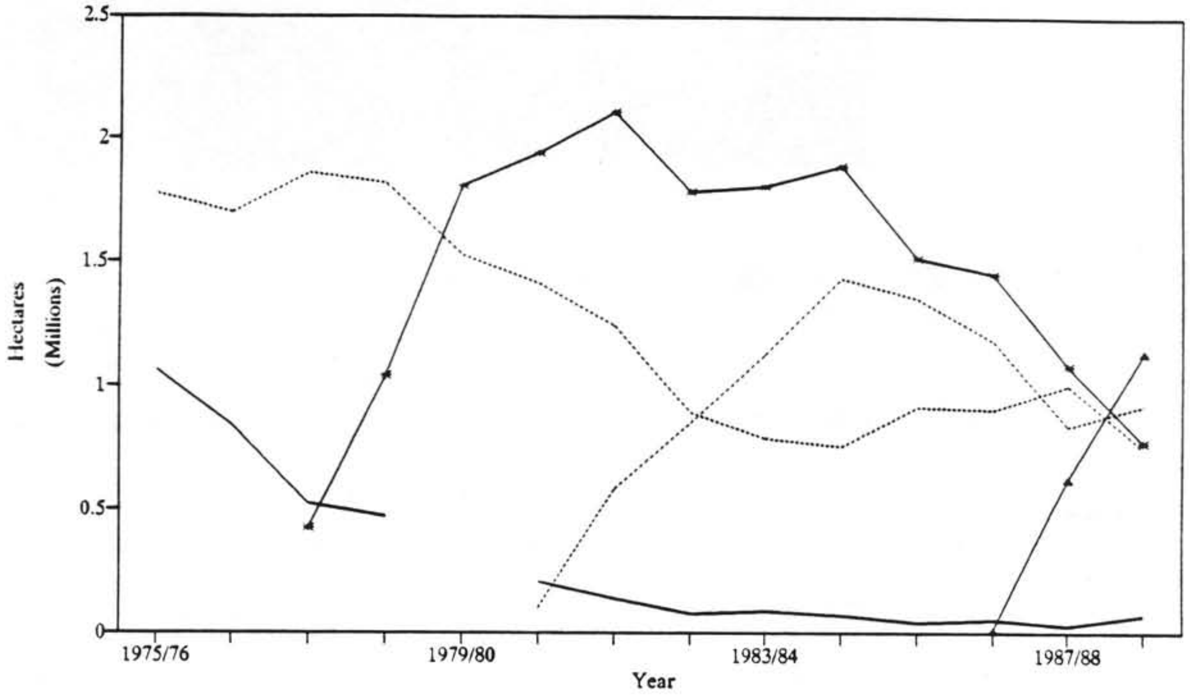


The four appendix figures A3.3 to A3.6 illustrate how these patterns of varietal adoption varied between the major island groups of Sumatra, Java and Bali, Sulawesi, and Kalimantan, and between seasons for each region. The most striking difference is the much higher level of adoption of AARD varieties on Java and Bali (up to 50%), and in particular the dominant position achieved by this group of varieties in the dry season in the mid- to late-1980s. By contrast, in both seasons in this region, the Pre-AARD varieties were reduced to a very minor role (< 10%) for most of the 1980s. Again, IRRI varieties were very important throughout the period, but the other categories were not large enough to warrant further consideration.

For all of the remaining islands, varieties bred by AARD were much less important than they were on Java and Bali, and in all cases were dominated by Pre-AARD and/or IRRI varieties. After Java and Bali, Sumatra is the island with the next largest area under rice, but apart from continuing to use Pre-AARD varieties, at the expense of AARD varieties, on a much larger proportion of area (from over 70% down to 3%), the picture is broadly similar to that in the Java rice bowl. On Sulawesi, IRRI varieties accounted for over half the total area throughout almost the entire period, and in the dry season extended their domain to the point where for all of the 1980s, area under IRRI varieties exceeded that for all other categories combined. The situation on Kalimantan is almost the exact reverse of that on Sulawesi, with Pre-AARD varieties covering almost all of the area for practically all of the period covered, declining to only 70% by the end of the period.

As noted above, grouping varieties into a limited number of categories inevitably conceals dramatic shifts in areas planted to individual varieties. However, while there are many sub-themes on the main plot, it transpires that the story of rice variety adoption during the late 1970s and 1980s is predominantly a tale of two key varieties, one imported and one bred by AARD. This is illustrated by figures 3.5 and 3.6, which for the wet and dry seasons show the areas for five principal varieties.

Figure 3.5: *Principal rice varieties by area; wet season, Indonesia*

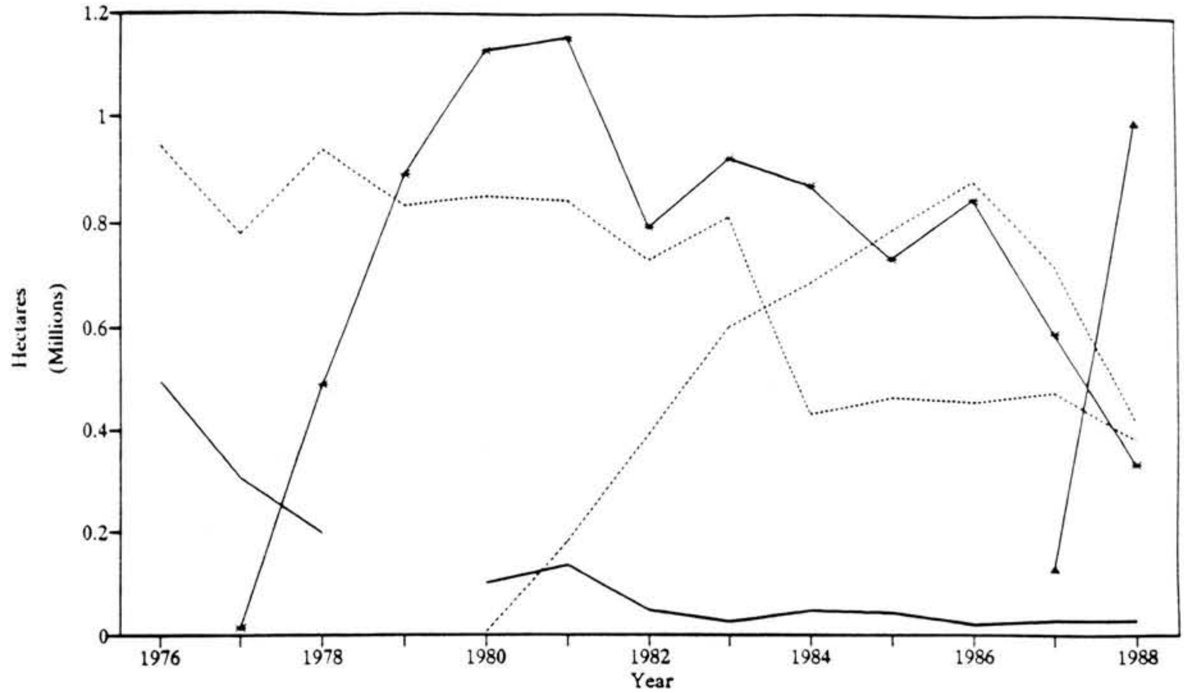


Legend : See figure 3.6.

In the period immediately prior to the inception of AARD, area planted to rice in both wet and dry seasons was dominated by a combination of traditional *(Lokal)* varieties, imported varieties (including in particular IR5 and IR8), and the locally bred varieties Pelita I-1 and Pelita I-2[12]. By the mid-1970s, the first serious outbreaks of brown planthopper had caused massive disadoption of the early imported IRRI varieties, and area under cultivation to the two Pelita's was declining rapidly. *Lokal* varieties still accounted for a significant proportion of area under cultivation, but the trend was unmistakably downward.

[12] According to the varietal adoption data summarized in Bernsten, Siwi, and Beachell (1981), during the 1972-74 wet seasons, IR5 accounted for an average of 18.9% of the area planted to rice, Pelita's I-1 and I-2 occupied 9.6% of the rice area, and C4-63 (an introduced variety) 7.1%. Corresponding figures for the dry season were 17% for IR5, 11.9% for Pelita's I-1 and I-2, and 8.4% for C4-63.

Figure 3.6: *Principal rice varieties by area; dry season, Indonesia*



Legend : —— Pelita(s); .... Lokal; —✳— IR36;
.... Cisadane; —▲— IR64

In 1977, the imported variety IR36 was released by AARD, and diffused so rapidly that within a few short years, it took over as the single most important variety. By 1980, it accounted for in excess of 37% of total area growing rice in both the wet and dry seasons[13]. Cisadane was released three years later in 1980, and although its rate of diffusion was somewhat less explosive than that for IR36, by the mid-1980s it was second only in importance to IR36 in the wet season, and had surpassed that variety in the dry season. The growth in Cisadane area was achieved by displacing several different varieties rather than any one variety in particular. In part Cisadane took over from such imported varieties as IR32, IR36, and IR38, but area under the Pelita's also continued to decline, and areas planted to *Lokal* varieties dropped dramatically. The introduction of IR64 in 1986 marked the beginning of the end of the dominant role of both IR36 and Cisadane. As figures 3.6 and 3.7 illustrate, this variety diffused extremely rapidly, and by the end of the decade was the single most important variety in both seasons.

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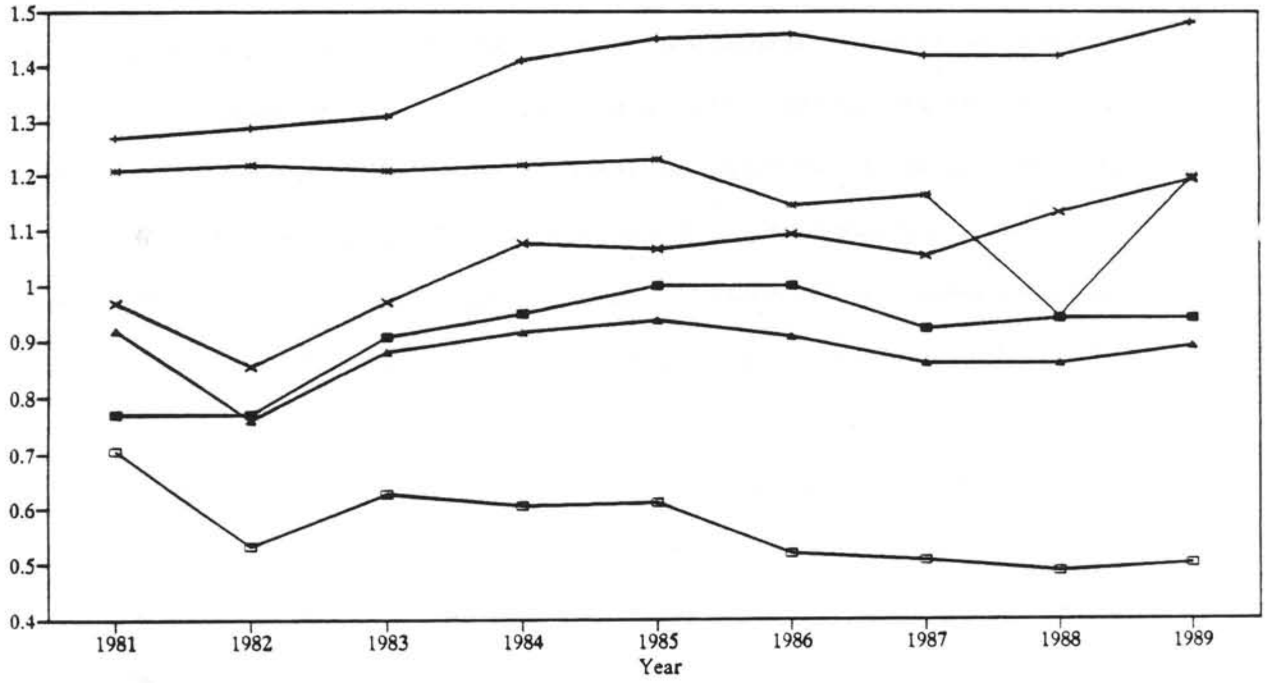
[13]Quoting Bernsten, Siwi, and Beachell (1981 p.24) "Its popularity was primarily due to its resistance to BPH biotype 2 ... Yet, in addition farmers preferred PB36 because it matured almost three weeks earlier than PB32 (the previously introduced BPH-2 resistant variety), reduced the risk of drought damage in double cropped environments and allowed farmers to grow a third non-rice crop such as soybeans."

Intensified cropping systems

Initially adoption of this technology was slow because the vigorous, good quality, and high-yielding Pelita varieties which were widely accepted by farmers also were longer maturing. The introduction of IRRI varieties with a field duration of about 90 days when transplanted, removed a key impediment to the intensification of cropping patterns. Adoption of these earlier maturing varieties has drastically reduced the risk of growing two or even three crops in partially irrigated and fully irrigated areas, and ensured that one good crop can be grown in the rainfed areas.

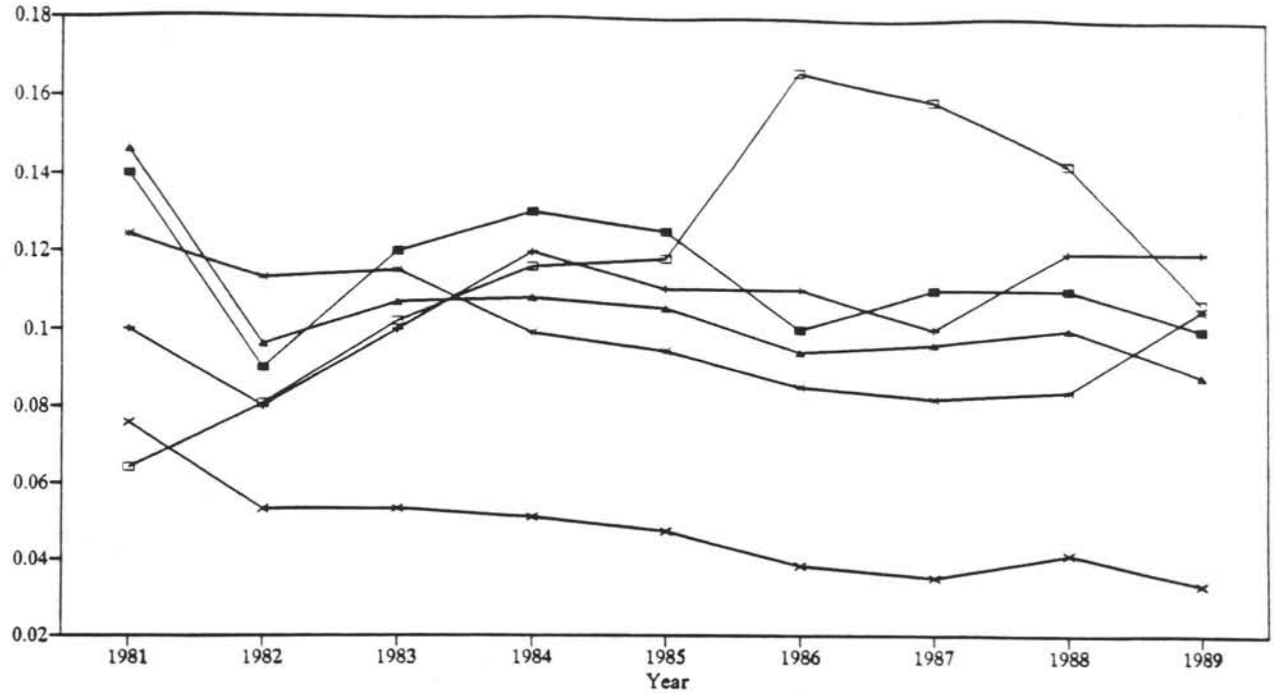
Despite widespread adoption of short growing period varieties such as IR36, cropping intensity indices suggest that most of the potential gain in productivity seems to have been realised by increasing area under cultivation to *palawija* crops. Cropping intensity indices were calculated by dividing the sum of areas planted in both wet and dry seasons by available land for cultivation. The indices for lowland and upland rice are illustrated in figures 3.7 and 3.8, and it can be seen that cropping intensity has not increased for most areas. However, there are strong upward trends in the indices for lowland and upland soybean, and presumably a similar picture could be derived for other *palawija* crops.

Figure 3.7: *Cropping intensity, lowland rice*



Note : For details see figure 3.8.

Figure 3.8 *Cropping intensity, upland rice*



Source : Data provided by CARP, AARD.

Legend : Sumatra; Java; Bali & SARA; Kalimantan; Sulawesi; Off-Java

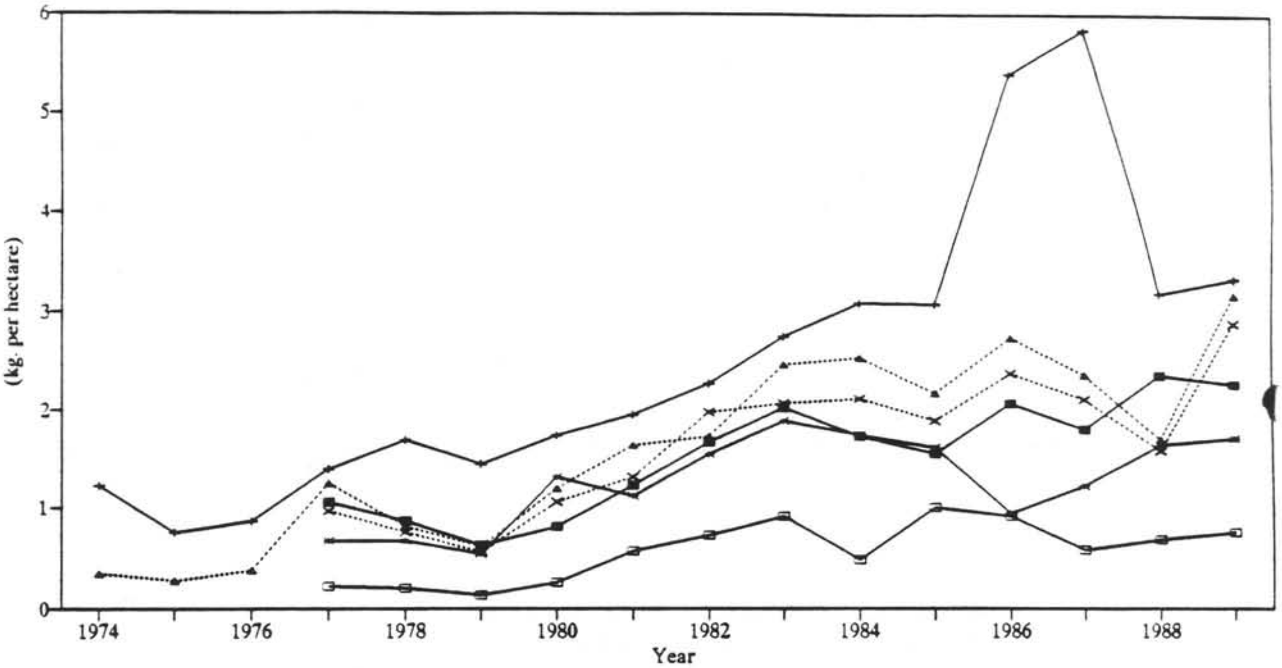
There is also evidence of a more limited nature that adoption of this technology has been widespread. For instance, Siwi (1985) reports that adoption of *gogo rancah* in Lampung increased from negligible levels in 1978/79 to over 13,000 hectares by 1981/82. In North Aceh, where traditionally paddy rice was grown only once a year and the fields were then left fallow until the following rainy season, the introduction of zero-tillage has led to an increase in the soybean planted area from less than 10,000 hectares in 1981 to more than 40,000 hectares in 1984, and a doubling of the corn area. These zero-tillage upland crops were planted after lowland (unirrigated) rice. Adoption of zero-tillage techniques was estimated to have also increased the yield of soybean from one to two tons/ha and corn from two to three tons/ha.

IPM in South Sulawesi

There are at least two possible sources of objective evidence on successful adoption of the IPM system to control tungro virus in South Sulawesi. One is evidence on the incidence of tungro virus since the introduction of the program. Statistics collected by the Directorate of Crop Protection clearly reveal a decline in incidence of this disease since the major outbreak in 1973. Another possible source of evidence is a reduction in pesticide application rates relative to other regions in Indonesia since implementation of the program. Figures 3.9 and

3.10 present slightly different views of the same basic data. It is a moot point whether this data indicates a significant degree of adoption.

Figure 3.9: ***Pesticide use, regional average***



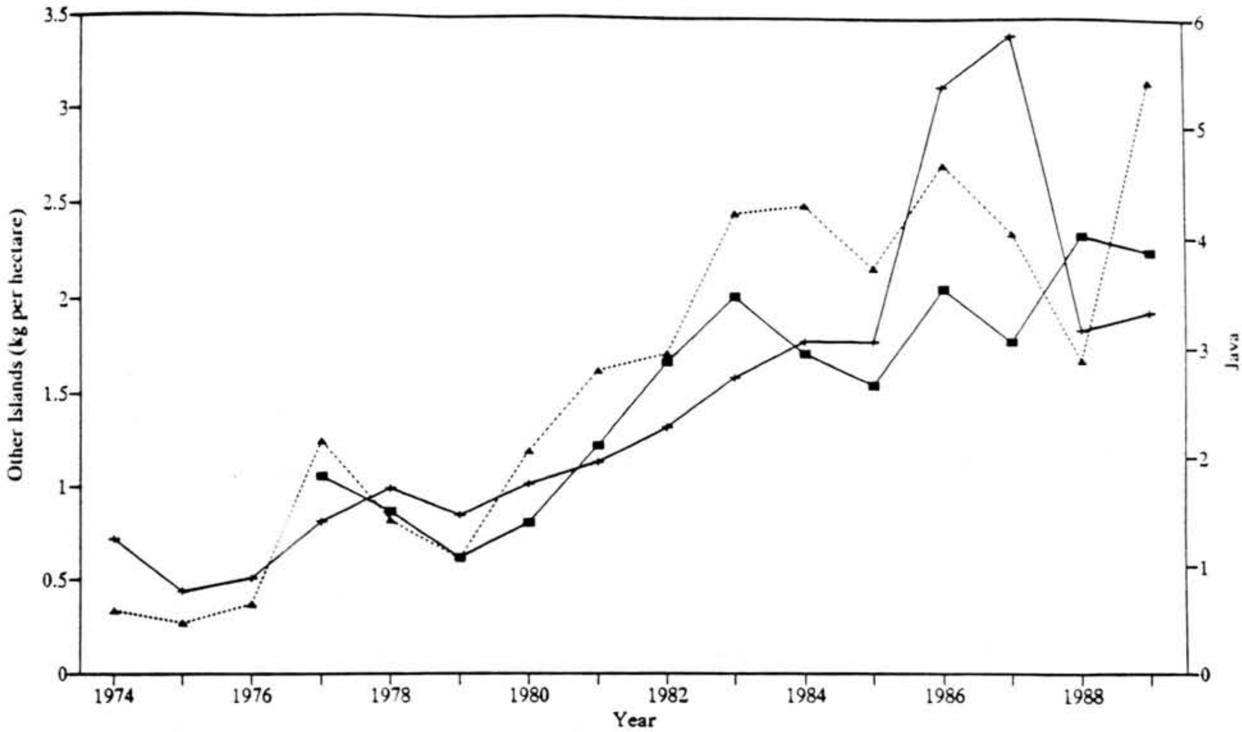
Source : Compiled by authors from BPS, Struktur Ongkos (various issues).

Legend : Sumatra; Java; Bali & NT; Kalimantan; Sulawesi; S. Sulawesi

Reduced phosphorus applications in central java

There are no primary statistics available to document levels of adoption of this innovation. However, ceteris paribus, adoption might show up in regional farm level statistics on fertiliser application rates as a differential trend in fertiliser application rates between those regions adopting the innovation and other regions. Fertiliser application rates for Java, Sumatra, and Sulawesi enumerated in the BPS *Struktur Ongkos* (cost of production) survey are illustrated in figure 3.11. While the evidence is far from definitive, it does appear that fertiliser application rates on Java do appear to have been declining relative to rates on the other islands.

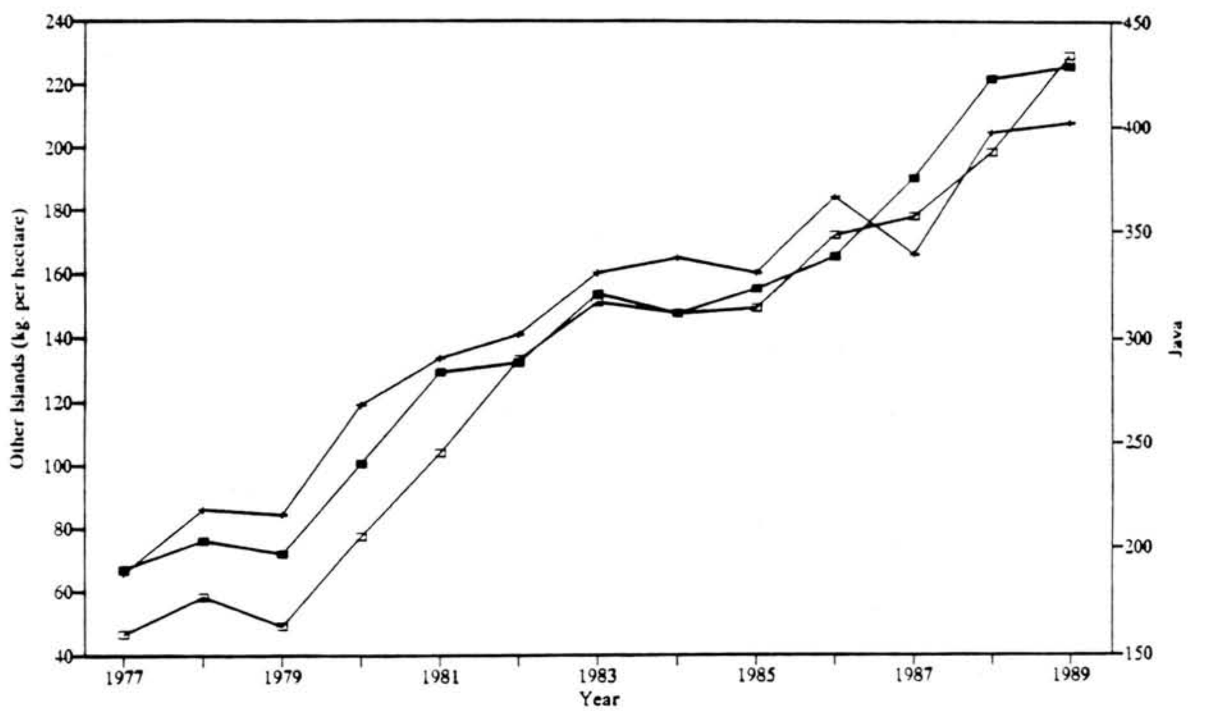
Figure 3.10: *Pesticide use, regional average*



Source : Compiled by authors from BPS, Struktur Ongkos (various issues).

Legend : Sumatra; Java; S. Sulawesi

Figure 3.11: *Fertilizer application rates*



Source : Compiled by authors from BPS, Struktur Ongkos (various issues).

Legend : Sumatra; Java; Sulawesi

Serrated sickle

Objective evidence could not be found on adoption of the superior serrated sickle selected at Sukamandi by Suismono et al. Based on numbers participating in the revolving credit scheme, it has been estimated that about one million such sickles are now in use.

3.5 Research Use: Soybean

3.5.1 Adoption of new varieties

Unlike rice, comprehensive statistics on area under cultivation to different soybean varieties were not collected for most of the years since the creation of AARD. To date, area by variety data is only available for the 1988 and 1989 dry and rainy seasons. Examination of this data set confirmed anecdotal evidence, as well as the findings of local field surveys in selected regions carried out as part of this study, that Wilis became the most important variety during the 1980s. Table 3.10 summarises adoption levels for major categories of varieties for 1988 and 1989. It can be seen that pre-AARD varieties still accounted for a large proportion of total area, but that varieties bred and released by AARD during the 1980s occupied more than 54% of total area by 1989. More striking is the fact that 45% of total area was sown to Wilis alone.

Calculation of research benefits also requires the varietal diffusion pattern to be estimated. Diffusion of innovations in general, and of new varieties in particular has been studied extensively, and it is widely accepted that diffusion curves generally follow a logistic pattern. Making the conservative assumption that Wilis reached its ceiling level of adoption in 1989, the area planted to this variety for the five years following its release in 1983 was estimated using

$$A_t = A_{89} (1 + \alpha e^{-\beta t})^{-1} \qquad (3.1)$$

where A_t = estimate of the area planted to Wilis in year t

A_{89} = area planted to Wilis in 1989

α = logistic curve coefficient (i.e., a constant of integration that positions the curve on the time sales)

β = logistic curve coefficient (i.e., the rate of adoption coefficient)

t = years since variety released (in 1983)

Table 3.10: *Soybean Variety by Area*

Location	Year/ Season[a]	Variety: Pre-AARD	Orba (1974)[b]	Galunggung (1981)[b]	AARD (1982)[b]	Wilis (1983)[b]	AARD (> 1983)[b]	Other	Total
					(hectares)				
Java	1988D	84,912	6,797	968	14,509	107,278	4,215	199	218,878
Java	1988R	131,261	23,085	13,444	11,032	102,098	9,459	288	290,667
Java	1989D	60,338	2,752	2,741	4,296	77,558	5,099	2,497	155,281
Java	1989R	188,028	63,242	3,670	8,331	254,270	30,013	754	548,308
Sumatra	1988D	44,142	8,376	7,840	3,208	10,316	763	147	74,792
Sumatra	1988R	6,934	3,776	5	2,227	3,494	633	346	17,415
Sumatra	1989D	3,540	658	193	1,280	1,592	1,791	1,354	10,336
Sumatra	1989R	30,104	27,203	9,882	11,671	40,646	1,288	943	121,740
Other	1988D	3,955	2,497	71	420	1,237	21	61	8,262
Other	1988R	3,458	4,822	2,757	324	2,821	79	5	14,266
Other	1989D	2,271	177	70	0	15,292	5	0	17,815
Other	1989R	12,429	12,039	661	1,360	10,119	785	1,151	38,544
Indonesia	*1988D*	*133,009*	*17,670*	*8,879*	*18,137*	*118,831*	*4,999*	*407*	*301,932*
Indonesia	*1988R*	*141,653*	*31,683*	*16,206*	*13,583*	*108,413*	*10,717*	*639*	*322,348*
Indonesia	*1989D*	*66,149*	*3,587*	*3,004*	*5,576*	*94,442*	*6,823*	*3,851*	*183,432*
Indonesia	*1989R*	*230,561*	*102,487*	*14,213*	*21,362*	*305,035*	*32,086*	*2,848*	*708,592*
					(percentage of area grown)				
		%	%	%	%	%	%	%	%
Java	1988D	39	3	0	7	49	2	0	100
Java	1988R	45	8	5	4	35	3	0	100
Java	1989D	39	2	2	3	50	3	2	100
Java	1989R	34	12	1	2	46	5	0	100
Sumatra	1988D	48	30	1	5	15	0	1	100
Sumatra	1988R	24	34	19	2	20	1	0	100
Sumatra	1989D	13	1	0	0	86	0	0	100
Sumatra	1989R	32	31	2	4	26	2	3	100
Other	1988D	59	11	10	4	14	0	0	100
Other	1988R	40	22	0	13	20	4	2	100
Other	1989D	34	6	2	12	15	17	13	100
Other	1989R	25	22	8	10	33	1	1	100
Indonesia	*1988D*	*44*	*6*	*3*	*6*	*39*	*2*	*0*	*100*
Indonesia	*1988R*	*44*	*10*	*5*	*4*	*34*	*3*	*0*	*100*
Indonesia	*1989D*	*36*	*2*	*2*	*3*	*51*	*4*	*2*	*100*
Indonesia	*1989R*	*33*	*14*	*2*	*3*	*43*	*5*	*0*	*100*

Source: Compiled by authors from unpublished BPS provincial survey data.

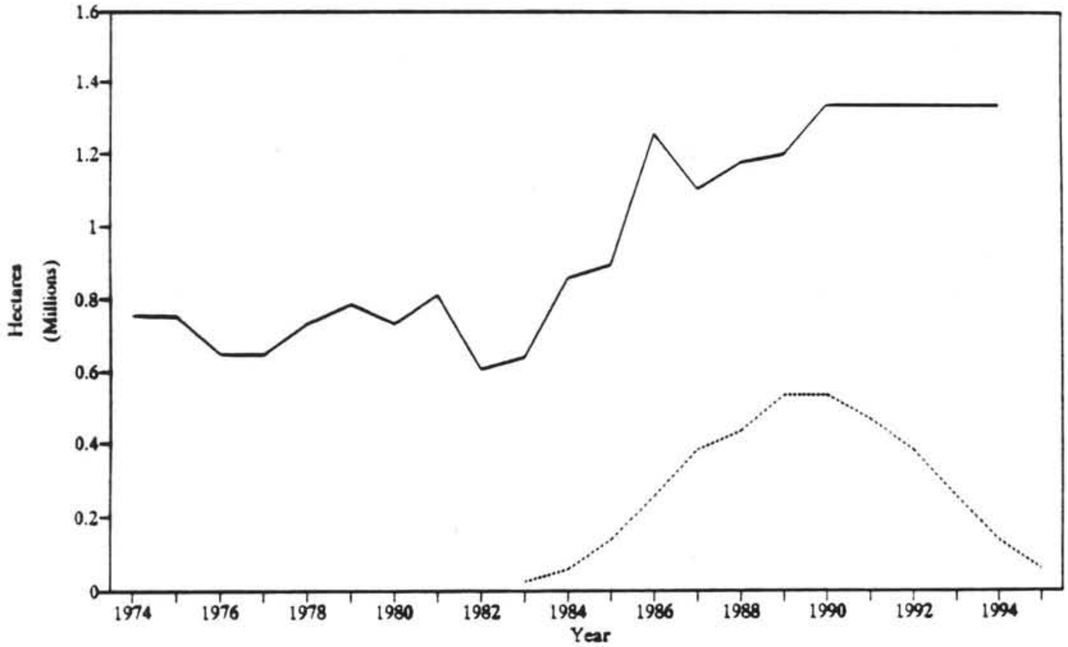
[a]"D" designates dry season and "R" designates rainy or wet season.

[b]Bracketed figures indicates year of release.

After some experimentation, setting $\alpha=22$ and $\beta=1.0$ gave a plausible looking cumulative adoption curve.[14] For the years 1988 and 1989 A_t equalled the area planted to Wilis as reported in unpublished BPS provincial survey data. It was assumed the adoption of Wilis took place at the expense of a combination of earlier released varieties, including in particular Orba. A disadoption process was also presumed to begin in 1989 (whereby, for example, farmers substitute the variety Tidar, released in 1987, for Wilis) so the estimated area planted to Wilis in year $(1989+t)$, $t=1,2,\ldots T$, was set equal to the area planted to this variety in year $(1989-t)$. The diffusion pattern for this key variety is illustrated in figure 3.12.

The same logistic curve approach was used to estimate diffusion patterns for the other soybean varieties released prior to Wilis except that the release date used was specific to each variety. For AARD varieties released post-Wilis the adoption profile was approximated by a simple linear interpolation between the year of release and the actual area planted in 1989. The area sown to pre-AARD varieties was found as the residual between total soybean area and the categories specified above. The results of these calculations are presented in figure 3.13. Clearly the AARD soybean breeding program has been most successful in breeding varieties suited to Indonesian conditions.

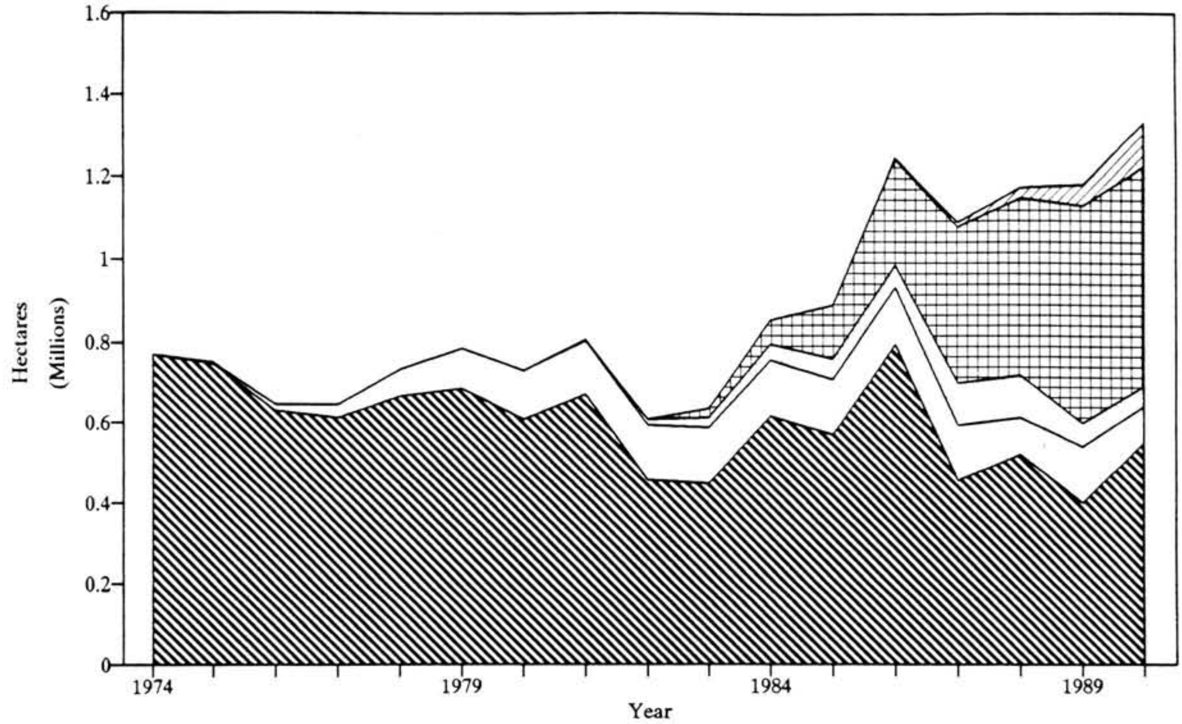
Figure 3.12: *Soybean harvested area; estimated diffusion of variety Wilis*



Legend : —— Total Harvested; ------ Wilis

[14]For extremely useful discussions of the use of a logistic curve in this context see Griliches (1957) and Lekvall and Wahlbin (1973). Equation 3.1 is simply the integral of $\partial A_t/\partial t = \beta A_t(K-A_t)/K$ where K is the ceiling level of adoption, $\alpha = -\ln(c^{-1})$, and c is the constant of integration. By this specification the rate of adoption, $\partial A_t/\partial t$, is proportional to the adoption already achieved and the distance from the ceiling level of adoption.

Figure 3.13: *Adoption of soybean varieties; estimated area harvested by source*



Legend : Pre AARD; Orba (74); AARD (81/2); Wilis (83); AARD (84/9)

4. THE IMPACT OF AGRICULTURAL RESEARCH: AGGREGATE ANALYSES

To gain some understanding of the nature and sources of productivity growth in the rice and soybean subsectors, a variety of aggregate analyses, drawing largely on BPS *Struktur Ongkos* data, are reported in this section. Regional and national level "total" factor productivity (TFP) indices[15] are constructured for both commodities. These TFP indices represent upper bound estimates of the growth-promoting consequences of research-induced technical changes, given that unmeasured changes in the quality of included inputs, as well as omitted inputs such as infrastructural and extension services, also contribute to measured changes in TFP. To make full use of the available price and quantity data our econometric work employs both primal and dual approaches. On the primal side, we estimate commodity-specific production functions that include current and lagged research expenditures as explanatory variables. The results from these analyses are then used to calculate marginal internal rates of return to research.[16] Cost function estimates are also presented in order to shed some light on the biased nature of technical change in the rice and soybean subsectors over the post-1974 period.

4.1 Total-Factor Productivity Assessment

The basic idea of productivity as a measure of output produced per unit of measured input is both straightforward and intuitive. But its measurement and interpretation raise a good number of conceptual and practical problems that must be addressed before the effects of agricultural research on productivity can be more completely understood.

4.1.1 Aggregation methods

We can begin by defining a partial factor productivity (*PFP*) measure at, say, the industry level as

$$PFP = \frac{Q}{X_i}, \qquad i = 1,\ldots m, \tag{4.1}$$

where Q represents aggregate (i.e., industry-level) output and X_i represents any particular aggregate input i—be it land, labor, fertilizer, or what have you. Unfortunately, for our purposes, *PFP* levels and their change over time are affected not only by advances in the state of technology, which enable increased levels of output to be produced per unit of measured input, but also by unmeasured changes in the quality of input X_i as well as changes in the quantities of other inputs used in production. For example, unmeasured changes in the quality

[15]The term "total" is used here in deference to its common usage in the literature. In fact measured TFPs are more appropriately described as "multi"-factor productivity indices in recognition of the fact that measured inputs do not capture the totality of all factors of production.

[16]See Echeverría (1990) for a recent global compilation of rates of return to research studies. Jatileksono (1987) and Widodo (1989) are recent studies of the effects of technical change on the Indonesian rice sector. Salmon (1984) reports on his attempt to estimate the rates of return to Indonesian rice research.

of land and/or higher rates of fertilizer applications will generally raise yields and consequently land productivity, while additional physical capital, be it in the form of a larger hand-held sickle or a bigger combine harvester, can raise labor productivity.

Thus, a more general concept of productivity is required if the goal is to distinguish between those changes in output due to technical changes arising from research (or any other productivity-enhancing factors) and those arising as a consequence of changes in the mix of inputs due to shifts in their relative factor prices. To this end a measure of "total" factor productivity (*TFP*) can be defined as

$$TFP = \frac{Q}{X}, \tag{4.2}$$

where *TFP* gives output Q produced per unit of an *input aggregate*, X, for a given state of technology. Obviously some suitable means of aggregating across different types of inputs is required when calculating such a *TFP*[17]. In this instance it is desirable to generate a "real" input aggregate that is invariant to shifts in relative factor prices. Changing relative factor prices will cause optimizing producers to alter their mix of inputs and, unless steps are taken to mitigate these effects, such responses to prices can result in a change in measured *TFP* even in the absence of technical change.

The method commonly used to minimize the impact of relative price changes when forming aggregate input quantity indices is to use a *Divisia* indexing procedure. As Richter (1966) and Hulten (1973) describe, the Divisia index is desirable because of its invariance property; if nothing real has changed (i.e., the only input quantity changes involve movements around an unchanged isoquant) the index itself is unchanged. The formula for the index is

$$XI_t^D = XI_b^D \exp \int_b^t \frac{\mathbf{W}_s' \Delta \mathbf{X}_s}{\mathbf{W}_s' \mathbf{X}_s} ds, \tag{4.3}$$

where XI_b^D is the index value of the base period, b, and $\mathbf{X}$ and $\mathbf{W}$ are vectors of input quantities and input prices respectively.

If the economy -- measured at either the sector, industry or even farm level -- is moving along an unchanged transformation (i.e., production) surface, the changes in inputs, ΔX, weighted by current factor prices

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[17] In many cases it is also necessary to form an output measure that involves aggregating across different outputs or different qualities of a given output. In practice, though, we may only have access to preaggregated measures that involve an implicit aggregation across different qualities and therefore have to live with any resulting biases, as is the case with the rice and soybean aggregates used in this study.

will be approximately zero; the index will be unchanged. If the economy's transformation surface is shifting, current price-weighted changes will be different from zero leading to changes in the index value. This invariance property is, one should note, dependent upon a maintained assumption of optimizing agents.

Unfortunately, the calculation of a Divisia index requires continuous measurement of input prices and quantities. In any discrete approximation, some information is lost, but the advantage of using a chained index always reduces to the notion that recent quantity changes are weighted by the most recently observed prices. Intuitively, these indices are attempting to evaluate current behavior in the light of current prices. In proceeding from the base period to some distant period t, the small steps are chained together, to minimize the measurement error that is possible when only base-period prices, and period t prices, are used to evaluate real input quantity changes.

There are, of course, many possible discrete approximations to the Divisia index. The most commonly used approximation, and the one adopted for this study, is the *Törnqvist* (1936) or *Törnqvist-Theil* approximation. It uses both current value shares and lagged value shares in weighting quantity changes yielding:

$$XI_t^{DT} = XI_{t-1}^{DT} \prod_{i=1}^{m} \left[\frac{X_{it}}{X_{it-1}} \right]^{\bar{W}_i}$$

$$\text{where } \bar{W}_i = \frac{1}{2}\left[\frac{W_{it}X_{it}}{W_t^{\prime}X_t} + \frac{W_{it-1}X_{it-1}}{W_{t-1}^{\prime}X_{t-1}} \right] = \frac{1}{2}(S_{it} + S_{it-1}). \qquad (4.4)$$

and where the input cost shares, in any particular period t, are given by

$$S_{it} = X_{it}W_{it} \Big/ \left(\sum_{i=1}^{m} X_{it}W_{it} \right).$$

An equivalent input quantity index, in summation rather than vector notation, can be written as

$$\ln(X_t/X_{t-1}) = \frac{1}{2}\sum_{i=1}^{m} (S_{it} + S_{it-1}) \ln(X_{it}/X_{it-1}), \qquad (4.5)$$

An input series index is formed by scaling the series so as to set $XI_b^{DT} = 1.0$ for any arbitrarily chosen base year b (so that, equivalently, $\ln(X_t/X_{t-1}) = \ln(XI_t^{DT}/XI_{t-1}^{DT})$), and accumulating the measure forward (and if necessary backward) in time according to equations 4.4 or 4.5.

Accounting Perspectives on Indexing

From equation (4.2) it follows directly that

$$tfp_t = q_t - x_t, \tag{4.6}$$

where $tfp_t = \frac{dTFP_t}{dt}\frac{1}{TFP_t}$, $q_t = \frac{dQ_t}{dt}\frac{1}{Q_t}$, and $x_t = \frac{dX_t}{dt}\frac{1}{X_t}$.

Thus the observed proportionate rate of growth of total factor productivity (tfp_t) is simply equal to the rate of growth of measured output (Q_t) minus the rate of growth of measured inputs (X_t). For relatively small changes in a variable Z_t, $dZ_t/Z_t = d\ln Z_t \approx \ln Z_t - \ln Z_{t-1}$ (so that proportionate rates of change, dZ_t/Z_t, are approximately equal to logarithmic differences, $\ln Z_t - \ln Z_{t-1}$), and a discrete approximation for equation (4.6) is given by:

$$\begin{aligned} 1 + tfp_t &\approx \ln(TFP_t/TFP_{t-1}) \\ &= \ln(Q_t/Q_{t-1}) - \ln(X_t/X_{t-1}) \\ &\equiv \ln(Q_t/Q_{t-1}) - \ln(X_t^{DT}/X_{t-1}^{DT}). \end{aligned} \tag{4.7}$$

Thus the rate of change in *TFP* is obtained simply by taking the difference between the rate of change in measured output, for this study simply calculated as $ln(Q_t/Q_{t-1})$, and the Divisia input index, given by equations 4.4 or 4.5. Direct application of equations like 4.7, to obtain estimates of the level and rate of change of *TFP*, respectively, is often referred to as the accounting, index number, or even axiomatic, approach to constructing measures of *TFP*. It represents a parsimonious approach to *TFP* measurement, involving relatively marginal (but nonetheless fundamental) appeals to economic theory in its construction.

In principle, input (and, if necessary, output) aggregates could be formed using the Divisia indexing procedure and it would be possible to calculate *tfp* without imposing any restrictive assumptions about the functional form of the underlying production relationship. The only assumptions interposing between the data and the *tfp* measures would be the ones concerning optimizing behavior, whereby technically efficient producers (or a technically efficient industry) substitute around isoquants and production possibility frontiers in response to changes in relative prices of inputs and outputs. If the underlying technology is assumed to be input-output separable (so that the output measure, Q_t, and the input aggregate, X_t, can in fact be formed) then the *TFP* measure follows directly. But, in practice, we are presented with observations at discrete intervals, not the continuous observations required to use equation 4.3, so it is possible to calculate only approximations to the rate of change in *TFP*, by using the approximate indices in place of their corresponding exact counterparts. Work by Diewert (1976), extended for the discrete variable case by Denny and Fuss (1983), showed that the use of the Törnqvist-Theil approximation to the Divisia index carries with it an implicit assumption that the underlying technology is of the translog form. To the extent that the translog represents a second-order, local, approximation (around the point of approximation) to an arbitrary functional form, this may be regarded as imposing fewer restrictions between the data and the *tfp* measure, compared with choosing some other approximation, which brings with it less flexible (and, therefore, possibly less desirable) implicit notions about what the underlying (and unobservable) technological relationships are like.

Production Function Perspective on Indexing

The most straightforward approach to more formally linking *TFP* measurement and the theory of production is to maintain the assumption of technically efficient, optimizing producers, used in the accounting approach to *TFP* measurement -- and to assume further that technical change is of the *extended Hicks-neutral* form. We can then write a production function such as:

$$Q_t = \mathrm{f}(X_t, \tau_t), \tag{4.8}$$

where τ_t is an index of the state of technology. Under these assumptions, technological progress (i.e, where $d\tau_t/dt > 0$) is perceived as an upward shift of the production function, f(.), or, alternatively, a downward shift of the corresponding isoquant map. Rates of change in output over time can be partitioned into components due to changes in input use, and those due to changes in the state of technology, by differentiating Q_t with respect to time and dividing throughout by Q_t (or, equivalently, taking logarithms and differentiating $\ln Q_t$ with respect to time) to give:

$$\frac{d\ln Q_t}{dt} = \frac{\partial \ln Q_t}{\partial \ln \tau_t}\frac{d\ln \tau_t}{dt} + \sum_{i=1}^{m} \epsilon_{Q,i}\frac{d\ln X_{it}}{dt}. \tag{4.9}$$

where $\epsilon_{Q,i}$ ($= d\ln Q_t/d\ln X_i$) is the elasticity of output with respect to changes in the quantity of the i^{th} input. If competitive equilibrium is assumed, so that price equals marginal cost and factors are paid the values of their marginal products, then equation 4.9 may be rewritten, equivalently, as:

$$\frac{d\ln Q_t}{dt} = \frac{\partial \ln Q_t}{\partial \ln \tau_t}\frac{d\ln \tau_t}{dt} + \epsilon_{Q,C}\sum_{i=1}^{m} S_{it}\frac{d\ln X_{it}}{dt}. \tag{4.10}$$

where $S_{it} = X_{it}W_{it}/\Sigma_i X_{it}W_{it}$ is the i^{th} factor's share of total cost in time t and $\epsilon_{Q,C} = (d\ln C_t/d\ln Q_{t-1})^{-1}$ is the inverse of the elasticity of cost with respect to output that can be used to define returns to scale. Using more compact notation, we can transform equation 4.10 to obtain:

where g_t ($= (\partial \ln Q_t/\partial \ln \tau_t)(d\ln \tau_t/dt)$, the elasticity of output with respect to the index of technology multiplied

$$g_t = q_t - \epsilon_{Q,C} x_t, \quad (4.11)$$

by the growth rate of the index)[18] is taken to represent the *primal rate of technological change*, q_t (= $d\ln Q_t/dt$) the rate of growth in output, and x_t (= $d\ln X_t/dt = \Sigma_i (S_i d\ln X_{it}/dt)$) is the Divisia index of the growth in aggregate input. In words, equation 4.11 expresses the primal rate of technological change as the rate of change of output, minus a scale-adjusted index of the rate of change in input. Clearly, if we make the assumption of constant returns to scale -- in addition to the assumptions of input-output separability, efficient and optimizing producers, and extended Hicks-neutral technological change -- then the rate of change in *TFP* given by equation 4.6 also measures the rate of technological change or shift of the production function.

4.1.2 TFP results

Regional TFPs for rice and soybean are presented in tables 4.1 and 4.2 respectively. They represent residual growth in output once changes in the use of measured land, labor, fertilizer, seed, pesticide, animal power, and irrigation inputs have been taken into account. According to our estimates, TFP for rice in Indonesia grew at an annual average rate of 3.1% since 1974 while for soybeans the rate was 3.6% per annum. The period from the late 1970s to mid-1980s experienced the fastest annual rate of increase in rice output in contemporary Indonesian history and is also the period when rice TFPs grew fastest. For soybeans, output and TFP growth were the most rapid during the latter half of the 1980s. TFPs for both rice and, particularly, soybeans exhibit substantial cross-regional variability. Since 1969 the productivity gains for rice were higher than the national average in Eastern Java and Sulawesi, while Sumatra, which accounted for over 20% of Indonesia's total rice production by the late 1980s (table 2.1), showed the smallest productivity gains. The striking result for soybeans is Sumatra where, despite substantial increases in output (averaging 15.1% per annum since 1969) and area harvested (particularly for Aceh and Lampung), productivity levels were actually lower in the late 1980s compared with 1974.

While spatial and temporal differences in measured TFPs come about from research-induced technical changes, there are a variety of other factors that have a bearing in this regard. By comparing equation 4.6 with equation 4.11 it is evident that increasing returns to scale (whereby $\epsilon_{Q,C} > 1$) will reduce the primal rate of technical change, g, as will the increased use of omitted inputs such as rural extension and infrastructure services. Unaccounted changes in input and output quality will also contribute to observed variations in TFP measures. Those improvements in input quality (such as improvements in the quality of labor through formal

[18] Most studies use time as the technology index thereby implicitly assuming $d\ln\tau/dt=1$ so that $g_t=\partial \ln Q_t/\partial t$.

Table 4.1: *Regional Total Factor Productivities for Rice, 1974-89*

	Sumatra	Java					Bali & Nusatenggara	Kalimantan	Sulawesi	Indonesia
		West Java	Central Java	Yogyakarta	East Java	Total				
						(1974 = 100)				
1974	100	100	100	100	100	100	100	100	100	100
1975	95.40	102.13	97.43	112.61	107.86	103.44	94.95	100.19	108.25	103.48
1976	112.27	110.83	107.69	104.95	122.12	114.31	95.06	113.24	119.77	113.96
1977	110.78	100.32	100.02	103.08	111.87	105.02	103.48	110.53	123.00	108.88
1978	106.04	99.55	80.31	111.82	117.90	100.34	100.19	104.67	120.18	104.74
1979	114.09	114.36	96.70	117.74	120.36	111.67	107.50	121.83	126.80	115.09
1980	110.75	99.89	117.41	138.69	145.53	121.18	112.19	115.35	127.28	121.21
1981	117.21	120.38	126.35	134.37	157.49	135.42	123.23	118.19	135.88	133.27
1982	120.84	124.03	133.29	138.13	170.89	142.99	133.39	116.66	148.20	140.30
1983	118.93	131.18	139.76	145.40	175.14	148.73	134.91	122.21	155.99	145.20
1984	127.62	139.65	142.92	147.26	187.41	156.31	140.75	138.03	163.04	153.39
1985	124.02	143.70	151.73	160.43	187.29	161.36	141.96	131.80	158.00	156.18
1986	120.78	149.94	151.06	168.65	181.29	162.39	142.72	133.84	161.85	156.98
1987	118.41	151.00	159.42	160.80	184.62	166.06	143.86	136.89	153.81	158.20
1988	119.81	143.48	150.50	157.79	174.43	157.32	142.63	139.33	158.65	153.16
1989	119.85	149.14	155.24	164.68	178.08	162.32	144.15	152.32	162.33	158.25
Annual growth rate										
	%	%	%	%	%	%	%	%	%	%
1974-79	2.67	2.72	-0.67	3.32	3.78	2.23	1.46	4.03	4.86	2.85
1980-84	3.61	8.74	5.04	1.51	6.53	6.57	5.83	4.59	6.39	6.06
1985-89	-0.85	0.93	0.57	0.66	-1.25	0.15	0.38	3.68	0.68	0.33
1974-89	*1.22*	*2.70*	*2.98*	*3.38*	*3.92*	*3.28*	*2.47*	*2.85*	*3.28*	*3.11*

Table 4.2: *Regional Total Factor Productivities for Soybean, 1974-89*

		Java								
	Sumatra	West Java	Central Java	Yogyakarta	East Java	Total	Bali & Nusatenggara	Kalimantan	Sulawesi	Indonesia
						(1974 = 100)				
1974	100	100	100	100	100	100	100	100	100	100
1975	88.53	110.00	109.22	78.26	97.69	99.76	78.86	52.75	73.43	96.62
1976	111.87	115.00	120.93	101.95	100.03	102.80	111.83	73.12	82.93	101.97
1977	117.47	69.11	122.92	101.65	95.73	101.44	98.93	76.37	86.96	99.57
1978	82.33	71.21	106.70	79.58	118.88	111.39	133.45	70.77	85.67	107.09
1979	66.28	80.18	156.54	82.40	132.31	132.58	116.26	62.57	78.53	126.61
1980	52.50	90.00	122.98	68.54	127.15	125.36	148.16	87.96	94.97	119.73
1981	75.08	77.87	118.38	84.39	118.23	120.60	114.52	95.17	106.20	114.73
1982	72.70	77.79	131.15	104.39	102.18	110.48	127.43	159.88	109.33	106.07
1983	77.53	86.58	122.31	91.87	95.83	105.24	99.16	118.44	88.94	103.56
1984	89.91	97.50	140.75	106.00	121.46	129.10	182.92	187.92	97.98	125.22
1985	78.13	105.94	157.81	104.36	137.49	147.73	142.15	117.30	117.55	138.80
1986	94.00	107.86	169.12	113.45	122.46	136.61	142.92	96.79	178.40	138.40
1987	91.44	114.63	164.81	112.10	138.15	148.89	164.59	133.32	134.50	148.82
1988	92.97	124.77	150.31	121.10	134.23	146.78	151.08	129.09	141.63	144.83
1989	97.88	148.52	145.51	129.05	125.46	148.11	287.94	148.23	149.81	168.98
Annual growth rates										
	%	%	%	%	%	%	%	%	%	%
1974-79	-7.90	-4.32	9.38	-3.80	5.76	5.80	3.06	-8.95	-4.72	4.83
1980-84	14.40	2.02	3.43	11.51	1.14	0.74	5.41	20.90	0.78	1.13
1985-89	5.80	8.81	-2.01	5.45	-2.26	0.06	19.30	6.03	6.25	5.04
1974-89	*-0.14*	*2.67*	*2.53*	*1.71*	*1.52*	*2.65*	*7.31*	*2.66*	*2.73*	*3.56*

education or learning by doing, or improvements in the quality of inputs such as seed, fertilizer, and pesticide), and even variations in weather and climate, that for data reasons are omitted from measured inputs, X, can bias the rate of growth in the input aggregate and thereby the measured growth in TFP. Similarly, the preaggregated output quantity measure used here does not reflect the substantial differences in the varietal mix of soybean and, especially, rice output (see sections 3.4 and 3.5) so will tend to understate q and thereby TFP growth. To the extent that any quality improvements in output (which are often embodied in new seed varieties) are due to research, it is wholly appropriate that TFP grows as a consequence given our intention here is to identify the growth promoting effects arising as a direct consequence of Indonesian research investments.

4.2 Production Function Estimates

4.2.1 Conceptual framework

The primal approach to ex post evaluation of agricultural research involves three elements. They are: (a) the relationship between the size of the investment in research and output (or output per unit of (aggregate) input in the case of a model of a yield (or productivity) function), (b) the relationship between increases in output (or productivity) and flows of economic benefits, and (c) a procedure to account for the timing of streams of benefits and costs. Successful investment in agricultural research leads, among other things, to increases in agricultural productivity so that either more measured output can be produced with the same amount of total inputs or the same amount of output can be produced with fewer measured inputs. These increases in productivity stem from the development of new or improved outputs, new, better, or cheaper inputs or through changes in knowledge that enable producers to choose and combine inputs more effectively. We can think of current knowledge (be it embodied in inputs or outputs, or not) as being a capital stock which has been created by past investment, which depreciates over time, which can be augmented by new investment, and which yields a service flow as an input into agricultural production. An investment in agricultural research is an investment in maintaining or increasing this capital stock. While the stock of knowledge may be expanded as a result of research, this new knowledge might not be used immediately. The extent of utilization of the stock of knowledge -- the rate of adoption (and ultimately disadoption) of research results -- will depend principally on its applicability as determined by the expected profitability of using the innovation and the costs of acquiring the information at the farm level.

These ideas can be represented algebraically in terms of a production function f(.) in which agricultural output in time t (Q_t) depends on quantities of conventional inputs (X_t), uncontrollable factors such as weather (U_t), and the flow of services (which we can represent by a technology index, τ_t) from the stock of knowledge

(K_t), and other (i.e., noneconomic) factors:

$$Q_t = f(X_t, \tau_t, U_t), \tag{4.12}$$

Research investments can lead to a change in productivity (output per unit of conventional inputs, Q/X) by changing the quality of conventional inputs or their prices (i.e., through a change in the technology used to produce those inputs), through an increase in the stock of knowledge, or by increasing the utilization of the existing stock of knowledge. Thus the state of technology (τ_t)—in so far as it is driven by knowledge-related aspects—is endogenous: the extent of *utilization* of available knowledge depends upon relative factor prices (W_t), the stock of farmers' human capital (H_t), and the extent and quality of extension services (E_t), among other things. For now we will model this relationship as follows

$$\tau_t = \tau(K_t, W_t, H_t, E_t). \tag{4.13}$$

The stock of useful knowledge on the one hand depreciates (D_t) as it is replaced by better information or when circumstances change to make it less useful, and on the other hand increases (I_t) due to the incorporation of results from past investments in research.

$$K_t = K_{t-1} + I_t - D_t. \tag{4.14}$$

The dynamics of the relationship between past investments in research (R_{t-k}) and extension (E_{t-j}) and increments to useful knowledge (I_t) are complicated and uncertain. A general form of the relationship is:

$$I_t = i(R_{t-1}, R_{t-2}, \ldots R_{t-k}, E_{t-1}, E_{t-2}, \ldots E_{t-j}, K_{t-1}, Z_t). \tag{4.15}$$

This relationship between research investments and changes in the stock of useful knowledge is sometimes termed a *research production function* or a *knowledge production function*, a central component in relating agricultural output to research (and extension) inputs.

Usually, since the stock of knowledge cannot be observed directly, the research (knowledge) production function is more a part of the conceptual apparatus rather than an empirical tool. The empirically useful variant of the research (knowledge) production function is the function that relates output (or productivity) to lagged values of research investments. Loosely combining equations (4.12) through (4.15) we can suggest a reduced-form relationship between investments in research and output (or productivity) in which current output (or productivity) depends upon current flows of conventional inputs (X_t), indefinitely long lags of past investments in agricultural research (R_{t-k}) and extension (E_{t-j}), the stock of human capital (H_t), other factors such as infrastructure and changes in input quality (Z_t), and uncontrollable, random, factors such as weather and pests

(U_t):

$$Q_t = f(X_t, U_t, \tau_t[(R_{t-1}, \ldots R_{t-k}), (E_{t-1}, \ldots E_{t-j}), W_t, H_t, Z_t])$$
$$= \tilde{f}(X_t, R_{t-1}, \ldots R_{t-k}, E_{t-1}, \ldots E_{t-j}, W_t, H_t, Z_t, U_t). \tag{4.16}$$

A yield model variant of this model expresses output per unit of an input, say, land; but such a specification involves an explicit or implicit strong separability assumption that might not be justified. Implementation of this conceptual model requires decisions on which of these variables to include (a choice that is dictated in large part by the availability of data on suitable proxies), which functional form for the relationship to use in the estimation, and how to specify the random part of the model that will be treated as an unexplained residual in the estimation.

4.2.2 Data measurement and estimation issues

To keep our estimation exercise tractable, while still preserving a reasonable degree of flexibility, we chose the following functional form:

$$\ln Q_{jt} = \alpha_0 + \alpha_1 t + \sum_{i=1}^{10} (\beta_{1i} + \beta_{2i} t)\ln X_{ijt} + \beta_g D_g + e_{jt} \tag{4.17}$$

where provinces (or island groups) are denoted by $j = 1, \ldots, J$, and $t = 1,2,3,\ldots,16$ denotes annual observations for the years 1974, 75,...,89, to give a total of 368 observations for the rice production function and 128 observations for soybeans. Here Q_j represents rice and soybean output measured in milled-rice and dry-shelled equivalent terms respectively with X_i, $i = 1,\ldots,7$, including conventional inputs such as land, labor, fertilizer, seed, pesticide, animal power, and area irrigated. There is also a road density variable to proxy infrastructural developments (along the lines suggested by Antle [1983]), a measure of the number of extension workers per locale, and a research investment or stock of useable knowledge variable indicated by X_i, $i = 8,9$, and 10 respectively. Also included were a set of regional dummy variables, D_g, $g = 2,\ldots G$, presumed here to represent time-persistent, regional differences in social, economic and natural endowments not accounted for by the other variables, a time trend, t, and a disturbance term e_{ji}.

This quasi-translog function represents a compromise between a translog specification, which admits interaction effects between all inputs and, in this case, a time trend, and a Cobb-Douglas production function, which imposes separability between all inputs and time. Given the strongly trending nature of many inputs into Indonesian agriculture over this 16-year period, multicollinearity problems pose significant estimation difficulties, particularly in the translog case. Constancy in production elasticities as implied by the Cobb-Douglas form are questionable because of the biased nature of the technical change implicit in the changing factor shares noted earlier. The quasi-translog specification does impose separability between all measured inputs but not between these inputs and a time trend. In this way the "effectiveness" of each measured input is allowed to vary overtime even though the effects among inputs are indirect through time. So while this specification reduces to a Cobb-Douglas form in any particular year, its production elasticities vary over time.

Investments in agricultural research eventually add to the stock of useful knowledge which in turn leads to productivity gains in agriculture. But the production of new knowledge and technologies is a complex, risky and time-intensive process. For instance, the lags between investing in research and developing new knowledge and agriculture technologies depend on a host of factors not least the commodity, scientific discipline and research problems under consideration. There are further lags in the uptake of these new technologies and often site-specific variation in their productivity effects. Search, screening and selection activities on the part of farmers, and the availability and effectiveness of extension services all play a role in this regard. Linking research investments directly to changes in an aggregate measure of agricultural output, as we do here, is clearly a reduced-form specification but one that does enable us to examine quantitatively the productivity effects of research. Temporal and spatial differences in input quality (including that of labor as commonly signaled by educational levels) and the like, which also contribute to the measured growth of the agricultural sector, are subsumed in the time and dummy variables included in equation (4.17). This quasi-translog specification has the attractive feature that it allows the impact of research on agricultural output to be conditioned by these omitted variables through time. Moveover, it does this in a way that skirts some of the multicollinearity and degrees of freedom problems that are associated with more general forms of the production function.

One of the thornier problems to resolve when including a research variable in an aggregate production function concerns the choice of an appropriate lag structure. Studies using long-run US data suggest that the productivity effects of agricultural research can persist for upwards of 30 years (Pardey and Craig 1989). The evidence concerning R&D lags and adoption lags for rice and soybean presented in section 3 suggest that somewhat shorter lags may be appropriate for Indonesia, especially for the post-1974 period under study here. Drawing directly on this evidence, we included a research or stock of usable knowledge variable that was a deflated, weighted sum of past research expenditures, R_{t-i}, given by

$$X_{10t} = \prod_{i=0}^{17} R_{t-i}^{w_i} \qquad (4.18)$$

where the normalized weights, w_i, in table 4.3 were used.

Table 4.3: *Weights Used to Form the Stock of Knowledge Variable*

	w_0	w_1	w_2	w_3	w_4	w_5	w_6	w_7	w_8	w_9	w_{10}	w_{11}	w_{12}	w_{13}	w_{14}	w_{15}	w_{16}	w_{17}
Rice	0	0	0	0	0.01	0.061	0.086	0.112	0.142	0.137	0.12	0.091	0.079	0.071	0.051	0.03	0.01	0
Soybean	0	0	0	0.06	0.014	0.029	0.069	0.109	0.121	0.144	0.144	0.121	0.109	0.069	0.029	0.014	0.006	0

Given the unavoidable uncertainty concerning the structure of this lagged relationship some sensitivity analyses were performed in which both the lag length and its form (as represented by the weights placed on the lagged research expenditures) were varied. This work indicated that neither the qualitative nor quantitative details reported below were appreciably altered as a consequence.

4.2.3 Empirical results

Estimated production functions for rice and soybean are presented in table 4.4. For rice, the coefficients on all conventional inputs have positive signs and especially for specification (2) have generally acceptable levels of statistical significance. But the infrastructure and extension proxy have negative coefficients at $t = 0$ (i.e., 1974) although their corresponding time by variable interaction terms were positive so that by $t = 7$ (i.e., 1980) both had become positive and were increasingly so during the latter years of the sample. According to these rice estimates, the marginal growth promoting effects of land, labor, fertilizer, irrigated area and the stock of knowledge have been increasing over time, while the marginal gains from additional seed, pesticide, and animal power are now lower than they were in earlier years. The extension and infrastructure variables both had negative coefficients, but this may well reflect the crudeness of our proxies for these inputs rather than indicate their effects on rice production. It was also observed that both variables were colinear with the other explanatory variables, particularly the regional dummy variables, which as a group (and in most cases individually) were highly significant across most of the specifications that were estimated. This makes it difficult to identify the seperate (ceteris paribus) influence of these two factors on output growth.

Attempts to econometrically estimate a production function for soybean were generally less satisfactory than was the case for rice. A significant feature of these data were the exceptionally strong upward trend in area harvested for most of the Off-Java island groups, particularly Sumatra, Kalimantan, and, in more recent years, Bali and Nusatenggara (appendix A2.8). The soybean production function reported in table 4.4 fits the data well but gives an implausibly high coefficient on the land variable and negative coefficients on several others. In any case, the production functions for both commodities indicated modestly increasing returns to scale on the conventional inputs.

Table 4.4: *Production Function Estimates for Rice and Soybean*

	Rice		Soybean
Specification	(1)	(2)	(3)
Constant	2.195 (0.314)[a]	-16.972 (-1.980)	1.961 (1.678)
Land	0.537 (3.711)	0.545 (3.702)	0.949 (14.630)
Labor	0.022 (0.721)	0.069 (1.921)	-0.040 (-1.619)
Fertilizer	0.019 (0.640)	0.048 (1.303)	0.028 (1.606)
Seed	0.432 (2.874)	0.344 (2.308)	0.142 (2.803)
Pesticide	0.023 (0.759)	0.036 (1.179)	0.015 (0.726)
Draft Animal	0.030 (1.783)	0.025 (1.406)	-0.015 (-1.059)
Area irrigated	0.036 (1.239)	0.075 (2.216)	0.003 (0.135)
Infrastructure	-	-0.038 (-1.293)	-0.035 (-2.204)
Extension	-	-0.063 (-1.799)	0.027 (1.213)
Research	0.232 (0.481)	1.531 (2.503)	0.223 (2.805)
N	368	368	128
Adjusted R^2	0.980	0.981	0.986
	%	%	%
Marginal internal rate of return to research	80	116	48

Note: See appendix for details of data and variable construction. Specifications (1) and (2) are of quasi-translog form. Specification (1) includes variable by time interaction terms while specification (2) also includes regional (i.e., island group) dummy variable normalized on Sumatra. Specification (3) is of Cobb-Douglas form.

[a]Numbers in parentheses are t-values.

It is the long-run, growth-promoting consequences of agricultural research that are of special interest in this study. Because the full effects of the current stock of research investments will continue to be felt for some time into the future it is convenient to collapse this over-time dimension into a summary statistic such as the marginal internal rate of return to research. After substituting equation 4.18 for $X_{10,t}$ in equation 4.17 and taking the partial derivatives of Q with respect to R_{t-i}, i.e., $\partial Q/\partial R_{t-i}$, the marginal internal rate of return (evaluated at the geometric mean of the observed research expenditures $\bar{R}$) is obtained by solving for r in

$$\sum_{i=0}^{17}\left(\beta_{10}\ w_i\ \frac{\bar{PQ}}{\bar{R}}/\ (1+r)^i\right)\ -\ 1\ =0 \tag{4.19}$$

where β_{10} is the estimated coefficient on the stock of research variable in equation 4.17 and $\bar{P}\bar{Q}$ is the geometric mean of the value of production.[19] Notice that in equation 4.19 the inverse of the commodity-specific research intensity ratio, i.e., $(\bar{R}/\bar{P}\bar{Q})^{-1}$, is a critical determinant of the internal rate of return. Estimates of the marginal internal rate of return to rice and soybean research, r, estimates are presented in the lower part of table 4.4. Here the marginal internal rate of return represents the rate of interest that makes the discounted benefit stream generated by the marginal rupiah invested in research in year t equal to the rupiah. The estimates for rice were in the 80% to 115% range while for soybeans the rate of return was almost half this level. These rates of return compare more than favorably with those obtained in a large number of similar studies reviewed by Echeverria (1990).

4.3 Cost Function Estimates

4.3.1 Conceptual framework

The application of duality theory to economic problems has resulted in many useful results for the study of production and cost relationships. The choice between the primal and dual approaches to estimation of production functions should be made on statistical grounds. The primal is attractive when the level of output is endogenous. The dual is more attractive, however, if the level of output is exogenous. The government has intervened heavily in the production of rice and soybeans in Indonesia. Thus, the specification that input levels are endogenous variables, and that the output level is an exogenous variable, is plausible in this context. In addition, the rice and soybean sectors compete with other crops for factors of production, so that the specification that input prices are exogenous variables is also reasonable.

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[19]In equation 4.17 $\partial Q_t/\partial R_i = \beta_{10}w_i\ \bar{Q}/\bar{R}$ when evaluated at the geometric mean of the sample.

Important characteristics of production can be represented by the extent and direction of factor substitution, economies of scale, and the ways in which technical change occurs. Treating crops and livestock as two distinct outputs, Ray (1982) estimated a translog cost function for U.S. Agriculture 1939-77 with an explicit restriction that technical change was Hicks-neutral. Unlike Ray, when Ball and Chambers (1982) modeled the U.S. meat products industry using a nonhomothetic translog cost function, they did not impose any prior restrictions on the characteristics of technical change. In this study, the Ball and Chambers framework and Ray's specification are combined. It is considered that there is no basis of prior information to enable us to specify any specific type of technical change in rice and soybean production in Indonesia in the past. In addition, the model in this paper also departs from those previous studies by including regional dummy variables to capture the variations across regions which may be caused by weather or economic factors.

Specifically, the m-output-n-input translog cost function is:

$$\begin{aligned} \ln C = \alpha_0 &+ \sum_{i=1}^{n} d_i D_i + \sum_{r=1}^{m} \alpha_{Y_r} \ln Y_r + \frac{1}{2}\sum_{r=1}^{m}\sum_{j=1}^{m} \beta_{Y_r Y_j} \ln Y_r \ln Y_j \\ &+ \sum_{r=1}^{n} \alpha_i \ln W_i + \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} \beta_{ij} \ln W_i \ln W_j + \sum_{r=1}^{m}\sum_{j=1}^{m} \gamma_{Y_r j} \ln Y_r \ln W_j \\ &+ \phi_T t + \frac{1}{2}\phi_{TT} t^2 + \sum_{r=1}^{m} \phi_{TY_r} t \ln Y_r + \sum_{i=1}^{n} \phi_{Ti} \ln W_i t. \end{aligned} \tag{4.20}$$

Here C is total production costs of both rice and soybean, Y_r is output of product r, W_i is price of input i, t is an annual index of time used to reflect technical change and D_i is a dummy variable for region i. This function can be regarded as a quadratic approximation to the unknown "true" cost function when it is believed that $\beta_{Y_rY_j} = \beta_{Y_jY_r}$ and $\beta_{ij} = \beta_{ji}$ for all r, i, and j.

In order to correspond to a well-behaved production function (F(X)), a cost function must be homogeneous of degree one in prices; that is, for a fixed level of joint outputs, total cost must be doubled when all prices are doubled. This implies the following relationships:

$$\sum_{i=1}^{n} \alpha_i = 1, \tag{4.21}$$

$$\sum_{i=1}^{n} \beta_{ij} = \sum_{j=1}^{n} \beta_{ji} = 0 \qquad \forall\, i,j, \tag{4.22}$$

$$\sum_{i=1}^{n} \gamma_{Y_j i} = 0 \quad \forall i. \tag{4.23}$$

$$\sum_{i=1}^{n} \phi_{Ti} = 0. \tag{4.24}$$

The translog cost function 4.20 does not constrain the structure of production to be homothetic, nor does it impose restrictions on the elasticities of substitution or economies of scale. However, these restrictions can be tested statistically. If any of the restrictions are valid, it is preferable to adopt the simplified model.

Assuming there exists marginal cost pricing for each output, we obtain the relations:

$$S_{Y_r} = \frac{\partial \ln C}{\partial \ln Y_r} = \frac{\partial C}{\partial Y_r} \cdot \frac{Y_r}{C} = \frac{P_r . Y_r}{C}, \tag{4.25}$$

for each output r with P as the output price. Equation 4.25 is essentially the revenue share equation for output r. From model 4.20, it can be written further as:

$$S_{Y_r} = \frac{\partial \ln C}{\partial \ln Y_r} = \alpha_{Y_r} + \sum_{j=1}^{m} \beta_{Y_r Y_j} \ln Y_j + \sum_{i=1}^{n} \gamma_{Y_r i} \ln W_i + \phi_{TY_r} t. \tag{4.26}$$

Economies of scale are usually defined in terms of the relative increase in output resulting from a proportional increase in all inputs. Hanoch (1975) suggests that it is more appropriate to represent scale economies by the relationship between total cost and output along the expansion path—where input prices are constant and costs are minimized at every level of output. Hence, it can be defined that the elasticity of scale for output ϵ_y, keeping other outputs and input prices constant, is the reciprocal of the elasticity of cost with respect to output along the expansion path, that is

$$\epsilon_y = [S_Y]^{-1}. \tag{4.27}$$

Equation 4.27 is exactly the inverse of the revenue share of output r defined in equation 4.26. The interpretation of equation 4.27 is that when $\epsilon_y < 1$, the production function (F(X)) exhibits decreasing returns to scale in output r; $\epsilon_y = 1$ implies constant returns, and $\epsilon_y > 1$ implies increasing return to scale.

The specific technology of F(X) can be tested as a null hypothesis which is nested in model 4.20:

Test for homotheticity of F(X):

Test for homogeneity of F(X):

$$H_0: \quad \gamma_{rj} = 0 \quad \forall r \text{ and } \forall j$$
$$\phi_{TY_r} = 0 \quad \forall r \tag{4.28}$$

$$H_0: \quad \gamma_{rj} = 0 \quad \forall r \text{ and } \forall j$$
$$\phi_{TY_r} = 0 \quad \forall r \tag{4.29}$$
$$\beta_{Y_r Y_j} = 0 \quad \forall r \text{ and } \forall j$$

Test for linear homogeneity of F(*X*):

$$H_0: \quad \gamma_{rj} = 0 \quad \forall r \text{ and } \forall j$$
$$\phi_{TY_r} = 0 \quad \forall r$$
$$\beta_{Y_r Y_j} = 0 \quad \forall r \text{ and } \forall j \tag{4.30}$$
$$\sum_{r=1}^{m} \alpha_{Y_r} = 1.$$

Another advantage of applying the cost function approach is that the derived demand functions for the factors of production can be derived easily using Shephard's lemma (1953), that is:

$$\frac{\partial C(X, W)}{\partial W_i} = X_i. \tag{4.31}$$

In the current context, it is expressed as:

$$\frac{\partial \ln C(X, W)}{\partial \ln W_i} = \frac{X_i W_i}{C} = S_i. \tag{4.32}$$

where S_i indicates the cost share of the i^{th} factor input. Thus the expenditure share equations from model 4.20 can be written as

$$S_i = \frac{\partial \ln C}{\partial \ln W_i} = \alpha_i + \sum_{j=1}^{n} \beta_{ij} \ln W_j + \sum_{i=1}^{m} \gamma_{Y_{ji}} \ln Y_j + \phi_{T_i} t. \tag{4.33}$$

Uzawa (1961) has shown that Allen partial elasticities of input substitution can be computed from the cost function by the formula:

$$\sigma_{ij} = \frac{C C_{ij}}{C_i C_j}. \tag{4.34}$$

From model 4.20, equation 4.34 can be written as:

$$\sigma_{ij} = \frac{\beta_{ij} + S_i S_j}{S_i S_j} \quad \forall i \neq j$$
$$\sigma_{ii} = \frac{\beta_{ii} + S_i^2 - S_i}{S_i^2}. \tag{4.35}$$

The own-price elasticity of demand for i^{th} factor of production is

$$\eta_i = \sigma_{ii} S_i . \tag{4.36}$$

The rate of technical progress, which reflects the cost reduction from technical change in model 4.20, is

$$\epsilon_t = -\frac{\partial \ln C}{\partial t} = -\left[\phi_T + \phi_{TT} t + \sum_{r=1}^{m} \phi_{TY_r} \ln Y + \sum_{i=1}^{n} \phi_{Ti} \ln W_i\right]. \tag{4.37}$$

For a specific input i, technical change is input-saving, input-neutral, or input using as ϕ_{Ti} is less than, equal to, or greater than zero, respectively. The null hypotheses of different types of technical progress nested in model 4.20 are:

Test for variable Hicks Neutral Technical Change:

$$H_0: \ \phi_{T_i} = 0 \quad \forall i.$$

Test for constant Hicks Neutral Technical Change:

$$H_0: \quad \phi_{T_i} = 0 \quad \forall i,$$
$$\sum_{r=1}^{m} \phi_{TY_r} = 0 \quad \forall i.$$

4.3.2 Estimation procedure

In the present framework, estimation of share equations 4.26 and 4.33 alone is not sufficient since the parameters that will be used to derive the rate of technical progress (ϕ_T, ϕ_{TT}, ϕ_{TY_r}) appear only in the cost function. Furthermore, only the cost function captures the effect of regional production variations. Thus, additive error terms are assumed for all share equations and the cost function. They are assumed to be distributed as intertemporally independent multivariate normal random variables with zero mean and nonzero contemporaneous covariances. Because cost shares must all sum to one, one of the share equations from 4.33 is dropped to avoid singularity of covariance matrix in the actual estimation. Barten showed that the estimations are invariant with the equation dropped if maximum likelihood estimation is used. The share equation of input 5 (defined later) is dropped in the empirical maximum likelihood estimation. The revenue shares need not add to one. Even under competitive conditions, total revenue may be greater or less than costs in the short run (Ray, 1982). Restrictions must be imposed across equations to ensure uniqueness of estimated parameters when they enter in more than one equation.

Likelihood ratio tests are employed to test all of the null hypotheses outlined earlier:

$$\lambda = -\frac{1}{2}[\ln\tilde{\lambda} - \ln\hat{\lambda}] \sim \chi^2(r) \tag{4.38}$$

where $\ln\tilde{\lambda}$ is the value of log-likelihood function from the restricted model, $\ln\hat{\lambda}$ is the value from the unrestricted model, and r is the number of restrictions. The conventional R^2 generated by the computer program is not appropriate in present context, the generalized R^2 suggested by Baxter and Cragg (Ball and Chambers, 1982) was applied.

$$\tilde{R}^2 = 1 - \exp[2(L_0 - L_1)/N] \tag{4.39}$$

where L_0 is the sample maximum of the log-likelihood when all the slope coefficients are zero, L_1 is the sample maximum of the log-likelihood when some β's are zero.

4.3.3 Variable definitions and data description

Time series and cross-provinces data over the period 1974-1989 are used in this study. Sources and construction details for all the data are provided in the appendices. There are 27 provinces that are grouped into regions as defined in appendix table A2.4. For the purpose of this study, the provincial data are aggregated at the regional level prior to the estimation. In the cases when some provinces in a given region have more data observations than the others, the minimum data set is generated for the region. Hence, each region in general has a different time series which are then pooled for estimation.

There are two outputs: rice (Y_1) and soybeans (Y_2). Both are measured in thousand metric tons. Eight inputs are included: land, labor, seed, fertilizer, pesticide, animal, irrigation, and others (government taxes, government infrastructure investment, etc.). To save degrees of freedom, seed, pesticide, and animal (SPA) are grouped together defined as input 4, and irrigation and others are grouped as input 5. Corresponding input prices are the land price (W_1), labor price (W_2) and the wage of hired labor (W_3); Divisia price indices are generated respectively for input 4 (SPA) and input 5 (others).

4.3.4 Empirical Results

Six alternative versions of the model 4.20 are estimated in this study to test hypotheses including (i) homotheticity, (ii) homogeneity, (iii) constant returns to scale, (iv) variable Hicks neutrality, and (v) Hicks neutrality. The statistical test results are presented in table 4.5. All null hypotheses are rejected at the 1% significance level. Therefore, the estimated results of the unrestricted model 4.20 are reported in table 4.6. The estimates for other versions of the model are not reported here, but are available from the authors upon request.

Table 4.5: *Chi-squared Statistics for Hypothesis Tests*

Item	Calculated Value	Degrees of Freedom	Critical Value 5%	Critical Value 1%
Homotheticity	325.07	10	21.02	26.21
Homegeneity	443.56	13	24.99	30.57
Constant Returns to Scale	454.10	14	26.29	31.99
Variable Hicks Neutrality	53.67	4	11.07	15.08
Constant Hick Neutrality	71.65	6	14.06	18.47

The estimates and statistics for share equations are reported in appendix table A4.1. The estimated parameters are satisfactory in terms of expected signs and statistical significance. Of the 49 variables included in the system, 40 estimated parameters are statistically significant at the 5% or 1% level. The others are significant around 10% to 20%. The highly significant t values on the coefficients of regional dummy variables are consistent with the earlier variance decomposition exercises that showed significant productivity variation across regions.

One of the important pieces of information coming from these estimates is the elasticities of substitution between pairs of inputs. The own-price elasticities of factor demand are reported in table 4.7 and the Allen elasticities of substitution, which are computed using formula 4.35, are presented in table 4.8. For the own-price elasticities, all of the signs of the estimates are consistent with theory (i.e., negative) and none of them are elastic. The elasticity of demand for capital tends to be relatively small, although it appears to increase over time. The intuition for the low elasticity of demand for land (0.3) is that land is a fixed and limited resource. The elasticity of demand for labor is fairly constant over time (about 0.55) whereas that for fertilizer rises during the same period. These are consistent with the fact that farm labor is abundant in Indonesia and most modern rice and soybean varieties have become increasingly dependent on chemical fertilizer applications. The cost shares of fertilizer increased for both rice and soybean production over the period. Consequently farmers

Table 4.6: *Estimated Coefficients of the Translog Cost Function*

Variable	Coefficient	Standard error	Asymptotic T-ratio
ONE	7036.9	3663.9	1.92
D1	-0.84553	0.07206	-11.73
D2	-1.40570	0.15564	-9.03
D3	3.16880	0.06943	45.64
D4	0.54984	0.11161	4.93
LNY1	16.44900	10.85800	1.52
LNY2	-0.43071	7.06980	-0.06
LNY11	0.14685	0.03718	3.95
LNY22	0.03943	0.01264	3.12
LNY12	-0.07838	0.01478	-5.30
LNW1	9.44010	2.56100	3.69
LNW2	-8.64540	2.48080	-3.49
LNW3	-3.90660	0.72334	-5.40
LNW4	2.32570	1.17880	1.97
LNW5	1.78610	0.98442	1.81
LNW11	0.06964	0.00322	21.61
LNW12	-0.04937	0.00278	-17.77
LNW13	-0.00639	0.00067	-9.50
LNW14	-0.01151	0.00117	-9.86
LNW15	-0.00237	0.00099	-2.41
LNW22	0.04214	0.00584	7.21
LNW23	0.00162	0.00210	0.77
LNW24	0.00886	0.00256	3.46
LNW25	-0.00325	0.00305	-1.07
LNW33	0.01054	0.00237	4.45
LNW34	0.00183	0.00115	1.59
LNW35	-0.00761	0.00160	-4.75
LNW44	0.00319	0.00173	1.84
LNW45	-0.00237	0.00151	-1.57
LNW55	0.01560	0.00271	5.75
LNYW11	-0.11184	0.01029	-10.87
LNYW12	0.09616	0.01050	9.16
LNYW13	0.01138	0.00301	3.79
LNYW14	-0.00020	0.00512	-0.04
LNYW15	0.00450	0.00456	0.99
LNYW21	0.01007	0.00538	1.87
LNYW22	-0.01104	0.00516	-2.14
LNYW23	0.00179	0.00151	1.19
LNYW24	0.00495	0.00260	1.90
LNYW25	-0.00577	0.00224	-2.57
T	-7.22610	3.70440	-1.95
T2	0.00370	0.00187	1.98
TLNY1	-0.00828	0.00553	-1.50
TLNY2	0.00066	0.00363	0.18
TLNW1	-0.00385	0.00130	-2.96
TLNW2	0.00395	0.00127	3.12
TLNW3	0.00193	0.00035	5.47
TLNW4	-0.00112	0.00060	-1.86
TLNW5	-0.00091	0.00050	-1.81

Note: System $R^2 = 0.95$. Log of the Likelihood Function = 843.23.

Table 4.7: *Own-price Elasticities of Factor Demand in Indonesia, 1977-89*

Year	Land	Labor	Fertilizer	SPA[a]	Other Inputs
1977	-0.214	-0.548	-0.388	-0.853	-0.346
1978	-0.245	-0.565	-0.396	-0.847	-0.288
1979	-0.264	-0.554	-0.360	-0.867	-0.412
1980	-0.288	-0.561	-0.396	-0.869	-0.626
1981	-0.308	-0.549	-0.496	-0.873	-0.590
1982	-0.310	-0.544	-0.623	-0.868	-0.617
1983	-0.328	-0.544	-0.655	-0.873	-0.623
1984	-0.275	-0.528	-0.557	-0.870	-0.096
1985	-0.314	-0.551	-0.697	-0.873	-0.396
1986	-0.338	-0.523	-0.692	-0.876	-0.362
1987	-0.328	-0.543	-0.734	-0.872	-0.400
1988	-0.340	-0.534	-0.729	-0.872	-0.324
1989	-0.348	-0.534	-0.749	-0.863	-0.407

[a]SPA = seed, pesticide and animal input.

have become more sensitive to the changes in the fertilizer prices.

The Allen elasticities in table 4.8 measure substitutability among inputs. Except for fertilizer with input 5 (irrigation, government infrastructure investment and government taxes etc.) and input 4 (seed, pesticide, and animal) with input 5 (other inputs), all other inputs are paired as substitutes. The highly complementary relation between fertilizer and input 5 in the earlier years may be a reflection of the fact that fertilizer was subsidized by the government then. Substitutability between land and labor stands constant (0.65) over time, but that for land and fertilizer increases rapidly over time. Land is highly substitutable for fertilizer, and for seed, pesticide and animal inputs, although the extent appears to decline. Similar results hold for substitution between fertilizer and SPA. Rice and soybean production in Indonesia are labor-intensive activities. When labor is abundant and cheap it will be used to replace other inputs, such as chemical fertilizer and pesticides.

The estimated returns to scale (ϵ_i) for rice and soybeans are reported in table 4.9. It shows that both rice and soybean production in Indonesia were in the range of increasing returns to scale (*IRTS*) over the sample period. Their joint scale economy,

$$SCE = [\ \Sigma_i(1/\epsilon_i)\ ]^{-1},$$

however, is in the decreasing range. The *SCE* can be interpreted as the relationship of a given (and simultaneous) percentage change in each output with respect to the changes in the total cost. For example, the computed *SCE* will be greater than one if total costs increase by a lower proportion than the outputs. Conversely, *SCE* is less than one when costs increase by a greater proportion than outputs. Note that the extent

Table 4.8: *Allen Elasticities of Input Substitution for Rice and Soybean Production in Indonesia, 1977-89*

Year	S12	S13	S14	S15	S23	S24	S25	S34	S35	S45
1977	0.57	0.49	0.62	0.86	1.62	2.37	0.18	4.17	-18.32	-1.55
1978	0.61	0.50	0.64	0.83	1.52	2.11	0.26	4.07	-19.09	-1.50
1979	0.62	0.44	0.74	0.86	1.56	1.64	0.40	2.61	-16.00	-0.31
1980	0.62	0.46	0.72	0.91	1.47	1.63	0.71	2.82	-7.35	0.27
1981	0.66	0.51	0.67	0.89	1.31	1.57	0.71	2.59	-7.24	0.08
1982	0.64	0.63	0.65	0.90	1.24	1.70	0.73	2.21	-4.06	0.07
1983	0.66	0.65	0.66	0.90	1.18	1.53	0.77	1.95	-3.43	0.21
1984	0.60	0.64	0.75	0.77	1.48	1.66	0.09	2.05	-15.11	-0.83
1985	0.66	0.71	0.72	0.84	1.16	1.46	0.56	1.63	-5.85	-0.23
1986	0.67	0.67	0.70	0.81	1.15	1.43	0.58	1.63	-6.46	-0.24
1987	0.67	0.76	0.72	0.83	1.13	1.45	0.55	1.52	-4.63	-0.16
1988	0.68	0.74	0.72	0.80	1.12	1.40	0.52	1.52	-5.92	-0.30
1989	0.63	0.74	0.72	0.83	1.12	1.40	0.57	1.42	-4.13	-0.10

Note: 1=land, 2=labor, 3=fertilizer, 4=SPA, and 5=other input.

of increasing returns to scale to rice appears to be constant (1.1%) over time. Clearly the sustained decrease in average cost from *IRTS* must be due to the technological advances in production over time. The extent of *IRTS* for soybeans has been increasing over time. This would imply stronger technical progress was experienced in soybean production in the more recent years.

Table 4.9: *Partial and Overall Scale Economies for Rice and Soybean Production in Indonesia, 1977-89*

Year	Rice	Soybean	Overall
1977	1.12	1.58	0.64
1978	1.10	1.59	0.64
1979	1.10	1.62	0.65
1980	1.06	1.62	0.63
1981	1.02	1.61	0.61
1982	1.01	1.58	0.61
1983	1.02	1.62	0.62
1984	1.13	1.65	0.66
1985	1.06	1.73	0.65
1986	1.11	1.86	0.68
1987	1.11	1.84	0.68
1988	1.10	1.87	0.68
1989	1.09	1.86	0.67

The estimated rates of technical progress are reported in table 4.10. They reflect the cost reduction from technical change for a given joint rice and soybean production level. The results show that on average the rate of technical progress was around 3% annually, similar to the growth rate of *TFP* reported in section 4.1. It should be noted that the rate of technological progress tended to decline between 1977 and 1988 (from 4.6% to 0.2%). It became negative (-0.1%) in 1989 which would suggest increasing average cost from technical change -- apparently technological regression.

Another important point is that, given by the signs on the product terms of the index T and $\ln W_i$ (table 4.6), the technical changes have been input-using for labor and fertilizer and input-saving for land, seed, pesticide, and others. These estimates are consistent with the empirical observations that rice and soybean are labor-intensive activities in Indonesia. High-yielding varieties improve crop productivity, but they usually require higher levels of fertilizer applications. Land is a fixed resource while seed and pesticide are scarce inputs.

Table 4.10: *Rate of Technical Progress for Rice and Soybean Production in Indonesia, 1977-89*

Year	Rate of technological progress
1977	0.046
1978	0.043
1979	0.038
1980	0.035
1981	0.031
1982	0.028
1983	0.023
1984	0.021
1985	0.015
1986	0.010
1987	0.006
1988	0.002
1989	-0.001

4.3.5 Concluding observations

Using time-series and cross-section data, a translog cost function and the associated factor demands have been estimated for important components of the Indonesian food crops sector. Rice and soybeans were treated as two distinct outputs with five separate major farm inputs. The rejection of homotheticity implies that a model with a single index of agricultural products will lead to invalid inferences. The estimates of scale economies show that both rice and soybean production in Indonesia experienced increasing returns to scale over the sample period but the joint production shows decreasing return to scale.

The results indicate that the own-price elasticities of demand for all inputs are inelastic with those of the land and labor being steady and that of fertilizer rising over time. Besides fertilizer for input 5 ("other inputs") and input 4 (SPA) for input 5 all other input pairs are found to be substitutes. Technological change has been input-using for labor and fertilizer and input-saving for land, seed, pesticides, and others. The rate of technical progress over the sample period is found to be the same as reported in the primal estimation, but the return from technical advance tended to decline over time.

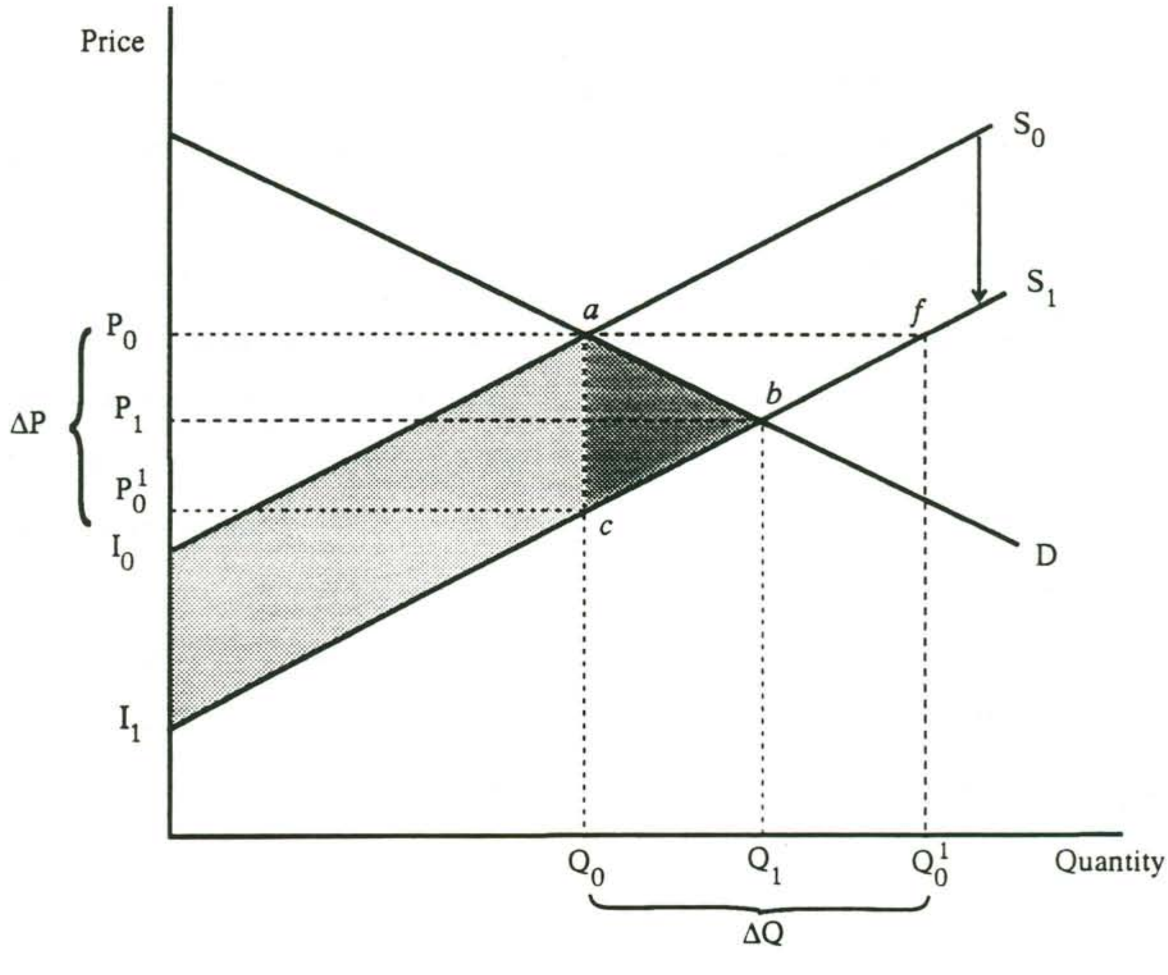
5. THE RETURNS TO AGRICULTURAL RESEARCH: CASE STUDY ANALYSES

5.1 Conceptual Issues

The Economic Benefits from Research - A Basic Closed Economy Model

The basic model of research benefits in a closed (i.e., no international trade) economy is shown in figure 5.1. In this model D represents domestic demand for a homogeneous product, and S_0 and S_1 represent, respectively, the supply of the product before and after a research-induced technical change. All of the curves are defined as representing annual flows and thus the economic surplus measures are annual flows. The initial equilibrium price and quantity are P_0 and Q_0; after the supply shift they are P_1 and Q_1.

Figure 5.1: *Surplus measures of research benefits in the basic model*



The total (annual) benefit from the research-induced supply shift is the change in total economic surplus, ΔTS, as measured by the area beneath the demand curve and between the two supply curves (ΔTS =

area I_0abI_1). This area may be thought of as being equal to the sum of two parts (a) the cost saving on the original quantity (the area between the two supply curves to the left of Q_0 -- area I_0acI_1), and (b) the economic surplus due to the increment to production and consumption which is equal to the triangular area *abc* (the total value of the increment to consumption -- area Q_0abQ_1 -- less the total cost of the increment to production -- area Q_0cbQ_1). Alternatively, we can consider the total benefit as comprising the sum of benefits to "consumers" in the form of the change in producer surplus (ΔCS = area P_0abP_1) and the benefits to "producers" in the form of the change in consumer surplus (ΔPS = area P_1bI_1 minus area P_0aI_0). Under the special assumption of a parallel supply shift (so that the vertical difference between the two curves is constant) area $P_0'cI_1$ = area P_0aI_0, and the change in producer supply is equal to area P_1bcP_0'.

This model shows how the total research benefit depends primarily on (a) the size of the cost-saving per unit (or the productivity improvement) due to research, and (b) the size of the industry (the number of units of production affected by the new technology). These benefits also depend on the extent of adoption of research output as the supply shift is only realized once the new technologies are actually used on farms. The distribution of that total benefit between producers and consumers depends on how the research affects the price of the product and the quantities consumed and produced. In one extreme case, when price is not affected (i.e., demand is perfectly elastic), all of the benefits go to producers. In the opposite extreme case, when price falls by the full extent of the per unit cost-saving (i.e., supply is perfectly elastic), all of the benefits go to consumers. In intermediate cases, the distribution of benefits depends on the relative sizes of the elasticities of supply and demand.[20] In the context of traded goods, the distribution of benefits between producers and consumers determines the domestic share of benefits from a country's research.

In this study, a comprehensive set of experimental yield data were compiled (see sections 5.2.2 and 5.3.1) and used to infer the proportionate unit cost reduction represented by $K = \Delta P/P_0$ (i.e., ac/P_0) in figure 5.1[21]. A commonly used and conservative approximation of area I_0abI_1 is given by

$$\text{Research Benefits}_{\text{approx.}} = (P_0Q_0)K$$

$$= Q_0\Delta P = \text{area } P_0acP_0' \qquad (5.1)$$

[20]It also depends in important ways on the nature of the research-induced supply shift as discussed by Alston and Pardey (1991) and Gardner (1990). In particular, with an inelastic demand, producers are made worse off by a research-induced proportional or pivotal shift of supply.

[21]Proportionate yield increases were taken to represent $J = \Delta Q/Q_0$ (i.e., af/Q_0) in figure 5.1. In first difference notation, the elasticity of supply at point a is given by $\epsilon = (\Delta Q/Q_0)/(\Delta P/P_0)$ so that $K = J/\epsilon$.

Assuming a parallel shift in supply then area P_0abI_1 = area I_0acI_1 so that $Q_0\Delta P$ understates the true benefits by area *abc*, an area that diminishes relative to area I_0acI_1 as demand becomes more inelastic.[22]

The Economic Benefits from Research -- An Open Economy Model

For the past three decades Indonesia has been a net importer of rice. During the late-1970s imports equalled upwards of 20% of total domestic production but trended downward thereafter. For the four years beginning in 1985 the country imported only marginal quantities of rice and was essentially self-sufficient, although this trend was reversed in more recent years. Trade in soybean was negligible through to the mid-1970s but over the past 15 years imports have risen quite dramatically.

Modelling the impacts of agricultural research in an open economy framework that admits the possibility of trade is a more realistic approach for these two commodities. In the case of rice, Indonesia is a *large country* in trade as it influences international prices for that commodity. Thus technical change in the Indonesian rice sector will have external effects on other countries through effects on the price of (traded) rice. These effects are termed price spillovers.

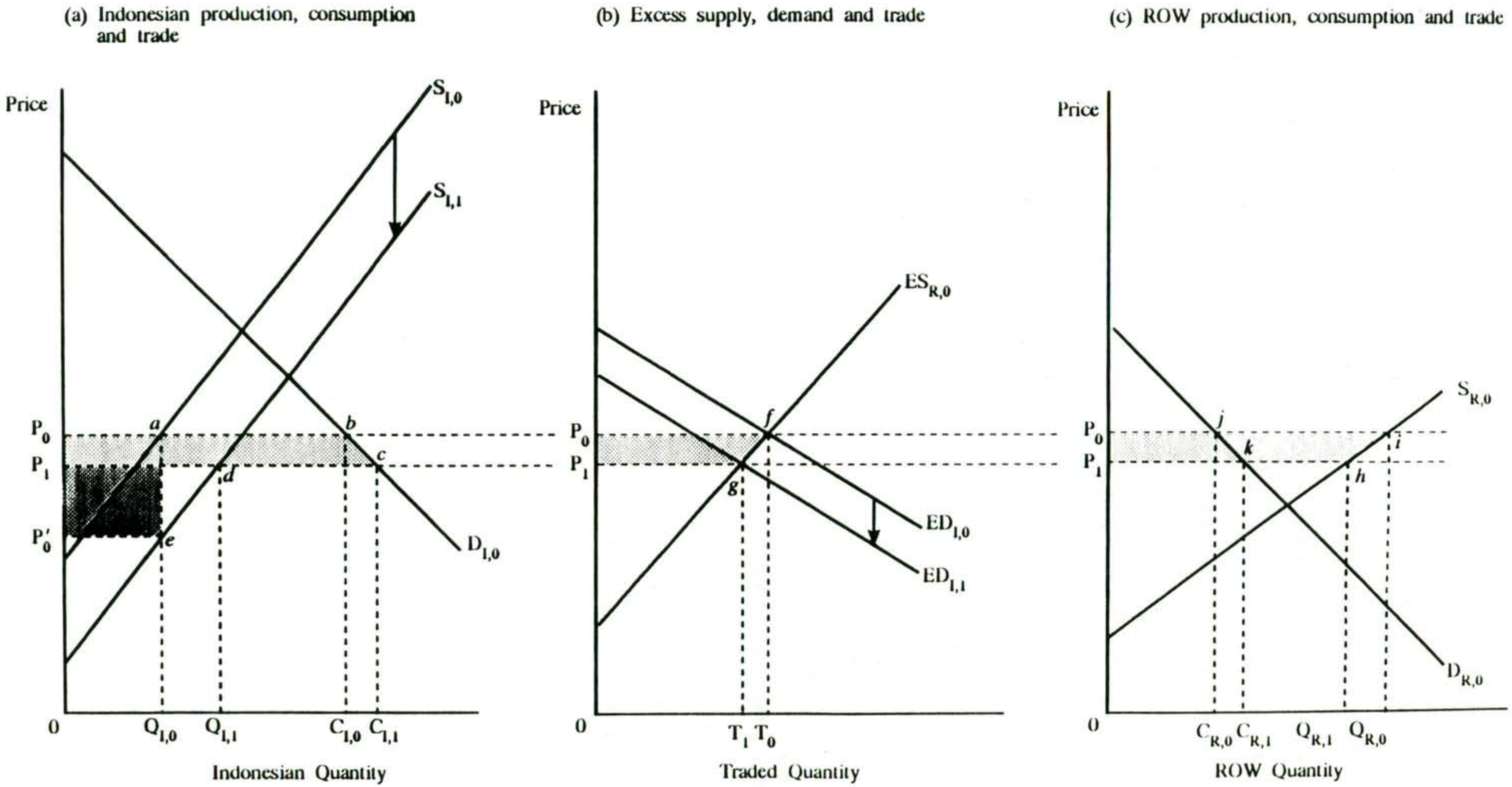
To analyze research-induced price spillovers in an excess supply, excess demand framework, we model the worldwide market in terms of trade between Indonesia and all other countries (*ROW*) so that market clearing is enforced by equating excess supply (the difference between domestic supply and demand) and excess demand (the difference between *ROW* demand and supply). This situation is represented in figure 5.2 in which panel *a* represents supply and demand in Indonesia and panel *c* represents aggregated supply and demand in the *ROW*. In the case shown here, Indonesia is a large country importer and the *ROW* is a large country exporter.[23] All of the supply and demand curves are assumed to be linear.

The excess (export) supply in Indonesia is shown as $ES_{I,0}$ in panel *b* -- given by the horizontal difference between domestic supply (initially $S_{I,0}$) and demand (initially $D_{I,0}$). The initial excess (or import) demand from the *ROW* is shown as $ED_{R,0}$ in panel *b* -- given by the horizontal difference between *ROW* demand (initially $D_{R,0}$) and supply (initially $S_{R,0}$). International market equilibrium is established by the intersection of excess supply and demand at a price P_0. The corresponding domestic quantities are shown as consumption ($C_{I,0}$), production ($Q_{I,0}$), and exports (T_0); the *ROW* quantities are shown as consumption ($C_{R,0}$), production

[22]More formally, the change in total surplus, ΔTS = area $I_0abI_1 = P_0Q_0K(1 + 0.5Z\eta)$ where $Z = K\epsilon/(\epsilon + \eta)$ and η is the elasticity of demand. As $\eta \rightarrow 0$ then $Z \rightarrow K$ and ΔTS tends to $(P_0Q_0)K$.

[23]Indonesia's soybean imports constitute a negligable share of world trade so a *small country* model is appropriate for this commodity. In this case the ROW excess supply curve ($ES_{R,0}$) is perfectly elastic, world prices are unaffected by research-induced shifts in the domestic supply curve, and all the benefits to Indonesian soybean research accrue to local producers.

Figure 5.2: *Size & distribution of research benefits for an imported good (Indonesia innovates; no technology spillovers; large country)*



($Q_{R,0}$), and imports (T_0). Rice research in Indonesia causes a parallel shift of domestic supply from $S_{I,0}$ to $S_{I,1}$ and, in consequence, the excess supply shifts from $ES_{I,0}$ to $ES_{I,1}$. The new equilibrium price is P_1. The corresponding domestic quantities are shown as consumption ($C_{I,1}$), production ($Q_{I,1}$), and exports (T_1); the *ROW* quantities are shown as consumption ($C_{R,1}$), production ($Q_{R,1}$), and imports (T_1).

The research-induced supply shift in Indonesia causes the world price to fall, so consumers worldwide benefit as a consequence. From the domestic standpoint (in panel *a*), consumer benefits are given by area P_0bcP_1 behind the demand curve and the benefits to producers are given by the area P_1deP_0' behind the supply curve. Since *both* consumers and producers benefit in the innovating country national research benefits are unambiguously positive. By contrast the *ROW* loses because the loss of *ROW* producers (area P_0ihP_1 in panel *c*) exceeds the benefit to *ROW* consumers (area P_0jkP_1 in panel *c*). The net *ROW* loss is shown as the area P_0fgP_1 in panel *b* of figure 5.2. If the approximation described by equation 5.1 is used in this instance, then a conservative estimate of domestic research benefits is obtained to the extent that $(P_0Q_0)K$ = area P_0aeP_0' is less than the true benefits given by area P_0bcP_1 + area P_1deP_0'.

5.2 Rice Breeding Research

5.2.1 Overview

Plant breeders have many objectives in breeding new cultivars including, inter alia, yield potential, resistance to various pests and diseases, tolerance of adverse environmental conditions such as drought or cold temperatures, plus a number of different grain characteristics that interact in complex ways to determine "quality". Apart from the determinants of grain quality, virtually all of the other genotypic characteristics influence realised yield, at least some of the time. For this reason, *average* varietal yield over a number of growing season is a useful summary measure to encapsulate the success of the breeding program in achieving many of its objectives, and the greatest amount of effort in this part of the study was devoted to quantifying this measure.

In addition to average yield, yield variability is also influenced, albeit in complex ways, by most of the characteristics mentioned above as well as by responsiveness of yield to input applications (e.g., fertiliser, irrigation water); and by resistance to evolving pest and disease biotypes. Other aspects not captured by either average yield or variance of yields include new farming systems made possible by earlier maturity, and grain quality.

According to Nestel (1985), none of the modern improved varieties apart from Semeru manifest superior yield *potential* to such earlier varieties as Pelita I-1 and I-2, and IR5. The principal advantages of the newer varieties over these earlier modern varieties were first and foremost greater resistance to pests and diseases, followed by shorter growing periods. Better eating qualities are another advantage that most AARD-bred varieties possessed relative to earlier IRRI varieties, although this advantage started to erode after the release of IR64 in 1986. An attempt is made below to quantify some of the benefits from these sources of varietal superiority.

Because Cisadane was by far the most widely adopted variety bred by AARD, the analysis below is restricted to estimating its superiority relative to alternate varieties. Establishing the counterfactual situation, in this case what rice variety would have been grown on the land planted to Cisadane had that variety not been available, is always open to debate. In this case there are two credible alternative scenarios. The first assumes that Cisadane displaced some mix of traditional varieties and other better eating quality varieties such as Pelita. The second presumes that imported varieties, and in particular IR36, would have been used even more extensively had Cisadane and other similar varieties bred by AARD not been available.

The case for the former scenario rests on the fact that from the mid-1970s, when brown planthopper emerged as a major pest problem, it was largely the perceived poor eating quality of the imported rice varieties (prior to IR64) that limited the spread of such varieties even though the alternatives involved low yield, low risk, traditional varieties or higher yielding but very high risk locally bred modern varieties. Of the latter group, Pelita was easily the most widely grown, and has been ranked as similar to Cisadane in terms of both length of growing season and taste quality. Consequently, one approach is to use estimated yield superiority of Cisadane vis-a-vis Pelita as a measure of the benefits of breeding Cisadane. To the extent that Cisadane displaced traditional varieties rather than Pelita, this approach underestimates the improved yield due to the breeding program, although the price premium paid for traditional varieties over even "good" tasting modern varieties would at least partially offset this underestimation.

The alternative scenario requires that the benefit of breeding Cisadane be measured relative to imported varieties, and in particular relative to IR36. The experimental evidence presented below indicates that Cisadane also produces higher yields on average than IR36. Two other differences between these two varieties are also likely to influence the magnitude of research benefits. As noted above, Cisadane commanded a price premium over IR36 because of consumer preference for the taste characteristics of Cisadane. The other is the longer growing period for Cisadane, 140 days versus 115 for IR36. The former enhances the magnitude of research benefits deriving from Cisadane's yield superiority, while the later diminishes it. Because it is difficult to accurately measure these two factors, and so to objectively establish the tradeoff between them, the main focus of the yield comparisons is on the choice between Pelita I-1 and Cisadane.

5.2.2 Varietal yield superiority

As demonstrated by the statistics presented in section 2 above, there have been impressive increases in aggregate rice yields in Indonesia over the period covered by this study. Clearly not all of this growth in yields can be attributed to improved varieties produced by the breeding program and/or imported from foreign research institutes. Apart from significant increases in input levels (some of which undoubtedly was research induced because of the greater responsiveness of the new varieties to fertiliser and other purchased inputs), other likely contributory causes were increases in the area irrigated as well as in the degree of water control in existing irrigated areas, the impact of extension programs (*BIMAS*), and learning by doing (e.g., improved management of modern inputs).

At any given point in time, there are also likely to be considerable differences between farms in yields of alternative varieties that are only partly due to inherent characteristics of the varieties. There are many reasons for this, including different levels of input application rates, variability in micro-climates, soils, and so on, as well as differences between farmers in the skills of raising crops.

To avoid these problems of interpretation, an analysis of experimental yield data was undertaken to estimate inter-varietal differences in average yields. The main advantage of using experimental yield data as a basis for estimating yield increase due to plant breeding is that growing conditions typically are standardised for evaluation purposes. Hence, most of the observed differences can be attributed to varietal superiority. A further advantage of standardised growing conditions is that the analysis is not confounded by variety specific cost of production differences which may occur in practice (Tabor 1989, pp.200f).

Breeder seed trials

The first data set contains yields of different varieties obtained during reproduction of mainline varieties for breeding and/or as a source of pure stock for dissemination to seed distributors/growers. A limitation of the data set is that all trials were conducted at Bogor or Sukamandi in West Java province, and therefore may not be representative of varietal yield differences in other locations. Advantages of the data set are that growing conditions have remained largely unchanged over long time periods, and that plot size is typically larger than for some variety yield trials.

A summary of the results for the principal varieties of interest in this study are set out in table 5.1.

Data were available for both wet and dry seasons from 1973/74 to 1991. Unfortunately, only a subset of varieties were grown in any season. Pelita I-1, IR36, and Cisadane were grown in six, nine, and five of the wet seasons, and average yields were 3.54 tons/ha, 2.99 tons/ha, and 5.01 tons/ha respectively. In the dry season trials, only IR36 and Cisadane were grown on eight and six occasions, and on average yielded 3.48 tons/ha and 5.42 tons/ha respectively. Because varieties were often grown in different seasons, it is conceivable that part of the yield differential noted above could be due to inter-seasonal variability in growing conditions, incidence of pests and diseases, and so on.

To get around this problem, further comparisons were made for those years in which both IR36 and Cisadane were grown "side-by-side". There were only four such years in the wet season trials, and on average over these years, Cisadane outyielded IR36 by 1.91 tons/ha, or by in excess of 60%. In dry season trials, these two varieties were grown together in five years, and the yield differential was an even larger 2.57 tons/ha, which implies that substituting Cisadane for IR36 had the potential to increase yield by an incredible 74%. On the one occasion when Pelita I-1 and Cisadane were grown in the same wet season, the respective yields were 2.4 tons/ha and 6.85 tons/ha respectively.

A closely related data set comes from recorded yields in "supplemental" breeder seed trials at several locations in West Java. Observations were available for fewer growing seasons, but because these trials were not the primary source of supply of breeder seed, recorded yields are less likely to be distorted by the need to discard seed of suspect varietal purity. Despite these differences, the findings are broadly consistent with those reported above. From table 5.2, it can be seen that average yields across all sites in West Java for Pelita, IR36, and Cisadane were 3.38, 3.73, and 4.58 tons/ha in the wet season, and 2.67, 3.58, and 4.65 tons/ha respectively in the dry season. If the comparison is restricted to the seven wet season and ten dry season trials in which both IR36 and Cisadane were grown at the same site and at the same time, on average Cisadane outyielded IR36 by 31% in the wet seasons, and by 34% in the dry seasons.

There are a number of reasons for discounting these extremely large yield differentials, some of which have already been discussed above. Another possible reason for doing so is that the growing conditions at the field sites in West Java were peculiarly and uniquely suited to Cisadane for some reason, so that observed yield

Table 5.1: *Breeder Seed Trial Yields for Rice, West Java*

	Variety							
	PB-5	Pelita I-1	PB-36	PB-42	IR-64	Cisadane	Cipunegar	Kr. Aceh
Wet Season					*(tons per hectare)*			
1973-74	2.09	2.89						
1974-75	2.53	2.60						
1975-76		7.93						
1976-77	3.53		3.36					
1977-78	2.52	2.20	2.40	2.57				
1978-79		2.40	1.30	4.20		6.85		
1979-80								
1980-81			4.85	5.95				
1981-82								
1982-83								
1983-84								
1984-85	4.65		1.52	3.12		2.50	4.66	6.40
1985-86	2.80	3.20	2.5		2.5		3.47	
1986-87			2.5					
1987-88			4.5	5	6	4.30		
1988-89			4	2.65	3.09	5.30	2.30	2.70
1989-90					5.78	6.10	3.54	4.68
Average	*3.02*	*3.54*	*2.99*	*3.92*	*4.34*	*5.01*	*3.49*	*4.59*
Dry Season								
1974								
1975								
1976								
1977								
1978			2.42	4.89				
1979	1.64		1.18	4.58				
1980								
1981								
1982								
1983						1.77		
1984			6.33	3.33				
1985			3.48	5.5		6.53	4.26	2.88
1986			3.2	2.7	3	6.25		3.40
1987								
1988			3	5.66	6.7	5.6	3.4	4.2
1989			4.05	2.56	5.05	6.78	4.52	3.64
1990								
1991			4.14	2.96	5.82	5.56		
Average	*1.64*		*3.48*	*4.02*	*5.14*	*5.42*	*4.06*	*3.53*

Source: Authors calculations based on unpublished CRIFC data.

Table 5.2: *Supplemental Breeder Seed Trial Yields for Rice*

		Variety							
Season[a]	Location	Pelita I-1	K. Aceh	Cisadane	IR-26	IR-36	IR-42	IR-46	IR-64
					(tons per hectare)				
WS 73-74	Cikeumeuh	2.9							
WS 74-75	Cikeumeuh	2.6			2.9				
WS 84-85	Citayam			3.0		3.9	4.5		
WS 85-86	Citayam					5.0		5.0	5.0
WS 86-87	Citayam		3.0	3.2		2.5			2.7
WS 87-88	Citayam			4.3			5.0		6.0
WS 88-89	Citayam			4.4		3.7	3.6	2.0	4.5
WS 75-76	Muara	5.9			4.2				
WS 76-77	Muara	4.3			4.1	5.0			
WS 77-78	Muara	2.2			3.4	2.4	2.6		
WS 78-79	Muara	2.4			2.0	2.6	2.1		
WS 80-81	Muara			6.9		4.8	5.9		
WS 84-85	Muara			5.1	2.6	3.0	3.1	2.2	
WS 88-89	Muara		5.5	5.3		4.0	5.3		4.2
WS 89-90	Muara		4.7	6.1		4.1			5.8
WS 84-85	Singamerta		2.4	2.9			2.8	2.5	
DS 84	Citayam		3.9			6.3	3.3	4.8	
DS 85	Citayam		3.0	2.6		2.1		3.1	
DS 86	Citayam								3.0
DS 88	Citayam		4.2	5.7		3.0	4.2		3.7
DS 89	Citayam			4.6					3.7
DS 78	Muara	2.4			1.6	2.4	4.9		
DS 79	Muara	3.2		5.5	2.7	2.4	2.3		
DS 85	Muara	2.4	4.3	4.9		3.5		3.8	
DS 86	Muara		1.9	3.1		3.2		2.8	3.0
DS 88	Muara			4.2		3.4	4.4		6.7
DS 89	Muara		3.6	3.4		4.0	5.1	5.5	5.1
DS 91	Muara			5.6		4.1	3.0		5.8
DS 84	Singamerta			5.3		5.9	5.3	5.5	
DS 86	Singamerta		5.1	6.2		2.6	2.1	4.1	3.2

Table 5.2: *Supplemental Breeder Seed Trial Yields for Rice*

Season[a]	Location	Variety							
		Pelita I-1	K. Aceh	Cisadane	IR-26	IR-36	IR-42	IR-46	IR-64
		(tons per hectare)							
Summary statistics									
WS Count	W. Java	6	4	9	6	11	9	4	6
WS Avg.	W. Java	3.38	3.90	4.58	3.20	3.73	3.88	3.18	4.70
DS Count	W. Java	3	7	11	2	12	9	7	8
DS Avg.	W. Java	2.67	3.71	4.65	2.15	3.58	3.84	4.23	4.28
WS Count	Muara	4	2	4	5	7	5	1	2
WS Avg.	Muara	2.70	5.10	5.85	3.26	3.70	3.80	2.20	5.00
DS Count	Muara	3	3	6	2	7	5	3	4
DS Avg.	Muara	3.27	3.37	4.45	2.15	3.29	3.94	4.03	5.15

Source: Authors calculations based on unpublished CRIFC data.

[a]"WS" indicates wet season; "DS" indicates dry season.

differentials from this site are atypical of other regions in Indonesia, and even for the rest of Java. To investigate this possibility, two different sources of data on variety yields were analysed.

The first data source is derived from a set of closely related trials used to multiply up seed for breeding trial use at a variety of locations throughout Indonesia. Like the breeder seed trials in West Java, these trials were conducted on experiment stations under closely controlled and uniform conditions.

Wet season yields for some commonly planted varieties at three different sites on Java are reported in table 5.3. For undetermined reasons, Cisadane was either not planted in the dry season trials, or the yields were not reported. While the results from these trials confirm the superior yield potential of Cisadane over both Pelita and IR 36 (as well as other widely planted varieties), it is also evident that this superiority is much more marked in West Java than in other areas. For instance, Cisadane can be seen to have outyielded IR36 on average by 1%, 4%, and 53%, in Central Java, East Java, and West Java respectively. However, once the impact of intra-seasonal variation is removed from these results by restricting the comparison to those years and sites where both Cisadane and IR36 were grown, the average yield superiority of Cisadane was found to be 6%, 1%, and 55% in Central Java, East Java, and West Java respectively.

Table 5.3: *Breeder Seed Multiplication Trial Yields for Rice, Wet Season*

	Central Java					East Java					West Java				
Season	IR-5	IR-36	IR-42	Pelita I-1	Cisadane	IR-5	IR-36	IR-42	Pelita I-1	Cisadane	IR-5	IR-36	IR-42	Pelita I-1	Cisadane
1968-69						4.73					4.57				
1969-70	5.95					4.13					4.27				
1070-71	5.58					5.86			6.37						
1971-72				5.93											
1972-73														5.23	
1973-74															
1974-75									3.60		3.70			4.65	
1975-76				4.20					3.05					4.25	
1976-77												3.60			
1977-78		4.54	3.30	3.89	4.50		3.24	4.10	2.75	4.78		2.44	5.00	4.44	
1978-79			3.40	3.30	3.90		5.70	3.40	2.13	4.40		2.20	4.10	5.50	5.30
1979-80		5.65	4.67	3.90			3.49	3.42	3.55			1.30	5.20	5.70	5.80
1980-81		4.67	7.10	4.06	6.60		4.60	1.60	3.26	3.70		4.78	5.80	5.24	5.80
1981-82															
1982-83			3.43		5.73		5.49			6.33		3.91			
1983-84		4.95					4.46					4.86			
1984-85		4.19			4.61		5.78			5.24		5.16			3.48
1985-86		4.74					5.67								
1986-87		5.08			3.95		5.00			5.60		4.30			7.36
Average	*5.77*	*4.83*	*4.38*	*4.23*	*4.88*	*4.69*	*4.83*	*3.12*	*3.67*	*5.01*	*4.18*	*3.62*	*5.03*	*5.00*	*5.55*

Source: Authors calculations based on unpublished CRIFC data.

Multilocation variety evaluation trials

To further investigate intra-regional influence on relative average yields of some of the principal varieties, data from variety evaluation trials conducted as part of the breeding program also were analysed. These trials are the final stage in the plant breeding process (after crossing, screening, preliminary variety evaluation trials, and advanced variety evaluation trials), and are carried out at a large number of locations all over Indonesia as an integral part of the variety certification and release process. Hence they are a rich source of information on inter-regional differences in the relative yield and other performance characteristics of the various varieties. Not all trials were conducted on experiment stations, so growing conditions could be viewed as being more representative of those occurring in farmers' fields. Limitations of the data set arise because very few varieties were grown over an extended period. As a result, it was difficult to account adequately for year-to-year differences in growing conditions. This problem was exacerbated by the fact that it proved impossible to recover the results of trials for all years covered by this study.

An important feature of these trials is standardised growing conditions, which in addition to weed and pest control as required, also includes:

for irrigated lowland :

- plant spacing of 25 cm x 25 cm
- seedling age 21-25 days
- fertiliser applications of

120 kg N + 60 kg P2O5	
+ 40 kg N + 60 kg P2O5	[at planting]
+ 40 kg N	[4 wk. after planting]
+ 40 kg N	[7 wk. after planting]

for dryland :

- plant spacing of 40 cm x 15 cm

135 kg N + 30 kg P2O5 + 75 kg K2O	
+ 45 kg N + 30 kg P2O5 + 75 kg K2O	[at planting]
+ 45 kg N	[4 wk. after planting]
+ 45 kg N	[7 wk. after planting]

The first step taken was to subdivide the data set on the basis of agroecological zones, and to concentrate on varietal yield trial results for lowland irrigated sites, since the overwhelming majority of rice produced in Indonesia is grown in this environment. Further partitioning into a limited number of regions also was undertaken to further reduce site-specific impacts on inter-trial differences in yield, and to provide a basis for estimation of the regional distribution of research benefits.

An overview of the results is provided in table 5.4. Note in particular that while there are inter-regional differences in yields, the average yield of Cisadane was higher than both IR36 and Pelita in all regions. Relative to IR36, the average yield of Cisadane was 29%, 19%, 2%, and 4% greater in Java, Kalimantan, Sulawesi, and Sumatra respectively. The corresponding percentage yield margins for Cisadane over Pelita I-1 were 11%, 19%, 13%, and 18% for the same four regions.

When the comparisons were restricted to sites and seasons where both varieties were grown alongside each other, the estimates changed for some regions. On average, Cisadane outyielded Pelita I-1 by 36%, 20%, 6%, and 6% greater in Java, Kalimantan, Sulawesi, and Sumatra respectively. The yield superiority of Cisadane over IR36 was less evenly distributed, and averaged 9%, -8%, 13%, and -4% across the same four regions. However these results are of very limited value in estimating differentials in average yields, as the overwhelming majority came from a single growing season (1986/87), and the remainder came from one or two other growing seasons. Given that outbreaks of pests and diseases are episodic, and that resistance, in particular to brown planthopper, is such a crucial determinant of average varietal yields, it is not surprising that these results suggest that Cisadane was less of an improvement over the available alternatives than the other comparisons described above, which were based on results from many seasons. Nevertheless, this finding highlights the well known fact that many agricultural research results are location specific, and that location specificity is particularly acute for plant breeding research and new varieties.

Conclusions

Taking an unweighted average across all seasons and all multi-location variety evaluation trial sites in Indonesia, average experimental yields of Cisadane were found to be 12% greater than that of both Pelita I-1 and IR36. Given that this value is derived from all sites, including those where Cisadane is inferior, and that farmers will only tend to plant Cisadane in areas where it outperforms other varieties, the above figure underestimates the potential yield increase on areas actually planted to this variety. This figure also underestimates the true average by a substantial margin because 90% of the rice produced from Cisadane has been grown on Java where the yield differential is much higher.

Because almost all Cisadane is grown on Java, the results of all trials of all types carried out on Java have been collated and summarised in table 5.5. IR36 was included in 227 such trials, followed by 142 trials with Pelita I-1 and 121 trials with Cisadane. However, after standardising for site and season, there were 35 matched pairs of trials containing both Cisadane and Pelita I-1, and 53 matched pairs of trials containing both Cisadane and IR36. This latter set were taken as the most reliable indicator of average yield differentials for reasons already discussed above. To sum up, Cisadane was found to outyield Pelita I-1 by 33% on average, and to outyield IR36 by 27%.

5.2.3 Benefits from Yield Increase

To estimate benefits from yield increase, the 33% improvement of Cisadane over Pelita I-1 was used because it avoids complications if there are also differences in grain quality and time to maturity. This difference reflects productivity gains under experimental growing conditions, that may need to be adjusted to arrive at a yield *differential* under typical farm conditions. Certainly there is a widely acknowledged, but somewhat understudied, "yield gap" between on-farm and experimental yields. Davidson and Martin's 1965 paper is one of the better studies in this regard. They sought to establish if there was any systematic relationship between average yields in experiments and on-farms when farmers used recommended practices.[24] This involved comparing on- and off-station yields for particular crops at specific locales and specific points in time in a way that abstracted from differences in measurable inputs such as the rate and timing of fertilizer applications. With this approach, residual on- versus off-farm yield differentials largely reflect researcher and farmer differences in technical and managerial inputs. They compared on-station with on-farm yields for wheat, rice, sugar, tobacco, and beans in different locales and got farm yield to experimental yield ratios ranging from 57% through to 95%. The average rice yield differential was 65%, but subject to a good deal of variation across the 74 paired observations available. No systematic studies could be found that were directly applicable for Asian growing conditions, but by inference, the findings of Pingali (1990) suggest that the ratio for rice in Asia is likely to be much closer to unity.

[24]For additional discussion on this issue see Swanson (1957), Johnson (1957), and Davidson, Martin and Mauldon (1967), Scobie and Posada (1976) consider this aspect when attempting to estimate the returns to varietal improving rice research in Colombia.

Table 5.4: *Average Yield of Rice Varieties in Multi-Location Evaluation Trials*

Variety name	Year of release	Breeding source	Java		Kalimantan		Sulawesi		Sumatera		Indonesia	
			No.	Avg.	No.	Avg.	No.	Avg.	No.	Avg.	No.	Avg.
							(tons per hectare)					
Pelita I-1	1971	pre-AARD	105	3.78	23	3.69	52	4.84	102	4.98	230	4.44
Pelita I-2	1971	pre-AARD	15	3.54			4	4.84	2	4.83	22	4.00
Gemar	1976	AARD	2	3.55			3	4.47	5	5.32	13	4.99
PB-26	1975	IRRI	34	4.12	1	3.49	10	4.60	19	3.98	72	4.32
BP-28	1975	IRRI	7	3.16	5	2.28	7	3.09	6	2.77	30	2.81
BP-30	1975	IRRI	7	4.14	5	2.76	7	3.51	7	2.89	30	3.51
BP-32	1977	IRRI	38	3.36	5	3.38	14	4.58	18	5.30	83	4.20
BP-34	1976	IRRI	24	3.64	1	3.57	3	3.36	10	4.14	42	3.98
BP-36	1977	IRRI	166	4.42	24	3.70	52	4.39	108	4.38	404	4.43
BP-38	1978	IRRI	4	3.00	4	4.61	1	2.74	5	2.99	16	3.65
BP-42	1980	IRRI	50	4.01	5	3.80	20	5.16	28	5.77	112	4.74
BP-46	1983	IRRI	1	2.90			1	2.90	17	5.58	19	5.30
BP-50	1981	IRRI	9	4.30			2	6.18	2	8.00	16	5.30
IR-64	1986	IRRI	39	5.14			15	3.91	20	4.95	92	4.74
IR-70	1989	IRRI	7	5.11			6	3.12	20	4.74	35	4.50
IR-72	1989	IRRI	18	5.33			1	6.20	9	5.53	39	5.14
Semeru	1980	SELIMP	70	4.13	6	2.90	18	5.03	39	5.65	152	4.66
Cisadane	1980	AARD	77	4.88	9	4.39	28	4.94	80	5.18	211	4.97
Cimandiri	1980	AARD	34	4.54	5	3.36	17	5.10	21	5.70	87	4.94
Barito	1981	AARD	33	4.57	3	3.10	25	4.96	29	5.53	100	4.98
Kr. Aceh	1981	AARD	16	4.64	1	1.90	10	5.68	14	5.69	46	5.24
Bt. Agam	1981	AARD	2	3.40					2	5.65	4	4.53

Table 5.4: *Average Yield of Rice Varieties in Multi-Location Evaluation Trials*

Variety name	Year of release	Breeding source	Java		Kalimantan		Sulawesi		Sumatera		Indonesia	
			No.	Avg.	No.	Avg.	No.	Avg.	No.	Avg.	No.	Avg.
							(tons per hectare)					
Citanduy	1983	SELIMP	47	4.56	3	3.17	17	4.74	21	5.34	97	4.84
Porong	1983	AARD	5	4.24	4	4.57	2	5.78	3	4.30	18	4.84
Cikapundung	1984	AARD	9	5.36	1	8.75	2	5.96	14	5.11	33	5.44
Cisokan	1985	AARD	29	5.56	4	3.76	15	4.63	26	4.13	82	4.71
Progo	1985	AARD	24	5.74			9	4.60	22	4.49	61	4.98
Tuntant	1985	AARD	6	6.74			3	4.10	4	4.64	15	5.53
Bt. Pane	1985	AARD	10	5.35			5	4.12	7	4.37	24	4.84
Way Seputih	1989	AARD	22	4.94			12	4.13	15	4.57	56	4.59
Walanae	1989	AARD	18	6.01	2	4.13	4	6.25	22	5.03	56	5.60

Source: Authors calculations based on unpublished CRIFC data.

Table 5.5: *Rice Variety Yield Comparison for Java, Summary of Results for Pelita I-1, IR-36, and Cisadane*

			All trials			Matched pairs	
Data source[a]	Season	Location	Pelita I-1	IR-36	Cisadane	Cisadane Pelita	Cisadane IR-36
BSTY	Wet Count	Bogor	6	9	5	1	4
BSTY	Wet Avg.	Bogor	3.54	2.99	5.01	4.45	1.91
BSTY	Cisadane % incr.		42%	67%			64%
BSTY	Dry Count	Bogor		8	6		5
BSTY	Dry Avg.	Bogor		3.48	5.42		2.57
BSTY	Cisadane % incr.			56%			74%
SBST	Wet Count	W. Java	6	11	9		7
SBST	Wet Avg.	W. Java	3.38	3.73	5.42		1.14
SBST	Cisadane % incr.		35%	23%			31%
SBST	Dry Count	W. Java	3	12	11	2	10
SBST	Wet Avg.	W. Java	2.67	3.58	4,65	2.40	1.23
SBST	Cisadane % incr.		74%	30%		90%	34%
BSMT	Wet Count	Java	22	21	13	8	12
BSMT	Wet Avg.	Java	4.34	4.35	5.14	0.35	1.09
BSMT	Cisadane % incr.		18%	18%		8%	25%
MLYT	Count	Java	105	166	77	24	15
MLYT	Avg.	Java	3.78	4.42	4.88	1.35	0.39
MLYT	Cisadane % incr.		29%	11%		36%	9%
	Total trials		142	227	121	35	53
	Grand average		3.82	4.24	4.90	1.27	1.13
	Cisadane % incr.		28%	15%		33%	27%

Source: Authors calculations based on unpublished CRIFC data.

[a]BSTY = Breeder Seed Trials Yields - West Java (t/ha); SBST = Supplemental Breeder Seed Trial Yields (t/ha); BMST = Breeder Seed Multiplication Trial Yields; MLYT = Multi-location Yield Trial (Yield potential of a number of rice varieties).

Whether or not the experimental yield *superiority* of Cisadane over Pelita is greater or less in practice is a moot point. But high-yielding, dwarf rice varieties respond well to higher levels of purchased (and managerial) inputs. So, it is likely that on-station varietal yield gains are higher than corresponding on-farm yield differentials due to the poorer weed and pest control, suboptimal timing of planting, tending and harvesting operations, and so on that is usually the case on farms. For this reason taking realised yield gains to be 50% of the potential yield increases obtained on-station, as we do here, is likely to bias downward the benefit estimate.

On the other hand, it should be noted that varieties differ in factor productivity, and to the extent they do, there may be variety specific differences in farm input levels and costs. Tabor (1989 p.202) suggests that production cost per hectare might be lower for IR36 in East Java than for Cisadane in West Java, but as most of the difference is due to higher harvesting costs in West Java, and because other input levels could widen the yield gap, it seemed reasonable to assume no appreciable differences in production costs.

In order to estimate the reduction in average costs of production from any given yield improvement, it is necessary to know the long-run elasticity of supply for the commodity. Based on Rosegrant and Kasryno (1992), a value of 0.7 was assumed for the domestic elasticity of supply for rice[25]. Given all of the above assumptions, the reduction in average cost of the marginal unit of output of Cisadane rice grown on Java was estimated to be 23.6%[26] . The research benefit stream was then calculated using the proceedure described in section 5.1. For each year of the study, this value was multiplied by value of production (measured in farm-gate terms)[27] and by the proportion of area sown to Cisadane in order to calculate estimated gross annual research benefits from adopting this variety. Prospective future benefits for a further five years also were calculated by assuming no further increase in value of production, and that Cisadane would be totally disadopted during this time period. These assumptions are regarded as being extremely conservative.

Results of these calculations are presented in table 5.6 in the form of annual net research benefits that are derived by deducting the cost of all rice research by AARD (table 3.2) as well as all rice extension

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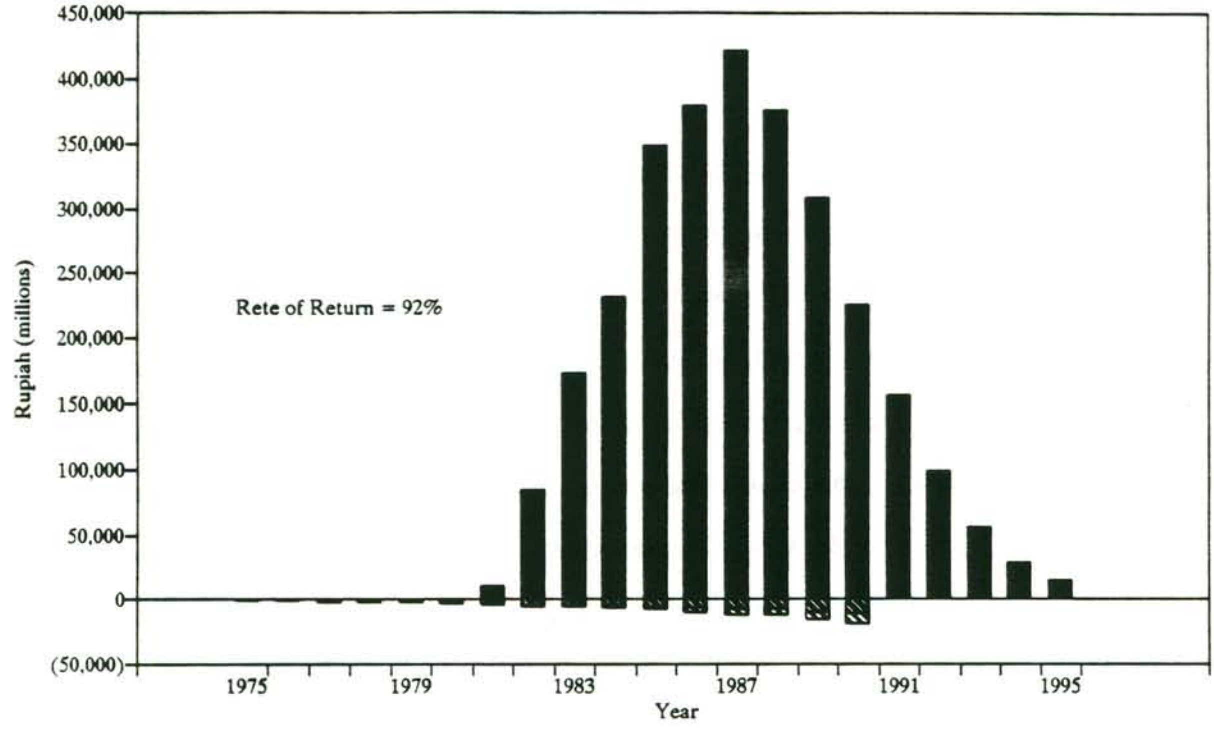
[25]A summary of elasticity estimates for Indonesian food crops is found in Eveleens, Bahri, and Suhaeti (forthcoming).

[26]In terms of the nomenclature used in section 5.1, $J = 33$, $\epsilon = 0.7$, so $K_{expt} = 33/0.7 = 47.1$ and $K_{farm} = 0.5K_{expt} = 0.5*47.1 = 23.6$.

[27]To form a time series of the nominal value of production, quantity data taken from various issues of BPS *Statistik Indonesia* were multiplied by a corresponding producer prices series taken from various issues of BPS *Indikator Pertanian*.

expenditure (table 3.7) from the benefits from adopting new rice cultivars.[28] Associated estimates of benefit-cost ratios (in 1990 present value terms) and internal rates of return to rice breeding research are also presented for five separate cases[29]. The first case category (in the left hand column) is a polar case in the sense that benefits are severely underestimated by only taking account of the impact of adoption of Cisadane on Java. Figure 5.3 illustrates the associated time profile of annual benefits and costs so that the magnitude of the benefits relative to the costs can be clearly seen.

Figure 5.3: *Benefit-cost profile. Benefits from Cisidane on Java versus ALL rice research and extension costs*



Legend : Benefits; Rice Res. Costs; Rice Ext. Costs

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[28]In the calculations of rates of return to rice research, a common K factor was assumed for all rice varieties and all regions. For those cases based solely on the benefits of adoption of Cisadane on Java only, this clearly is a conservative assumption. For all other cases considered, the same assumption is arguably less than conservative. However, since the latter subsumes the former, and because there are relatively small differences in calculated rates of return between cases for Cisadane on Java only and cases for all AARD varieties for all of Indonesia, any possible overestimation of rates of return for the more general cases will be small relative to underestimation of rates of return for the very conservative case of Cisadane on Java alone.

[29]Nominal research benefit and cost streams $Z_t = (B_t, C_t)$ for $t = 1, \ldots, T$ are converted to present values by applying the standard formula $PV(Z) = Z_t/(1 + r)^t$ where the nominal rate of interest, r, was set at 15%, i.e., 10% plus the 1974 to 1989 average annual rate of inflation in Indonesia as given by the rate of increase in the domestic consumer price index. The internal rate of return is simply the rate of return, IRR, which satisfies $\Sigma_t(B_t - C_t)/(1 + IRR)^t = 0$.

Table 5.6: *Rate of Return to Rice Breeding Research (Net of Costs for AARD Rice Research and Rice Extension)*

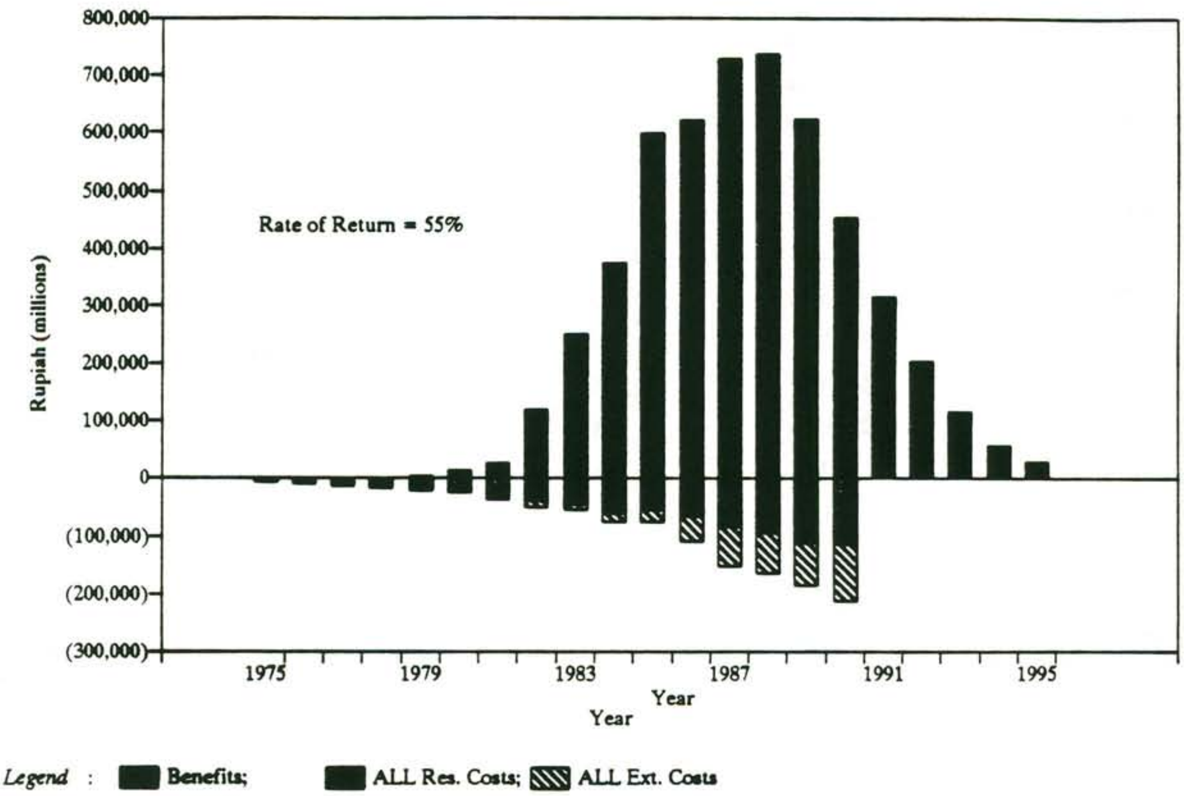
Varieties	Cisadane	Cisadane	AARD-low[a]	All AARD[b]	All ROI[c]
Region	Java only	Indonesia	Indonesia	Indonesia	Indonesia
Year ending March			Annual Net Research Benefits *(millions of rupiah)*		
1975	-1,387	-1,387	-1,387	-1,387	-1,387
1976	-1,466	-1,466	-1,466	-1,466	-1,466
1977	-2,045	-2,045	-2,045	-2,045	-2,045
1978	-2,868	-2,868	-2,868	-2,868	-2,868
1979	-3,327	-3,327	-1,528	-93	832
1980	-4,030	-4,030	10,556	10,556	14,837
1981	4,118	4,163	20,344	20,437	35,879
1982	77,780	84,172	110,745	110,839	139,567
1983	165,482	178,647	241,501	244,026	271,531
1984	222,211	264,990	357,851	366,754	402,297
1985	340,039	379,547	578,163	588,586	643,110
1986	367,084	407,919	585,928	607,433	695,251
1987	408,087	445,701	687,623	714,164	876,396
1988	361,226	408,907	677,081	720,778	875,872
1989	290,881	333,253	574,956	605,291	742,297
1990	203,470	234,342	410,447	432,548	532,371
1991	156,145	177,585	299,884	315,232	384,556
1992	99,365	113,008	190,835	200,602	244,717
1993	56,780	64,576	109,049	114,630	139,838
1994	28,390	32,288	54,524	57,315	69,919
1995	14,195	16,144	27,262	28,657	34,960
1996	0	0	0	0	0
1974/75 BC ratio[d]	16.4	18.3	27.7	28.7	33.7
IRR[d]	92%	94%	109%	111%	117%

[a]All HYV bred by AARD for lowland areas.
[b]All HYV bred by AARD.
[c]All HYV bred or selected by AARD or Atomic Energy Agency.
[d]Assumptions are

33% Increase in Experimental Yield.
0.70 Elasticity of Supply.
0.5 Farm:Experimental Yield Ratio.
15% Discount Rate Used in Benefit:Cost Ratios.

The second case also includes benefits from adoption of Cisadane off Java, while the third case includes benefits from other lowland varieties bred by AARD as well. The fourth case can be viewed as the benchmark because it includes all benefits for all rice varieties bred by AARD. A time profile of annual benefits and costs for this case is illustrated in figure 5.4. The final case (in the right hand column) arguably overestimates some benefits because it also includes other varieties released by AARD and by the Atomic Energy Agency. On the other hand, the cost side of the equation includes many other types of research that yielded benefits which have been ignored.

Figure 5.4: *Benefit-cst profile. Benefits from ALL AARD rice varieties versus ALL AARD research and extension costs*



Clearly the returns to this line of research have been very high, and more than sufficient to also pay for all other rice research and extension besides rice breeding research. In fact, as can be seen from table 5.7 which substitutes *all* AARD research expenditure and *all* extension expenditure for those on rice alone, even if the only output of AARD research had been the new rice cultivars which it bred, the rate of return to all research and extension would have been 55%, as compared with the 111% rate of return for the benchmark case for rice research alone. The corresponding time profile of annual benefits and costs is illustrated in figure 5.5.

Table 5.7: *Rate of Return to Rice Breeding Research (Net of Costs for ALL AARD Research and ALL Extension)*

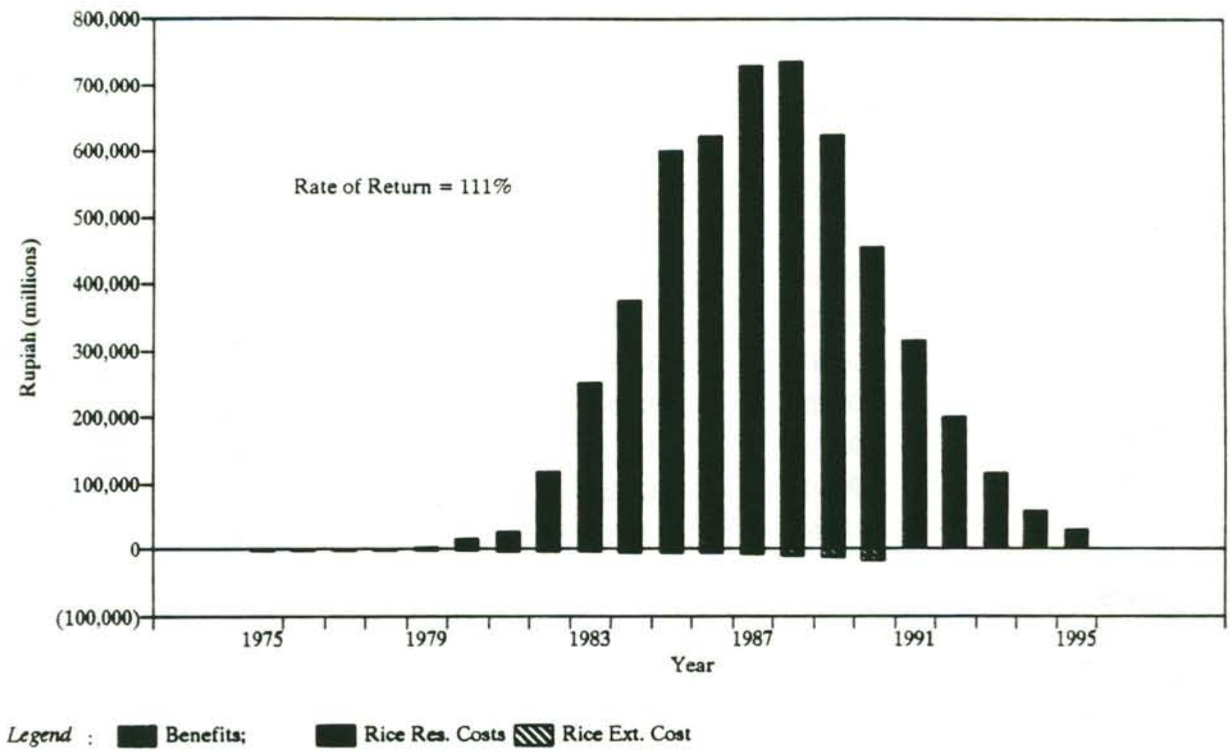
Varieties	Cisadane	Cisadane	AARD-low[a]	All AARD[b]	All ROI[c]
Region	Java only	Indonesia	Indonesia	Indonesia	Indonesia
Year ending March			Annual Net Research Benefits *(millions of rupiah)*		
1975	-6,512	-6,512	-6,512	-6,512	-6,512
1976	-8,872	-8,872	-8,872	-8,872	-8,872
1977	-15,534	-15,534	-15,534	-15,534	-15,534
1978	-20,801	-20,801	-20,801	-20,801	-20,801
1979	-25,037	-25,037	-23,238	-21,803	-20,878
1980	-28,251	-28,251	-13,665	-13,665	-9,384
1981	-32,820	-32,775	-16,594	-16,501	-1,058
1982	31,562	37,954	64,528	64,621	93,350
1983	113,421	126,586	189,440	191,965	219,470
1984	149,504	192,283	285,144	294,047	329,590
1985	272,709	312,218	510,833	521,256	575,781
1986	268,118	308,953	486,962	508,467	596,285
1987	265,785	303,399	545,321	571,862	734,094
1988	209,874	257,555	525,729	569,425	724,520
1989	119,594	161,965	403,669	434,003	571,009
1990	10,226	41,098	217,203	239,304	339,127
1991	0	0	0	0	0
1992	0	0	0	0	0
1993	0	0	0	0	0
1994	0	0	0	0	0
1995	0	0	0	0	0
1996	0	0	0	0	0
1974/75 BC ratio[d]	1.9	2.1	3.2	3.3	3.9
IRR[d]	39%	42%	55%	55%	60%

[a]All HYV bred by AARD for lowland areas.
[b]All HYV bred by AARD.
[c]All HYV bred or selected by AARD or Atomic Energy Agency.
[d]Assumptions are

- 33% Increase in Experimental Yield.
- 0.70 Elasticity of Supply.
- 0.5 Farm:Experimental Yield Ratio.
- 15% Discount Rate Used in Benefit:Cost Ratios.

In fact, the benefits from Cisadane on Java alone were so large that even in the absence of any other research output, they would have yielded a 39% rate of return on *all* AARD expenditure plus *all* extension expenditure for all agricultural commodities. The time profile for this extreme case is illustrated in figure 5.6.

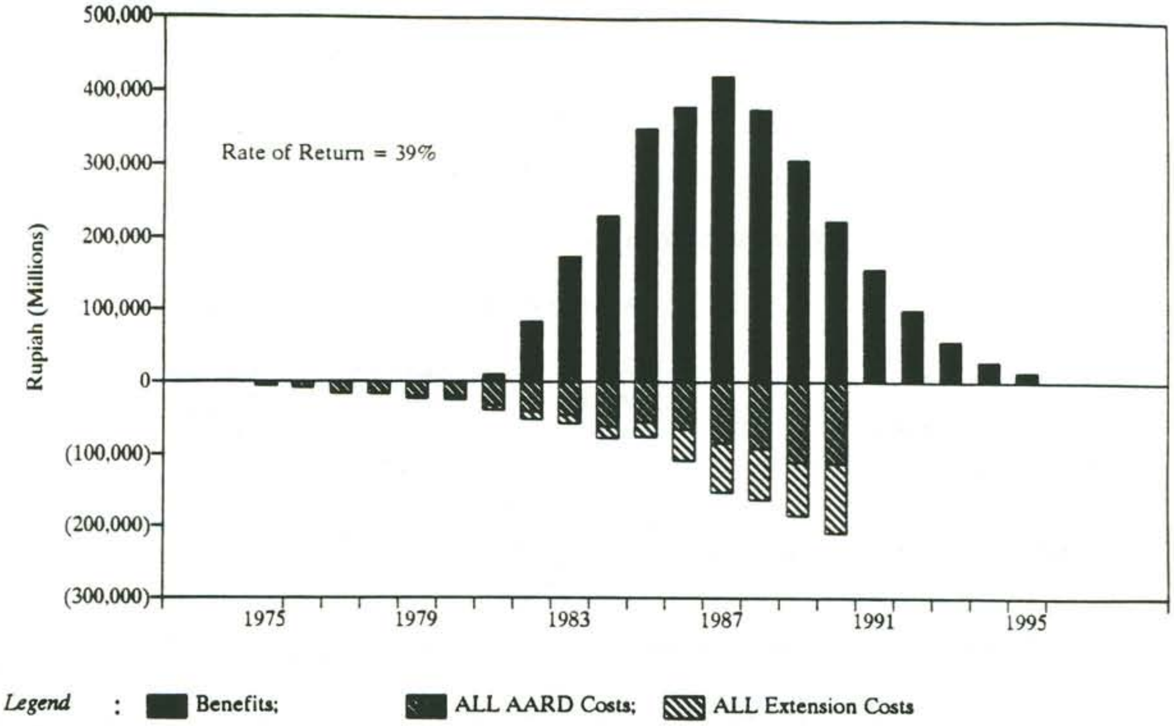
Figure 5.5: *Benefit-cost. Benefits from ALL AARD rice varieties versus ALL rice research and extenstion costs*



5.2.4 Averting yield losses through bred-in pest and disease resistance

For reasons discussed above, the threat of major outbreaks of brown planthopper and other pests and diseases shaped the objectives of the rice breeding program, and also was a principal determinant of the pattern of successive waves of adoption of new rice varieties. The benefit from adoption of new rice varieties with enhanced resistance to evolving biotypes of pests and diseases takes the form of avoided crop losses in those seasons when an outbreak would have occurred. Because it is difficult to simultaneously breed for resistance

Figure 5.6: *Benefit-cost profile. Benefits from Cisidane on Java versus ALL AARD Research and extension costs*



and to maintain yield potential, let alone to enhance it, benefits from this type of plant breeding research are most unlikely to be manifest as an increase in yield relative to older varieties. Consequently, to estimate avoided crop losses, it is necessary to establish the counterfactual situation of what would have happened to yields if older susceptible varieties had continued to be grown rather than being replaced by more resistant cultivars.

Yield losses for most pests and diseases are episodic, so empirical estimation of the rate at which average yields of specific varieties decay over time due to emergence of new biotypes and the consequent breakdown of varietal resistance requires data from field trials for the same variety over a period of many years. Long term yield trials are quite uncommon, and it is even more uncommon for the same variety to be grown continuously in such trials.

Possibly the best data source for our purposes comes from a long-term continuous cropping experiment that commenced in 1968 at IRRI in the Philippines, and is on-going. Most of the original varieties in this trial have been replaced as usage by farmers has declined, but one variety, IR8, has been retained throughout the duration of the trial. Selected results from the analysis of this data set by Dr. K. Cassman of IRRI are shown in figure 5.7. A striking finding from this trial is that average yields of the highest yielding cultivars has been declining steadily, so that even the most modern varieties produce less grain today than IR8 did some twenty odd years ago. However, on average the yield of IR8 has declined even more rapidly, and the difference in rates of change in yield can be treated as an estimate of the avoided loss in yield attributable to success of the breeding program in continuing to develop new, more resistant cultivars.

The derivation of these estimates are summarised below:

	Average Annual Change in Yield (tons/ha)		
	Dry Season	Early wet Season	Late wet Season
Highest yield cultivars	-0.13	-0.10	-0.07
IR8	-0.21	-0.20*	-0.08
Difference	-0.08	-.10	-0.01

(* Represents a 20 year average from quadratic function)

There are obvious dangers in extrapolating from these findings for IR8 in the Philippines to the situation in Indonesia for other HYV's, so an attempt was made to obtain supporting evidence from Indonesian sources even though the underlying data sets are less well suited to the purpose. Using data from supplementary (regional) breeder seed production trials, and regressing dry season yield of Pelita I-1 against time, the following results were obtained:

$$Y = 687.7 - 0.35T$$

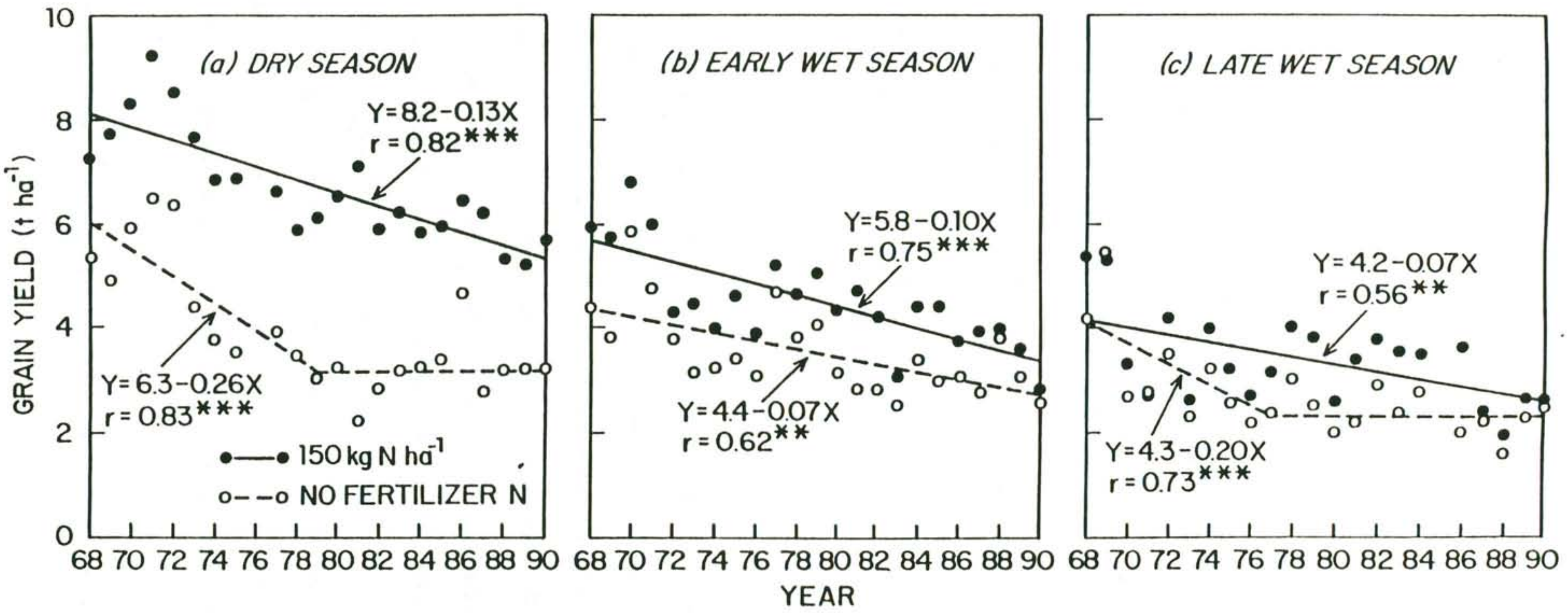
Standard Errors 1.36 0.23

No. observations = 7 $R^2 = 0.31$

where Y = yield (tons/ha), and T = year trial conducted.

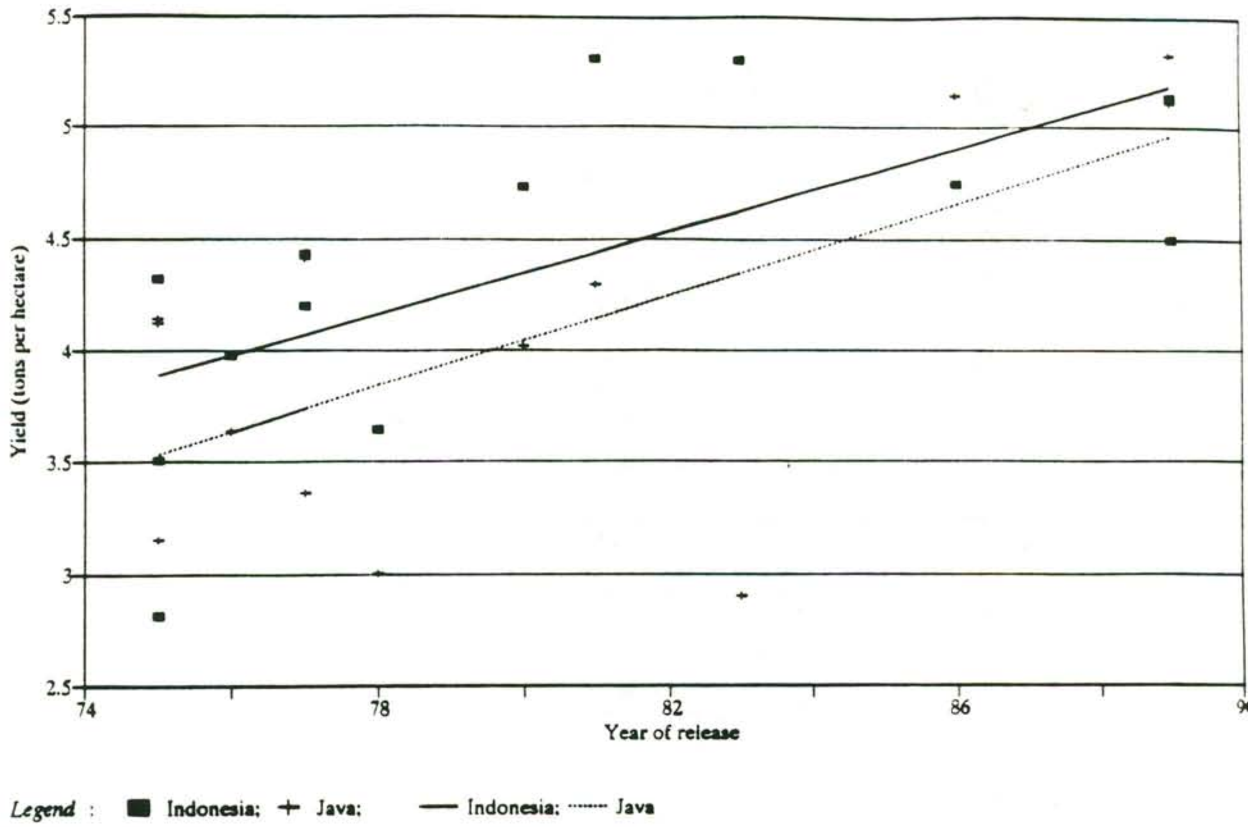
While these results are consistent with those from IRRI, they do need to be treated with some caution because of the small number of observations (7), and the fairly low R^2. Furthermore, it was not possible to estimate whether yield ceilings also were declining in a manner similar to that at IRRI. Figure 5.8 derived from results of yield trials in Indonesia, and depicting average yield of imported IRRI varieties since time of release plotted against year of release is not consistent with the scenario of a decline in yield ceilings, but is consistent with a decline in average yields due to resistance breakdown. On the assumption that they were, this result overestimates the yield loss over time due to breakdown of resistance.

Figure 5.7: *Decline of rice HYV (IR8) yields over time*



Source: Unpublished data from Cossman (1991).

Figure 5.8: *Yield tr-r-ds of IRRI varieties in Indonesia*



Based on all of the above, it would seem likely that average yields declined by at least 0.05 tons/ha/year (i.e., 1.25% per annum) due to breakdown of resistance[30]. Plant breeding that succeeds in producing a continuing stream of new varieties with resistance to evolving disease biotypes prevents this yield loss. Even if AARD had not existed, Indonesian farmers would have had access to a stream of resistant varieties because of the rice breeding program at IRRI. It has already been argued above that while AARD plant breeding research facilitated importation of these varieties, they would still have diffused in Indonesia in the absence of this research, albeit more slowly. A conservative assumption is that AARD resulted in adoption of IRRI varieties one year earlier than otherwise would have been the case. Therefore the estimated benefit was derived by calculating the present value of speeding up the avoidance of yield losses by one year. In 1990 Rupiah, this value was estimated at nearly 32,000 million Rp. or US$16 million, which is approximately 18% of total AARD

[30] At this rate of decay it would take around 80 years for a variety to breakdown completely although in reality its yield would probably plateau somewhere well below its maximum yield potential.

rice research costs over the sixteen years covered by this study.

5.2.5 Quality improvement research

At least in part, Cisadane displaced IRRI varieties with inferior eating quality rather than varieties such as the Pelita's with good eating quality. Many of these varieties had shorter growing periods than Cisadane, but an offsetting factor is the price premium paid in the market for "good" tasting varieties vis-a-vis "poor" tasting varieties. Furthermore, based on evidence from Tabor (1989), Cisadane commands a slight price premium over Pelita in most markets. Table 5.8 summarises this evidence and appendix table A5.1 describes the quality characteristics that are relevant in this instance. In addition to the price premium for Cisadane over Pelita, it can be seen that there is a price premium of about 12% for "smooth-tasting modern brands" such as Cisadane over the "hard tasting modern brands" such as IR36. If a 12% price increase as well as a 27% yield superiority were both used to estimate benefits from Cisadane, the resulting rate of return would far outweigh those presented above. However, at least part of these extra benefits would be offset by IR36's advantage of a shorter growing period. Unfortunately no objective basis could be found to value this factor, so the above results have to be taken as the best available given the evidence.

5.3 Soybean Breeding Research

5.3.1 Varietal yield superiority

Evidence on the yield superiority of the soybean variety Wilis was obtained from an analysis of variety evaluation trials. Because the number of trial data sets for soybeans was fewer than for rice, no attempt was made to separately analyse data sourced from different trial types. The importance of different regions in soybean production has changed quite dramatically over the past two decades. This presents some problems in deriving an overall figure for yield increase which is representative because the number of trials conducted in the various regions does not necessarily resemble the pattern of production. During the past few years when Wilis has emerged as the dominant variety, its percentage of total area harvested on Java, Sumatra, and the other islands has been 56%, 26%, and 18% respectively. These values were used to impute Indonesia-wide average yields from regional variety yield trial results. The average yield estimated for the variety Orba was 1.41 tons/ha, while for Wilis the comparable value was 1.7 tons/ha, which is more than a 20% increase.

In order to verify that these results were not biased due to area or year specific effects, the subset of trials where Orba and Wilis were both grown at the same site and in the same year under identical agronomic

Table 5.8: *Mean Urban Price of Rice by "Brand Type" and City*

	"Hard-tasting" modern brands	"Smooth-tasting" modern brands				Traditional brands					
City	IRRI (≤ IR48), GOI stock	Cisadane	Pelita	Krueng Aceh	Average	Cianjur	Rojelek	Saigon	Pandanwangi	Wulmentik	Average
					(Rp per kilogram)						
Jakarta (42)[a]	403[b]	414	–	–	414	469	527	514	592	418	504
Solo (18)	311[c]	383[e]	402[g]	–	393	360	825	–	–	–	593
Surabaya (26)	325[d]	378[f]	327	356[h]	356	389[i]	450	–	–	–	420
Simple average	346	392	365	356	388	406	600	514	592	418	506

Source: Derived from Urban Java Consumer Survey data for May and October 1987 as reported in Tabor (1989, p. 69).

Note: Rice varieties, particularly traditional varieties such as Cianjur, Rokelek, and Pandanwangi, are often either falsely labelled, blended, or adulterated. Hence the term rice "brands" rather than varieties is probably a more accurate description of how these commodities are marketed.

[a] Bracketed figures indicate number of markets surveyed in each city.
[b] Includes varieties labelled simply as IRRI, which are presumably IR48 or earlier, as well as ex-GOI stockpile, and "DN".
[c] IR36; [d] Also includes Lamongan; [e] Also includes C4; [f] Also includes C4, Sedati and Gedangan; [g] Also includes Citandui and IR54; [h] Also includes Galur Harapan; [i] Also includes Mentik and Seripit.

conditions also were analysed. There were 12 such trials, and the average yield superiority of Wilis over Orba was 0.08 ton/ha, which translates into a yield increase of about 7%. This figure is treated as a lower bound estimate in the analysis below because of the small number of trials on which it is based.

5.3.2 Benefits from yield increase

Calculation of rates of return to soybean breeding research used essentially the same methodology and assumptions as for rice except for the different value for yield increase noted above, and a different estimate of elasticity of supply (0.25) which again came from Rosegrant and Kasryno (1992).

Results are presented in table 5.9 for two cases, namely benefits from Wilis alone, and from all AARD released varieties. Time profiles of benefits and cost for these two cases are depicted in figures 5.9 and 5.10. When all AARD soybean research costs and estimated soybean extension costs are accounted for, the estimated rate of return from all AARD soybean varieties was 49%, but the rate of return still would have been 43% if Wilis had been the only variety released. Moreover, these results probably underestimate realised returns because at least some Wilis displaced lower yielding varieties than Orba. It is arguably also overly conservative to deduct all soybean extension costs, and for this reason rates of return to investment in AARD research alone of 52% and 47% were calculated for the two cases of all AARD varieties and Wilis alone.

Table 5.9: *Rate of Return to Soybean Breeding Research*

Variety/source	Wilis	AARD[a]	Wilis	AARD[a]
Region	Indonesia	Indonesia	Indonesia	Indonesia
Costs	Soybean AARD only	Soybean AARD only	Soybean AARD + Extension	Soybean AARD + Extension
Year ending March	Annual Net Research Benefits *(millions of rupiah)*			
1975	-239	-239	-247	-247
1976	-251	-251	-257	-257
1977	-373	-373	-382	-382
1978	-463	-463	-576	-576
1979	-613	-613	-792	-792
1980	-736	-736	-1,000	-1,000
1981	-1,121	-1,121	-1,449	-1,449
1982	-1,177	-923	-1,561	-1,306
1983	-1,224	-579	-1,647	-1,003
1984	-834	314	-1,437	-289
1985	1,925	4,645	1,118	3,838
1986	7,755	11,600	6,055	9,900
1987	19,279	24,586	16,601	21,908
1988	37,597	50,663	34,758	47,824
1989	43,156	58,187	39,527	54,558
1990	53,675	66,002	48,560	60,887
1991	61,137	78,932	61,137	78,932
1992	53,245	68,742	53,245	68,742
1993	43,578	56,262	43,578	56,262
1994	29,178	37,671	29,178	37,671
1995	15,371	19,845	15,371	19,845
1996	0	0	0	0
1974/75 BC ratio[b]	6.5	8.5	4.3	5.7
IRR[b]	47%	52%	43%	49%

[a]Soybean varieties bred or selected by AARD.
[b]Assumptions are

7%	Increase in Experimental Yield
0.25	Elasticity of Supply
0.5	Farm:Experimental Yield Ratio
15%	Discount Rate Used in Benefit:Cost Ratios

Figure 5.9: *Benefit-cost profile. Benefits from ALL AARD soybeans versus ALL soybean research and extension costs*

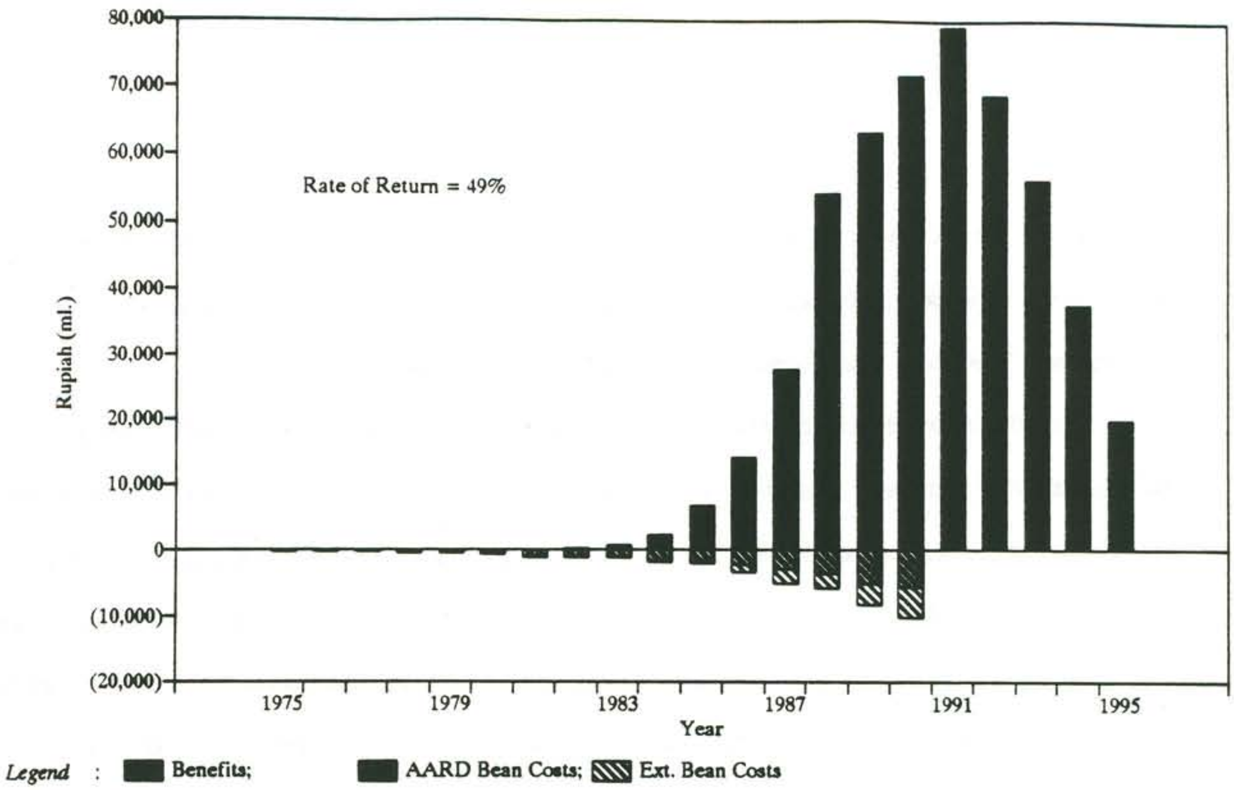
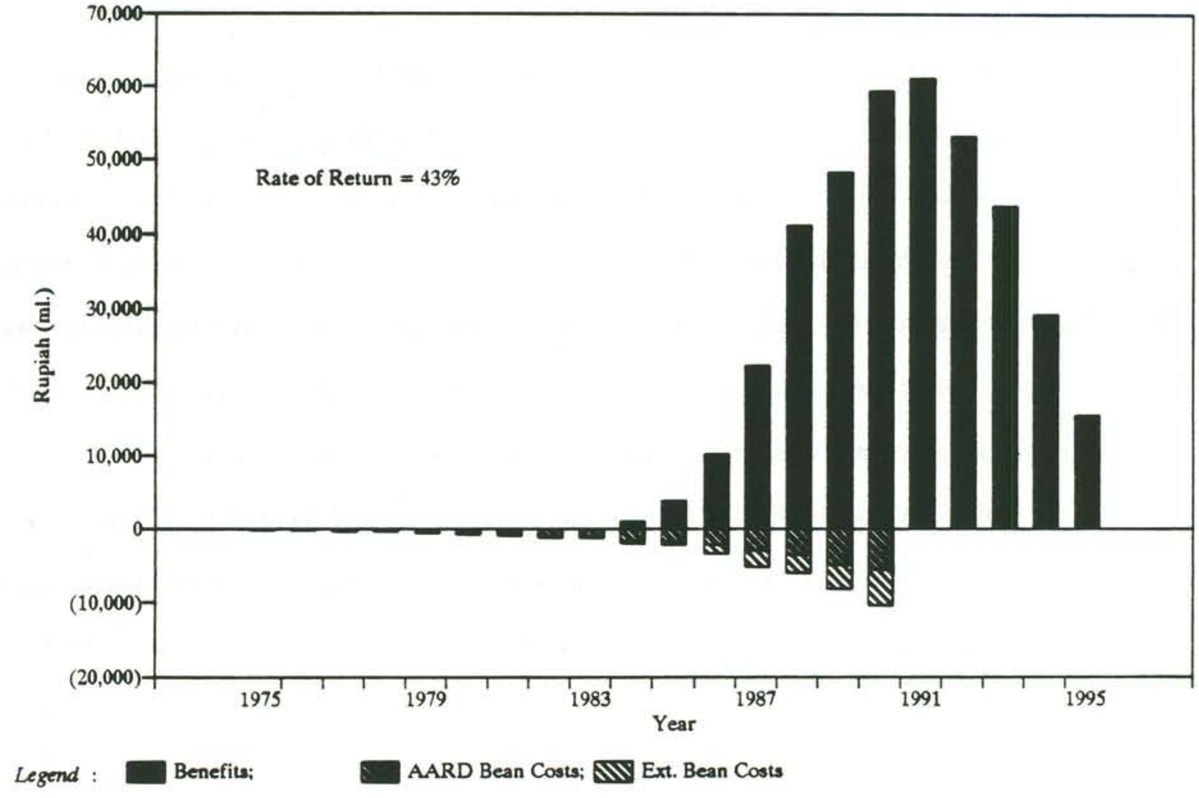


Figure 5.10: *Benefit-cost profile. Benefits from Wilis soybean variety versus ALL Soybean research and extenstion costs*



6. SUMMARY COMMENTS

Output increases and yield gains for both rice and soybeans have been substantial over the past two decades. More than two-thirds of the output growth for rice was due to an increase in yields rather than expansion of area. Yields for rainfed rice grew by 3.03% per annum compared with 3.28% per annum for the lowland, largely Javanese, rice production systems where over 90% of Indonesia's rice is grown. While output growth for soybeans has been 1.3-fold higher than that for rice, about 62% of this growth is attributable to the area expansion that occurred in provinces such as Aceh, Lampung, and (to a large but still significant extent) West Nusatenggara, West Java, North Sumatra, and North and South Sulawesi.

Not all this growth in output and yields can be attributed to public investments in technology generation and dissemination activities. There have been substantial increases in the use of inputs such as irrigation services, pesticides and, especially, fertilizers that account for a good deal of these gains. The total factor productivity (TFP) indices constructed for this study took account of measurable changes in the use of these purchased inputs, as well as unpurchased inputs such as land, and operator and unpaid family labor. Even after having done this, the "unexplained" annual growth in output since 1974 averaged 3.11% and 2.56% for rice and soybean, respectively. Moreover, our econometric estimates of the cost-reducing effects of technical change corroborate these TFP findings. They indicate that the unit costs of production of rice and soybean fell by an average of 3% per annum since 1974. We note, however, this rate of decline slowed considerably in more recent years.

Taken together, these findings demonstrate significant contributions to output growth from the technical advances that are embodied in unmeasured quality improvements in seeds, fertilizers, pesticides and new crop management practices. No doubt Indonesia has also realized allocative efficiencies due to unmeasured improvements in agricultural labor and the more widespread dissemination of existing (not only new) production technologies. A good portion of these less tangible gains stem from public investments in research and extension services. But the role of other public and even private (e.g., input supply) agencies, along with the search and screening activities on the part of farmers themselves, is not to be ignored in this regard.

Past public investments in rice and soybean research have paid handsome dividends. Aggregate production function estimates suggest that the returns to these investments for both commodities were substantial, although the rapid increase in soybean area over the past one and a half decades constrained our ability to statistically identify the effects of research for this commodity using this approach.

To gain a more concrete appreciation of the process of technical change in contemporary Indonesian agriculture, and AARD's particular role in this process, we concentrated our attention on the sources, rate of uptake, and economic effects of the varietal improvement aspects of new rice and soybean technologies. Around 48 varieties of rice and 19 varieties of soybean have been released in Indonesia since 1974. During the 1980s rice production was dominated by successive "waves" of superior varieties. Following its local release in 1977 the imported variety IR36 rapidly displaced a combination of *Lokal* varieties, early IRRI varieties such as IR5 and IR8, and modern varieties bred in Indonesia such as Pelita I-1 and I-2. Within three years it occupied 37% of the total area growing rice in both the wet and dry season. The AARD-bred variety Cisadane became the next dominant variety and in 1985, just five years after its release, accounted for 24% of all area sown to rice. In 1986 the imported IRRI variety IR64 was released, and by the late 1980s was well on its way to taking over from IR36 and Cisadane as the next superior variety. A similar pattern of varietal turnover occurred with soybeans, with the locally-bred variety Wilis being grown on 45% of the total area sown to soybeans within six years of its release in 1983. Another breeding line imported by AARD and released as the variety Tidar may assume an equally dominant position in the 1990s.

We used the results from a large number of experimental varietal trials to isolate the plant breeding effects on crop yields from other sources of yield gains. Based on conservative assumptions about the corresponding on-farm gains due to these research-induced varietal improvements, we estimated that the adoption of Cisadane on Java alone yielded a 92% rate of return on the total investment in rice research by AARD *plus* the total investment in associated extension services. Even if the only output of AARD research had been the new rice cultivars which it bred, the rate of return to *all* research of AARD and *all* extension expenditures by the country would have been 55%.

Somewhat less dramatic but still sizable benefits flowed from the soybean breeding program. We estimate that the adoption of Wilis alone yielded a 43% rate of return on the total investment in soybean research by AARD (not just the breeding aspects of this program) plus the investment in associated extension services.

There are a number of fundamental policy insights to be derived from this analysis. Research is an inherently risky business. Only a very limited number of the promising lines that are developed (or imported), then tested and eventually released as new varieties realize large social dividends. But these few winners are more than enough to pay for the whole technology generation and transfer enterprise. However, the winners do not continue to bear fruit indefinitely. There are clear vintage effects associated with varietal technologies. The yield and/or cost-of-production superiority of new varieties eventually begins to erode. This is either in response to a physical deterioration of the new technology (as bred-in pest and disease resistance begins to wear down) or due to obsolescence (as new varieties with superior yield, disease resistance, and taste characteristics become available). This demands a continuing investment in the technology generation process simply to maintain the productivity gains coming from past research investments.

The varietal adoption data also highlight the site-specific characteristics of these new varietal technologies. Most of AARD's success with regard to new rice varieties was realized in the important lowland production systems of Java and Bali. Introduced varieties from IRRI were also adopted widely in these regions, as well as Sumatra and Sulawesi. Although pre-AARD varieties declined in importance from a dominant position in the late 1970s (accounting for 75% of total rice area) to one of secondary importance (<20% of total area) by the end of the 1980s, there are still areas such as Kalimantan where they account for an overwhelmingly large share of the area.

Claims on the resources used in production agriculture from other sectors in the Indonesian economy will intensify if current development trends continue into the future. To adjust to this changing pattern of factor demand will require an increasingly science-based agriculture. Continued productivity gains will enable new products, processes and know-how to substitute for the land, labor and other inputs currently used in agriculture thereby releasing these resources for use in other sectors of the economy.

There is no doubt that Indonesia has been well rewarded from its public investments in agricultural research. To reap these rewards required a sustained, patient and creative commitment to the enterprise by government, donors, and researchers alike. To judge whether or not other aspects of AARD's research program have done as well would involve applying the evaluation methods described in this report, suitably modified to account for the data constraints that are specific to each evaluation exercise. While these high historical rates of return give a very favorable account of AARD's past investments in rice and soybean breeding, they leave no room for complacency with regard to AARD's future research program. The slowing of productivity gains in the rice and soybean sectors over recent years suggests that changes to the natural and economic environment facing farmers require AARD to take a hard-nosed look at its own priorities and practices in order to successfully tackle the technological challenges confronting the Indonesian agricultural sector in the 1990s.

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APPENDICES

Appendix 1: *Data Description and Variable Definition*

In this appendix we describe in some detail our attempts to construct plausible estimates of output and conventional input data for use in the production function, cost function, and total factor productivity analyses reported in chapter 4.

Output Quantity, Value, and Price

The BPS *Struktur Ongkos* data report per hectare harvested estimates of both the quantity and value of rice and soybean production. Due to sampling differences, the yields reported in the *Struktur Ongkos* data differ from the "official" BPS yields as reported, for example, in *Statistik Indonesia* (see Roach et al., 1992, for additional details), although the differences appear relatively minor for the more recent years. The production value is measured in farm-gate terms so that the unit price obtained by dividing the value of production by the corresponding quantity gives an implicit "prices received by farmers" series. Rice production data is reported in "dry-stalk paddy before milling" (*gagang kering giling*) form for the 1972-80 period and "dry-unhusked paddy before milling" (*gabah kering*) form for the post-1980 period. The official BPS *Food Balance Sheet* conversion factor of 0.765 was used to convert dry-stalk rice into dry-unhusked rice. Soybean data are reported in "dry-shelled" (*biji kering*) form for all years.

Seed

The BPS *Struktur Ongkos* data report per hectare harvested estimates of both the quantity and value of "purchased" seed as well as "own produced" seed that is used in production. A unit price of seed was derived by dividing the reported total value of seed used by the reported total quantity. The rice data are reported in "dry unhusked paddy before milling" form and the soybean data in "dry-shelled" form.

Fertilizer

The BPS *Struktur Ongkos* data include per hectare harvested estimates of the chemical and manurial fertilizer used for rice and soybean production. Chemical fertilizers are partitioned into three types (urea, TSP/DAP, and "others") and reported in both value and quantity terms while value-only data are available for manurial fertilizers. Unfortunately these data are reported in units of raw fertilizer rather than in active ingredient terms. According to the *Struktur Ongkos* estimates for 1989 (per hectare) manurial fertilizer applications for Indonesian accounted for just 2.7% of the value of total fertilizer used on rice while the corresponding soybean figure was 12.0%.

Unpublished MOA, DGFC (Annual Farm Management Survey) data for the 1989/90 season (i.e., first and second planting) suggest that manurial fertilizers account for only 0.4% of the value of fertilizers used on rice throughout Indonesia and 4.2% of the quantity of fertilizer used. Corresponding value and quantity shares for soybeans are 1.4% and 47.3% respectively. There are no obvious reasons for the large discrepancies between the BPS and MOA data. In any event, the MOA data point to substantial differences in the average quality of manurial and chemical fertilizers used in Indonesia. (Fan and Pardey [1992] report FAO estimates for China which indicate that the elemental nutrient content of manure is only 2.2% by weight.). When constructing an implicit price series for fertilizer using BPS data we therefore elected to divide the total value of fertilizer used data (i.e., inclusive of an imputed value for manurial fertilizer) by the quantity of chemical fertilizer used. This was deemed to give a more representative fertilizer price than would have been the case if some estimate of the quantity of raw manurial fertilizers were included in the calculation.

Pesticides

The BPS *Struktur Ongkos* data report per hectare harvested estimates of both the value and quantity of pesticides used in rice and soybean production. The pesticide data are partitioned into insecticides and "others", this latter category includes herbicides, fungicides and rodenticides. A unit price for pesticides was obtained by dividing the value estimates by the corresponding quantity-used figures.

Labor

The BPS *Struktur Ongkos* data includes value-only (rupiah per hectare) data for hired labor that are broken down into six categories of work namely grubbing (hoeing), ploughing, sowing (planting), weeding, harvesting and others. In 1989, preplanting (grubbing and ploughing) activities accounted for around 25.2% of the hired labor cost for rice and 25.5% for soybeans, planting activities around 15.4% and 18.1% for rice and soybeans respectively, and postplanting field work (i.e., weeding and related work) for about 15.1% of rice and 16% of soybean hired labor costs. At 40.3% and 29.5% for rice and soybean respectively, harvesting costs accounted for a sizeable share of hired labor costs.

A major limitation of the cost of production data, for our purposes, is its omission of family and operator labor and wage rate data for both hired and own labor. Fortunately there are reasonably good BPS data available that make it possible to construct a plausible rural wage rate series, but the lack of comprehensive family labor data meant that some ad hoc, but nevertheless informed, procedures were required to construct these data.

Wage Rates

To estimate a wage rate series the following procedure was used. Nominal, rural wage rate data (rupiah per day) for grubbing and hoeing, planting, and plant care and weeding operations for 14 provinces over the 1980-90 period are given in BPS, *Statistik Upah Buruh Tani Di Pedesaan* (1991). The wage rate data are reported on the basis of one-half of a work day and include meals and cigarettes. Naylor (1990) attests to the reliability of this series and indicates that equivalent data are available back to 1976 but only for Java provinces. For this variable the South Sumatra series was taken to be representative of Jambi, Bengkulu and Riau; West Nusatenggara representative of East Nusatenggara, Maluku, Irian Jaya, and East Timor; South Kalimantan representative of West, Central and East Kalimantan; and North Sulawesi representative of Central and South Sulawesi. A simple average of these three labor series was taken to be our representative hired labor wage rate series given that (a) data presented in Roche et al. (1992, appendix table 1) indicates a reasonable cross-provincial correspondence between harvesting wage rates and the wages for the other labor categories reported in the BPS series, and (b) there are no readily available quantity (labor hour) weights by which to calculate a weighted average series (e.g., using a Divisia or indeed any other aggregator function).

To backcast this series from 1980 to 1970 the annual rate of change in the average earnings of estate crops workers taken from BPS *Upah Pekerja Perkebunan,* (various issues) was used. This series is only available for West, Central and East Java, North and South Sumatra and Kalimantan. For the remaining provinces the following correspondences were assumed; Central Java was taken to be representative of Yogyakarta; East Java of Bali, East and West Nusatenggara, Maluku, Irian Jaya and East Timor; North Sumatra of Aceh, West Sumatra, Riau, Jambi and Bengkulu; South Sumatra of Lampung; Kalimantan of South Sulawesi; and South Sumatra of the rest of Sulawesi. Missing data for 1973-77 (and for Kalimantan also 1978-9) were obtained by geometric interpolation.

Operator and family labor

In the absence of a comprehensive set of survey data on operator and unpaid family labor inputs to rice and soybean production we opted to use the available evidence from village level surveys to construct a synthetic family labor series. But even these village-level data fall substantially short of what one would like. There are no longitudinal studies spanning the complete period being analysed here and what studies are available have a narrow geographical orientation that is generally limited to Javanese rice and soybean production systems.

After some degree of experimentation we settled on the following procedure. For rice, a good number of the available village level studies (especially those summarized by Collier [1980]) indicate that the ratio of family to hired labor did not appear to vary systematically across wet or dry seasons or across farms using modern versus local varieties. However, there was a fairly systematic relationship between farm size and the *share* of family labor in the total labor input. Specifically, the family labor to hired labor ratio for small farms (< 0.1 hectares) averaged around 50% in 1979, for mid-sized farms (> 0.1 hectares but < 0.5 hectares) around 20%, and for large farms (> 0.5 hectares) about 15%. Using these percentages, in conjunction with provincial data on the size distribution of farm holdings (taken from the 1983 BPS *Sensus Pertanian*), it was possible to construct a "scaling factor" by which to recalibrate the hired labor *Struktur Ongkos* data for 1979. Data presented by Collier (1980) and more recently by Kasryno, Chong, and Rosegrant (1991) point to a trend toward more family labor intensive systems. Collier's data suggests that there was a 7% increase in the family to hired labor ratio in rice production from 1970 to 1979, a trend that we projected into the 1980s and used to adjust our scaling factor before recalibrating the *Structur Ongkos* hired labor data for years other than 1979.

For soybeans a slightly different procedure was used. Village level data presented by Kawagoe et al. (1990) and Morooka and Mayrowani (1990) indicate that the family labor to hired labor ratio for upland production systems was around 81%, somewhat higher than the 69% reported for lowland systems. There was no evidence available to suggest these ratios had significantly changed over time. Using provincial data on the area of lowland versus upland (rice-based) production systems we constructed a scaling factor for soybeans that was used to recalibrate the *Struktur Ongkos* hired labor series for soybeans.

Land

The land area data used for the econometric aspects of this study is the harvested area data taken from BPS *Struktur Ongkos*. These data sometimes vary from the official area harvested data reported in BPS *Statistik Indonesia* but the differences are generally trivial and probably the result of updates and revisions to the underlying series. This harvested area measure is a flow-type variable that captures the over-time and, especially, cross-section variation in cropping intensities, which are substantial in the case of irrigated rice systems in Indonesia.

Rental rates

In the absence of a comprehensive data set of land rental rates in Indonesia, synthetic estimates of provincial rental rates for land area under rice (or island group estimates in the case of soybean) were developed. Ritche et al. (1992) report unpublished MOA,DGFC estimates of 1989 land rental rates (rupiah per hectare per season) for wet and dry season irrigated rice as well as wet and dry season rainfed and irrigated land under soybeans. Both sets of rental rates are further differentiated by agroecological zone. The series includes estimates for North and South Sumatra, Western and Eastern Java, Bali, Nusatengarra, and South and "Other" Sulawesi. For this variable the following correspondences were assumed: North Sumatra was taken to be representative of Aceh; South Sumatra of West Sumatra, Jambi, Riau, Bengkulu, and Lampung; Western Java of Central Java; Eastern Java of Yogyakarta; Nusatengara of East and West Nusatengara, Maluku, Irian Jaya, and East Timor; and "Other" Sulawesi of North, Central, and Southeast Sulawesi and West, Central, South, and East Kalimantan.

After forming simple averages of the rental rates across agroecologies for each combination of region, season, and commodity, the soybean rainfed to irrigated rental ratio was applied to the respective irrigated rice rental rate to impute a corresponding rainfed rental rate for rice. Using these rental rates, in conjunction with our estimate of the proportion of irrigated rice area per province, a weighted average 1989 rental rate for the harvested rice area in each province was calculated. The ratio of irrigated to nonirrigated rice area was taken to be a tolerable proxy for the corresponding provincial soybean areas so that a weighted average rental rate for soybeans could be calculated.

To construct a time-series back to 1974 based on these 1989 estimates we had several options. Bottema (1992) and Bottema and van Loon (1992) report a time series of rental rates for land under rice running from 1992 back to 1970 that was derived from village survey data in East Java. Using this time-series to backcast the 1989 figures gave rise to some dificulties. For one, the resulting labor to land price ratio grew by more than a factor of five over the 1974 to 1989 period, an implausibly rapid rate of increase for an increasingly land scarce country such as Indonesia. Even more critically, the implicit total cost of production (including both family labor and land costs) for the earlier years in the sample exceeded the total value of output (measured in farm gate terms), an unlikely result. To overcome these difficulties a "shadow rental rate" for land was constructed by deducting the costs of production (inclusive of family labor) from the total value of production and dividing the resulting figure by the area harvested to give a quasi-shadow rental rate. Using this shadow rental rate to backcast the 1989 benchmark estimates gave a far more satisfactory series. The total value of output always exceeded the total cost of production and the resulting labor to land price ratio increased by a multiple of 1.49 over the 1974 to 1989 period, a more plausible result.

Irrigated Area

BPS statistics provide details of the harvested area and production of rice split between wetland (or lowland, i.e., *padi sawah*) and dryland (*padi ladang*). However, it does not provide data on the proportion of the wetland rice area which was irrigated. Specifically, an estimate was required by province and by year, from 1971-1989, of the proportion of harvested area under irrigation.

During the period 1973-1989 there exists occasional data on the availability of irrigated land and, for one of those years, 1983, there also exists data from the agricultural census on the area of irrigated land actually harvested. Thus, a two stage estimation procedure was adopted: (i) generate a provincial time series of the availability of irrigated land (ii) assuming actual use of irrigated land follows the same trend as generates the required time series of the proportion of harvested wetland that was irrigated.

(i) Provincial Time Series of Irrigated Area Availability

The Agricultural Census (BPS, *Sensus Pertanian*, 1973, 1983) and the Agricultural Indicator series (BPS, *Indikator Pertanian*, 1987 and 1989) contain estimates of the breakdown of available wetland rice area by: number of harvests per year, and within that, by areas which are irrigated and not irrigated. The irrigated areas are further split into three classes; technical, semi-technical and non-technical. For the purposes of the factor productivity analysis, the final category was omitted so only the technical and semi-technical areas and their respective proportions were considered further. In three of the four years, 1973, 1987 and 1989 the data were available by province for Java and by island group for Off-Java. For 1983 data for all provinces were available (BPS [1986] table 6, pp. 85-86) -- thus, Off-Java island level figures for 1973, 1987 and 1989 were disaggregated into provincial values by applying the 1983 proportions. Finally a complete annual time series was made by geometric interpolation between 1973 and 1983, 1983 and 1985 and 1985 and 1987, and 1987 to 1989 -- and was backcast by geometric extrapolation from 1973 to 1971.

(ii) Provincial Time Series of Proportion of Irrigated, Harvested Wetland Rice Area

The actual proportion of available irrigated area that was harvested was available only for 1983 (BPS [1986] table 7, pp. 87-88), and was broken down to the province level. On the assumption that the growth rate in harvested irrigated areas is the same as the growth rate of available irrigated areas, the available irrigated area time series for each province was recalibrated to match the irrigated proportion of harvested wetland in 1983. This provided the required series for the productivity analysis.

Irrigation Costs

The cost of irrigation services was obtained directly from the BPS *Struktur Onkgos* data for the 1974-83 period by summing the reported irrigation fee and irrigation maintenance charges. According to BPS officials, the reported irrigation maintenance fee for the post-1983 period is in fact an irrigation cost estimate (i.e., it includes an irrigation fee component). An implicit price of irrigation services was calculated by dividing the total irrigation cost series by the estimated area under irrigation.

Draft Animal Power

While the cost of animal services reported in the BPS *Struktur Ongkos* data are incomplete and apparently subject to some reporting error, they appear to be the most comprehensive set of estimates of this input presently available. There are only a very limited number of village level studies on the use of animal inputs in rice-based production systems and they offer only patchy data whose representativeness for a country-wide study such as this is questionable. Discussions with BPS personnel concerning the *Struktur Ongkos* data indicate that there are real difficulties in getting reliable estimates of the inputs coming from *own* animals as well as problems in distinguishing (hired) animal inputs from those of the animal operator. For the period 1971-74 seperate estimates of the cost of own and hired animals are reported and were summed to give a draft animal cost total. For the years 1975-83 and 1987-89 the *Struktur Ongkos* data report only a cost of hired animal figure which, according to BPS officials, most likely excludes an own animal component (They could not be definitive on this point, because the instructions given to the BPS enumerators were not especially clear in this regard).

Appendix 2: *Construction of Research Expenditure Data for Rice and Soybean*

Research Budget Sources

Cost series have been constructed to reflect the overall levels of AARD (not simply CRIFC) investment in rice and soybean research. Three sources of investment have been considered:

1. GoI routine expenditures (*Anggaran Rutin*)
2. GoI development expenditures (*Anggaran Pembangunan*)
3. Non-GoI sourced development project loans and grant (*Kerjasama Luar Negeri, KLN*)

Wherever possible and appropriate supplementary budget sources (e.g., priority GoI projects funded through *Anggaran Belanjaran Tahunan, ABT*, and USA's PL480 payments) have also been included. Not included are the sometimes significant levels of locally contracted research undertaken on behalf of third party agencies, institutions or private sector interests outside of the Ministry of Agriculture (*Kerjasama Pihak Ketiga, KPT*).

The routine budget provides AARD's basic operational funding in terms of salaries, utilities, maintenance, consumables and essential travel and communications. To execute specific research activities, the development budget provides additional support for construction, equipment, experimentation and related travel, research data collection, analysis and reporting, project administration and dissemination of research results.

Externally funded grants and loans are generally channeled through specific, targeted projects formulated by GoI and donor/lender groups. However, severe GoI budget constraints in recent years have lead to some direct support of GoI development budget from grant/loan sources, most notably USAID's Agriculture and Rural Sector Support Program (ARSSP). GoI counterpart funding of grant/loan assisted projects is channeled through a *KLN* component in its development budget.

Approach and Assumptions

Construction of the expenditure series for rice and soybean was initiated by an examination of the historic pattern of CRIFC development budget allocations both by research station and by research program. Subsequently, this analysis was also used to condition the allocation of routine budget shares to rice and soybean research. Finally, it provided a framework within which estimates were made of the commodity allocation of grant/loan project monies.

In reality the analysis has been based largely on *budget allocations* and not *actual expenditures*. This was a practical constraint imposed by the availability of data. Although there is in general a good correspondence between budgeted amounts and total expenditures for GoI routine and development budgets, there can be, and are, some significant differences in timing between planned and actual expenditures. Until 1983(?) it was possible for unspent GoI development project monies (*DIP sisa anggaran, SIAP*) to be carried over for up to three years. Although this is no longer possible with GoI funds, budget carryover remains a feature of many grant/loan projects where planned budgets and actual expenditure patterns are seldom coincident. Given the funding levels and overall time span of some loan projects this represents a potential source of error given the time sensitive nature of subsequent discounting calculations. The problems which give rise to the delay of expenditures may ultimately result in overall underspending and subsequent deobligation/decommitment of donor funds. For this reason more effort was made to obtain actual expenditure totals for all major grant/loan projects.

An important principle on which the cost allocation has been based is that *all* expenditures must, in the final analysis, be allocable to a specific commodity. Thus, expenditures include not just the direct cost of research activities, but also include a commodity share of the non-commodity research (e.g., rice's share of the germplasm or farming system research programs) *and* a commodity share of the general research development and operation overhead. This has resulted in an expenditure series showing significantly higher levels of research investment than is usually reported on a commodity basis for Indonesia. A further implication, in the case of technical assistance, is that no differentiation is made between grant or loan expenditures, nor for overseas remittances (e.g., expatriate savings or international procurement). The objective is simply to capture, as realistically as possible, *any* expenditures that directly or indirectly support AARD's rice and soybean programs. The differential returns to various sources and types of funding, be they GoI or foreign, has not been addressed.

GoI Development Budget

(a) Budget Structure

The general structure of CRIFC development budgets has, until recent years, been fairly consistent. The main budget categories and their typical shares are;

I.	Commodity specific research (25-30%)	e.g., *padi*, & *palawija* (*kacang-kacangan*, *jagung*, *ubi-ubian* etc.)
II.	Non-commodity specific research (30-35%)	e.g., farming systems, cropping patterns, post-harvest technology, biotechnology
III.	Development support activities (30-40%)	
a.	Research development and dissemination (10%)	
b.	Infrastructure (10%)	
c.	Staff development (3%)	
d.	Project administration (10%)	
e.	International collaboration (*KLN*, 3%)	e.g., counterpart funds for grant/loan projects.

To facilitate analysis of the development budget a standardized budget structure was designed and the annual budgets for each experiment station (*balai*) and the coordinating center (*puslit*) were set out in the standard format (table A2.1). Prior to 1980 little disaggregated budget information was available, but fairly complete information is available since that time.

The restructuring of actual year-by-year budgets into the standardized budget structure presented no significant difficulties. However two types of adjustment were necessary.

Horticulture Adjustments

Between 1981 and 1984 coordination of the horticulture research activities was transferred from DGFC to CRIFC. It was necessary, therefore, to remove the horticulture component from the CRIFC budgets during this period. Two adjustments were made. Firstly, all budget allocations related to horticulture institutes temporarily under the coordination of CRIFC, e.g., Lembang and Solok, were deducted from the Food Crops totals. Secondly, budgets allocated for fruit and vegetable research activities at Food Crops research stations, e.g., Sukarami and Malang, were also deducted.

Thus, for each of the relevant years and for each *balai*, a "Horticulture Adjustment" total was estimated. Deducting this total from the Food Crops total budgets during the 1981-1984 period yielded a "net" Food Crops development budget.

Total Expenditure Adjustment

For a variety of reasons the detailed budgets reported in *DIP* documents and annual reports occasionally differ from the official aggregate statistics subsequently produced in time series format by both CRIFC and AARD. Some of these differences arise from late changes in budget allocations, some arise from known differences between actual expenditure and budget allocations, and some reflect simple arithmetic errors in the initial tabulations.

Table A2.1: *Standardisation of the CRIFC Development Budget Structure*

Development budget components			
Primary	Secondary	Commodity elements	Standardised elements
I Commodity Specific Research	*Padi*	*PADI* *Padi Hybrid*	Ia RICE .1 Hybrid Rice
	Palawija	*PALAWIJA*	Ib *PALAWIJA*
		Jagung, Sorgum, dll	.1 Maize, Sorghum
		Kacang-Kacangan *Kedelai* *Kacang Lain*	.2 Beans & Pulses i Soybean ii Others
		Ubi-Ubian	.3 Roots & Tubers
II Non-Commodity Specific Research	*Pola Tanam* *Teknologi benih* *Bioteknologi* *Plasma Nuftah* *Usaha Tani Terpadu* *Sosial Ekonomi* *Peralatan* *Sinar* *Surya/Klimatologi* *Irigasi/Peng. Air* *Pasca Panen* *Lain*		II.1 Cropping Patterns .2 Seed Technology .3 Biotechnology .4 Germplasm .5 Integrated FS. .6 Socioeconomics .7 Machinery .8 Radiation/Climate .9 Irrig/Water Man. .10 Post Harvest .11 Other
III Development Support Activities	*Pengembangan & Penyaluran Hasil*		III.1 Development & Dissemination
	Sarana		.2 Infrastructure
	Pembinaan Tenaga		.3 Staff Development
	Administrasi Proyek		.4 Administration
	Kerjersama Luar Negeri		.5 International Collaboration

Note: Although the above structure has been broadly followed since 1974, there were some variations to this basic structure over the past few years. However, all budgets up to 1991-92 were successfully classified in this format. Non-commodity specific research activities for which no budget element existed were aggregated into an "other" category.

The budget elements in groups I and II are biased to rice and soybean, so some other commodities, e.g., roots and tubers, remain aggregated. Although *balai* budgets always show rice as a separate budget entity, soybean has only been identified as a separate budget item in the past two to three years. Soybean research was formerly included either in the *palawija* or the *kacang-kacangan* elements of *balai* budgets.

To provide compatibility between the "official" aggregate AARD/CRIFC budget series and the disaggregated *balai*/program development budget (*DIP*) data, the official *totals* were used but the detailed budget breakdown was obtained by from CRIFC/*balai* annual reports and *DIP* documentation. Where a mismatch occurred between the two data sources the discrepancy was calculated -- and this was labelled "column adjustment" in the standardised budget (one column being assigned in the spreadsheet for each *balai* for each year). Thus:

Official *balai* development budget total = Sum of reported *DIP* budget items + column adjustment.

In general this adjustment was less than three percent of the total budget and was usually zero. Even where significant discrepancies occured no attempt was made to apportion differences across individual development activities. The disaggregated data would be subsequently be used to look at cost shares and, in the absence of other data, it was assumed that the discrepancy in total budget would not significantly affect the budget shares.

(b) Commodity Specific Development Budget Shares

The CRIFC-supplied estimates of commodity expenditures reflected only those elements of the development budget that are explicitly allocated to commodity research activities. For example, the reported development budget expenditure on rice research was taken directly from the rice element of the commodity specific research component (see Ia in table A2.1) of the budget. Although more complex to extract, the soybean allocation was obtained in the same way, being estimated as a proportion of either the general *palawija* element or, if it existed, the *kacang-kacangan* element. Except in the past two to three years, research costs for soybean have never been specifically identified in CRIFC budgets.

On the basis of our assumption of *total cost allocation on a commodity basis*, however, we recalculated total development costs for each commodity as follows:

$$E = E_C + E_{NC}$$

$$E_c = e_{rice} + e_{corn} + e_{soy} + e_{cassava} + \ldots = \Sigma e_i \qquad \text{(A2.1)}$$

$$E^{rice} = e_{rice} + \left(\frac{e_{rice}}{E_C} * (E - E_c) \right)$$

where
E = total development budget (per *balai*, per financial year)
E_C = commodity specific research costs (budget component I)
E_{NC} = non-commodity specific costs (budget components II and III)
e_{rice} = rice specific (direct) research costs (and similarly for the other commodities).
E^{rice} = total direct and indirect rice research costs

Thus, the *total* development budget costs related to a commodity were taken to be the commodity specific research costs (e_{rice}) plus a proportion of *all* of the non-commodity specific costs. The proportion used is the ratio of rice commodity specific research costs to the total of commodity specific research (e_{rice}/E^{rice}). On this basis the calculation of total GoI development budget costs for rice are shown in table A2.2.

Table A2.2: *Estimate of Rice Research Costs -- Development Budget Component ('000 nominal rupiah)*

Year End	CRIFC development budget				Commodity research component[b]	Comm/dev (Cols 6/5)	Rice research			Rice/dev (Cols 10/5)	Rice/comm (Cols 10/16)	Non-commodity dev. costs (Cols 5-6)	Rice cost share (Cols 12*13)	Total rice[c] (Cols 10+14)
	APBN	Non-APBN		Total			APBN	Non-APBN	Total					
		ARSSP	Other[a]											
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
						%				%	%			
1971	*786,116*			*786,116*	*141,501*	18.0			*94,334*	12.0	66.7	644,615	429,744	524,078
1972	*899,496*			*899,496*	*161,909*	18.0			*107,940*	12.0	66.7	737,587	491,725	599,664
1973	*1,029,228*			*1,029,228*	*185,261*	18.0			*123,507*	12.0	66.7	843,967	562,645	686,152
1974	*1,177,672*			*1,177,672*	*211,981*	18.0			*141,321*	12.0	66.7	965,691	643,794	785,115
1975	1,347,525			1,347,525	242,554	18.0	162,399		162,399	12.1	67.0	1,104,970	739,818	902,217
1976	1,541,875			1,541,875	277,538	18.0	152,210		152,210	9.9	54.8	1,264,338	693,401	845,611
1977	1,764,257			1,764,257	317,566	18.0	250,993		250,993	14.2	79.0	1,446,690	1,143,413	1,394,406
1978	2,025,913			2,025,913	364,664	18.0	239,061		239,061	11.8	65.6	1,661,249	1,089,056	1,328,117
1979	2,170,000			2,170,000	390,600	18.0	268,190		268,190	12.4	68.7	1,779,400	1,221,754	1,489,944
1980	2,571,000			2,571,000	462,780	18.0	291,687		291,687	11.3	63.0	2,108,220	1,328,796	1,620,483
1981	3,314,000			3,314,000	606,623	18.3	351,220		351,220	10.6	57.9	2,707,377	1,567,506	1,918,726
1982	3,641,100			3,641,100	717,500	19.7	413,474		413,474	11.4	57.6	2,923,600	1,684,784	2,098,258
1983	4,061,639			4,061,639	1,069,800	26.3	592,974		592,974	14.6	55.4	2,991,839	1,658,331	2,251,305
1984	4,177,097			4,177,097	1,225,825	29.3	682,782		682,782	16.3	55.7	2,951,272	1,643,852	2,326,634
1985	3,620,857			3,620,857	1,096,609	30.3	631,450		631,450	17.4	57.6	2,524,248	1,453,514	2,084,964
1986	3,258,000			3,258,000	1,054,669	32.4	622,255		622,255	19.1	59.0	2,203,331	1,299,966	1,922,221
1987	2,075,000			2,075,000	936,095	45.1	568,052		568,052	27.4	60.7	1,138,905	691,124	1,259,176
1988	643,600	1,982,800		2,626,400	1,723,051	65.6	245,088	699,241	944,329	36.0	54.8	903,349	495,086	1,439,415
1989	742,272	2,609,710	1,793,630	5,145,612	1,386,016	26.9	0	720,411	720,411	14.0	52.0	3,759,596	1,954,129	2,674,540
1990	2,379,000	2,623,000		5,002,000	1,375,498	27.5	0	701,504	701,504	14.0	51.0	3,626,502	1,849,516	2,551,020
1991	2,050,000	1,700,000		3,750,000	1,679,054	44.8	233,808	387,442	621,250	16.6	37.0	2,070,946	766,250	1,387,500
1992	4,840,000		1,109,799	5,949,799	3,242,871	54.5	1,008,403	153,850	1,162,253	19.5	35.8	2,706,928	970,170	2,132,423

Source: CRIA; *LP3*; CRIFC Balai Annual Reports; CRIFC *DIP* documents 1987-91; CRIFC Master Research Plan 1990; BPS *Statistik Pertanian* 1992; Palwija Evaluation 1984; Nestel 1985; CARP (various published and unpublished documents).

Note: Italicized figures estimated by backward, geometric extrapolation.

[a] Other sources include ABT and PL480 funds. AARP & ARM development budget support are included in Loan/Grant expenditure estimates.
[b] All of budget component I. See table A2.1.
[c] Total rice allocation of development budget.

The case of soybean is made more complex by the unavailability of the e_{soy} cost element. Soybean research costs are included either in a general *palawija* budget or in a more specific grain legumes (e.g., *kacang-kacangan*) total so that:

$$E_c = e_{rice} + e_{palawija}$$

where $$e_{palawija} = e_{other\ cereals} + e_{grain\ legumes} + e_{root\ crops} \qquad (A2.2)$$

and $$e_{grain\ legumes} = e_{soybean} + e_{peanut} + e_{mungbean} + \ldots$$

Until very recently *DIP* budgets were not disaggregated below the $e_{grain\ legume}$ level, and sometimes not below the $e_{palawija}$ level. The only explicit information on the detailed breakdown of research to the level of specific commodities was contained in the various volumes of the Food Crops Master Research Plans for CRIFC and each *balai*.

On the basis of researcher time allocation the Master Research Plan reported the following allocation to soybean for 1989/90.

	Researcher Time Allocation - CRIFC institutes					
	BORIF	SURIF	MARIF	MORIF	BARIF	SARIF
Soybean/legumes	.551	.730	.887	.617	.844	.768
Soybean/*palawija*	.278	.512	.529	.407	.417	.416

In the absence of other information these proportions have been used for all years. This assumes a constant relationship between the relative funding levels of the legume crops. In the case where only *palawija* totals are available, the allocation assumes a constant relativity of soybean to all other *palawija* crops (in aggregate). Furthermore, these time allocations are assumed to reflect the expenditure allocations $e_{soy}/e_{grain\ legumes}$ and $e_{soy}/e_{palawija}$ respectively. The estimation of total GoI development budget costs for soybean are shown in table A2.3.

GoI Routine Budget

Given the high proportion of routine expenditures that are used for salaries (65-75%), it would be most appropriate to allocate routine budgets on the basis of researcher time allocation by commodity. However, as described in the previous section, these data are generally incomplete for all but the most recent years.

It was decided to utilize the detailed development budget data as the basis for apportioning the routine budget. To reflect the slower time response in the reallocation of human capital, e.g., an instantaneous reprogramming of budget cannot convert a rice breeder into a soybean breeder, the following means of smoothing the trends in development budget patterns was used

$$R_t^{rice} = R_t * \left(\frac{\dfrac{E_{t-2}^{rice}}{E_{t-2}} + \dfrac{E_{t-1}^{rice}}{E_{t-1}} + \dfrac{E_t^{rice}}{E_t}}{3} \right) \qquad (A2.3)$$

where R_t = total routine budget in year t
R_t^{rice} = rice research component of routine budget in year t
E_t^{rice} = rice research component of development budget in year t
E_t = total development budget in year t

Table A2.3: *Estimate of Soybean Research Costs -- Development Budget Component ('000 nominal rupiah)*

	CRIFC Development Budget													
		Non-APBN			Commodity research component[b]	Comm/dev (cols 6/5)	Soybean research			Soy/dev (Cols 10/5)	Soy/comm (Cols 10/16)	Non-commodity dev. costs (Cols 5-6)	Soybean cost share (Cols 12*13)	Total soybean[c] (Cols 10+14)
Year end	APBN	ARSSP	Other[a]	Total			APBN	Non-APBN	Total					
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
						%				%	%			
1971	*786,116*			*786,116*	*141,501*	18.0	*16,462*		*16,462*	2.09	11.6	644,615	74,995	91,457
1972	*899,496*			*899,496*	*161,909*	18.0	*19,342*		*19,342*	2.15	11.9	737,587	88,113	107,455
1973	*1,029,228*			*1,029,228*	*185,261*	18.0	*22,725*		*22,725*	2.21	12.3	843,967	103,526	126,251
1974	*1,177,672*			*1,177,672*	*211,981*	18.0	*26,700*		*26,700*	2.27	12.6	965,691	121,635	148,335
1975	1,347,525			1,347,525	242,554	18.0	32,779		32,779	2.43	13.5	1,104,970	149,327	182,106
1976	1,541,875			1,541,875	277,538	18.0	29,388		29,388	1.91	10.6	1,264,338	133,879	163,267
1977	1,764,257			1,764,257	317,566	18.0	49,152		49,152	2.79	15.5	1,446,690	223,915	273,067
1978	2,025,913			2,025,913	364,664	18.0	55,834		55,834	2.76	15.3	1,661,249	254,355	310,189
1979	2,170,000			2,170,000	390,600	18.0	61,219		61,219	2.82	15.7	1,779,400	278,887	340,106
1980	2,571,000			2,571,000	462,780	18.0	68,983		68,983	2.68	14.9	2,108,220	314,256	383,239
1981	3,314,000			3,314,000	606,623	18.3	83,712		83,712	2.53	13.8	2,707,377	373,609	457,321
1982	3,641,100			3,641,100	717,500	19.7	91,674		91,674	2.52	12.8	2,923,600	373,544	465,218
1983	4,061,639			4,061,639	1,069,800	26.3	136,798		136,798	3.37	12.8	2,991,839	382,574	519,372
1984	4,177,097			4,177,097	1,225,825	29.3	193,108		193,108	4.62	15.8	2,951,272	464,923	658,031
1985	3,620,857			3,620,857	1,096,609	30.3	164,398		164,398	4.54	15.0	2,524,248	378,422	542,820
1986	3,258,000			3,258,000	1,054,669	32.4	171,088		171,088	5.25	16.2	2,203,331	357,424	528,512
1987	2,075,000			2,075,000	936,095	45.1	122,355		122,355	5.90	13.1	1,138,905	148,864	271,219
1988	643,600	1,982,800		2,626,400	1,723,051	65.6	281,684		281,684	10.73	16.3	903,349	147,679	429,363
1989	742,272	2,609,710	1,793,630	5,145,612	1,386,016	26.9	359,337		359,337	6.98	25.9	3,759,596	974,709	1,334,046
1990	2,379,000	2,623,000		5,002,000	1,375,498	27.5	317,804		317,804	6.35	23.1	3,626,502	837,891	1,155,695
1991	2,050,000	1,700,000		3,750,000	1,679,054	44.8	330,203		330,203	8.81	19.7	2,070,946	407,273	737,476
1992	4,840,000		1,109,799	5,949,799	3,242,871	54.5	1,061,604		1,061,604	17.84	32.7	2,706,928	886,155	1,947,759

Source: CRIA; *LP3*; CRIFC Balai Annual Reports; CRIFC *DIP* documents 1987-91; CRIFC Master Research Plan 1990; BPS *Statistik Pertanian* 1992; Palwija Evaluation 1984; Nestel 1985; CARP (various published and unpublished documents).

Note: Italicized figures estimated by backward, geometric extraploation.

[a]Other sources include ABT and PL480 funds. AARP & ARM development budget support are included in Loan/Grant expenditure estimates.
[b]All of budget component I. See table A2.1.
[c]Total soybean allocation of development budget.

The three year moving average embodied in this equation reflects the underlying trends and variations in development budget research expenditures, but obviously has the effect of damping sudden changes. This formulation is considered to provide a reasonable approximation to the slower rate at which routine budget allocation may move in response to trends in the development budget.

The routine budget allocations for rice and soybean research calculated on this basis are shown in tables A2.4 and A2.5.

Figure A2.1 illustrates the extent to which rice and soybean cost allocations (routine plus development) have changed over time and identifies the remaining costs allocable to other palawija crops

Grant/Loan Expenditures

The initial challenge in estimating grant/loan related expenditures was to compile a list of those grant/loan projects may that contain significant elements of support for rice and soybean research. Furthermore, such projects are not only limited to those undertaken in direct partnership with CRIFC; several AARD-wide projects have also supported CRIFC research activities.

From a review of annual reports of AARD, CRIFC and several key donors, a project list was compiled, including details of budget, start and end dates, location and, where possible, technical assistance personnel inputs. Since no year-by-year budget allocations were available a simple approach was taken to estimate actual disbursement.

$$P_t = \frac{TP}{EY-SY+1} \qquad SY \leq t \leq EY \qquad \text{(A2.4)}$$

TP = total grant/loan project budget (non-GoI sourced)
P_t = annual project budget allocation in year t
SY = start year of project
EY = end year of project

This yields a constant level of annual disbursement over the life of the project.

It was then necessary to provide, for each project, weights that reflected the likely degree to which the project was targeted to specific commodities. Of necessity this was a relatively subjective process, but the following set of procedures were used.

(1) Non-Commodity Specific Projects

Where projects had no specific commodity focus, e.g., the National Agricultural Research (NAR) Project or the Agroecosystem (*KEPAS*) Project, the CRIFC commodity specific development budget weights, e.g., E_t^{rice}/E_t were applied (these are equivalent to those show in column 12 of tables A2.2 and A2.3). Since only one weight per commodity was to be applied to each project, weights were averaged over the life of the project, for example,

Project	*Period*	*Av. Rice Weight*	*Av. Soybean Weight*
KEPAS I	1984-1986	0.57	0.15
KEPAS II	1985-1988	0.57	0.16
KEPAS III	1989-1992	0.50	0.20

(2) Commodity Targeted Projects

Table A2.4: *Estimate of Rice Research Costs, Routine Budget Component ('000 nominal rupiah)*

Year end	CRIFC routine research	Rice/development		Routine rice share
		Annual	3 yr moving average	
1	2	3	4	5
		%	%	
1971	119,294	66.7	66.7	79,529
1972	147,023	66.7	66.7	98,016
1973	181,877	66.7	66.7	121,251
1974	225,849	66.7	66.7	150,566
1975	262,732	67.0	66.8	175,406
1976	389,388	54.8	62.8	244,618
1977	453,088	79.0	66.9	303,317
1978	557,093	65.6	66.5	370,348
1979	697,198	68.7	71.1	495,601
1980	783,422	63.0	65.7	515,092
1981	1,188,420	57.9	63.2	751,034
1982	1,783,721	57.6	59.5	1,061,635
1983	1,798,334	55.4	57.0	1,024,769
1984	2,368,230	55.7	56.3	1,332,171
1985	2,160,891	57.6	56.2	1,215,216
1986	2,659,814	59.0	57.4	1,527,459
1987	3,584,555	60.7	59.1	2,118,057
1988	3,391,972	54.8	58.2	1,972,871
1989	3,851,075	52.0	55.8	2,149,746
1990	4,244,319	51.0	52.6	2,232,268
1991	5,056,943	37.0	46.7	2,359,521
1992	6,134,353	35.8	41.3	2,532,266

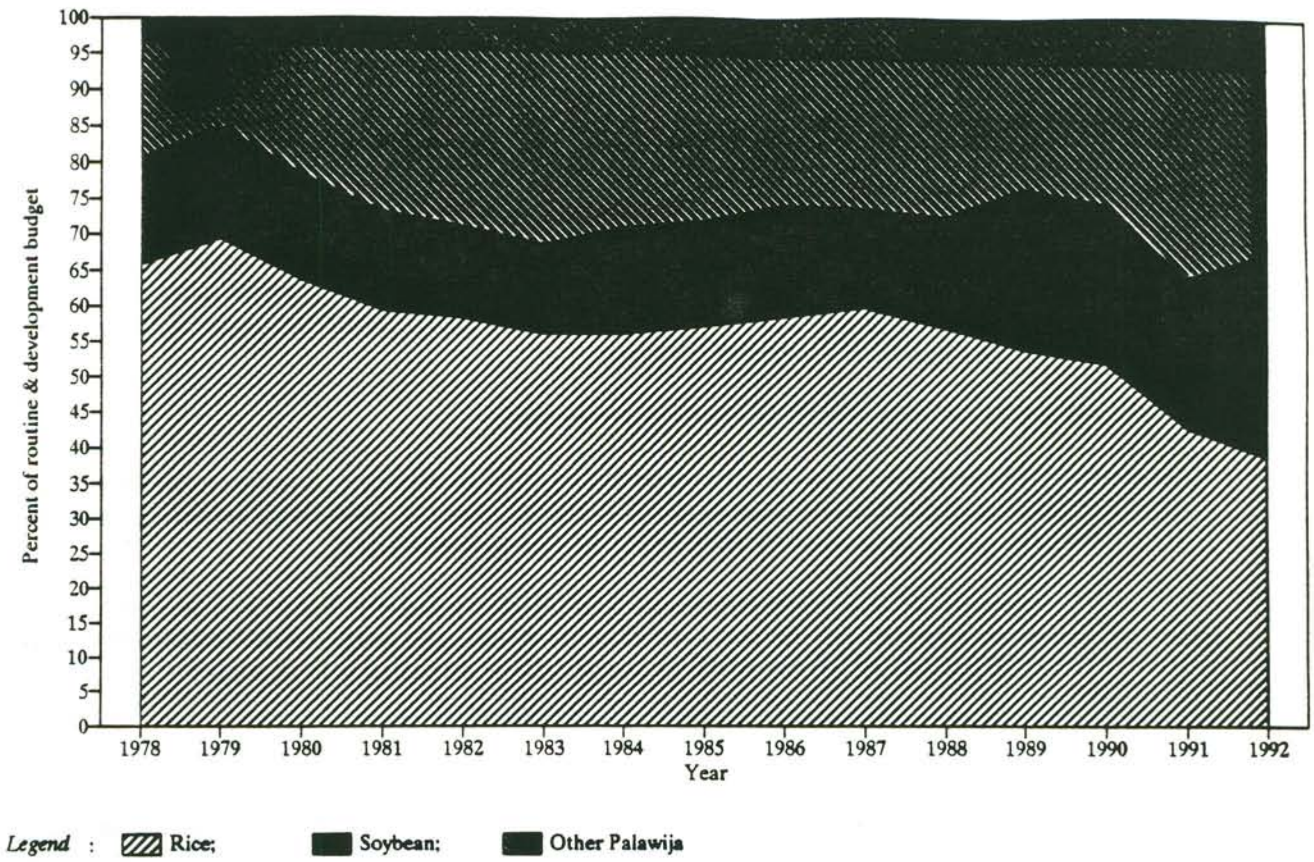
Source: Routine budgets from CARP and CRIFC. Weights from table A2.2.

Table A2.5: *Estimate of Soybean Research Costs Routine Budget Component ('000 nominal rupiah)*

Year end	CRIFC routine budget	Soybean/development		Routine soybean share
		Annual	3 yr moving average	
1	2	3	4	5
		%	%	
1971	119,294	11.6	11.6	13,879
1972	147,023	11.9	11.8	17,334
1973	181,877	12.3	11.9	21,732
1974	225,849	12.6	12.3	27,710
1975	262,732	13.5	12.8	33,609
1976	389,388	10.6	12.2	47,633
1977	453,088	15.5	13.2	59,778
1978	557,093	15.3	13.8	76,837
1979	684,463	15.7	15.5	106,005
1980	783,422	14.9	15.3	119,838
1981	1,188,420	13.8	14.8	175,803
1982	1,783,721	12.8	13.8	246,646
1983	1,798,334	12.8	13.1	235,964
1984	2,368,230	15.8	13.8	326,164
1985	2,160,891	15.0	14.5	313,560
1986	2,659,814	16.2	15.7	416,409
1987	3,584,555	13.1	14.8	529,131
1988	3,391,972	16.3	15.2	516,040
1989	3,851,075	25.9	18.4	710,455
1990	4,244,319	23.1	21.8	924,958
1991	5,056,943	19.7	22.9	1,157,982
1992	6,134,353	32.7	25.2	1,543,960

Source: Routine Budgets from CARP and CRIFC. Weights from table A2.3.

Figure A2.1: *Commodity research shares of CRIFC's routine & development expenditures, 1978-92*



Where projects had a specific commodity orientation subjective weights were assigned to reflect that focus. For example,

Project	*Weights*	
JICA ATA 218-1 Joint Food Crop Research	Rice: 0.8	Soybean: 0.05
USAID Grain Legumes N-Fixation	Rice: 0.0	Soybean: 0.6
USAID Hybrid Rice Research	Rice: 1.0	Soybean: 0.0

(3) *AARD Projects*

Where projects were managed at the AARD level, an additional weight was applied to reflect the proportion of CRIFC activities supported by the project. This was done by applying a ratio of the CRIFC total development budget to the AARD total development budget during the period of the project. For example in the case of the GoI/IBRD NAR II project the following procedure was used.

During the period of the project - 1981-1990:

CRIFC development budget was 20% of AARD development budget
Rice was 57% of CRIFC development budget
Soybean was 15% of CRIFC development budget
Hence, NAR II rice weight = 0.2 x 0.57 = 0.114
NAR II soybean weight = 0.2 x 0.15 = 0.03

A listing of CRIFC and AARD projects together with their assigned rice and soybean weights is shown in table A2.6. In a limited number of cases project budgets have not yet been confirmed (e.g., Swamp I) and in other cases insufficient information is known to apply sensible weights. This problem tends to occur with projects that were targeted to specific, limited geographical locations, for example, the Upland Agricultural Project.

Three special cases are worthy of note:

CGPRT (ESCAP)

Given CGPRT's institutional autonomy and regional mandate neither ESCAP expenditure nor ESCAP personnel data have been included in the research impact analysis for rice and soybean. Given the intensity of CGPRT's activities on soybean research in Indonesia this may be a significant but appropriate omission, for the purposes of this study given that ESCAP is not part of AARD.

ARSSP and Direct Non-GoI Support of the Development Budget

Since ARSSP was used almost exclusively to support GoI (AARD) development budget it has been taken into account in the development budget allocation described above. Thus, rice and soybean weights of zero are given in the table. The project is included in the table for the sake of completeness.

In recent years there have also been elements of CRIFC development budget support from both AARP and ARM projects. However, this has been handled not as development budget but as loan/grant budget since, unlike the ARSSP project, AARP and ARM are providing both direct and indirect support.

Applied Agricultural Research Project, AARP

Although it is an AARD project, the focus and activities of the project are mostly food crops related. Thus, a higher than usual proportion of the project (estimated at 80%) has been allocated to CRIFC. As stated above, AARP support to CRIFC development budget in 1988-91 has been handled through the grant/loan allocation procedures and those for GoI development budget.

In summary, for year t the contributions of a grant/loan project to rice and soybean research respectively are

$$\begin{aligned} P_t^{rice} &= w^{rice} * P_t \\ P_t^{soybean} &= w^{soy} * P_t \end{aligned} \tag{A2.5}$$

where P_t is the total grant/loan project budget for year t and w^{rice} and w^{soy} are the weights shown in table A2.6.

Total Commodity Specific Expenditures

The total commodity specific expenditure, T_t, in any year t is simply the sum of development, routine and grant/loan expenditure estimates.

$$T_t^{rice} = E_t^{rice} + R_t^{rice} + P_t^{rice} \tag{A2.6}$$

These values are set out for both rice and soybean in table 3.2 of the text.

Table A2.6: *Loan/Grant/TA Projects having CRIFC Related Components*

Project					Donor Funding					Cost shares	
No.	Funding source	Reference	Name	Type	Amount	Currency	Start year	End year	Responsible/Location	Rice	Soybean
1	2	3	4	5	6	7	8	9	10	11	12
CRIFC Projects											
1	Netherlands	ACP-1	Ag. Cooperation (ACP-1?)	G	162,918	Dfl	1968	1975	CRIA & MAROS	0.67	0.12
2	JICA	ATA218-I	Joint Food Crop Res.	G	1,455,000	US$	1971	1978	CRIFC/BORIF (CRIA)	0.8	0.05
3	Neth/USAID?	IRRI	Regional Rice Res.	G	1,138,000	US$	1972	1982	MAROS	1	0
4	USAID	IRRI	Ag. Research (IRRI-CRIFC)	G	2,167,000	US$	1972	1982	CRIFC/BORIF	0.8	0.1
5	IBRD	IDA	CRIA-IRRI Sukamandi	G	1,768,000	US$	1972	1982	SURIF, Sukamandi	0.8	0.05
6	Netherlands	ATA-110	Ecol. Res. Rice, Soy, Corn	G	1,056,000	US$	1974	1980	CRIA	0.67	0.12
7	USAID	SAR	Sumatra Ag. Research	L/G	9,500,000	US$	1978	1986	SARIF, Sukarami	0.8	0.1
8	JICA	ATA218-II	Strength Legumes	G	2,320,000	US$	1979	1985	CRIFC/BORIF	0.05	0.6
9	ESCAP	ESCAP	CGPRT/ESCAP Centre	G	3,160,000	US$	1980	1985	CRIFC	0	0
10	IBRD	SWAMP I	Swamp Reclamation	L	?		1981	?	CRIFC	0.58	0.15
11	Netherlands	ATA272-I&II	Strengthening MARIF	G	1,650,000	US$	1981	1984	MARIF, Malang	0.25	0.25
12	USAID	ATA-304	Hybrid Rice Res.	G	550,000	US$	1983	1988	SURIF	1	0
13	Ford	KEPAS-I	Agroecosystem Network	G	105,400	US$	1984	1986	CRIFC	0.57	0.15
14	Netherlands	ATA272-III	Strengthening MARIF	G	1,650,000	US$	1984	1987	MARIF, Malang	0.2	0.35
15	USAID	Grain Leg.	Grain Legumes - N fix.	G	150,000	US$	1984	1988	SURIF	0	0.6
16	Ford	KEPAS-II	Agroecosystem Network	G	270,000	US$	1985	1988	CRIFC	0.57	0.16
17	IDRC	Leg/Rice	Legume after Rice	G	175,580	US$	1985	1989	BORIF	0.1	0.7
18	IBRD	SWAMP II	Swamp Reclamation	L	7,200,000	US$	1985	1992	CRIFC	0.55	0.2
19	ACIAR	Second FC	Second. Food Crops	G	120,000	US$	1986	1988	CRIFC	0.1	0.4
20	JICA	ATA-378	Pioneer Palawija Res.	G	5,053,000	US$	1986	1990	BORIF	0.1	0.4
21	ADB	Rice Prodn.	Rice Production	G	650,000	US$	1987	1990	BORIF	1	0
22	Netherlands	AARD/TFDL	Lab & Field Equip.	G	2,250,000	US$	1987	1990	MARIF	0.2	0.35
23	Netherlands	ATA272-IV	Strengthening MARIF	G	5,922,000	US$	1987	1991	MARIF, Malang	0.2	0.35
24	Ford	KEPAS-III	Agroecosystem Network	G	130,000	US$	1989	1992	CRIFC	0.5	0.2
25	JICA	ATA-467	Food Crops Physiol.	G	799,000	Yen	1990	1993	CRIFC	0.2	0.1
26	JICA	ATA-468	Lab. Construction	G	549,000	Yen	1990	1993	CRIFC	0.05	0.05
27	ACIAR	8829	Nit. Fixation in Soybean	G	72,420	A$	1990	1994	BORIF	0	1
AARD Projects											
28	IBRD	NARE	Ag Research & Ext. I	L	16,700,000	US$	1976	1981	AARD/AETE (NAR I)	0.067	0.015
29	IBRD	NAR II	National Ag. Research	L	65,000,000	US$	1981	1990	AARD	0.114	0.03
30	USAID	AARP I+II	Applied Ag. Research	L/G	31,885,000	US$	1981	1992	AARD	0.36	0.04
31	IBRD/USAID	UACP	Upland Agriculture	L	1,886,000	US$	1986	1991	AARD/CSAR, Salatiga	0	0
32	IBRD	NTASP	NusTeng Agricultural Support	L	5,732,700	US$	1986	1992	AARD/CASER, Kupang	0	0
33	USAID	ARSSP	Ag. & Rural Sector Supprt	G	43,000,000	US$	1987	1992	AARD	0	0
34	IBRD	ARM 1	Ag. Research Management	L	38,700,000	US$	1989	1994	AARD	0.07	0.044
DGFC Projects											
35	IBRD	NFCEP	Nat. Foodcrops Extension	L	22,000,000	US$	1977	1982	DGFC/CRIFC-IRRI	0	0
36	IBRD	NAE II	National Ag. Extension	L	42,000,000	US$	1981	1986	DGFC	0	0
37	USAID	SFCP	Secondary Food Crops	L/G	7,400,00	US$	1983	1990	DGFC	0	0
38	IBRD	NAE III	National Ag. Extension	L	?	US$	1986		DGFC	0	0

Note:

Projects: Some small projects considered to have no rice or soybean relevance may be absent from this list.
Type codes: L - Loan, G - Grant
Currency: Funding levels expressed in nominal US$ currency units. Actual expenditures used whenever possible.
ESCAP: Not included in the analysis for CRIFC.
ARSSP: Included in Development Budget (Anggaran Pembangunan) estimates (tables A2.2 and A2.3).
Other: Data for SWAMP I & NAE III not yet available.
DGFC: Extension costs obtained separately -- weights for the purpose of deriving research cost series set to zero (see section 3.1.4).

Appendix 3: *Detrending and Variability Decomposition Methods*

Total production for a region is defined as:

$$Q = \sum_{i=1}^{N} \sum_{t=1}^{T} A_{it} YLD_{it}, \tag{A3.1}$$

where
Q = production, in thousands of tons,
A_{it} = area harvested in the i^{th} province in year t, in thousands of hectares,
Y_{it} = yield in the i^{th} province in year t, in tons per hectare,

Prior to computing the *coefficient of variation* (CV) in table 2.4 and decomposition of production variances in table 2.6, it is necessary to detrend the raw data on production and area harvested. The purposes of detrending are twofold: to avoid heteroscedasticity and to make the data compatible to allow us to compare the production variability across crops over time.

A_{it} and YLD_{it} will be detrended by the following method. First we define

$$Z_{it} = f(T, \alpha, \epsilon_t), \tag{A3.2}$$

where
Z_{it} = A_{it} or YLD_{it},
T = a time trend,
f = functional form, linear or quadratic, and
α, ϵ_t = constant and error term.

Then,

$$\hat{Z}_{it} = \bar{Z}_{it} + \hat{\epsilon}_t, \tag{A3.3}$$

where
$\bar{Z}_i$ = mean value for Z_i, and
$\hat{\epsilon}$ = estimated residuals.

Therefore, our primary working data will be residuals centered on the mean.

Following Bohrnstedt and Goldberger's (1969) method, the mean (E(Q)) and variance (V(Q)) of Q are decomposed as:

$$E(Q) = \sum_{i=1}^{N} \bar{A}_i \overline{YLD}_{it} + \sum_{i=1}^{N} cov(A_i\, YLD_i),$$

$$\begin{aligned} V(Q) = & \sum_{i=1}^{N} \bar{A}_i^2\, V(YLD) + \sum_{i=1}^{N} YLD_i^2\, V(A_i) \\ & + \sum_{i=1}^{N} \alpha \bar{A}_i \overline{YLD}_i cov(A_i\, YLD_i) - \sum_{i=1}^{N} cov(A_i, YLD_i)^2 \\ & + \sum_{i=1}^{N} \sum_{j \neq i}^{N} cov(A_i\, YLD_j, A_j\, YLD_j), \end{aligned} \tag{A3.4}$$

or

$$V(Q) = a + b + (c\text{-}d) + e,$$

where a = variation in area within province, b = variation in yield within province, $(c\text{-}d)$ = interaction of area and yield variation within province, and e = variation across provinces; or $(a+b+c\text{-}d)$ is the intra-province variation and e is the inter-province variation.

APPENDIX TABLES

Table A2.1: *Total Rice Area Harvested by Province*

	Total rice			
	1969-71		1987-89	
Province[a]	Area	Share of national total	Area	Share of national total
	(hectares)	%	*(hectares)*	%
West Java	1,728,974	21.2	2,069,781	20.3
East Java	1,213,842	14.9	1,564,634	15.4
Central Java	1,255,796	15.4	1,495,209	14.7
South Sulawesi	523,766	6.4	710,266	7.0
North Sumatra	523,164	6.4	666,570	6.6
South Sumatra	341,826	4.2	433,557	4.3
Lampung	219,065	2.7	364,644	3.6
West Sumatra	265,349	3.3	351,043	3.5
South Kalimantan	224,823	2.8	330,104	3.2
West Kalimantan	307,068	3.8	297,009	2.9
Aceh	218,444	2.7	282,317	2.8
West Nusa Tenggara	193,554	2.4	253,878	2.5
Jambi	124,955	1.5	170,066	1.7
Bali	153,100	1.9	169,121	1.7
DI Yogyakarta	123,945	1.5	139,133	1.4
Riau	149,501	1.8	133,018	1.3
Central Kalimantan	105,851	1.3	131,431	1.3
Central Sulawesi	82,916	1.0	119,940	1.2
East Nusa Tenggara	124,741	1.5	118,503	1.2
East Kalimantan	64,250	0.8	99,836	1.0
Bengkulu	77,776	1.0	89,829	0.9
North Sulawesi	63,989	0.8	86,942	0.9
S. E. Sulawesi	45,569	0.6	49,221	0.5
East Timor	-	0.0	17,549	0.2
Maluku	9,956	0.1	10,618	0.1
DKI Jakarta	14,940	0.2	8,611	0.1
Irian Jaya	534	0.0	8,325	0.1
Indonesia	8,157,695	100.0	10,171,156	100.0

Source: Adapted from BPS, *Statistik Indonesia* (various issues).

[a]Provinces ranked in decending order by their 1987-89 share of national total.

Table A2.2: *Upland Rice Area Harvested by Province*

Province[a]	Upland rice			
	1969-71		1987-89	
	Area	Share of national total	Area	Share of national total
	(hectares)	%	*(hectares)*	%
West Java	188,855	13.0	146,741	12.6
Lampung	141,116	9.7	116,851	10.1
West Kalimantan	128,400	8.8	115,795	10.0
South Sumatra	153,178	10.5	98,111	8.5
East Java	70,765	4.9	87,340	7.5
North Sumatra	139,984	9.6	82,700	7.1
Central Java	52,065	3.6	61,822	5.3
East Kalimantan	44,075	3.0	59,316	5.1
East Nusa Tenggara	92,059	6.3	55,669	4.8
Central Kalimantan	50,140	3.5	48,145	4.1
Riau	64,070	4.4	45,236	3.9
DI Yogyakarta	38,672	2.7	40,423	3.5
Jambi	20,695	1.4	37,130	3.2
South Kalimantan	28,685	2.0	27,673	2.4
Bengkulu	32,328	2.2	22,689	2.0
Central Sulawesi	35,802	2.5	19,122	1.6
S. E. Sulawesi	21,117	1.5	16,032	1.4
West Nusa Tenggara	20,377	1.4	15,761	1.4
South Sulawesi	47,401	3.3	15,730	1.4
North Sulawesi	21,532	1.5	14,004	1.2
West Sumatra	18,730	1.3	13,635	1.2
Maluku	9,631	0.7	7,890	0.7
Aceh	19,180	1.3	7,465	0.6
Bali	11,906	0.8	2,390	0.2
Irian Jaya	195	0.0	2,018	0.2
East Timor	-	0.0	663	0.1
DKI Jakarta	1,582	0.1	-	0.0
Indonesia	1,452,540	100.0	1,160,351	100.0

Source: Adapted from BPS, *Statistik Indonesia* (various issues).

[a]Provinces ranked in decending order by their 1987-89 share of national total.

Table A2.3: *Lowland Rice Area Harvested by Province*

Province[a]	Lowland rice			
	1969-71		1987-89	
	Area	Share of national total	Area	Share of national total
	(hectares)	%	*(hectares)*	%
West Java	1,540,119	23.0	1,923,040	21.3
East Java	1,143,076	17.0	1,477,294	16.4
Central Java	1,203,731	18.0	1,433,387	15.9
South Sulawesi	476,364	7.1	694,536	7.7
North Sumatra	383,180	5.7	583,870	6.5
West Sumatra	246,619	3.7	337,409	3.7
South Sumatra	188,648	2.8	335,446	3.7
South Kalimantan	196,137	2.9	302,431	3.4
Aceh	199,264	3.0	274,852	3.1
Lampung	77,949	1.2	247,793	2.7
West Nusa Tenggara	173,177	2.6	238,117	2.6
West Kalimantan	178,668	2.7	181,213	2.0
Bali	141,194	2.1	166,731	1.9
Jambi	104,260	1.6	132,936	1.5
Central Sulawesi	47,114	0.7	100,818	1.1
DI Yogyakarta	85,273	1.3	98,710	1.1
Riau	85,432	1.3	87,782	1.0
Central Kalimantan	55,711	0.8	83,286	0.9
North Sulawesi	42,457	0.6	72,938	0.8
Bengkulu	45,448	0.7	67,139	0.7
East Nusa Tenggara	32,682	0.5	62,834	0.7
East Kalimantan	20,175	0.3	40,520	0.4
S. E. Sulawesi	24,452	0.4	33,190	0.4
East Timor	-	0.0	16,886	0.2
DKI Jakarta	13,358	0.2	8,611	0.1
Irian Jaya	340	0.0	6,307	0.1
Maluku	325	0.0	2,728	0.0
Indonesia	6,705,156	100.0	9,010,805	100.0

Source: Adapted from BPS, *Statistik Indonesia* (various issues).

[a]Provinces ranked in decending order by their 1987-89 share of the national total.

Table A2.4: *Regional Area Harvested of all Rice, 1969-89*

	Sumatra	Java: West Java	Java: DKI Jakarta	Java: Central Java	Java: DI Yogyakarta	Java: East Java	Java: Total	Bali & Nusatenggara	Kalimantan	Sulawesi	Maluku and Irian Jaya	Indonesia
						(*hectares*)						
1969	1,893,021	1,701,348	16,754	1,238,763	119,241	1,217,985	4,294,091	449,801	672,822	696,425	7,463	8,013,623
1970	1,883,885	1,713,528	14,008	1,250,246	123,802	1,200,618	4,302,202	488,215	724,106	723,853	12,817	8,135,078
1971	1,983,335	1,772,046	14,059	1,278,379	128,792	1,222,922	4,416,198	476,170	709,048	728,442	11,192	8,324,385
1972	1,924,877	1,715,541	13,472	1,259,347	132,212	1,215,070	4,335,642	469,260	690,754	551,339	11,528	7,983,400
1973	1,988,426	1,860,500	10,516	1,302,893	135,373	1,252,695	4,561,977	467,278	711,609	638,737	14,540	8,382,567
1974	1,916,855	1,892,209	10,837	1,350,729	147,134	1,323,227	4,724,136	487,622	724,744	669,507	14,132	8,536,996
1975	1,887,088	1,864,344	9,120	1,306,186	145,810	1,327,810	4,653,270	473,579	741,789	721,332	18,038	8,495,096
1976	1,913,699	1,802,374	13,210	1,183,574	128,300	1,338,111	4,465,569	479,938	772,688	712,707	24,158	8,368,759
1977	1,951,595	1,692,177	18,084	1,236,231	118,324	1,312,903	4,377,719	467,343	790,672	747,943	24,296	8,359,568
1978	2,006,547	1,861,234	19,400	1,360,848	138,171	1,370,646	4,750,299	514,882	805,112	828,113	24,216	8,929,169
1979	2,026,337	1,805,862	18,496	1,291,917	114,628	1,397,593	4,628,496	500,389	818,552	808,134	21,656	8,803,564
1980	2,049,288	1,859,239	21,008	1,338,645	129,430	1,428,817	4,777,139	532,652	805,461	813,845	26,680	9,005,065
1981	2,095,981	1,944,531	16,558	1,415,449	151,934	1,517,503	5,045,975	550,871	849,299	811,485	28,228	9,381,839
1982	2,142,001	1,797,745	14,106	1,321,263	142,044	1,473,915	4,749,073	547,422	811,954	721,809	16,196	8,988,455
1983	2,275,542	1,832,110	9,601	1,316,356	136,848	1,484,240	4,779,155	533,511	749,865	807,391	17,005	9,162,469
1984	2,334,681	2,012,602	9,738	1,473,123	151,794	1,564,342	5,211,599	535,828	794,712	868,270	18,490	9,763,580
1985	2,340,693	2,085,193	10,424	1,495,191	139,362	1,571,237	5,301,407	531,825	811,266	900,397	16,705	9,902,293
1986	2,357,475	2,082,038	9,518	1,505,033	140,541	1,593,430	5,330,560	531,034	831,754	927,369	10,261	9,988,453
1987	2,436,435	2,036,709	8,946	1,464,953	137,489	1,537,041	5,185,138	546,164	839,402	902,047	13,408	9,922,594
1988	2,537,767	2,043,843	8,501	1,473,429	137,675	1,544,331	5,207,779	549,303	864,403	956,174	22,729	10,138,155
1989	2,498,932	2,128,790	8,385	1,547,245	142,235	1,612,530	5,439,185	581,688	871,334	1,040,888	20,692	10,452,719

Table A2.4: *Regional Area Harvested of all Rice, 1969-89*

		Java										
	Sumatra	West Java	**DKI Jakarta**	Central Java	DI Yogyakarta	East Java	Total	Bali & Nusatenggara	Kalimantan	Sulawesi	Maluku and Irian Jaya	Indonesia
Annual growth rate												
	%	%	%	%	%	%	%	%	%	%	%	%
1969-74	0.25	2.15	-8.34	1.75	4.29	1.67	1.93	1.63	1.50	-0.79	13.62	1.27
1975-79	1.80	-0.79	19.34	-0.27	-5.84	1.29	-0.13	1.39	2.49	2.88	4.68	0.90
1980-84	3.31	2.00	-17.49	2.42	4.07	2.29	2.20	0.15	-0.34	1.63	-8.76	2.04
1985-89	1.65	0.52	-5.30	0.86	0.51	0.65	0.64	2.27	1.80	3.69	5.50	1.36
1969-89	*1.40*	*1.13*	*-3.40*	*1.12*	*0.89*	*1.41*	*1.19*	*1.29*	*1.30*	*2.03*	*5.23*	*1.34*

Note: *Sumatra* includes the provinces of Aceh, North, West, and South Sumatra, Riau, Jambi, Bengkulu and, Lampung; *Bali & Nusatenggara* includes East and West Nusatenggara, Bali, East Timor; *Kalimantan* includes West, Central, South, and East Kalimantan; *Sulawesi* includes North, Central, South and South East Sulawesi.

Source: Adapted from BPS, *Statistik Indonesia* (various issues).

Table A2.5: *Regional Area Harvested for Upland Rice, 1969-89*

	Sumatra	Java						Bali & Nusatenggara[a]	Kalimantan	Sulawesi	Maluku and Irian Jaya	Indonesia
		West Java	DKI Jakarta	Central Java	DI Yogyakarta	East Java	Total					
							(hectares)					
1969	612,920	183,697	2,807	47,449	37,554	75,146	346,653	124,384	252,149	126,538	7,006	1,469,650
1970	567,259	187,694	1,045	51,706	37,554	65,069	343,068	144,901	262,930	125,927	12,262	1,456,347
1971	587,663	195,175	895	57,039	40,907	72,081	366,097	103,740	238,822	125,091	10,209	1,431,622
1972	551,357	162,782	1,027	49,356	44,153	71,466	328,784	112,066	228,734	79,062	10,606	1,310,609
1973	505,863	156,070	255	51,952	37,987	70,722	316,986	107,584	198,131	90,153	12,315	1,231,032
1974	449,048	130,193	90	48,793	42,330	64,899	286,305	105,613	220,601	87,871	11,881	1,161,319
1975	467,637	108,340	77	47,705	43,304	65,419	264,845	107,863	211,815	91,293	17,169	1,160,622
1976	441,662	102,091	160	43,389	42,302	61,098	249,040	102,804	226,445	96,107	23,284	1,139,342
1977	467,500	114,001	320	36,904	35,981	57,649	244,855	90,882	230,905	99,670	23,396	1,157,208
1978	477,472	128,516	537	52,014	44,718	61,012	286,797	97,994	233,455	112,422	22,620	1,230,760
1979	434,166	97,778	1,384	43,518	16,123	59,188	217,991	92,860	248,915	114,408	20,106	1,128,446
1980	448,675	115,302	489	42,347	29,751	60,313	248,202	109,885	240,600	108,779	24,878	1,181,019
1981	426,390	109,350	274	43,594	43,587	69,678	266,483	109,067	253,397	109,031	26,451	1,190,819
1982	426,611	95,241	232	39,622	41,675	70,869	247,639	92,918	241,486	93,016	14,185	1,115,855
1983	483,313	129,918	56	48,294	34,083	78,372	290,723	90,472	202,361	94,186	14,505	1,175,560
1984	455,849	162,424	39	60,099	41,950	85,531	350,043	80,923	224,125	89,360	16,155	1,216,455
1985	434,595	153,495	-	61,259	35,969	77,698	328,421	74,421	216,203	79,104	13,828	1,146,572
1986	378,261	144,202	-	67,297	36,352	85,441	333,292	73,588	239,320	70,756	5,224	1,100,441
1987	416,525	132,085	-	57,249	40,516	81,547	311,397	72,377	254,460	62,897	8,617	1,126,273
1988	441,303	153,073	-	65,870	40,070	88,918	347,931	76,504	263,503	71,582	11,958	1,212,781
1989	413,623	155,064	-	62,346	40,684	91,555	349,649	74,568	234,823	60,185	9,150	1,141,998

Table A2.5: *Regional Area Harvested for Upland Rice, 1969-89*

	Sumatra	Java						Bali & Nusatenggara[a]	Kalimantan	Sulawesi	Maluku and Irian Jaya	Indonesia
		West Java	DKI Jakarta	Central Java	DI Yogyakarta	East Java	Total					
Annual growth rate												
1969-74	-6.03	-6.65	-49.74	0.56	2.42	-2.89	-3.75	-3.22	-2.64	-7.03	11.14	-4.60
1975-79	-1.84	-2.53	105.90	-2.27	-21.89	-2.47	-4.75	-3.67	4.12	5.80	4.03	-0.70
1980-84	0.40	8.94	-46.86	9.15	8.97	9.13	8.98	-7.36	-1.76	-4.80	-10.23	0.74
1985-89	-1.23	0.25	-	0.44	3.13	4.19	1.58	0.05	2.09	-6.61	-9.81	-0.10
1969-89	*-1.95*	*-0.84*	*-24.81*[b]	*1.37*	*0.40*	*0.99*	*0.04*	*-2.53*	*-0.36*	*-3.65*	*1.34*	*-1.25*

Source: Adapted from BPS, *Statistik Indonesia* (various issues).

[a]Bali and Nusatenggara includes East Timor.
[b]Represents rate of growth for the 1969-84 period.

Table A2.6: *Regional Area Harvested for Lowland Rice, 1969-89*

		Java										
	Sumatra	West Java	DKI Jakarta	Central Java	DI Yogyakarta	East Java	Total	Bali & Nusatenggara[a]	Kalimantan	Sulawesi	Maluku and Irian Jaya	Indonesia
						(hectares)						
1969	1,280,101	1,517,651	13,947	1,191,314	81,687	1,142,839	3,947,438	325,417	420,673	569,887	457	6,543,973
1970	1,316,626	1,525,834	12,963	1,198,540	86,248	1,135,549	3,959,134	343,314	461,176	597,926	555	6,678,731
1971	1,395,672	1,576,871	13,164	1,221,340	87,885	1,150,841	4,050,101	372,430	470,226	603,351	983	6,892,763
1972	1,373,520	1,552,759	12,445	1,209,991	88,059	1,143,604	4,006,858	357,194	462,020	472,277	922	6,672,791
1973	1,482,563	1,704,430	10,261	1,250,941	97,386	1,181,973	4,244,991	359,694	513,478	548,584	2,225	7,151,535
1974	1,467,807	1,762,016	10,747	1,301,936	104,804	1,258,328	4,437,831	382,009	504,143	581,636	2,251	7,375,677
1975	1,419,451	1,756,004	9,043	1,258,481	102,506	1,262,391	4,388,425	365,716	529,974	630,039	869	7,334,474
1976	1,472,037	1,700,283	13,050	1,140,185	85,998	1,277,013	4,216,529	377,134	546,243	616,600	874	7,229,417
1977	1,484,095	1,578,176	17,764	1,199,327	82,343	1,255,254	4,132,864	376,461	559,767	648,273	900	7,202,360
1978	1,529,075	1,732,718	18,863	1,308,834	93,453	1,309,634	4,463,502	416,888	571,657	715,691	1,596	7,698,409
1979	1,592,171	1,708,084	17,112	1,248,399	98,505	1,338,405	4,410,505	407,529	569,637	693,726	1,550	7,675,118
1980	1,600,613	1,743,937	20,519	1,296,298	99,679	1,368,504	4,528,937	422,767	564,861	705,066	1,802	7,824,046
1981	1,669,591	1,835,181	16,284	1,371,855	108,347	1,447,825	4,779,492	441,804	595,902	702,454	1,777	8,191,020
1982	1,715,390	1,702,504	13,874	1,281,641	100,369	1,403,046	4,501,434	454,504	570,468	628,793	2,011	7,872,600
1983	1,792,229	1,702,192	9,545	1,268,062	102,765	1,405,868	4,488,432	443,039	547,504	713,205	2,500	7,986,909
1984	1,878,832	1,850,178	9,699	1,413,024	109,844	1,478,811	4,861,556	454,905	570,587	778,910	2,335	8,547,125
1985	1,906,098	1,931,698	10,424	1,433,932	103,393	1,493,539	4,972,986	457,404	595,063	821,293	2,877	8,755,721
1986	1,979,214	1,937,836	9,518	1,437,736	104,189	1,507,989	4,997,268	457,446	592,434	856,613	5,037	8,888,012
1987	2,019,910	1,904,624	8,946	1,407,704	96,973	1,455,494	4,873,741	473,787	584,942	839,150	4,791	8,796,321
1988	2,096,464	1,890,770	8,501	1,407,559	97,605	1,455,413	4,859,848	472,799	600,900	884,592	10,771	8,925,374
1989	2,085,309	1,973,726	8,385	1,484,899	101,551	1,520,975	5,089,536	507,120	636,511	980,703	11,542	9,310,721

Table A2.6: *Regional Area Harvested for Lowland Rice, 1969-89*

		Java										
	Sumatra	West Java	DKI Jakarta	Central Java	DI Yogyakarta	East Java	Total	Bali & Nusatenggara[a]	Kalimantan	Sulawesi	Maluku and Irian Jaya	Indonesia
Annual growth rate												
	%	%	%	%	%	%	%	%	%	%	%	%
1969-74	2.77	3.03	-5.08	1.79	5.11	1.94	2.37	3.26	3.69	0.41	37.56	2.42
1975-79	2.91	-0.69	17.29	-0.20	-0.99	1.47	0.13	2.74	1.82	2.44	15.57	1.14
1980-84	4.09	1.49	-17.08	2.18	2.46	1.96	1.79	1.85	0.25	2.52	6.69	2.23
1985-89	2.27	0.54	-5.30	0.88	-0.45	0.46	0.58	2.61	1.70	4.53	41.53	1.55
1969-89	*2.47*	*1.32*	*-2.51*	*1.11*	*1.09*	*1.44*	*1.28*	*2.24*	*2.09*	*2.75*	*17.52*	*1.78*

Source: Adapted from BPS, *Statistik Indonesia* (various issues).

[a]Bali and Nusatenggara includes East Timor.

Table A2.7: *Soybean Area Harvested by Province*

	Soybean			
	1969-71		1987-89	
Province[a]	Area	Share of national total	Area	Share of national total
	(hectares)	%	*(hectares)*	%
East Java	377,792	58.8	388,654	33.6
Central Java	122,825	19.1	147,154	12.7
Aceh	1,739	0.3	108,908	9.4
Lampung	14,068	2.2	106,984	9.3
West Nusa Tenggara	43,824	6.8	98,286	8.5
West Java	25,789	4.0	59,531	5.2
DI Yogyakarta	24,862	3.9	54,809	4.7
South Sulawesi	6,069	0.9	33,505	2.9
North Sulawesi	382	0.1	26,104	2.3
North Sumatra	7,644	1.2	25,584	2.2
Bali	11,604	1.8	22,121	1.9
West Sumatra	735	0.1	16,323	1.4
South Sumatra	960	0.1	15,753	1.4
Central Sulawesi	990	0.2	7,221	0.6
Riau	72	0.0	6,949	0.6
Irian Jaya	35	0.0	6,425	0.6
Jambi	179	0.0	6,199	0.5
S. E. Sulawesi	109	0.0	5,387	0.5
Central Kalimantan	1	0.0	3,913	0.3
East Kalimantan	138	0.0	3,521	0.3
South Kalimantan	471	0.1	3,477	0.3
Bengkulu	249	0.0	3,157	0.3
West Kalimantan	826	0.1	2,186	0.2
East Nusa Tenggara	328	0.1	1,527	0.1
Maluku	1,022	0.2	1,139	0.1
East Timor	-	-	196	-
DKI Jakarta	-	-	-	-
Indonesia	642,713	100.0	1,155,013	100.0

Source: Adapted from BPS, *Statistik Indonesia* (various issues).

[a]Provinces ranked in decending order by their 1987-89 share of national total.

Table A2.8: *Regional Area Harvested for Soybean, 1969-89*

	Sumatra	Java					Bali & Nusatenggara[a]	Kalimantan	Sulawesi	Maluku and Irian Jaya	Indonesia
		West Java	Central Java	DI Yogyakarta	East Java	Total					
						(hectares)					
1969	27,240	23,816	76,246	23,629	351,900	475,591	40,271	1,187	9,131	363	553,783
1970	24,247	26,230	145,529	25,593	399,365	596,717	61,816	1,340	8,100	2,512	694,732
1971	25,452	27,321	146,700	25,365	382,110	581,496	65,180	1,784	5,418	295	679,625
1972	38,334	24,723	125,152	29,976	402,198	582,049	69,020	3,113	4,570	414	697,500
1973	56,378	34,246	172,953	28,374	371,344	606,917	74,883	3,226	8,775	327	750,506
1974	67,463	37,665	165,472	33,853	358,983	595,973	75,162	3,168	11,419	314	753,499
1975	58,113	28,339	147,716	31,262	393,763	601,080	78,260	3,180	10,724	332	751,689
1976	58,869	28,650	102,261	26,798	341,335	499,044	70,430	3,707	13,908	322	646,280
1977	53,051	20,924	131,980	30,830	333,676	517,410	51,708	3,839	19,948	323	646,278
1978	56,292	30,750	174,353	39,236	349,578	593,917	58,480	4,107	18,601	1,543	732,941
1979	72,283	25,359	170,968	49,370	373,712	619,410	59,573	4,335	26,634	1,782	784,018
1980	62,664	29,130	135,735	48,490	373,113	586,469	47,365	4,356	29,488	1,653	731,995
1981	73,563	31,237	171,011	55,004	395,505	652,757	56,820	2,553	22,127	2,275	810,095
1982	62,091	23,374	85,150	40,178	313,544	462,245	56,736	2,850	22,755	1,033	607,710
1983	71,679	28,052	126,127	35,606	285,087	474,871	53,765	4,398	31,752	3,310	639,776
1984	119,581	67,060	156,224	58,162	336,340	617,786	70,897	6,812	40,687	3,091	858,854
1985	181,252	50,236	137,503	43,948	350,072	581,759	80,003	7,907	41,952	3,347	896,220
1986	312,230	88,656	168,999	64,277	411,884	733,816	115,125	14,746	71,901	5,949	1,253,767
1987	286,550	53,215	125,348	54,030	380,873	613,466	100,793	13,190	78,871	7,695	1,100,565
1988	292,897	61,077	150,158	56,789	388,386	656,410	122,834	14,304	81,674	9,241	1,177,360
1989	290,124	64,301	165,955	53,608	396,703	680,568	142,765	11,800	56,103	5,755	1,187,114

Table A2.8: *Regional Area Harvested for Soybean, 1969-89*

	Sumatra	Java					Bali &	Kalimantan	Sulawesi	Maluku and	Indonesia
		West Java	Central Java	DI Yogyakarta	East Java	Total	Nusatenggara[a]			Irian Jaya	
Annual growth rate											
	%	%	%	%	%	%	%	%	%	%	%
1969-74	16.36	3.54	14.14	5.76	2.27	4.79	14.21	21.79	3.27	-1.77	6.30
1975-79	5.61	-2.74	3.72	12.10	-1.30	0.75	-6.59	8.06	25.54	52.21	1.06
1980-84	17.53	23.18	3.58	4.65	-2.56	1.31	10.61	11.83	8.38	16.94	4.08
1985-89	12.48	6.37	4.81	5.09	3.18	4.00	15.58	10.53	7.54	14.51	7.28
1969-89	12.56	5.09	3.97	4.18	0.60	1.81	6.53	12.17	9.50	14.82	3.89

Source: Adapted from BPS, *Statistik Indonesia* (various issues).

[a]Bali and Nusatenggara includes East Timor.

Table A2.9: *Regional Total Rice Yields, 1969-89*

		Java											
	Sumatra	West	Jakarta	Central	Yogyakarta	East	Total	Bali and Nusatenggara[a]	Kalimantan	Sulawesi	Maluku and Irian Jaya	Indonesia
							(kilograms per hectare)					
1969	1,451	1,707	1,307	1,601	1,498	1,986	1,748	1,313	829	1,215	561	1,529
1970	1,520	1,708	841	1,931	1,543	1,954	1,834	1,323	887	1,516	564	1,616
1971	1,458	1,821	1,018	1,997	1,724	1,984	1,912	1,396	867	1,520	744	1,649
1972	1,515	1,793	1,222	1,875	1,623	2,009	1,870	1,424	940	1,520	622	1,652
1973	1,581	1,871	1,312	1,981	1,703	2,044	1,944	1,724	1,011	1,673	492	1,743
1974	1,664	1,878	1,588	2,017	1,899	2,166	1,999	1,798	1,082	1,471	420	1,790
1975	1,665	1,943	1,509	2,005	1,925	2,106	2,006	1,766	1,033	1,530	515	1,788
1976	1,745	2,074	1,591	2,136	1,979	2,257	2,141	1,829	1,072	1,717	515	1,893
1977	1,754	2,031	1,730	2,098	1,946	2,316	2,132	1,811	1,168	1,787	498	1,899
1978	1,747	2,104	1,651	2,247	2,083	2,417	2,233	1,837	1,238	1,760	513	1,963
1979	1,816	2,208	1,738	2,178	2,405	2,554	2,307	1,926	1,331	1,800	579	2,031
1980	1,884	2,412	2,011	2,630	2,488	2,909	2,622	2,057	1,374	1,910	708	2,239
1981	1,974	2,548	2,160	2,768	2,463	3,082	2,767	2,251	1,439	2,101	756	2,375
1982	2,100	2,811	2,373	2,972	2,628	3,253	2,986	2,354	1,490	2,281	761	2,541
1983	2,146	2,884	2,337	3,152	2,868	3,274	3,077	2,438	1,538	2,410	943	2,620
1984	2,183	2,881	2,425	3,187	2,870	3,301	3,092	2,498	1,523	2,480	898	2,656
1985	2,227	2,942	2,450	3,171	2,918	3,287	3,107	2,500	1,540	2,513	965	2,680
1986	2,278	2,968	2,949	3,175	2,934	3,284	3,120	2,533	1,545	2,556	1,245	2,705
1987	2,295	3,092	2,918	3,281	2,896	3,357	3,219	2,561	1,550	2,501	1,234	2,747
1988	2,343	3,173	3,089	3,326	2,957	3,393	3,276	2,636	1,586	2,589	1,400	2,795
1989	2,455	3,300	3,208	3,434	3,050	3,485	3,386	2,743	1,645	2,726	1,487	2,913
Annual growth rate												
	%	%	%	%	%	%	%	%	%	%	%	%
1969-74	2.78	1.93	3.98	4.73	4.85	1.75	2.71	6.48	5.46	3.88	-5.62	3.20
1975-79	2.20	3.24	3.59	2.08	5.72	4.94	3.56	2.19	6.54	4.16	2.95	3.23
1980-84	3.75	4.55	4.79	4.91	3.64	3.21	4.21	4.98	2.60	6.75	6.11	4.36
1985-89	2.47	2.91	6.97	2.02	1.11	1.47	2.17	2.35	1.66	2.06	11.41	2.10
1969-89	*2.66*	*3.35*	*4.59*	*3.89*	*3.62*	*2.85*	*3.36*	*3.75*	*3.49*	*4.12*	*4.99*	*3.28*

Source: Adapted from BPS, *Statistik Indonesia* (various issues)

Note: Yields are given in milled-rice equivalent units.

[a]Bali and Nusatenggara includes East Timor.

Table A2.10: *Regional Upland Rice Yields, 1969-89*

	Sumatra	Java: West	Java: Jakarta	Java: Central	Java: Yogyakarta	Java: East	Java: Total	Bali and Nusatenggara[a]	Kalimantan	Sulawesi	Maluku and Irian Jaya	Indonesia
							(kilograms per hectare)					
1969	788	763	776	771	472	885	759	584	672	721	526	737
1970	854	800	746	796	572	863	787	600	613	751	528	758
1971	801	741	790	827	769	887	786	776	602	753	686	757
1972	830	866	705	801	688	910	841	528	641	863	558	774
1973	977	837	940	1,105	759	1,168	945	796	812	1,033	399	925
1974	874	839	821	988	721	858	851	769	726	889	376	827
1975	933	916	851	983	881	898	918	737	762	866	477	868
1976	925	963	752	953	894	870	927	851	748	814	484	865
1977	987	1,050	686	1,018	890	883	982	794	787	801	460	904
1978	955	1,010	719	1,118	1,118	902	1,023	693	755	742	471	884
1979	1,006	1,038	704	1,103	802	967	1,012	740	895	831	524	935
1980	1,020	1,077	1,018	1,167	1,091	1,034	1,083	802	841	869	659	955
1981	1,031	1,176	1,022	1,230	1,073	1,351	1,214	880	914	960	708	1,020
1982	1,142	1,255	1,158	1,302	1,156	1,353	1,274	939	980	1,010	639	1,102
1983	1,169	1,284	1,069	1,341	1,318	1,413	1,332	1,014	1,017	1,107	812	1,162
1984	1,156	1,387	1,098	1,466	1,464	1,492	1,436	978	993	1,085	788	1,185
1985	1,131	1,426	-	1,495	1,517	1,589	1,487	912	1,013	1,077	834	1,189
1986	1,185	1,419	-	1,510	1,522	1,606	1,496	988	1,034	1,131	806	1,228
1987	1,238	1,491	-	1,604	1,546	1,657	1,562	1,123	1,088	1,047	929	1,273
1988	1,294	1,492	-	1,637	1,569	1,661	1,572	1,209	1,120	1,125	1,009	1,318
1989	1,398	1,573	-	1,709	1,625	1,781	1,658	1,297	1,145	1,198	1,099	1,406
Annual growth rate												
	%	%	%	%	%	%	%	%	%	%	%	%
1969-74	2.10	1.93	1.12	5.10	8.83	-0.63	2.32	5.65	1.58	4.26	-6.52	2.33
1975-79	1.91	3.17	-4.65	2.90	-2.33	1.86	2.47	0.11	4.11	-1.01	2.37	1.86
1980-84	3.18	6.54	1.92	5.87	7.63	9.62	7.29	5.09	4.25	5.71	4.58	5.53
1985-89	5.44	2.47	--	3.40	1.72	2.90	2.74	9.20	3.12	2.71	7.14	4.27
1969-89	*2.91*	*3.69*	*2.34*[b]	*4.06*	*6.37*	*3.56*	*3.98*	*4.07*	*2.71*	*2.57*	*3.75*	*3.28*

Source: Adapted from BPS, *Statistik Indonesia* (various issues).

Note: Yields are given in milled-rice equivalent units.

[a]Bali and Nusatenggara includes East Timor.
[b]For the period 1969 to 1984.

Table A2.11: *Regional Lowland Rice Yields, 1969-89*

		Java										
	Sumatra	West	Jakarta	Central	Yogyakarta	East	Total	Bali and Nusatenggara[a]	Kalimantan	Sulawesi	Maluku and Irian Jaya	Indonesia
							(kilograms per hectare)					
1969	1,769	1,822	1,414	1,634	1,970	2,058	1,835	1,592	923	1,325	1,096	1,707
1970	1,807	1,819	849	1,980	1,965	2,016	1,924	1,629	1,043	1,677	1,352	1,803
1971	1,735	1,954	1,034	2,052	2,169	2,053	2,013	1,569	1,002	1,679	1,353	1,835
1972	1,790	1,890	1,264	1,918	2,091	2,078	1,955	1,705	1,088	1,630	1,361	1,824
1973	1,787	1,966	1,321	2,018	2,071	2,097	2,018	2,001	1,088	1,778	1,003	1,884
1974	1,906	1,955	1,595	2,055	2,374	2,233	2,073	2,082	1,237	1,558	655	1,942
1975	1,906	2,007	1,515	2,044	2,366	2,169	2,072	2,069	1,141	1,626	1,272	1,934
1976	1,992	2,141	1,601	2,181	2,513	2,323	2,213	2,096	1,206	1,858	1,322	2,055
1977	1,996	2,102	1,748	2,132	2,408	2,382	2,200	2,056	1,326	1,939	1,481	2,059
1978	1,994	2,185	1,678	2,292	2,544	2,488	2,311	2,106	1,435	1,920	1,119	2,135
1979	2,037	2,275	1,822	2,215	2,667	2,624	2,371	2,196	1,522	1,960	1,293	2,192
1980	2,127	2,500	2,035	2,678	2,905	2,991	2,706	2,383	1,601	2,070	1,388	2,433
1981	2,215	2,630	2,179	2,817	3,022	3,166	2,853	2,589	1,662	2,278	1,467	2,573
1982	2,339	2,898	2,394	3,023	3,239	3,349	3,080	2,643	1,706	2,468	1,621	2,745
1983	2,409	3,006	2,344	3,221	3,382	3,378	3,190	2,729	1,731	2,582	1,701	2,835
1984	2,433	3,012	2,430	3,260	3,407	3,405	3,212	2,769	1,731	2,640	1,655	2,865
1985	2,476	3,063	2,450	3,242	3,406	3,377	3,214	2,758	1,732	2,651	1,592	2,876
1986	2,486	3,084	2,949	3,253	3,427	3,397	3,228	2,782	1,751	2,674	1,700	2,887
1987	2,513	3,204	2,918	3,350	3,461	3,452	3,325	2,780	1,751	2,610	1,783	2,935
1988	2,564	3,309	3,089	3,405	3,528	3,499	3,398	2,867	1,791	2,707	1,834	2,995
1989	2,664	3,436	3,208	3,507	3,621	3,587	3,505	2,956	1,829	2,820	1,793	3,098
Annual growth rate												
	%	%	%	%	%	%	%	%	%	%	%	%
1969-74	1.50	1.42	2.44	4.70	3.81	1.65	2.46	5.52	6.02	3.29	-9.78	2.61
1975-79	1.68	3.18	4.72	2.03	3.04	4.88	3.43	1.50	7.45	4.79	0.41	3.18
1980-84	3.42	4.77	4.54	5.04	4.07	3.29	4.37	3.82	1.97	6.27	4.50	4.18
1985-89	1.84	2.91	6.97	1.98	1.55	1.53	2.19	1.75	1.38	1.55	3.02	1.88
1969-89	*2.07*	*3.22*	*4.18*	*3.89*	*3.09*	*2.82*	*3.29*	*3.14*	*3.48*	*3.85*	*2.49*	*3.03*

Source: Adapted from BPS, *Statistik Indonesia* (various issues).

Note: Yields are given in milled-rice equivalent units.

[a]Bali and Nusatenggara includes East Timor.

Table A2.12: *Regional Soybean Yields, 1969-89*

	Sumatra	Java					Bali and Nusatenggara[a]	Kalimantan	Sulawesi	Maluku and Irian Jaya	Indonesia
		West	Central	Yogyakarta	East	Total					
							(kilograms per hectare)				
1969	604	638	683	689	731	717	594	661	742	424	702
1970	766	603	643	533	767	719	688	657	692	408	717
1971	686	796	755	515	801	777	636	642	667	797	759
1972	692	825	690	684	794	767	579	625	621	710	743
1973	849	667	723	689	732	724	611	620	645	945	721
1974	1048	735	716	717	799	767	675	774	700	694	782
1975	917	738	738	678	804	778	759	665	668	684	785
1976	809	726	748	772	844	814	798	666	659	683	807
1977	857	698	785	810	825	809	817	682	692	666	809
1978	785	692	683	643	981	856	806	621	701	759	841
1979	838	690	790	637	966	880	890	653	638	761	867
1980	793	662	740	769	996	901	1,024	629	743	762	892
1981	758	671	823	734	954	888	856	647	750	769	869
1982	782	696	765	698	936	872	861	670	812	635	858
1983	837	730	790	726	888	840	788	809	884	908	838
1984	841	781	895	801	969	914	883	802	823	796	896
1985	883	813	1,019	934	1,060	1,019	876	783	905	728	970
1986	972	942	1,060	938	952	974	997	931	1,031	960	978
1987	1038	981	1,085	984	1,091	1,070	1,074	850	1,009	1,023	1,055
1988	990	1,087	1,105	1,107	1,154	1,133	1,068	865	1,032	1,008	1,079
1989	942	1,109	1,202	1,208	1,158	1,168	1,087	990	1,065	1,020	1,096
Annual growth rate											
	%	%	%	%	%	%	%	%	%	%	%
1969-74	11.65	2.87	0.95	0.79	1.78	1.37	2.61	3.20	-1.15	10.35	2.17
1975-79	-2.22	-1.65	1.73	-1.54	4.70	3.12	4.08	-0.45	-1.12	2.71	2.53
1980-84	1.49	4.22	4.88	1.04	-0.68	0.35	-3.66	6.26	2.57	1.12	0.11
1985-89	1.64	8.06	4.22	6.63	2.24	3.46	5.56	6.04	4.16	8.80	3.08
1969-89	*2.25*	*2.80*	*2.87*	*2.85*	*2.33*	*2.47*	*3.07*	*2.04*	*1.83*	*4.48*	*2.25*

Source: Adapted from BPS, *Statistik Indonesia* (various issues).

Note: Yields are given in dry-shelled equivalent units.

[a]Bali and Nusatenggara includes East Timor.

Appendix Table A4.1: *The Estimated Coefficients of Share Equations*

Variable	Coefficient	Std.Error	Asymp. T-Ratio
Land Equation			
ONE	9.44010	2.56100	3.69
LNW1	0.06964	0.00322	21.61
LNW2	-0.04937	0.00278	-17.77
LNW3	-0.00639	0.00067	-9.52
LNW4	-0.01151	0.00117	-9.86
LNW5	-0.00237	0.00099	-2.41
LNY1	-0.11184	0.01029	-10.87
LNY2	0.01007	0.00538	1.87
T	-0.00385	0.00130	-2.96
Labor Equation			
ONE	-8.64540	2.47980	-3.49
LNW1	-0.04937	0.00278	-17.77
LNW2	0.04214	0.00584	7.21
LNW3	0.00162	0.00205	0.79
LNW4	0.00886	0.00256	3.46
LNW5	-0.00325	0.00305	-1.07
LNY1	0.09616	0.01050	9.16
LNY2	-0.01104	0.00516	-2.14
T	0.00395	0.00127	3.12
Fertilizer Equation			
ONE	-3.90660	0.67396	-5.80
LNW1	-0.00639	0.00067	-9.52
LNW2	0.00162	0.00205	0.79
LNW3	0.01054	0.00224	4.70
LNW4	0.00183	0.00116	1.58
LNW5	-0.00761	0.00159	-4.78
LNY1	0.01138	0.00300	3.79
LNY2	0.00179	0.00151	1.19
T	0.00193	0.00034	5.61
Pesticide, Seed and Animal Equation			
ONE	2.32570	1.17860	1.97
LNW1	-0.01151	0.00117	-9.86
LNW2	0.00886	0.00256	3.46
LNW3	0.00183	0.00116	1.58
LNW4	0.00319	0.00173	1.84
LNW5	-0.00237	0.00151	-1.57
LNY1	-0.00020	0.00512	-0.04
LNY2	0.00495	0.00260	1.90
T	-0.00112	0.00060	-1.86

Appendix Table A4.1: *The Estimated Coefficients of Share Equations*

Variable	Coefficient	Std.Error	Asymp. T-Ratio
Rice Revenue Equation			
ONE	16.44900	10.85800	1.52
LNW1	-0.11184	0.01029	-10.87
LNW2	0.09616	0.01050	9.16
LNW3	0.01138	0.00300	3.79
LNW4	-0.00020	0.00512	-0.04
LNW5	0.00450	0.00456	0.99
LNY1	0.14685	0.03718	3.95
LNY2	-0.07838	0.01478	-5.30
T	-0.00828	0.00553	-1.50
Soybean Revenue Equation			
ONE	-0.43071	7.06980	-0.06
LNW1	0.01007	0.00538	1.87
LNW2	-0.01104	0.00516	-2.14
LNW3	0.00179	0.00151	1.19
LNW4	0.00495	0.00260	1.90
LNW5	-0.00577	0.00224	-2.57
LNY1	0.03943	0.01264	3.12
LNY2	-0.07838	0.01478	-5.30
T	0.00066	0.00363	0.18

Table A5.1: *Quality Characteristics of Rice*

Quality Characteristics	Unit	Mean value[a]	Description and notes
Physical			
Moisture content	%	14.1	The majority of rice is sold at a mositure level of 14% to 15%. However moisture levels could rise to as much as 17.8% at the retail level (due partly to the common wholesale and retail practice of adding moisture to increase weight). Thus rice sold at a higher moisture level typically has a higher bulk density and would normally be consumed a few days after purchase.
Bulk density	gram / liter	810.9	
Size	mm	na	1 = extra long, 4 = short
Shape	mm	2.6	1 = slender, 2 = medium, 3 = round
Milling degree	%	83.8	The milling degree measures the degree to which the bran is removed from the kernel. The higher the milling degree the more white in appearance is the milled rice. Whiteness is also dependent on the size of the chalky embryonic portion. Poorly cleaned or damaged grains (through water logging or infestation) appear darker.
Whiteness	%	39.7	
Chalkiness	score	2.9	
Qpaque grains	%	1.2	
Yellow grains	%	2.5	
Translucency	score	2.8	
Chemical			
Protein content	%	8.0	Protein levels vary inversely to milling degree. Rice that has more of the bran removed, through polishing, has a lower protein level.
Amylose content	%	22.0	At a moderate amylose level, a high gel consistency would signal that after cooking the rice had a smooth texture (i.e., was smooth to the touch). Conversely a high alkali level, holding amylose constant, would imply that after cooking the rice was hard (or rough) and easily separating.
Gel consistency	mm	37.7	
Alkali test	score	2.7	
Water absorption[b]	gram	2.3	Water absorption is a measure of the weight of water to cooked rice. The higher the water absorption the more filling the rice would be in terms of a sustained release of energy
Rice volume[b]	cm	3.9	Volume expansion is a measure of the ratio of the volume of cooked rice to uncooked rice. The larger the volume expansion the greater the immediate feeling of satiation from a given unit weight of rice.
Cooking time	minutes	22.0	The required cooking time depends on the chemical compostion of the variety and also on the storage period.

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Table A5.1: *Quality Characteristics of Rice*

Quality Characteristics	Unit	Mean value[a]	Description and notes
Consumer taste test			
Color	score	3.5	1 = very white, 9 = very dark
Glossiness	score	3.6	1 = very shiny, 9 = very dull
Aroma	score	0.2	
Hardness	score	5.1	1 = very hard, 9 = smooth
Stickiness[c]	score	3.1	1 = very sticky, 9 = non-sticky
Consistency / stickiness	score	4.2	1 = sticky/soft, 9 = separating/hard

Source: Compiled from information reported in Tabor (1989).

[a] Mean value obtained from tests carried out as part of the May and October 1987 Urban Java Consumer Survey.

[b] Damardjati (1986) found that the rough modern rice brands, such as IR-36, have higher volume expansion and water absorption properties than the smooth modern brands such as Cisadane.

[c] Glutinous or sticky rice is used primarly for the preparation of specialty snack foods.

Figure A3.1: *Congruence between commodity share of AARD research (including AP3I) and value of production, 1990*

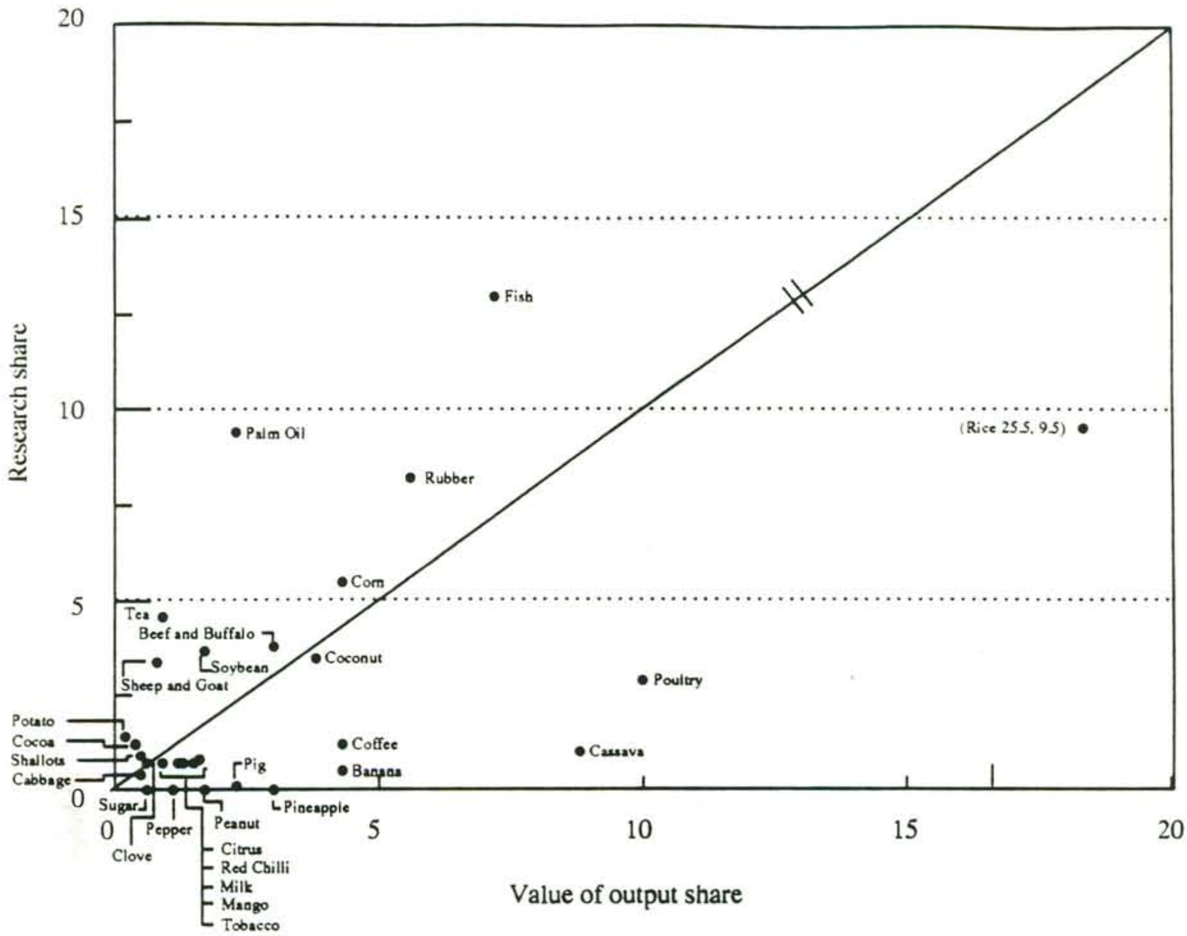


Figure A3.3: *Rice varieties by area, Java & Bali*

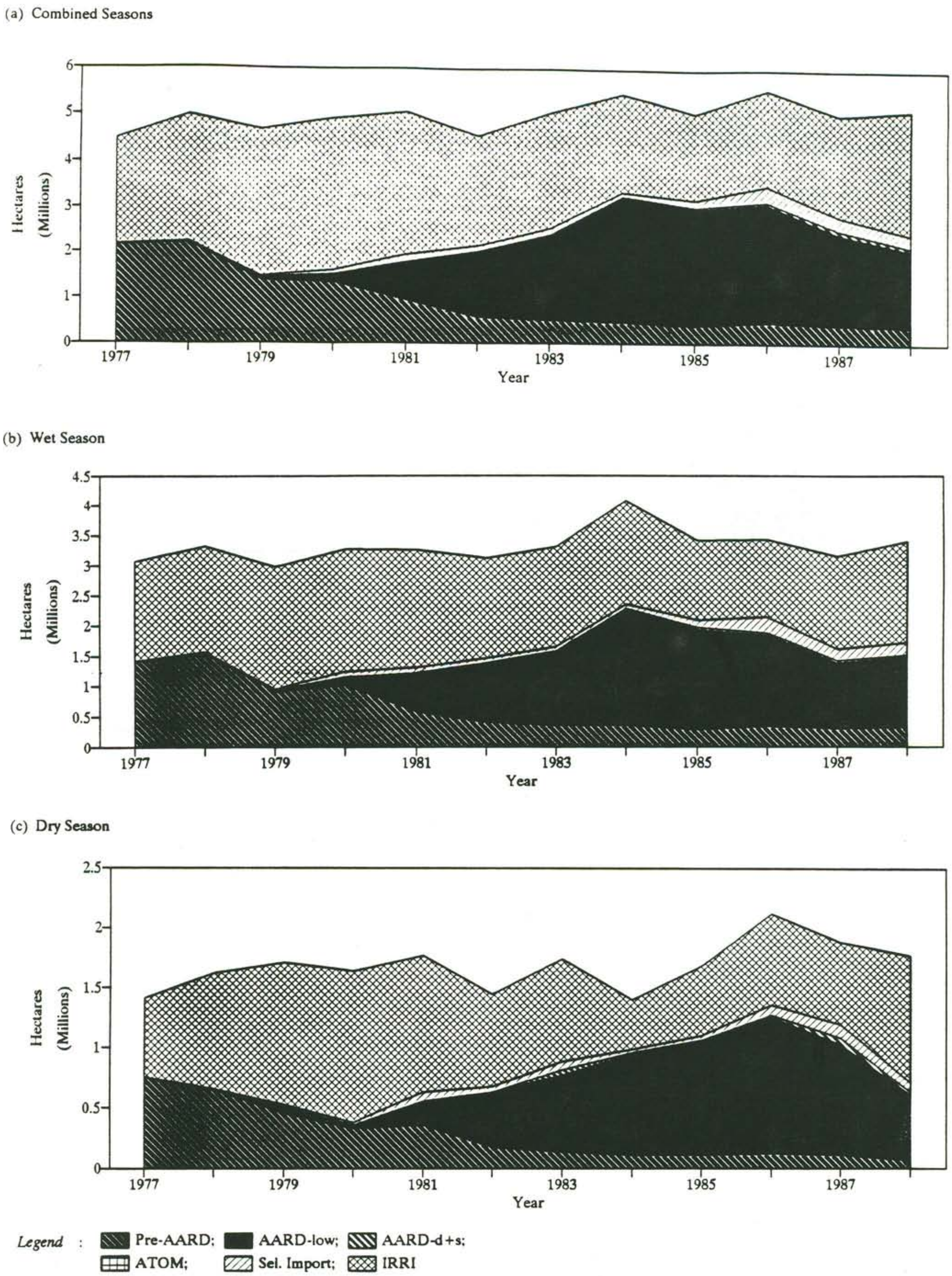


Figure A3.2: *Congruence between commodity share of AARD research (excluding AP3I) and value of production, 1990*

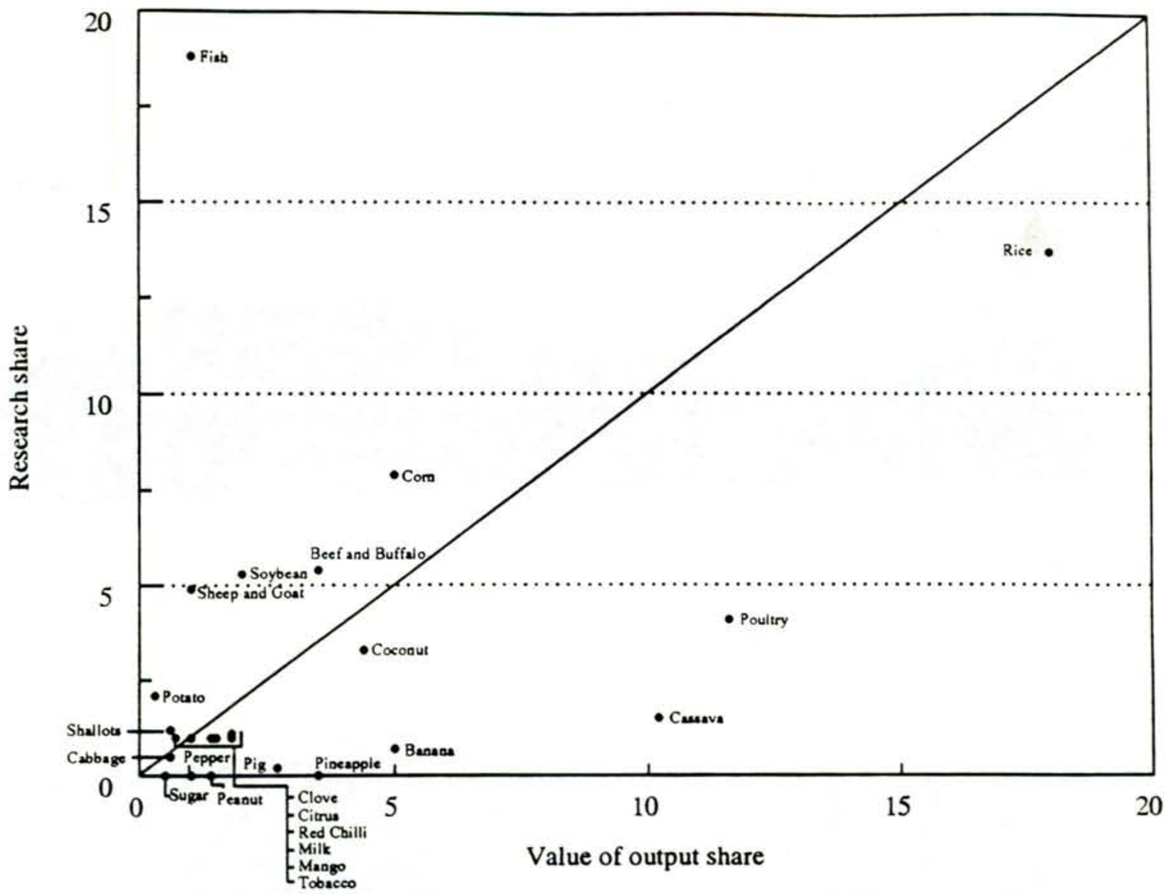


Figure A3.4: *Rice varieties by area, Sulawesi*

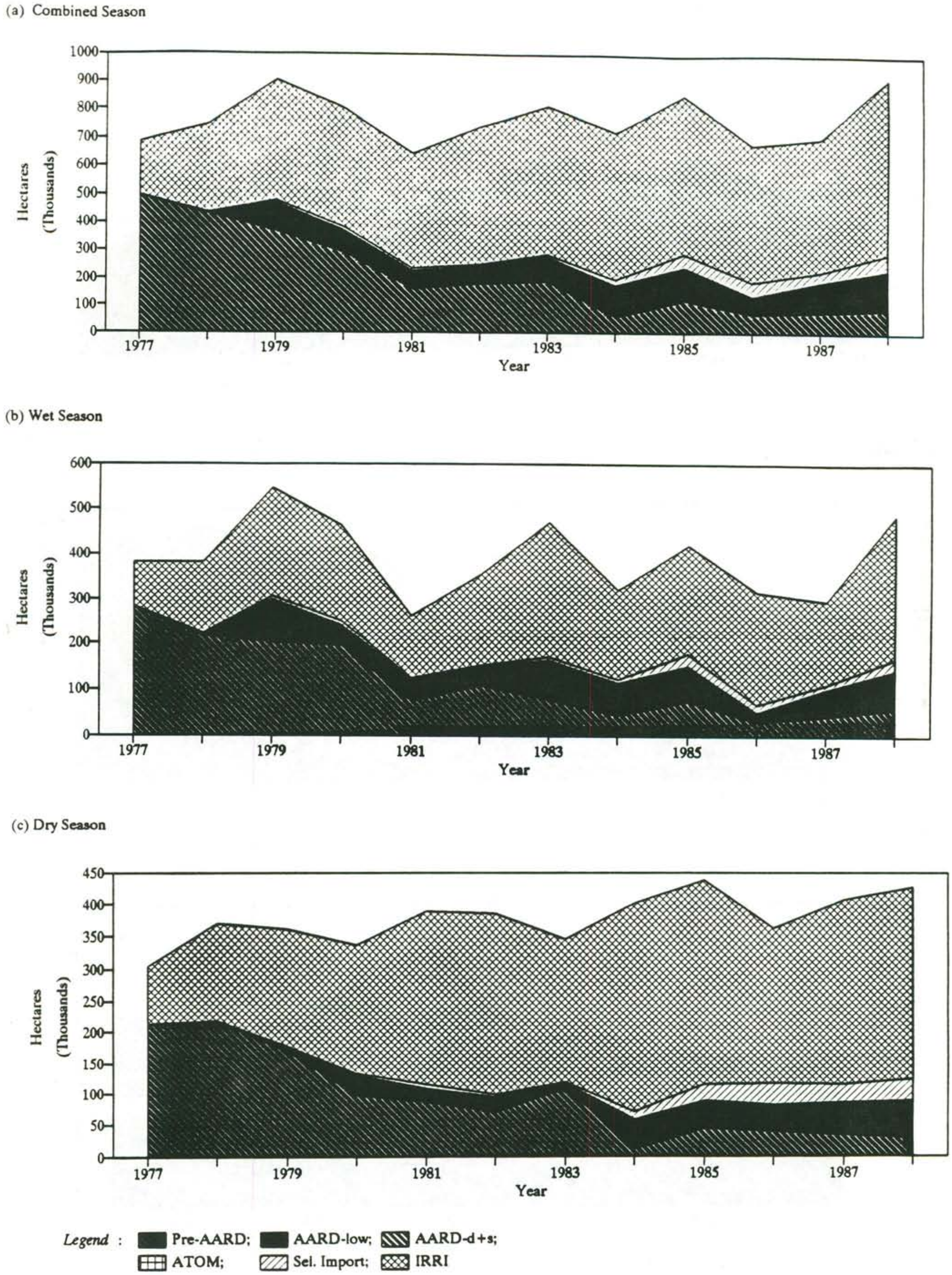
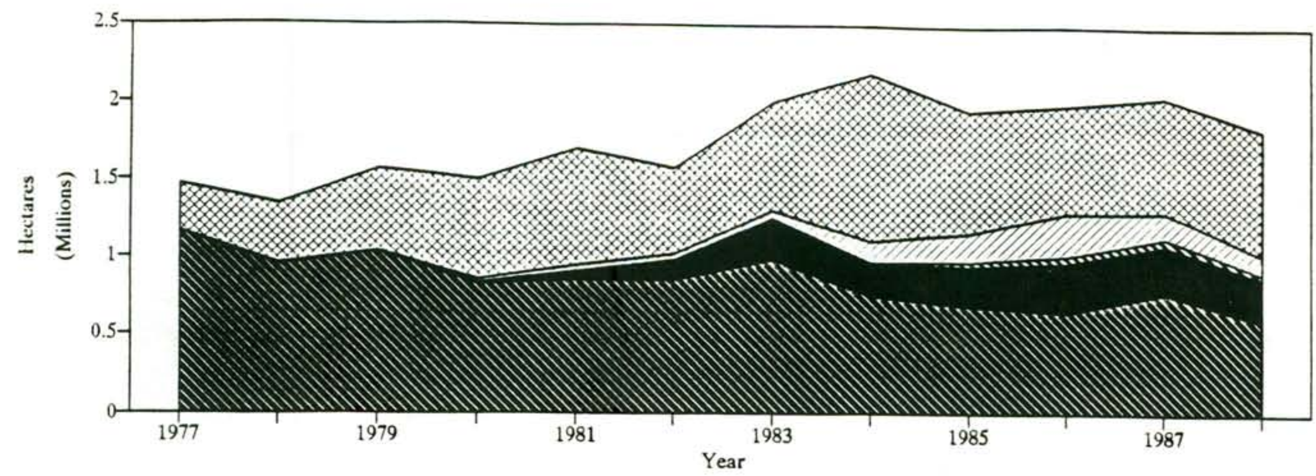
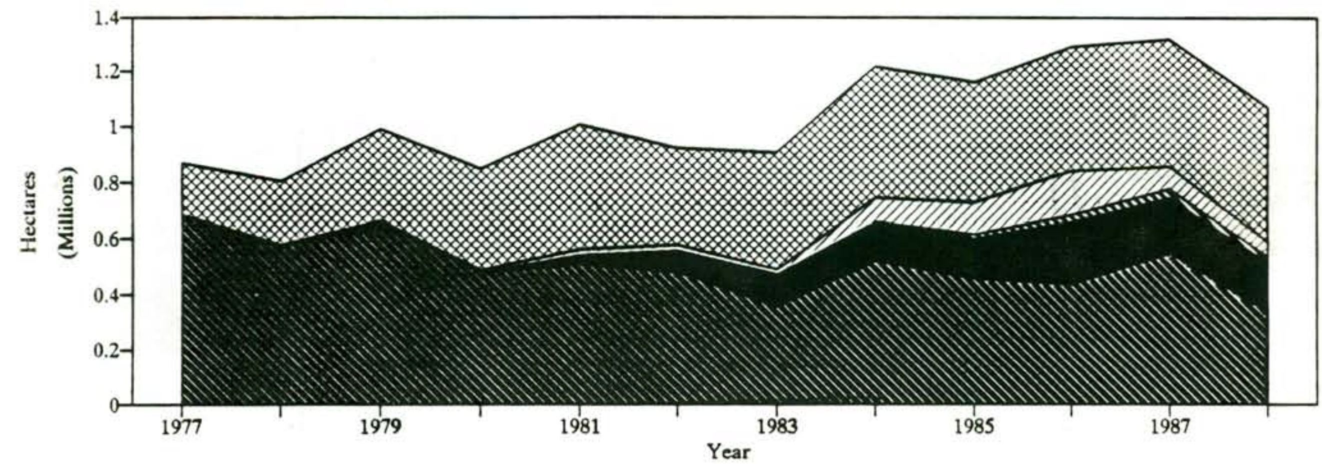


Figure A3.5: *Rice varieties by area, Sumatra*

(a) Combined Seasons



(b) Wet Season



(c) Dry Season