

AGRICULTURAL RESEARCH AND DEVELOPMENT POLICY IN INDONESIA

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PART A: OVERVIEW

A1. Broad characteristics of the Indonesian economy

Indonesia is a South-East Asian archipelago consisting of some 130,000 equatorial islands stretching in an east-west direction over 5,000 kilometers. It has a land area of 1.9 million square kilometers supporting in 2000 a population of 203.5 million (fourth largest in the world) which is growing at about 1.0 percent per annum. Whilst the overall population density is about 106 persons per square kilometer, 59 percent of the population live on the island of Java. Java has a population density of 944 persons per square kilometer. The overall ratio of urban to rural population was about 40:60 in 1999 (22:78 in 1980).

The Asian financial crisis that began in 1997 affected Indonesia severely – its economy shrank by around 15 percent between 1997 and 1998. Since then modest growth has resumed, but is substantially less than the growth rates recorded in the decades prior to the 1997 economic crisis. The global rankings published in World Development Report 200/2001 for the year 1999 place Indonesia in position 143 out of 206 economies in terms of real GNP per capita.

The extent of structural changes in the Indonesian economy between 1965 and 2000 is shown in Table 1. The population almost doubled over this period. Real GDP increased by about 750 percent and real per capita income by about 340 percent. There have been large changes in the sectoral shares of GDP, with agriculture's share declining from nearly 60 percent

to 17 percent, accompanied by significant increases in the shares of the services sector (now the dominant sector with a 44 percent share in 2000), manufacturing (26 percent) and mining, oil and gas (13 percent). Similar trends have occurred in sectoral employment shares, with agriculture's share declining from nearly 70 percent to 45 percent and the shares of services and manufacturing increasing. The services sector now accounts for almost as much employment as does the agricultural sector. The intensity of international trade has increased over the period with the share of exports in GDP almost doubling.

Table 1. Structural changes in the Indonesia economy

Indicators	1965	1975	1985	1995	2000
			(millions)		
Population	105.4	135.2	164.6	194.8	203.5
			(billions of 1999 international dollars)		
Gross Domestic Product	72.8	143.7	280.3	600.5	614.4
Share of GDP			(percent)		
Agriculture	58.7	31.7	23.7	17.1	16.9
Mining, Oil & Gas	2.5	19.7	16.3	8.8	12.9
Manufacturing	7.6	8.9	13.5	24.1	26.0
Services	31.2	39.8	46.5	49.9	44.1
Share of employment			(percent)		
Agriculture	69.2	61.6	54.7	44.0	45.3
Manufacturing	6.9	8.4	9.3	12.6	13.0
Services	23.9	30.1	36.1	43.4	41.8
			(1999 international dollars)		
Per capita income	691	1,063	1,703	3,083	3,020
			(percent)		
Exports as share of GDP	n.a.	23.4	21.9	22.6	41.1
Imports as share of GDP	n.a.	15.7	12.1	20.2	22.2

Sources: Population, GDP, sector shares, employment, exports, and imports from Statistical Yearbook of Indonesia, BPS. GDP deflator and international dollar exchange rate from World Bank and IMF.

Broad trends in the agricultural economy from the early-1960s to the mid-1990s are shown in Table 2. Real agricultural GDP has been increasing and food crop production dominates the sector at 56 percent of the total. However there has been a decline in the relative importance of crop production (food crops in particular) and increases in the relative importance of livestock, forestry and fisheries production. Indonesia possesses the second largest tropical forest (after Brazil) and among the largest salt water and coastal fishing grounds in the world. Rice production dominates the food-crop sector and production increased four-fold between the early-1960s and mid-1990s, mainly as a result of yield increases. The increased use of modern varieties and fertilizer have been important in securing higher yields. Rice remains the staple food and it is of great political importance. Cassava is the next most important food-crop after rice, closely followed by maize. Non-food “estate” crops, such as rubber, oil palm, sugar cane, and cacao, are becoming an increasingly important component of Indonesia’s agricultural sector.² Livestock production is also growing rapidly in response to the rising demand for animal protein commensurate with per capita income levels.

Although little new land is available for cropping on Java, there has been a steady increase in the area of land cropped in other islands. The number of farm households has steadily increased in both Java and elsewhere. The land constraint in Java has resulted in a decreasing average farm size (now about 0.6 hectares) but average farm size on other islands has been increasing slightly (now about 1.9 hectares).

Spending for agricultural research was at very low levels in the 1970s but doubled in real spending per farm and per capita by the 1990s. Nevertheless, Indonesia ranks near the bottom of Asian countries in agricultural research spending relative to agricultural GDP (Pardey, Roseboom and Fan, 1998).

Table 2. Trends in Indonesian agriculture

Indicators	1961-65	1971-75	1981-85	1991-95
	(millions of 1999 international dollars)			
Agricultural GDP	39,748	46,287	61,256	90,554
Agricultural research	n.a.	87.6	216.7	223.1
Share of Ag GDP	(percent)			
Food Crops	65.1	59.9	61.8	55.8
Non-food crops	17.3	17.1	15.7	16.6
Livestock	6.6	7.1	9.9	11.4
Forestry	3.0	10.3	5.7	6.9
Fisheries	8.0	5.7	6.8	9.3
Rice output (million tons of paddy)	12.4	21.2	35.8	47.5
Livestock (million head)	10.5	9.9	12.0	16.2
	(million ha)			
Total crop land	17.6	18.9	26.4	33.3
Java and Madura	9.0	8.8	8.5	8.9
Other islands	8.6	10.0	17.9	24.4
	(millions of farm households)			
Number of farms	12.14	13.88	15.63	18.10
Java and Madura	7.95	8.27	9.21	10.16
Other islands	4.19	5.61	6.42	7.94
	(ha/farm)			
Average size of farm *	1.07	1.02	1.06	1.17
Java and Madura	0.73	0.66	0.67	0.63
Other islands	1.72	1.54	1.61	1.85
Agricultural research spending	(1999 international dollars)			
Ag research/farm	n.a.	6.31	13.87	12.33
Ag research/capita	n.a.	0.68	1.37	1.16
Rice yield (kg/ha)	1,761	2,542	3,786	4,352
Irrigated cropland (%) **	15.2	16.1	17.9	22.8
Fertilizer use (kg/ha)	6.9	22.7	63.3	73.9
Agricultural wage (kg rice/day) ***	1.1	2.7	3.7	4.1
Ag exports/Ag GDP	n.a.	n.a.	n.a.	0.24
Ag imports/Ag GDP	n.a.	n.a.	n.a.	0.14

* Average farm size based on farm household land holdings and does not include large estate holdings.

** Percent of cropland planted to annuals that received irrigation at least part of year.

*** Wage of male worker in plantation in Java.

Sources: Agricultural GDP, shares of Ag GDP, and agricultural trade from BPS. Rice output, livestock numbers, rice yield and fertilizer use from FAO. Cropland, irrigated cropland, and agricultural wages from van der Eng. Farm numbers and farm size from Agricultural Census (for census years 1963, 1973, 1983, and 1993). For agricultural research see Table 8 sources.

A2. The Indonesian agriculture “success story”

Much has been written about the Indonesian “success story” in relation to increased agricultural production over the past three decades, particularly in rice production. Indonesia changed from being the world’s largest rice importer in the mid 1960s to becoming nearly self-sufficient by the mid 1980s (Jatileksono, 1987). But agricultural growth in Indonesia has not been limited to rice. Since taking on a more outward orientation in 1985, exports of agricultural commodities grew substantially. Agricultural exports as a share of agricultural GDP increased from 16 percent in 1985 to nearly 30 percent a decade later. By the mid 1990s, Indonesia emerged as the world’s second largest exporter of rubber and oil palm and third largest exporter of cacao and coffee. The value of shrimp exports also grew dramatically over this period, surpassing all but rubber as an agricultural export earner. Imports of agricultural products grew at an even more rapid rate over this period (Erwidodo, 1999).

The data in Table 3 are an embellishment of some of the data provided in Table 2 and trace the major changes in agricultural production and input use in Indonesia between 1961 and 2000.³ Quantities produced are shown in millions of metric tons (mmt) of “rice equivalents” in value terms (i.e., commodity prices are normalized on the price of rice in a given year). The average growth in agricultural production over this period was 2.95 percent per annum, with total output rising from 47 mmt/year in the early 1960s to 130 mmt/year by the early 1990s. Rice production itself grew by nearly 4 percent per annum during this period. Average annual growth rates for vegetables, animal and fish products also exceed 4 percent during these four decades.

In Table 3 we also show the performance of Indonesia’s agriculture during 1961-81, 1982-96 and 1997-2000. During the first period (1961-82), agricultural output grew by 3 percent per year but this growth was mostly resource-based (i.e., from increased use of land, labor, and

other inputs). Productivity growth played a major role in accelerating agricultural growth to nearly 4 percent during the second period, 1982-96. The third period describes the performance of the agricultural sector since the onset of the Asian financial crisis in 1997. The El Niño phenomenon also caused a significant drought in 1997-98 which caused crop production to drop. Overall growth in agricultural output has essentially stopped since 1997, although there are significant differences in the performance of individual commodities and commodity groups.

Table 3. Changes in agricultural production and input use, 1961 -2000

	Average quantity				Average annual growth rate			
	1961-65	1971-75	1981-85	1991-95	1962-00	1962-81	1982-96	1997-00
	(millions of tons of rice equivalents)				(%)			
Agriculture outputs, total	46.94	62.08	89.06	129.85	2.95	3.07	3.84	-0.82
Crop and animal outputs, total**	31.03	44.25	68.17	101.99	3.49	3.95	4.22	-0.88
Food crops, all	18.62	27.66	44.42	60.32	3.52	4.60	3.54	-0.56
Rice, paddy	12.39	21.18	35.77	47.50	3.94	5.40	3.53	-0.02
Cassava	2.33	2.28	2.63	3.19	1.20	1.03	1.61	-0.66
Maize	1.48	1.53	2.38	3.80	6.94	8.01	7.70	0.08
Horticultural crops, all	5.49	7.85	9.27	14.22	3.31	2.86	4.90	-0.44
Fruits, all	4.62	7.20	9.04	12.75	3.75	4.06	4.46	0.18
Vegetables, all	2.46	3.54	3.90	7.65	4.11	2.47	7.06	-0.73
Non-food crops, all	5.08	6.39	10.60	19.23	4.13	3.48	5.52	1.54
Cane sugar	1.05	1.46	2.44	3.65	2.95	4.00	3.92	-6.99
Rubber	1.73	1.99	2.45	3.56	2.06	1.74	2.84	-1.36
Palm oil	0.19	0.39	1.28	4.52	10.61	9.15	12.82	9.16
Animal products, all	2.59	3.51	5.94	11.71	4.09	3.68	6.99	-4.81
Meat	2.45	3.39	5.70	11.25	4.27	3.91	7.34	-5.38
Milk and eggs	0.41	0.57	1.74	3.33	6.43	7.13	7.25	-0.61
Fish products, all	2.91	3.89	6.42	11.12	4.41	3.87	5.43	2.84
Forest products, all	12.26	12.78	12.41	13.25	-0.48	-0.04	0.04	-6.23
Agricultural inputs	(million hectares)							
Cropland	17.55	18.91	26.02	32.25	1.99	1.67	2.43	2.02
Area harvested	17.52	19.62	22.66	28.35	1.67	1.65	2.31	-0.09
Irrigated cropland	2.42	2.66	3.31	4.56	1.93	1.49	2.85	0.67
Ag labor (million workers)	28.61	31.70	37.55	46.01	1.46	1.18	1.99	1.00
Fertilizer (million tons/year)	0.12	0.43	1.67	2.46	10.56	17.45	5.75	-1.25
Ag machinery (mil. horsepower)	0.07	0.16	0.19	0.58	12.98	14.81	11.10	8.21
Animals (million head of stock)	10.53	10.87	14.73	24.79	2.25	0.95	5.69	-4.54

**Net of seed and feed

Source: Fuglie (2002).

Agricultural growth intensified for all major commodity groups except food crops and forestry products between the first and second periods, but then production levels fell for all groups except non-food crops and fish since 1997. During 1982-96 when productivity growth accelerated, annual growth rates in production exceeded 5 percent for vegetables, non-food crops, animal products, and fish products. Agricultural growth in food crops was also impressive during the first two periods (1962-81 and 1982-96) at more than 3.5 percent per annum. During these years yield improvements from “Green Revolution” technologies were particularly important in rice and to a lesser degree in maize and other crops. During 1997-2000 agricultural production fell by 0.8 percent per year. The animal subsector, which relies heavily on imported feed, was particularly hard hit by the Asian financial crisis and the devaluation of the Rupiah that the crisis brought about.

Much of the growth in production that occurred during 1961-2000 can be accounted for by increases in conventional inputs, such as cropland, labor, fertilizers, etc. However, more important for long-term sustainability of growth in agriculture is gains in productivity. In Table 4 we show estimates of a Total Factor Productivity (TFP) index developed by Fuglie (2002). This index shows that TFP grew by about 1 percent per annum until the early 1980s but then accelerated to 2 percent per annum between 1982 and 1996. The drop in TFP during 1997-2000 reflects a number of factors, including a drought-induced decline in crop production, less public and private investment in agriculture, fewer workers exiting agriculture and expansion of cropland into more marginal areas.

Table 4 also shows changes in some indicators of food security (food and rice output per capita) and partial productivity (output per worker and output per unit of cropland). Indonesia’s

success in enhancing food security is illustrated by the impressive growth in per capita food production (an average 2.6 percent per annum during 1962-2000), and rice production in particular (more than 3 percent annual growth during 1962-2000). Per capita food production has fallen since 1997, however. Within the agricultural sector, output per worker grew by 2 percent and output per unit of cropland increased by 1.5 percent per year over 1962-2000. Cropland per person employed in agriculture continued to expand throughout the entire period, with virtually all cropland expansion occurring outside of Java.

Table 4. Productivity growth in Indonesian agriculture

	Average annual growth rate			
	1962-00	1962-81	1982-96	1997-00
	(%)			
Total outputs (crop and animal)	3.40	3.81	4.08	-0.54
Total inputs	2.14	2.76	2.01	0.32
Total Factor Productivity	1.25	1.05	2.07	-0.86
Labor productivity	2.00	2.73	2.19	-1.86
Land productivity	1.50	2.26	1.77	-2.84
Land/worker	0.52	0.48	0.44	1.02
Food crop output/population	2.64	3.63	2.71	-1.30
Rice output/population	3.05	4.43	2.70	-0.76

Source: Fuglie (2002).

The acceleration of growth in TFP from the 1980s corresponds to the period in which investment in agricultural research in Indonesia was substantially increased. But a number of factors in addition to research contributed to the increase in agricultural productivity, such as investments in irrigation, improvements in the quality of the agricultural labor force (rural education), agricultural price policies, government-led food crop “intensification” programs, trade and investment liberalization (Jatileksono, 1996; Van Der Eng, 1996; Erwidodo, 1999). Between 1970 and 2000, government development expenditures for agriculture first increased

and then declined relative to agricultural GDP (Table 5).⁴ Government expenditures for agricultural also declined as a share of total development expenditures, especially since 1989. Expenditures on fertilizer subsidies accounted for a large share of public expenditures for agricultural throughout much of this period, although the fertilizer subsidy was eliminated after 1999.

Table 5. Government development expenditures for agriculture since 1970

(million 1999 PPP dollars)

Year	Total development expenditures	Total development expend. for agric. and nat. resources	Agriculture and forestry	Irrigation	Fertilizer subsidy	Environment	Ag expend. (% of total expend.)	Ag expend. (% of Ag GDP)	Ag GDP (% of total GDP)
1970	3,485	955	486	400	69	-	27.4	2.1	47.2
1971	4,886	1,164	849	300	14	-	23.8	2.5	44.8
1972	4,890	1,246	777	395	73	-	25.5	2.7	40.2
1973	5,516	1,240	635	347	259	-	22.5	2.5	40.1
1974	5,699	1,671	952	286	433	-	29.3	3.8	32.7
1975	10,933	5,986	3,089	344	2,554	-	54.8	13.2	31.7
1976	13,765	3,865	2,013	518	1,335	-	28.1	8.2	31.1
1977	17,863	4,027	2,454	640	933	-	22.5	7.8	31.1
1978	17,133	3,460	2,090	928	441	-	20.2	6.5	30.5
1979	15,195	3,166	1,997	679	491	-	20.8	5.9	28.1
1980	18,217	3,967	1,952	902	567	545	21.8	7.7	24.8
1981	24,311	6,199	3,546	880	1,165	608	25.5	11.1	25.3
1982	26,889	6,569	3,395	1,018	1,439	717	24.4	10.8	26.3
1983	24,960	5,898	2,835	980	1,425	658	23.6	9.3	26.4
1984	30,675	5,443	2,581	846	1,418	598	17.7	8.6	22.7
1985	29,523	8,575	4,343	1,379	2,170	682	29.0	12.9	23.1
1986	31,305	6,049	2,574	1,402	1,373	700	19.3	8.5	24.1
1987	20,951	4,282	2,072	601	1,174	435	20.4	5.9	23.3
1988	21,936	7,159	4,062	884	1,750	463	32.6	9.0	24.1
1989	25,781	4,764	2,761	1,109	421	473	18.5	5.7	23.6
1990	27,025	6,400	3,944	987	543	926	23.7	7.8	21.5
1991	29,125	5,310	2,906	1,388	476	540	18.2	6.6	19.7
1992	34,070	5,883	3,171	1,629	515	569	17.3	6.8	19.5
1993	35,851	5,497	2,909	1,715	274	599	15.3	6.3	18.5
1994	36,625	5,453	2,846	1,629	385	594	14.9	5.7	17.3
1995	40,549	5,211	1,308	2,229	1,077	597	12.9	5.1	17.1
1996	34,991	4,627	1,342	2,483	174	629	13.2	4.3	16.7
1997	38,828	4,765	1,398	2,502	201	664	12.3	4.4	16.1
1998	22,859	3,195	902	1,559	326	409	14.0	3.0	18.1
1999	35,864	8,014	3,955	2,523	1,123	412	22.3	7.1	19.4
2000	37,275	4,290	2,196	1,650	0	444	11.5	4.1	19.4

Sources: Expenditures for 1970-1992 from August 15 Presidential Address to the Republic of Indonesia (1974, 1979, 1984, 1989, 1995); Expenditures for 1993-2000 from Statistical Year Book of Indonesia; GDP deflator and PPP exchange rate from World Bank and IMF.

The national averages described above mask important regional differences, especially between land-scarce Java and the relatively land-abundant islands of Sumatra, Kalimantan, Sulawesi, and elsewhere. Differences in agricultural productivity changes at a regional level are discussed in Booth (1988) and Van Der Eng (1996). Further work in this area is an important topic for research on agricultural productivity in Indonesia. A limitation of estimates of productivity growth in Indonesian agriculture is that environmental costs of agricultural development have not been taken into account. Growth in agricultural land area, forest and fish production have come at some cost to environmental resources including land degradation, loss of forest habitat, and a decline in water quality, none of which have so far been incorporated into agricultural productivity measurements for Indonesia.

A3. "Reality check": The 1997/98 crisis

Events since 1997 have afforded a somber reminder of Indonesia's vulnerable food security situation. A combination of drought, forest fires and the Asian monetary crisis adversely affected food crop production (especially rice) and animal production and exposed large segments of the population to food insecurity. Rice imports reached an all-time high of four million metric tons in 1998, more than double the peak level of rice imports in the 1960s (Kasryno, Nataatmadja and Rachman, 1999). Stringer (1999) describes the combination of adverse events and their consequences as follows:

"Indonesia's current socioeconomic crisis has dramatically reversed decades of rapid economic growth, steady progress in poverty reduction, and substantial improvements in food security. Before the crisis began in August 1997, Indonesia was frequently cited as one of the highest performing Asian economies with per capita GDP growth in the top 10 percent of all developing countries. Since the crisis however, the rupiah's value has dropped precipitously, inflation has soared and GDP has fallen an estimated 14 percent in 1998 (World Bank 1998). The country's poor and those facing food insecurity are especially vulnerable to the falling incomes, increasing food prices,

decreases in real wages and rising unemployment and underemployment brought on by these crisis induced events.

Indonesia's capacity to address the crisis has been greatly complicated by forest fires, drought, floods and a sharp decline in crude oil prices....Estimates of the economic damage to Indonesia's logging and timber industries, (excluding environmental and health costs) are set at more than US\$900 million (Tay, 1998)....

A prolonged drought throughout 1997/98 reduced export crop production and, more importantly for the country's food security objectives, contributed to a large drop in paddy production. Initial estimates suggest that the 1998 paddy crop is nearly 10 percent below the 1996 production level (FAO, 1998; CBS, 1999)....

Around one-third of the country's population spend 70 percent or more of their total expenditures on food (SUSENAS, 1996). Thus, the collapsing demand, rising unemployment, falling food production, increasing food prices and rapidly expanding numbers of malnourished stress the fundamental role agriculture must play in revitalizing the economy."

The crises during the late 1990s led to major changes in agricultural policy in Indonesia. Most important was the reduction in barriers to agricultural trade, including reduction or elimination of tariffs and the elimination of BULOG's (a state trading agency) import monopoly on major food items such as rice, wheat and soybean. Another important implication of the crises was that budget austerity measures reduced public spending on agriculture. In 1999, a long-standing fertilizer subsidy was scrapped. Funding for agricultural research and extension was also reduced in real terms.

Not all effects of the monetary crisis were deleterious for agriculture. The resulting devaluation of the Rupiah led to a general improvement in the farm-nonfarm terms-of-trade, as prices of tradable commodities rose faster than prices of non-tradable goods and services. Cacao producers in Sulawesi, for example, experienced a windfall gain as Rupiah prices rose five-fold in a matter of months (Ruf and Cerad-Tera, 1999). With the end of the 1997-98 drought, agricultural production in Indonesia recovered in 1999 and 2000. In fact, the value of agriculture to the wider economy was demonstrated by its ability to absorb nonfarm labor displaced by the economic crisis. As a result, unemployment and poverty rates did not increase as much as in some early projections (Manning, 2000).

Various policy makers have highlighted the need for an increased agricultural R&D effort to improve Indonesia's food security and meet other long-run development goals. H.S. Dillon, Director of the Center for Agricultural Policy Studies in Jakarta, has commented that one of the reasons for the slowdown in technological progress in Indonesian agriculture in recent years (especially when compared with other land-constrained Asian states) is "persistent under funding of the public sector R&D effort" and claims that "A substantial increase in the real expenditures on agricultural R&D is warranted, given the potential economic and social payoffs likely to result from raising smallholder productivity." (Dillon, 1999, p.12). He is also critical of various features of the Indonesian agricultural research system, including high fragmentation of the agricultural R&D effort, limited involvement of universities, weak linkages between Indonesia's own R&D effort and those of international R&D providers, disruption of research efforts in the Indonesian Agency for Agricultural Research and Development (IAARD)⁵ resulting from a 1995 internal reorganization, and weak intellectual property rights for agricultural technologies.

Recent trends in Ministry of Agriculture (MoA) expenditures for agriculture are shown in Table 6. Between 1994 and 1999 routine and development expenditures by MoA declined from \$1,190 million to \$440 million (constant 1999 international dollars). The precipitous decline in public spending on agricultural is part of overall government austerity measures needed to meet a commitment to the IMF to reduce deficit spending. MoA spending on agricultural research fell by about half in real terms over this period even though research grew as a share of all agricultural expenditures.

Table 6. Ministry of Agriculture expenditures by function

(million 1999 PPP dollars)

Function	1994	1995	1996	1997	1998	1999
Secretary General						
Main Office	30.6	219.4	63.2	13.3	32.9	8.5
Regional Offices	114.5	119.8	287.0	131.4	187.1	90.6
Quarantine	10.2	10.7	18.2	12.6	12.3	8.5
Foreign Office	0.7	0.8	0.8	0.9	0.6	0.9
Mass Guidance	108.4	74.1	49.2	42.7	27.2	25.8
Research and Development	125.1	131.2	125.5	126.5	76.7	65.7
Education and Training	70.5	73.0	70.7	70.9	42.9	41.5
Agribusiness Development	0.0	4.8	7.9	7.8	4.5	5.0
Sub-Total Secretary General	459.9	633.7	622.7	627.7	384.1	322.2
Inspectorate General	4.8	5.2	5.1	4.8	2.9	0.0
Dir. General of Food Crops	277.3	243.7	153.0	131.6	76.3	60.7
Dir. General of Plantation	240.7	198.4	118.5	104.3	65.5	0.0
Dir. General of Livestock	84.9	43.9	47.8	49.5	28.8	16.7
Dir. General of Fisheries	122.1	86.0	80.6	72.0	41.9	26.8
Total	1,189.7	1,211.0	1,027.8	989.8	599.4	440.5
% of total for R&D	10.5	10.8	12.2	12.8	12.8	14.9

Expenditures include routine and development expenditures

Source: Ministry of Agriculture, Jakarta, Indonesia.

A4. Planning for increased agricultural productivity: Challenges and constraints

Many of the science and technology issues confronting Indonesia's agricultural sector apply to the economy as a whole, such as the need to establish technology competence to effectively absorb new technology from abroad, and the need to increase international competitiveness through increased productivity rather than low wages. These issues have stood prominently in Indonesia's science and technology policy (Hill, 1995). Agriculture R&D have the additional goals of providing food security, reducing rural poverty and maintaining the quality of natural resources.

While Indonesia substantially increased its science and technology capacity in the 1980s and 1990s, it still remains behind many Asian countries in several important aspects. By the late

1980s, Indonesia's spending for all R&D was less than 0.2 percent of GNP, lower than most other countries of Southeast Asia and far below industrialized countries such as Japan and Korea (UNESCO, 2001). Public spending for education was also low by Asian standards, despite the rapid expansion of the educational system. The enrolment ratio for tertiary education (11.3 percent in 1996), though only half that of Thailand, was in the middle range of developing countries in Asia, as was the share of tertiary students enrolled in science and technology fields (UNESCO, 2001).

The State Ministry for Research and Technology (RISTEK) has responsibility for coordinating R&D policy in Indonesia but has little control over allocation of research expenditures. RISTEK operates a number of competitive grant and other programs for funding research, especially for universities. Budgets for government research institutions are allocated either through Ministries or directly to non-department agencies. The most important non-department research institutions include the Agency for Assessment and Application of Technology (BPPT) for industrial technology, the Indonesian Institute of Sciences (LIPI) for basic sciences, the Central Statistics Agency (BPS), the National Nuclear Energy Agency (BADAN), and the National Institute for Aeronautics and Space (LAPAN). But agriculture remains the highest priority for government-supported research. IAARD in the Ministry of Agriculture is the largest government research agency in Indonesia with over 3,000 researchers (Table 7). Together with IPARD (estate crops), FORDA (forestry) and the Center for Fisheries R&D, agriculture receives by far the largest allocation of research staff by government research institutions.

Table 7. Major government research institutions in Indonesia

Name of Research Institution	Fields of activity	Research staff*
Indonesia Agency for Agricultural Research and Development (IAARD)	Agricultural crops and livestock	3,063
Agency for Assessment and Application of Technology (BPPT)	Industrial technologies	2,074
Indonesian Institute of Sciences (LIPI)	Basic sciences	1,692
Central Statistics Agency (BPS)	Statistics	1,343
National Nuclear Energy Agency (BADAN)	Nuclear energy	1,314
National Institute of Aeronautics and Space (LAPAN)	Aeronautics and space	487
Forestry Research and Development Agency (FORDA)	Forestry	486
Indonesian Planters Association for Research and Development (IPARD)	Agricultural estate crops	429
Center for Oil and Gas Technology Research and Development	Oil and gas	343
Agency for Trade and Industry Research and Development	Industry and trade	328
Center for Fisheries Research and Development	Fisheries	308
Agency for Education Research and Development	Education	264
National Coordination Agency for Survey and Mapping (BAKOSURTANAL)	Mapping and surveying	239
Center for Mining Research and Development	Mining	145

Table only includes government institutions with at least 100 research staff.

*Research staff includes those with University degree (B.Sc., M.Sc., or Ph.D.). Data are from 1995-2000.

Sources: RISTEK (1996, 2002); IAARD (Statistik Penelitian Pertanian: Sumberdaya, Program dan Hasil Penelitian, 2000).

The policy direction for agricultural research in Indonesia is articulated in IAARD's Strategic Plan. The 1999-2004 Strategic Plan (IAARD, 1999) describes the main "constraints and challenges" facing the Indonesian agricultural sector (summarized below drawing heavily on the IAARD Strategic Plan, pp. 23-30):

- The industrial and service sectors have not absorbed surplus labour from the agricultural sector to the degree previously anticipated. At the same time, urban migration has occurred as a result of factors such as increased land fragmentation, low agricultural sector wages and limited rural employment opportunities. Investments are needed in rural areas to provide employment opportunities. Agricultural development will require increased commercialisation of agriculture in the form of agribusiness development and value-adding activities.

- While population growth remains high and rice is still the favoured food item, self-sufficiency is threatened by climatic variability, pest and disease outbreaks and unstable market forces. Moreover, the land area available for rice has diminished, especially on Java where land is being converted to industrial development and housing. Rice yields have levelled out. There is need for more irrigated land and the use of land of lesser inherent productivity for rice production. At the same time, there is a need for diversifying food production and consumption.

- Land fragmentation will remain a problem until industrialisation draws sufficient small landholders out of agriculture to allow for “extensification” of agricultural production. There is a need for farming systems research that allows for efficient agricultural production on small land holdings.

- Rural financial institutions have not performed well in providing capital to agriculture. Better incentives for these institutions to provide capital to agriculture need to be found.

- Future policy must try to capitalise on the competitive advantage of different agro-ecological zones. This entails a focus not only on cultivation techniques, but also on farming systems, integrated pest management and reduction in post-harvest losses.

- There is a need for more practical farm managements skills, decision-making tools and bookkeeping methods that normally accompany the transition from subsistence to commercial agriculture.

- There is a need for increased environmental awareness, not only for maintaining the resource base, but also to allow Indonesia to be competitive in international markets.

Elsewhere in the Strategic Plan attention is drawn to water scarcity as a factor potentially limiting increased agricultural output. One of the challenges will be to develop agricultural technology and plant varieties that result in efficient water use. Another will be the development of on-farm and multi-farm strategies for water management.

Finally, reference must be made to the political situation since the fall of the New Order government in 1998. An outcome of this (and to some extent, the cause) has been a demand for greater democracy and public participation in decision making. Decisions about agricultural R&D activity will need to be increasingly decentralized in the sense of taking account of farmers' wishes and perceived needs. This will entail more of a farming systems emphasis in research and less of a commodity orientation.

PART B. FINANCING AND PROVISION OF AGRICULTURAL R&D

B1. Brief history of agricultural research in Indonesia

Agricultural research in Indonesia dates back to the establishment of tropical botanical gardens by colonial authorities in the early 1800s. The purposes of these gardens were to collect and study tropical plant species and introduce new export commodities to the colonies. The most prominent of these was the botanical garden in Bogor, West Java, established in 1817. During the 19th Century, the garden accommodated a large number of specialists and made considerable contributions to fundamental studies in tropical botany, but scientists gave scant attention to the practical problems of farming (Oudejans, 1999).

Applied agricultural research was stimulated by plantation owners who demanded solutions to immediate crop management and disease problems. Plantation growers, who produced mainly for export, could not only profit from an expansion of supply but, through their associations, also had the means to fund commodity-oriented research. Sugar cane planters were among the first to establish a research station, in East Java in 1885, followed by coffee and cacao in 1901, tea in 1902, tobacco in 1907, and rubber in 1916. Most of these experiment stations remained relatively small, usually with fewer than 10 senior scientists. An exception was the sugar research station, which by the 1920s had a staff of 35 Europeans and more than 200 Indonesians (Oudejans, 1999). Sugar scientists achieved significant technical advances, such as discovering a method for sexually crossing sugar cane that allowed breeders to develop disease-resistant varieties. These advances led to dramatic increases in sugar yield in the early years of the 20th Century (Pray, 1991).

Government-supported agricultural research was given a firmer footing with the establishment of a Department of Agriculture in 1905 under the leadership of Melchior Treub. Treub was a highly-regarded Dutch scientist who sought to organize the new department along the lines of the U.S. Department of Agriculture, which at that time placed a heavy emphasis on research. While the new Department of Agriculture was mainly concerned with plantation crops, an experiment station for rice and secondary food crops was established near Bogor in 1907. Nevertheless, the commitment to food crop research was insufficient to significantly boost crop yields and in the 1920s and 1930s, rice production lagged behind population growth and Indonesia was often forced to import food staples.

Agricultural research in Indonesia was severely disrupted by World War II (1942-45), the War of Independence (1945-49) and a steadily deteriorating economy during the 1950s and early 1960s. Many foreign-owned plantations were nationalized during this period. A subsequent sharp decline in plantation production curtailed support for the plantation-supported experiment stations. The erosion of scientific and technical personnel engaged in agricultural research was not reversed until the late 1960s.

The “New Order” government of President Suharto, which came to power in 1965/66, put in place improved macroeconomic policies and established food self-sufficiency as a national priority. Funding for agricultural research was gradually increased. To improve the coordination of agricultural research, a new Agency for Agricultural Research and Development (IAARD) was established in 1974 within the Ministry of Agriculture. IAARD was given overall responsibility for food, forestry and fisheries research. In 1979, the Indonesian Planters Association for Research and Development (IPARD), a consortium of state-owned and private estates that support research on estate crops, was brought under IAARD’s oversight. In 1983,

forestry was spun off from IAARD into the newly established Ministry of Forestry, and in 2001, fisheries research was transferred from IAARD to the new Ministry of Marine Affairs and Fisheries. IAARD continues to have responsibility for crop, livestock, agricultural economics research, and through IPARD, estate crops research.

B2. Overview of the institutional structure of agricultural research

In Indonesia, the central government is the primary source of funds for agricultural research (Fuglie, 1999). The international donor community played a major role in supporting agricultural research in Indonesia, especially during the 1980s and early 1990s when Indonesia's capacity in agricultural research was greatly expanded (Pardey, Eveleens, and Abdurachman). Most government expenditures for agricultural research are directed toward commodities important to small-holders. Research institutes for estate and export commodities are largely funded through contributions by large growers. In-house research by private companies in Indonesia is growing but remains small (Pray and Fuglie, 2002).

Since 1974 most agricultural research in Indonesia has been coordinated and managed by IAARD within the Ministry of Agriculture. IAARD is the primary body responsible for conducting and coordinating crop and livestock research in the country. Research institutes for estate commodities are managed by the Indonesian Planters Association for Research and Development (IPARD). IPARD, though largely autonomous and self-financed, is nominally under the guidance of IAARD. Forestry and fisheries research were separated from IAARD when the Ministry of Forestry and Ministry of Marine Affairs and Fisheries were established.

The principal role of universities in agricultural research has been to train the scientific and technical personnel employed in government research institutes and the private sector. University scientists also engage in research activities when special project funding can be

obtained. Funding for university research may come from IAARD, the State Ministry of Research and Technology, international donors, the private sector, or other sources.

International agricultural research centers play an important role in Indonesia's agricultural research system. Indonesia hosts the headquarters of the Center for International Forestry Research (CIFOR) and the SE Asia regional offices of the International Center for Research on Agro-Forestry (ICRAF) and the International Potato Center (CIP). The UN ESCAP CGPRT Centre, which conducts socioeconomic research on secondary food crops, and the ASEAN-funded South East Asia Regional Center for Tropical Biology (BIOTROP) are also located in Indonesia. IAARD has cooperative research arrangements with several other international agricultural research centers as well (including AVRDC, CIMMYT, ILRI, and IRRI) and agricultural research institutes in Japan, Europe, North America, and Australia.

In the 1990s, IAARD research institutes and agricultural universities began to explore new ways of self-financing at least a part of the costs of agricultural research. Although government policy so far does not allow government agencies to retain funds raised through product sales, IAARD established a semi-autonomous foundation in 1999, the Intellectual Property and Technology Transfer Management Office (IPTTMO), to help commercialize IAARD innovations. This office has responsibility for patenting and licensing IAARD innovations to private firms. Examples of technologies recently licensed by IPTTMO include a biological fertilizer, a biological pesticides and an animal vaccine. As a semi-autonomous foundation, IPTTMO has the legal authority to retain earnings from technology licensing.

Intellectual property rights for inventions and creative arts are relatively new to Indonesia and remain poorly enforced. A national patent law was enacted in 1991 and amended in 1997 and 2001 to bring it into compliance with the Trade-Related Intellectual Property System

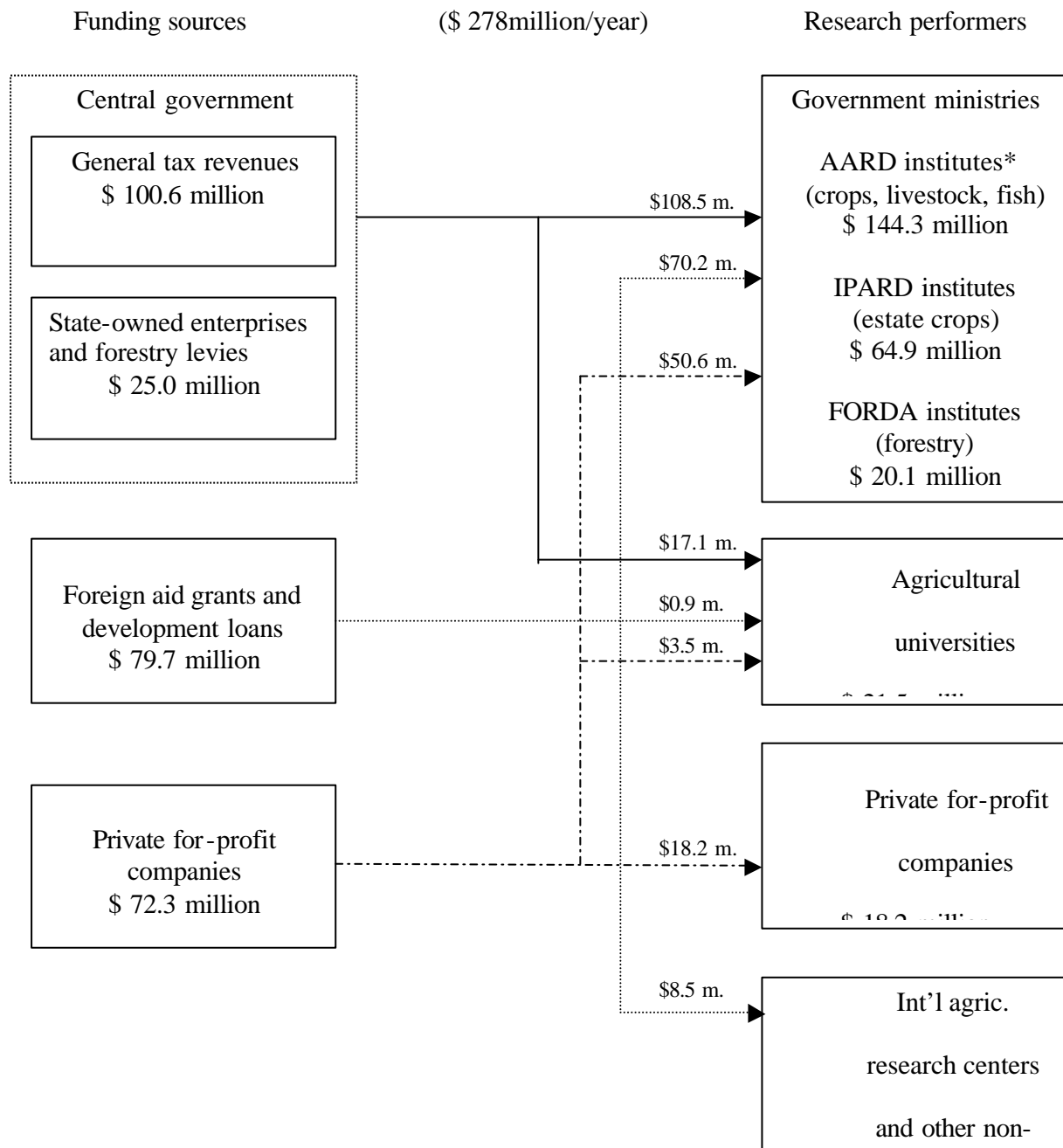
(TRIPS) of the World Trade Organization. In 1997, Indonesia signed the international Patent Cooperation Treaty. IPRs for agricultural innovations were strengthened by the 1997 amendments to the patent law which eliminated a provision barring plant and animal patents and by the passage of Plant Breeders Rights legislation in 2001.

The principal funders and performers of agricultural research in Indonesia are shown in Figure 1. We estimate that total spending for agricultural research in Indonesia in 1998/1999 was about \$278 million in 1999 international dollars. The central government provided about \$126 million from tax revenues, contributions of state-owned estates for estate crop research, and forest concession levies. Foreign aid (especially in the form of loans from the World Bank and Asian Development Bank) provided another \$80 million. Private companies conducted about \$18 million of their own research and purchased about \$50 million of planting materials and other technology products from estate crop research institutes. These earnings are used to support research on estate crops. Government institutes were the largest research performers, conducting \$229 million worth of research. Research at agricultural universities is estimated to be \$21.5 million. International agricultural research centers performed at least \$8.5 million worth of research in Indonesia.

B3. Organizational changes in public agricultural research

As described above, public agricultural research in Indonesia has undergone several reorganizations since the establishment of IAARD in 1974. These reorganizations reflect the growing capacity and widening agenda in agricultural research. Figure 2 shows the current organization of agricultural research within government Ministries as of 2001. More than 70 percent of agricultural scientists were housed in IAARD, with the other 30 percent distributed amongst IPARD, FORDA, and the fisheries institutes.

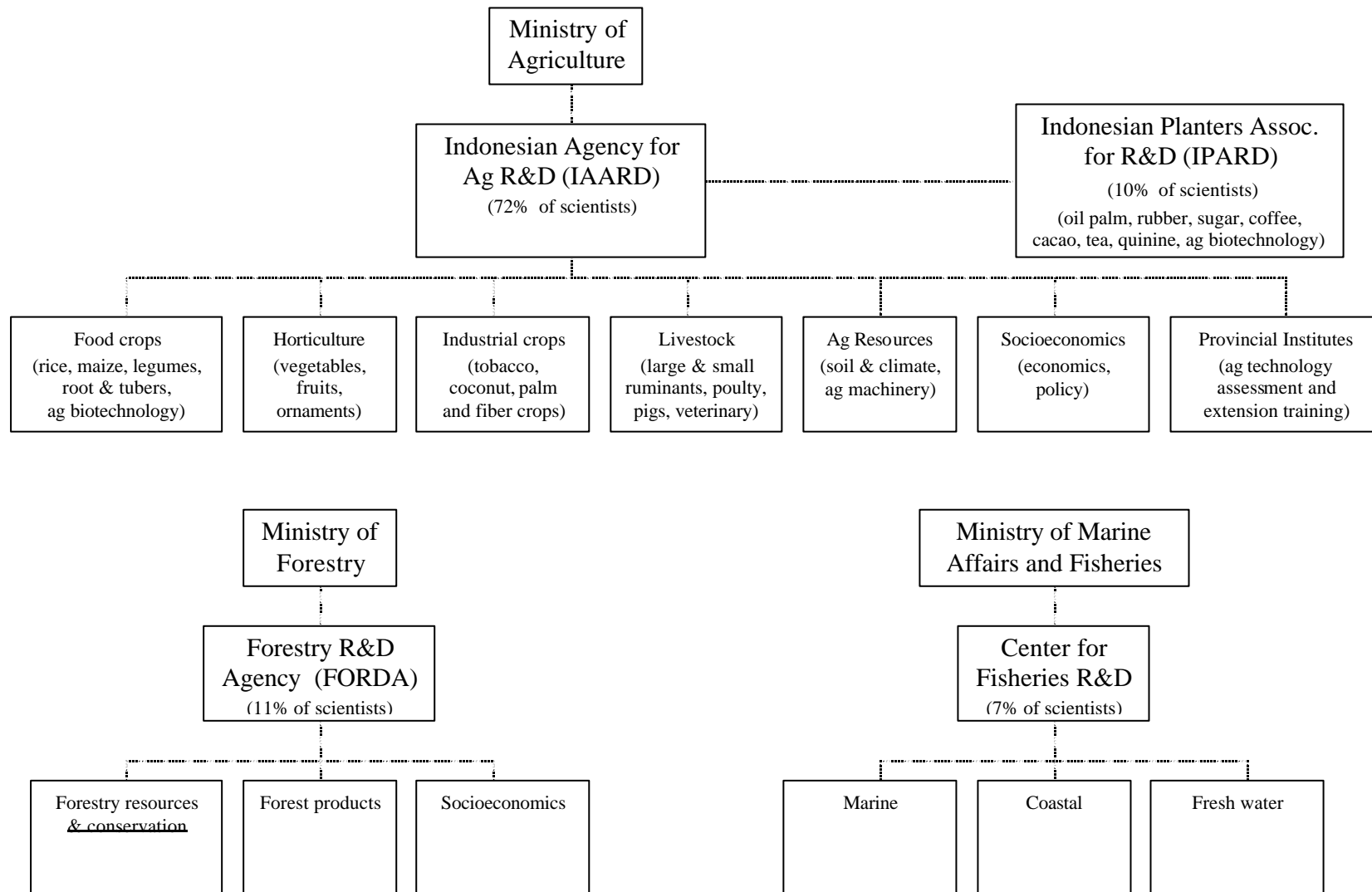
Figure 1. Funding channels for Indonesian agricultural research in 1998/1999



*In 2001, fisheries research moved from AARD to the Ministry of Marine Affairs and Fisheries. Figures are in 1999 international dollars and are estimates only.

Sources: Government finance and expenditures from AARD (2000), FORDA (1996), IPARD. University expenditures based on IPB (2000). Private expenditures from Pray and Fuglie (2002).

Figure 2. Organization of agricultural research in Indonesian government ministries in 2001



Agricultural research in IAARD underwent a major internal reorganization in 1995 to decentralize its research efforts. Some regional substations of the Central Food Crop Research Center (CRIFC) were upgraded and given mandates to lead research on specific commodities. In addition, technology assessment centers were established in each province to link research, extension and on-farm testing of new technologies. These changes reflected: (i) the steadily growing research capacity of the regional substations; (ii) an increased emphasis on other commodities once rice self-sufficiency was achieved in the mid-1980s; and (iii) a concern that linkages between research and extension were inadequate to move technology into the hands of small farmers quickly. These provincial-level Assessment Institutes for Agricultural Technology (AIAT) are scheduled to be eventually transferred to provincial government control as part of the trend toward greater decentralization of Indonesian government services.

IAARD-university and IAARD-private sector linkages in conducting agricultural research have recently been strengthened with support of loans from World Bank and Asian Development Bank (ADB). The ARMP-II (World Bank) and PAATP (ADB) projects set aside special funds for collaborative research projects between IAARD scientists and universities, international centers, and private companies. Foreign and private partners are required to provide matching funds. Through these projects IAARD raised 684 million Rupiah and IPARD 845 million Rupiah in matching contributions from private companies in 2001 (IAARD, 2001).

Since the 1980s the Government of Indonesia (GOI) has made a concerted effort to expand national capacity in biotechnology research. In 1988, GOI designated three institutes as “centers of excellence” for biotechnology research: 1) the University of Indonesia in Jakarta for medical applications, 2) the Agency for the Assessment and Application of Technology (BPPT) for industrial applications, and 3) IAARD for agricultural applications. Later, in 1993, the Center

for Research and Development of Biotechnology at the Indonesian Institute of Sciences (LIPI) was assigned as a second center of excellence for agricultural biotechnology (Sugiono, 1999). Agricultural biotechnology research within IAARD is concentrated at the Center for Agricultural Biotechnology and Genetic Resources in Bogor.⁶

IAARD has relied heavily on foreign-funded special projects to develop its agricultural biotechnology research capacity, such as the Rockefeller Foundation's Rice Biotechnology Network led by IRRI, the USAID-funded project on Agricultural Biotechnology for Sustainable Productivity led by Michigan State University, and World Bank loan funds (Fagi and Herman, 1998). Falconi (1999) reported that in 1997 IAARD spent US \$6.0 million (18.7 million in PPP dollars) on agricultural biotechnology research. Falconi estimated that about 85 percent of agricultural biotechnology research was done by government research institutes, 11 percent at universities, and 4 percent in the private sector. Food crops received the greatest share of these resources.

Several applications of biotechnology to agriculture have been under development, including cell/tissue culture for plant propagation, marker-selected breeding, the use of monoclonal antibodies for disease diagnosis, and development of genetically modified crops (Sugiono, 1999). In 1997, the Ministry of Agriculture issued biosafety regulations for field testing genetically modified organisms. In 2001, several hundred hectares of a bt-cotton variety developed by Monsanto were grown in Indonesia, the first GMO approved for commercial use in the country.

B4. Funding and staffing of public agricultural research

Indonesia achieved significant progress over the past three decades in building capacity in agricultural research. When IAARD was formed in 1974, it had only 7 Ph.D., 167 M.Sc., and

250 B.Sc.-level agricultural scientists. By 2000, the number of agricultural scientists employed in IAARD had risen to 291 Ph.D., 749 M.Sc. and 2,339 B.S.-level researchers, not counting the research staff for estate crops and forestry (Table 8). Research expenditures also increased in real terms, although funding per scientist declined. The sharp increase in number of IAARD between 1994 and 1995 (and the decline in funding per scientist) reflects an internal reorganization that amalgamated certain agricultural extension functions with research when provincial-level agricultural technology assessment institutes were formed. But despite this rapid growth, expenditures for agricultural research in Indonesia as a percentage of agricultural GDP and as a percentage of total government expenditure still ranked near the bottom of developing countries in Asia (Pardey, Roseboom, and Fan, 1998).

B5. Priority setting for agricultural research

The selection of agricultural research projects for the allocation of development funds at IAARD institutes involves a series of screening steps that start with the individual scientist and move up the IAARD hierarchy to the IAARD Secretariat. For example, a proposal on rice breeding would first be cleared by the Rice Research Institute at Sukamandi, West Java, then forwarded to the Central Research Institute for Food Crops in Bogor, and finally to the IAARD Secretariat in Jakarta. Evaluations at each step are mostly internal, although since 1999 IAARD has also used external reviewers from universities and other government science institutes. The principal criterion evaluated by IAARD is quality of research.

Proposals approved by the IAARD Secretariat are forwarded to the National Planning Agency (BAPANAS) where they are evaluated for their contribution to economic development goals and potential economic value. However, formal benefit-cost analysis is generally not used. Valuation is based largely on the importance of the commodity to Indonesia's agriculture.

Consideration is given to economic value, food security, poverty, and the geographic focus of the research.

Table 8. Agricultural research funding and staffing in Indonesia

Year*	Agricultural Research Expenditures			No. of Agricultural Scientists (SY)				Expenditure/scientist	
	Current Rupiah (millions)	Constant Rupiah (1999 millions)	Constant PPP \$ (1999 millions)	Ph.D.	M.S.	B.S.	Total	Constant Rupiah (million Rp/SY)	Constant PPP \$ (PPP \$/SY)
1974	6,934	165,824	88	7	167	250	424	391	206,665
1975	9,129	196,337	104	19	204	243	466	421	222,639
1976	13,776	256,687	136	22					
1977	17,907	294,563	156	23					
1978	20,074	301,742	159	24					
1979	22,846	257,021	136	34			1,005	256	135,141
1980	35,890	308,242	163	35					
1981	42,830	333,076	176	41					
1982	40,240	295,051	156	49					
1983	63,902	410,099	217	66					
1984	67,164	393,867	208	86	279	965	1,330	296	156,489
1985	68,745	385,931	204	111	296	965	1,372	281	148,642
1986	77,486	422,178	223	122	235	1,008	1,365	309	163,436
1987	87,374	415,775	220	159	431	1,227	1,817	229	120,917
1988	77,195	338,142	179	179	477	1,322	1,978	171	90,335
1989	62,829	250,209	132	187	490	1,302	1,979	126	66,810
1990	80,655	298,169	158	193	546	1,240	1,979	151	79,616
1991	111,072	377,308	199	194	548	1,249	1,991	190	100,140
1992	129,088	416,187	220						
1993	142,597	422,241	223	227	627	1,529	2,383	177	93,631
1994	179,377	492,825	260	241	672	1,565	2,478	199	105,094
1995	183,657	459,176	243	262	737	2,007	3,006	153	80,719
1996	230,500	530,316	280	276	738	1,994	3,008	173	91,162
1997	270,840	553,540	293	276	738	1,997	3,011	184	97,146
1998	398,255	449,122	237						
1999	372,843	372,843	197	292	733	2,150	3,175	117	62,054
2000	400,149	360,441	190	291	749	2,339	3,379	107	56,368

Expenditures include research for food, estate, and industrial crops, livestock and fisheries for all years and forestry research till 1982. Number of scientists include food and industrial crops, livestock and fisheries. SY's do not include estate crop research and forestry research after 1983. IPARD's estate research stations had 66 Ph.D., 141 M.S., and 222 B.S.-level staff in 1997. FORDA (forestry research) had 30 Ph.D., 117 M.S., 339 B.S.-level staff in 1995. The sharp increase in staff between 1994 and 1995 was due in part to an AARD reorganization that established provincial-level institutes and amalgamated some research and extension functions within these institutes (see text).

* 1974-1999 fiscal year is April-March; 2000 fiscal year is April-December.

Sources: 1974-1983 from Pardey and Roseboom (1989); 1984-1997 from AARD (Pocket Book: Organization, Resources and Research Program, various issues); 1998-2000 from AARD (Statistik Penelitian Pertanian, 1999 and 2000). Supplemented with unpublished statistics from IPARD.

Agricultural research in Indonesia has received substantial financial support through loan projects from the World Bank and Asian Development Bank. These loan projects typically require a matching-fund component from current government revenues. The Ministry of Finance has a role in evaluating and approving all government loan projects. In addition, the Ministry of Finance evaluates research project budgets against standard cost guidelines for land, labor, travel, materials, etc.

Since the national elections in 1999, the Indonesian House of Representatives (DPR) has emerged as an active player in establishing government policies and budget priorities. Cabinet ministers and directors of government agencies must increasingly provide justification for their budgets and programs to legislators. This has added a new dynamic in mobilizing support for agricultural research.

B6. Sources of funds for agricultural research

The financing of public research Indonesia comes from a number of sources, including the central government budget, special assessments on commodity groups, foreign aid, and funds raised by the research stations themselves through product sales, technology licenses, and contract research.

In times of financial austerity, GOI development budgets may be sharply reduced while routine budgets remain largely unaffected. Development budgets for agricultural research have been relatively unstable: between 1986-1990 and 1998-2000 the agricultural research development budget was cut more than 60 percent in real terms from the immediately preceding years (Table 9). Foreign loans and grants have played a major role in stabilizing research funds during these periods. In the late 1980s, the US government provided significant grant assistance for IAARD. In the late 1990s and early 2000s, the World Bank and the Asian Development

Bank provided large loans for agricultural research. The loan programs have been particularly crucial for supporting the strengthening of the provincial Assessment Institutes for Agricultural Technology.

Table 9. Sources of funds for agricultural research at AARD

Year	GOI Routine	GOI Development	Estates	Foreign	Total
(million 1999 PPP dollars)					
1974	11	49	18	21	98
1975	16	56	20	20	111
1976	16	80	16	35	147
1977	19	63	17	46	145
1978	22	75	17	41	155
1979	18	58	14	34	124
1980	20	68	17	45	151
1981	25	69	20	51	164
1982	25	74	19	52	170
1983	24	59	19	103	205
1984	24	59	19	107	208
1985	28	67	30	73	198
1986	33	29	33	127	223
1987	29	16	20	155	220
1988	30	8	20	123	181
1989	30	12	70	72	183
1990	32	19	92	72	215
1991	35	48	82	53	219
1992	41	56	85	61	243
1993	43	63	78	36	220
1994	59	76	80	44	258
1995	67	76	74	19	236
1996	62	78	75	40	254
1997	64	87	92	46	290
1998	36	32	69	100	237
1999	38	39	51	70	197
2000	36	23	46	85	190

GOI-Government of Indonesia

Source: AARD (Organization, Resources and Research Program, various issues), AARD (Statistik Penelitian Pertanian: Sumberdaya, Program dan Hasil Penelitian, various issues) and IPARD (unpublished data).

The main sources of funds for agricultural research differs significantly among commodities. Government revenues supplemented with foreign loans and grants make up the

bulk of IAARD's budget for crops and livestock. For forestry research, government revenues provide about one-third of the annual budget while nearly two-thirds comes from the forestry sector through a special assessment on forest concessions.

Research on estate crops is mainly financed by the plantation sector itself. The semi-autonomous status of the Indonesian Planter's Association for Research and Development (IPARD) allows estate crop research institutes to keep revenues from product sales. Further, members of IPARD contribute funds for research on estate crops.⁷ Own revenues from product sales and member contributions fund about 95 percent of plantation research in Indonesia. Government budgetary contributions account for only about 5 percent. Due in part to the different ways of financing agricultural research and the special status of IPARD,⁸ scientists working at the plantation crop research institutes are significantly better funded than researchers at IAARD. In 1996, research expenditures per scientist at IPARD institutes were about four times higher than at IAARD institutes.

Research at universities is funded mainly from government sources, including competitive grant programs. In 1998/1999, Bogor Agricultural University (IPB) raised over 10 billion Rupiah to support research projects. About 80 percent of this was from government research funds, 16 percent from the private sector, and the remainder from foreign sources (IPB, 2000).⁹

A small but growing share of agricultural research in Indonesia is conducted by private companies (Table 10). Research conducted by private companies is estimated to have increased from \$6.6 million to \$18.2 million between 1985 and 1996 (constant 1999 international dollars). Privately owned rubber and oil palm plantations conduct some in-house research outside of the IPARD system and spent about \$6 million for research in 1996. Private seed companies began

breeding activities in Indonesia in the late 1980s, mainly in hybrid corn and vegetables, but annual research expenditures were only \$2.1 million by the mid 1990s. Chemical companies conduct crop protection research for screening and registering new pesticides. At least one multinational chemical company operated a research station in Indonesia for screening new chemical compounds under tropical conditions. Research on animal production was mainly by large integrated poultry producers. As a share of total agricultural research conducted in Indonesia, private research increased from 3.1 percent to 7.0 percent between 1985 and 1996. Thus, private research, while still relatively small, grew more rapidly than public research. Private research also grew relative to the size of the Indonesian agricultural sector.

Table 10. Private agricultural research in Indonesia, 1985 and 1996

	1985	1996	1985	1996
	(million 1999 PPP dollars)		(companies doing research)	
Crop breeding	0.0	2.1	0	6
Crop protection	2.6	7.2	1	6
Plantations	2.0	6.0	3	4
Animals	2.0	3.0	3	3
All	6.6	18.2	7	19
% of all ag research	3.125	7.003		
% of ag GDP	0.010	0.018		

Source: Pray and Fuglie (2002).

B7. Allocation of agricultural research funds

More detailed evidence on the allocation of scientific resources for agriculture in Indonesia is presented in Table 11. Commodity institutes generally have about a 1-to-2 ratio of Ph.D.-to-M.Sc.-level staff. However, institutes that focus on biotechnology (one for food crops and one for estate crops) are more heavily weighted in favor of Ph.D. staff. The agricultural

Table 11. Number of agricultural researchers by institution in 1997

Institution	Ph.D.	M.S.	B.S.	Total
	(number of scientists by institution)			
Food Crops Research Center	8	13	22	43
Biotechnology	34	22	71	127
Rice	14	24	55	93
Legume & root crops	7	37	47	91
Corn & cereals	9	32	62	103
Swamp crops	6	24	44	74
Total food crops research	78	152	305	535
Horticultural Research Center	3	4	14	21
Vegetables	9	16	37	62
Fruits	4	9	43	56
Ornamentals	8	18	34	60
Total horticultural research	24	47	125	196
Animal Research Center	1	3	9	13
Animal production	40	40	56	136
Veterinary science	10	26	28	64
Total animal research	51	69	93	213
Fisheries Research Center *	4	5	13	22
Saltwater fish	14	27	55	96
Freshwater fish	5	27	57	89
Coastal water fish	3	20	60	83
Total fisheries research	26	79	185	290
Industrial Crops Research Center	5	10	28	43
Medicinal plants	13	32	77	122
Tobacco & fiber crops	6	20	62	88
Coconut & palms	2	17	26	45
Total industrial crops research	26	82	208	316
Agricultural machinery	1	7	36	44
Soil and climate	14	50	95	159
Agricultural socioeconomics	20	45	57	122
Provincial tech. assessment centers	27	167	793	987
AARD secretariat and planning	9	29	66	104
AARD library and information	0	11	31	42
Total AARD institutes	276	738	1,994	3,008
Oil Palm	11	31	46	88
Rubber	17	41	57	115
Sugar	16	29	67	112
Coffee and Cacao	8	17	17	42
Tea and Quinine	4	15	21	40
Biotechnology & agribusiness	10	8	14	32
Total estate crops (IPARD)	66	141	222	429
Forestry (FORDA)	30	117	339	486
Total agriculture	372	996	2,555	3,923

* In 2001, the fisheries research institutes were transferred from AARD to the newly formed Ministry of Marine Affairs and Fisheries. Sources: Scientists at AARD and IPARD institutes from AARD (Statistik Penelitian Pertanian: Sumberdaya, Program dan Hasil Penelitian, 1997). Forestry scientists from FORDA (1997).

technology assessment institutes (ATAI) have a relatively large number of B.Sc.-level staff, many of whom serve in extension training. Most of the growth in IAARD research staff since 1995 has occurred in the ATAI's.

We used the allocation of scientists among commodity-oriented institutes to develop some parity ratios for research resource allocation in Indonesia. We define the parity ratio as the number of scientist-years (SY) per billion PPP dollars in value-added production for a commodity group. Parity ratios provide a rough, first approximation for assessing the allocation of research resources among commodities, although equal parity among commodities may not be economically or socially optimal (Ruttan, 1982).

For all agriculture research, there was an average of 19 SY per billion dollars in value-added in the agricultural sector. The parity ratio for research on non-food crops (estate and industrial crops) was double the average, at 40 SY per billion dollars in value-added. Research on food crops, livestock, and horticulture received the least attention, with only 10-15 SY per billion dollars in value added. Also, funding per scientist at IPARD institutes (estate crops) is substantially higher than funding per scientist at IAARD institutes, further widening the gap in parity among commodity groups. The disparity in parity ratios between research on estate crops versus other crop and livestock commodities reflects both the longer history of estate crop research in Indonesia and the ability of these institutes to self-finance research through commodity sales and producer contributions.

Table 12. Parity ratios for agricultural research by commodity group

Commodity group	Value-added (billion \$/year)	Number of scientists (SY) in 1997				Parity ratio (SY/billion \$)
		Ph.D.	M.S.	B.S.	Total SY	
Non-food crops	17.5	88	221	396	705	40.4
Forestry	12.8	30	117	339	486	38.0
Fisheries	13.7	26	79	185	290	21.2
Livestock	13.7	51	69	93	213	15.6
Food crops	38.1	78	152	305	535	14.0
Horticulture	18.8	24	47	125	196	10.4
All	126.0	297	685	1,443	2,425	19.2

Value added is average over period 1989-1993 in 1999 international dollars

Sources: Commodity value-added is from Warr and Azis (1997). For number of scientists see Table 11.

B8. Accountability and impact of agricultural research

The investment in agricultural R&D has brought significant benefits to the Indonesian economy. One indicator of the achievement of agricultural research in Indonesia is the release and dissemination of new crop varieties. Between 1969 and 1998, at least 449 crop varieties were released in Indonesia (Table 13). About one fourth of the new releases were high-yielding rice varieties. Improved rice varieties had disseminated to nearly two-thirds of rice-growing areas by 1991 (mostly to wetland rice areas). New varieties of soybean and maize were also widely disseminated in the 1980s. Another indicator of the benefits of research is the increased rate of growth in total factor productivity in crop and livestock agriculture from the early 1980s up until the Asian monetary crisis of the late 1990s (Fuglie, 2002).

Measurement of the economic value of research outcomes has so far not entered into the formal evaluation of agricultural research in Indonesia. Only a few studies have been carried out on the economic impact of agricultural research in Indonesia. Salmon (1991) estimated that rice research expenditures between 1965 and 1977 achieved an annual internal rate of return of 151 percent. Evenson et al. (1997) estimated rates of return to research for eight food crops (1968-

Table 13. Number of crop varieties released in Indonesia

Period	1969-73	1974-78	1979-83	1984-88	1989-93	1994-98	Total	Estimated IV area in 1991 (%)
Rice	4	18	29	27	21	11	110	65
Maize	1	1	7	5	11	13	38	44
Soybean	-	1	4	5	15	7	32	66
Groundnut	-	-	5	1	9	3	18	
Mungbean	-	-	5	3	3	4	15	
Cassava	-	2	-	1	3	4	10	
Sweetpotato	-	1	2	-	2	3	8	
Sorghum	3	-	1	3	2	-	9	
Other legumes	-	-	-	1	4	5	10	
Wheat	-	-	-	-	2	-	2	
Total Food Crops	8	23	53	46	72	50	252	
Fruits	-	-	-	22	19	37	78	
Vegetables	-	-	-	17	1	8	26	
Total Horticulture	0	0	0	17	1	8	104	
Sugar cane	-	-	-	2	31	-	33	
Rubber	-	-	-	-	1	11	12	
Coffee	-	-	-	-	2	3	5	
Tea	-	-	-	5	-	-	5	
Cacao	-	-	-	-	-	4	4	
Oil palm	-	-	-	-	1	-	1	
Cotton	-	-	-	3	7	-	10	
Coconut	-	1	4	-	3	-	8	
Pepper	-	-	-	4	3	-	7	
Lemon grass	-	-	-	-	4	-	4	
Tobacco	-	1	-	1	-	-	2	
Kenaf	-	-	-	-	-	2	2	
Total Non-Food Crops	0	2	4	15	52	20	93	
Total Varieties Released	8	25	57	78	125	78	449	

Sources: Varieties released from AARD (Statistik Penelitian Pertanian: Sumberdaya, Program dan Hasil Penelitian, 1997 and 1999). Estimates of area in improved varieties (IV) from AARD (1992) and CIMMYT (1994).

1992), six vegetable crops (1982-1992), and six fruit crops (1982-1992). They found a significant correlation between the level of research investments and the rate of productivity growth for most of these commodities. Estimated rates of return to research exceed 100 percent

for wetland rice, dryland rice, maize, soybeans, sweetpotato, all six vegetable crops and three out of six fruit crops included in the study. Only research on cassava and mango showed no impact. The high rates of return to research reflected the very low level of research investment relative to commodity value. Thus, any positive statistical association found between research and productivity would necessarily result in a high marginal rate of return to research (Evenson et al., 1997).

One limitation of the returns-to-research studies is that they probably did not fully account for the contributions of research conducted outside the country. Indonesian agriculture has been able to benefit significantly from technologies developed elsewhere and introduced through public and private channels. The growing capacity in agricultural research within Indonesia has undoubtedly enhanced the country's ability to acquire and disseminate new technologies developed elsewhere. But in some cases technologies were introduced requiring little government-supported research. Several of the first releases of new rice varieties, for example, were varieties developed by IRRI in the Philippines. In 1991, one major IRRI variety (IR36) occupied about one-third of wetland rice growing area in Indonesia (IAARD, 1992). Pray and Fuglie (2002) identified several areas where the private sector played a major role in transferring technologies to Indonesia, including new clones of oil palm and rubber from Malaysia, hybrid vegetable and hybrid maize varieties, and hybrid poultry and integrated poultry production systems. The private sector also played a major role in the rapid expansion of coastal shrimp farming in the early 1990s based on technology developed in Taiwan, China (World Bank, NACA, WWF and FAO, 2002).

The return-to-research studies have been influential in strengthening financial support for agricultural research within the Indonesian bureaucracy and with the foreign aid community. In

the late 1990s, the Asian Development Bank and the World Bank financed several loans to expand and strengthen Indonesian agricultural research. The evidence on previous rates of return to research were cited in the loan proposals, and helped convince Bank officials that agricultural research was likely to be a high pay-off investment for Indonesia.

PART C. LESSONS TO BE LEARNED

Indonesia represents a case where agricultural R&D expanded rapidly from almost nil during the last 30 years of the 20th Century, but where R&D investment still remained low relative to the size of the country's agriculture. The initial focus on increasing the production of rice in order to enhance national food security was highly successful but ran into diminishing returns by the 1990s. A major goal of the current R&D effort is to diversify growth to other commodities and farming systems. To that end the agricultural R&D system has greatly increased the number of commodities, problem areas, and geographical locations in which it conducts research. However, the expansion of the scope of the system in the face of chronic under funding has resulted in fragmentation and lack of continuity in many agricultural research endeavors.

The Indonesian agricultural research system actually has several distinct components, each with different modes of financing and operations. The largest component of the system is IAARD in the Ministry of Agriculture. IAARD is financed primarily from general government revenues and foreign aid. Foreign assistance has been critical to counterbalance the instability in the government development budget for agricultural research. IAARD is attempting to diversify its source of financing to include revenue from technology licensing and other product sales. But given weak enforcement of intellectual property rights and restrictive government regulations on

the use of revenue earned by public institutions, it is unlikely that technology sales will become a significant source of funds for IAARD in the near term.

A second component of the system is IPARD, which has responsibility for estate crops. Although IPARD is nominally under IAARD's wing, it functions largely autonomously. It is almost entirely self-financed through sales of research products and from annual contributions by large state-owned and private estates. IPARD has been more successful than IAARD in mobilizing financial support for research and research intensity for estate crops is considerably higher than for food crops and livestock. An important issue facing IPARD is how it addresses the needs of small producers of estate crops. The productivity of small holders is far below that of the large estates (IAARD, 1992). Whether IPARD primarily serves the interests of large estates or can also develop effective delivery systems for small farms will have a major impact on future productivity growth in estate crop production in Indonesia.

Forestry and fisheries research, once part of IAARD, are other components of the system. Forestry and fisheries research institutes are now housed in separate ministries. Forestry research receives about two-thirds of its funding from the forestry sector itself and appears to be relatively well-funded. Fisheries research was only separated from IAARD in 2001. So far it remains relatively small and reliant on government revenue for most of its funding. It is too early to judge how its new status will affect its financing, policies, and impact.

The other components of the agricultural R&D system in Indonesia are the agricultural universities, the private sector, and the international agricultural research centers. Universities have significant intellectual capacity for research but rely primarily on winning competitive grants and other projects from the State Ministry for Research and Technology and other government sources. Private-sector research is still relatively small and focused on a few

commodities such as estate crops, hybrid crops, and poultry, and pesticide utilization. IAARD has had relatively good linkages with international agricultural research centers, especially IRRI's rice breeding program. In the 1980s two international centers with mandates for natural resources research (CIFOR and ICRAF) established a significant presence in Indonesia. Linkages between IAARD, universities and private companies were strengthened through special funds established as part of loans projects from the World Bank and ADB. But it is too early to evaluate the effectiveness (and sustainability) of these initiatives.

Like many developing countries, the Indonesian government has made a concerted effort to build a capacity in agricultural biotechnology research. Its strategy has been to concentrate this capacity in a limited number of research institutes. At the same time its biotechnology resources have been allocated across a large number of commodities and technologies. It has also established a regulatory system for field testing and approving genetically modified organisms for commercial use. By 2001 a few hundred hectares of genetically modified cotton developed by the private sector was grown commercially in Sulawesi, Indonesia.

Like much of the Indonesian central government, the agricultural research system faces a major challenge of adjusting to the new political climate brought about by the political and economic crises that have engulfed the country since 1997 and led to the change of government regime in 1998. An outcome of the crises is that public investment in agriculture, including agricultural research, has fallen significantly in real terms. To maintain and enhance its viability and impact, the agricultural research system will need to increase its base of support in the national parliament and among civil society at large. IAARD responded early to the need for greater decentralization of government services by establishing provincial-level agricultural research and extension training centers in each province. Most of the growth in IAARD staff

since 1995 has been in the provincial centers. A major question facing these centers is whether provincial governments will be willing and able to assume a larger role in supporting them financially. A major challenge for the agricultural research system as a whole is whether it can find new and creative means to increase its financial base and stability.

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ENDNOTES

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² Oil palm, rubber, sugar cane, coffee, tea, and cacao are classified as “estate” crops by the Ministry of Agriculture even though small holders play a major role in the production of these crops (and are in fact the major producers of rubber, coffee, and cacao). Large private and state-owned estates only have a significant presence in oil palm, sugar cane, rubber and tea. Other non-food crops are classified as “industrial crops,” and include coconut, other palms, tobacco, spices, and fiber crops. We follow these conventions in the paper.

³ For longer-run assessments of productivity changes in Indonesian agriculture, see Booth (1988) and Van Der Eng (1996). Geertz (1963) provides the classic treatment of changes in indigenous agricultural production in Indonesia (especially Java) from pre-colonial times to the 1950s.

⁴ The Government of Indonesia classifies its expenditures into *routine* expenditures (for salaries and capital maintenance) and *development* expenditures for everything else.

⁵ IAARD is the primary government institution responsible for agricultural research in Indonesia. IAARD is located within the Ministry of Agriculture.

⁶ IAARD's first laboratory for agricultural biotechnology was established in 1989 with financial support from Japan. In 1995, IAARD created the Research Institute for Food Crop Biotechnology (RIFCB) to house its growing biotechnology research capacity. In 2001, IAARD's crop and livestock biotechnology research was amalgamated into the newly formed Center for Agricultural Biotechnology and Genetic Resources.

⁷ Estate crop research was funded by a cess (tax) on commodity exports until the early 1980s. Now contributions are apportioned among IPARD members in proportion to their total sales. IPARD is composed of 14 state-owned plantation enterprises and 4 to 5 large private plantations (personal communication, Radhi Sumitro, August 1999). IPARD has research stations for oil palm, rubber, sugar cane, coffee, tea, and cacao.

⁸ For example, the salaries of scientists working at the plantation crop institutes are not subject to civil service rules and are substantially higher than that of civil servants of similar grade.

⁹ Agricultural research by Indonesian universities has not been systematically assessed or studied. For the purpose of this study, we examined the profile of research expenditures for Bogor Agricultural University (IPB) for 1998/1999 and simply multiplied these figures by three to obtain an estimate for agricultural research by all universities in Indonesia. IPB has by far the largest agricultural research program among universities in Indonesia. At the present time the financing of education and research activities at several national universities (including IPB) is being significantly changed as these universities acquire “autonomy” status. One implication is that government routine budget support will decline and universities will have greater flexibility (and need) to be financially self-sufficient.