Status and Performance of Irrigation in Indonesia and the Prospects to 1990 and 2000

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FOREWORD

The Rice Policies in Southeast Asia Project is a collaborative effort involving the International Food Policy Research Institute, the International Rice Research Institute, the International Fertilizer Development Center, and researchers and institutions in Indonesia, Malaysia, the Philippines, and Thailand.

As part of the project, a series of working papers was commissioned to provide an overview of the status, performance, and prospects of irrigation in the four countries. The papers review and summarize available information on the area, yield, production, and cropping intensity impact of rice-based irrigation and make preliminary assessments of long-term irrigation development prospects based on past trends and government investment plans. The papers in this series represent revised versions of papers originally presented at the Workshop on Rice Policy in Southeast Asian Countries, Los Baños, Philippines, May 22-25, 1979.

The working papers are intended to sketch the broad dimensions of irrigation development in the four countries and to identify key issues for further study, rather than to provide original analysis of these issues. Rigorous analysis of several of the important issues, including the income distribution impact of irrigation and the relative efficiency of investment in irrigation schemes of alternative sizes, water sources, and water allocation systems, is now under way by researchers at IFPRI and in the collaborating countries.

Mark W. Rosegrant
Coordinator, Rice Policies
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1. INTRODUCTION

Agriculture has been and continues to be the major labor-employing sector in Indonesia. Within agriculture, rice is the most important crop. The employment, production, and income generated from rice are greater than for any other crop. Government assistance to the agricultural sector for both development and production has focused on irrigation rehabilitation development and on credit-extension programs.

The amount of resources invested in irrigation from both internal and external sources was large during the 1970s. Approximately Rp 660 billion was spent on development. External agencies provided a billion dollars for irrigation during Repelita I and Repelita II. (See Table 1 for details.) Canal rehabilitation improved the quality of

Table 1--Expenditures on irrigation development, 1969/70-1978/79

Year	Type of Development: Rehabilitation	Expansion	River/Flood Control	Swamp/Tidal Development	Total
	(billion rupiah)				
Repelita I	50.0	25.0	6.3	33.1	114.4
1969/70	7.6	5.3	1.9	5.8	20.7
1970/71	7.9	4.6	0.9	6.3	19.7
1971/72	9.2	4.7	0.9	6.5	21.3
1972/73	11.0	5.4	1.4	7.0	24.8
1973/74	14.3	5.0	1.2	7.4	27.9
Repelita II	144.0	195.7	196.7	---a/	546.6
1974/75	10.7	14.3	10.1	a/	36.2
1975/76	16.8	26.1	36.8	a/	81.8
1976/77	26.5	36.2	37.6	a/	102.3
1977/78	36.2	50.2	46.8	a/	135.6
1978/79	53.7	68.8	65.4	a/	190.8
Total	194.0	220.7	103.0	---	661.0

Source: Indonesia, Directorate General of Water Resources Development, unpublished data.

Note: Totals may not equal sums due to rounding.

a/This figure is included in river/flood control except for small amounts for overhead that are included in the totals.

irrigation on almost 1.5 million hectares. However, many of the benefits of these investments were not realized as these benefits were discontinuous. Much of the work on tertiary development will complete rehabilitation in areas where rehabilitation was started.

Under the last five-year plans, the government planned to expand irrigation systems to an additional 1.38 million hectares but actually expanded them to only about half a million hectares. However, the development of tidal/swamp irrigation on 450,000 hectares surpassed the targets. Table 2 contains data on the physical irrigation development achieved during the last five-year plans.

This paper is primarily concerned with potential rice output over the next two decades. Therefore it reviews the components of production and attempts to determine their importance. Labor absorption is examined briefly, but is not reviewed in detail. Nor is the effect of irrigation on income distribution discussed. Income generation is so dependent on prices that only limited attention was focused on it.

It is generally conceded that most future irrigation development must occur off Java. This study concurs in that assessment as it finds that little undeveloped land remains on Java. Alternative types of irrigation, their costs, and their potential are reviewed.

Table 2--Irrigation development, 1969/70-1978/79

Year	Type of Development			
	Rehabilitation	Expansion	River/Flood Control	Swamp/Tidal Development
	(hectares)			
Repelita I	953,546	191,246	248,585	178,666
1969/70	230,330	43,153	73,259	21,059
1970/71	171,549	24,379	62,406	25,000
1971/72	135,754	46,400	57,045	14,905
1972/73	172,444	45,834	55,875	61,562
1973/74	263,469	31,480	40,853	56,140
Repelita II	526,769	273,198	---	272,034
1974/75	108,956	20,684	71,124	8,154
1975/76	105,143	88,522	97,688	51,134
1976/77	112,011	63,435	16,248	55,549
1977/78	112,015	41,157	n.a.	62,099
1978/79	88,644	59,400	n.a.	95,098
Total	1,480,315	464,444	---	450,700

Source: Indonesia, Directorate General of Water Resources Development, unpublished data.

Note: Where n.a. appears, the figure was not available.

Inventory estimates of irrigated area are derived from several sources, and the inconsistencies are discussed. Considerable use was made of unpublished data assembled by the Central Bureau of Statistics. Cropping intensities, fertilizer response functions, and other production information were obtained from sources not used before.

The 1978/79-1983/84 five-year plan allocates Rp 1.5 trillion to irrigation (this is approximately U.S. $2.4 million at the 1981 exchange rate). Since in previous plans expenditures were greater than targeted expenditures, it is probable that Rp 1.5 trillion will be a minimum. However, the physical targets for Repelita III appear to be optimistic. Previous area expansion targets, and other targets as well, were unrealized, yet expenditures were greater than planned. (See Table 3 for a summary of the targets and achievements of Repelita I, II, and III.) Therefore, this paper will assume that the physical targets for Repelita III will be achieved only by 1990. These data will form the base for future rice production projections.

To make the projections, a set of quantifiable data was developed to estimate irrigated area and yields. Past growth rates were ignored as it was assumed that the conditions affecting change in the future will be fundamentally different from those affecting it in the past.

Table 3--Irrigation development targets and realizations by project and five-year plan, 1969/70-1983/84

Project	Repelita I (1969/70-1973/74) Initial Target	Repelita I (1969/70-1973/74) Revised Target	Repelita I (1969/70-1973/74) Realized	Repelita II (1974/75-1978/79) Target	Repelita II (1974/75-1978/79) Realized	Repelita III (1979/80-1983/84) Target
	(hectares)					
Rehabilitation	830,000	928,554	953,546	834,698	526,769	813,865
Prosida		295,912		334,699		137,576
Prosijat		170,000		127,743		3,600
Other large projects		462,642		59,291		194,762
Inpres project				312,965[a]		477,927[a]
Expansion	430,000	192,533	191,246	950,000	273,198	766,140
Large		89,310		141,678		241,892
Small-medium		103,223[b]		259,322		209,248
Simple				550,000		315,000
Tidal/swamp	255,633[a]	148,797[a]	178,666	163,000	273,034	535,000
Tidal		31,037		65,990		400,000
Swamp		36,920		97,010		135,000
Tertiary development						500,000

Sources: Indonesia, Departemen Pekerdjean Umum dan Taraga Listrik (DPUTL), Direktorat Jendral Pengairan, Daftar Luas Areal Daerah Pemgairan Yang Dilola DPU Propinsi di Seluruh Indonesia, Tahun 1968 s/d 1978, Nopember 1978; Indonesia, DPUTL, Direktorat Jendral Pengairan, Mid-Term Review Repelita II, 1974/75-1976/77, Bidang Pengairan, Maret 1977; Indonesia, DPUTL, Direktorat Jendral Pengairan, Rencana Pembangunan Lima Tahun ke III, Repelita III, 1979/80 s/d 1983/84; Indonesia, DPUTL, Direktorat Jendral Pengairan, unpublished data.

a/This includes other items not listed.
b/This is the sum of the figures for small-medium projects and simple projects.

2. INVENTORY OF IRRIGATED AREAS

The area of land that falls within the command areas of the irrigation systems of the Department of Public Works (DPU) is well known. Table 4 lists it by province and type of irrigation. Although these data have limitations, they were used as the basis for later projections. The areas actually irrigable are known less well. Nor are the land areas classified as rainfed paddy land well defined.

Sixty percent of the DPU irrigation systems are concentrated on Java. Approximately 23 percent of them are located on Sumatera, which also contains most of the tidal/swamp irrigation. Sulawesi contains about 7 percent. The remaining tidal/swamp irrigation and most of the rest of the irrigation systems are on Kalimantan.

The more sophisticated types of irrigation are distributed even more unequally. About 85 percent of the technically irrigated land is on Java. Technically irrigated land has both higher yields and higher cropping intensities than other types of irrigation (see Table 5). Sixty percent of the semitechnically irrigated land and about 55 percent of the simple and rainfed irrigated land is on Java.

In 1976 the Central Bureau of Statistics surveyed rice lands in cooperation with the Ministry of Agriculture. The data from this survey correlate closely with the command area statistics (Table 4) for several provinces but are quite disparate for other provinces. Much of this disparity can be explained by the differences in definitions. Table 6 contains the survey data by province and reflects only those areas on which rice was grown. If rainfed areas are omitted or ignored, then the data are similar to those in Table 4 and the aggregates are as anticipated, that is, the land area in rice was about 260,000 hectares less than the aggregate command areas.

Tables 7 and 8 contain data on land areas with assured water supplies for the 1978 and 1978/79 dry and wet seasons. It is assumed that any land that would appear in the 1978 dry season statistics would also appear in the 1978/79 wet season data. There are many disparities between the data in Table 7 and in the previous two tables, but, again, some of these are caused by differences in definitions. Rainfed paddy land is defined as bunded fields that rely solely on rainfall for the water supply. In reality, however, these fields often receive drainage water from other paddy fields. Thus, while the provincial data by type of irrigation differ, the total irrigated areas are similar.

The data in Tables 7 and 8 show how much land has assured water supply and so is eligible for subsidized credit (intensification) programs. It does not mean that such intensification programs are used, nor does it necessarily mean that rice is grown. Table 9 contains data for each season on the actual areas on which rice is planted under intensification and nonintensification programs. These data grossly understate the total area on which rice is planted or harvested.

Table 4--Command areas of Department of Public Works irrigation systems, 1978

Province	Public Works				Tidal and Swamp Irrigation	Total
	Technical	Semitechnical	Simple	Total		
	(hectares)					
Aceh	---	22,703	91,071	113,774	---	113,774
Bali	---	46,641	6,432	53,073	---	53,073
Bengkulu	8,689	15,039	34,928	58,656	---	58,656
Jakarta	9,597	4,569	40	14,206	---	14,206
Jambi	675	5,096	19,228	24,999	28,080	53,079
Java						
Central	449,019	96,480	203,021	748,520	---	748,520
East	605,399	122,597	181,710	909,706	---	909,706
West	510,669	182,216	128,737	821,622	---	821,622
Kalimantan						
Central	---	---	---	---	54,729	54,729
East	1,167	1,214	30,173	32,554	168	32,722
South	3,500	12,634	2,454	18,588	51,859	70,447
West	---	11,220	2,250	13,470	22,856	36,326
Lampung	102,034	16,222	---	118,256	---	118,256
Nusatenggara						
East	---	9,803	13,860	23,663	---	23,663
West	33,379	71,612	51,764	156,755	---	156,755
Riau	---	21,260	8,430	29,690	88,290	117,980
Sulawesi						
Central	8,435	14,983	5,160	28,578	---	28,578
North	3,242	35,563	12,165	50,970	---	50,970
South	50,336	83,661	79,751	213,748	---	213,748
Southeast	7,674	13,440	---	21,114	---	21,114
Sumatera						
North	76,440	44,388	75,158	195,986	49,515	245,501
South	16,000	39,347	30,867	86,214	36,280	122,494
West	28,432	60,842	102,575	191,849	6,911	198,760
Yogyakarta	---	53,111	33,945	87,056	---	87,056
Total	1,914,687	984,641	1,113,719	4,013,047	338,688	4,351,735

Sources: Indonesia, Departemen Pekerdjean Umum dan Taraga Listrik, Direktorat Jendral Pengairan, Daftar Luas Areal Daerah Pengairan Yang Dilola DPU Propinsi di Seluruh Indonesia, Tahun 1968 s/d 1978, Nopember 1978.

Note: Rainfed irrigated lands are not included in the statistics of the Department of Public Works.

Table 5--Rice area harvested, yield, and production of wetland paddy, by province, 1978

Province	Area Harvested (1,000 hectares)	Yield[a] (kilograms/ hectare)	Production[a] (1,000 tons)
Aceh	194.5	2,968	577.2
Bali	158.8	3,526	560.1
Bengkulu	51.6	2,825	145.9
Irian Jaya	0.4	2,110	0.8
Jambi	115.9	2,892	335.2
Jakarta	18.6	2,576	48.0
Java			
Central	1,307.6	3,385	4,425.8
East	1,312.6	3,735	4,902.5
West	1,735.1	3,157	5,477.0
Kalimantan			
Central	67.6	1,673	113.2
East	32.4	1,672	54.1
South	277.9	2,262	628.5
West	193.4	2,175	420.6
Lampung	135.7	3,168	429.9
Maluku	0.5	2,138	1.1
Nusatenggara			
East	54.5	2,108	114.9
West	190.0	3,053	580.1
Riau	89.6	2,086	186.9
Sulawesi			
Central	61.1	2,125	129.9
North	64.3	2,978	191.5
South	558.0	3,010	1,679.6
Southeast	11.8	1,772	21.0
Sumatera			
North	421.3	3,245	1,367.1
South	251.6	2,694	677.8
West	254.4	3,318	844.1
Yogyakarta	93.5	3,771	352.5
Total	7,653.0[b]	3,171	24,265.6[b]

Source: Indonesia, Biro Pusat Statistik, Produksi Tanaman Bahan Makanan di Indonesia: 1978.

a/These figures are for gabah or dry paddy.
b/The sum of the figures above may not equal the total due to rounding.

Table 6--Land area in rice field by province and type of irrigation, 1976

Province	Public Works				Rainfed Land	Tidal and Swamp Irrigation	Other	Total
	Technical	Semitechnical	Simple/ Village	Total				
	(hectares)							
Aceh	12,893	31,504	73,182	117,579	72,053	3,074	300	193,006
Bali	2,238	42,872	74,640	119,750	876	---	40	120,666
Bengkulu	2,950	5,285	6,619	14,854	2,257	---	3,184	20,295
Jakarta	4,903	2,148	109	7,160	4,442	---	---	11,602
Jambi	428	4,542	11,000	15,970	9,601	747	15,332	41,650
Java								
Central	291,307	158,736	200,716	650,759	341,518	488	5,791	998,556
East	545,714	173,032	127,408	846,154	285,482	4,762	7,321	1,143,719
West	365,305	174,721	288,453	828,479	278,163	---	---	1,106,642
Kalimantan								
Central	1,784	4,801	37,885	44,470	8,951	11,829	1,100	66,350
East	645	176	3,809	4,630	41,862	2,595	5,058	54,145
South	200	2,320	6,752	9,272	98,017	85,987	4,475	197,751
West	516	2,187	16,713	19,416	74,439	39,768	3,641	137,264
Lampung	22,354	6,886	16,326	45,566	26,873	580	1,879	74,898
Nusatenggara								
East	1,250	10,880	14,496	26,626	9,602	885	220	37,333
West	53,322	47,398	28,614	129,334	30,541	45	---	159,920
Riau	335	3,109	3,732	7,176	23,407	43,757	19,629	93,969
Sulawesi								
Central	568	7,686	20,901	29,155	5,659	165	401	35,380
North	3,356	12,782	6,645	22,783	4,034	468	---	27,285
South	79,900	31,895	61,679	173,474	142,258	2,500	4,763	322,995
Southeast	665	975	6,831	8,471	5,458	610	---	14,539
Sumatera								
North	20,852	44,436	70,134	135,422	138,248	4,970	8,563	287,203
South	5,710	3,370	25,396	34,476	48,096	44,274	56,112	182,958
West	4,170	36,587	80,787	121,544	45,715	---	3,050	170,309
Yogyakarta	13,090	27,443	11,973	52,506	14,602	74	65	67,247
Total	1,434,455	835,771	1,194,800	3,465,026	1,712,154	247,578	140,924	5,565,682

Source: Indonesia, Biro Pusat Statistik, unpublished data.

Table 7--Area of land with assured water supply suitable for intensified rice production programs, by province and type of irrigation, dry season 1978

Province	Public Works			Private Works	Rainfed Land	Other	Total
	Technical	Semitechnical	Simple				
				(hectares)			
Aceh	---	20,331	---	6,570	---	---	26,901
Bali	---	30,107	4,083	25,810	---	---	60,000
Bengkulu	8,689	15,039	34,713	---	---	---	58,441
Jakarta	---	---	---	---	---	---	---
Jambi	400	3,700	9,630	4,335	---	49,820	67,885
Java							
Central	131,732	33,789	5,818	117,994	---	---	289,333
East	266,000	---	---	3,000	---	---	269,000
West	286,073	99,695	34,970	98,904	---	1,390	521,032
Kalimantan							
Central	---	---	500	---	---	19,300	19,800
East	620	160	2,250	---	10,995	3,054	17,079
South	725	1,275	300	950	4,900	40,819	48,969
West	---	7,880	3,290	11,930	54,760	104,730	182,590
Lampung	10,953	---	---	6,710	---	---	17,663
Nusatenggara							
East	2,750	1,870	1,045	6,700	---	---	12,365
West	18,782	5,877	650	---	---	---	25,309
Riau	---	2,957	2,897	6,666	12,620	15,320	40,460
Sulawesi							
Central	5,706	9,716	18,050	29,499	2,392	450	65,813
North	4,082	20,819	11,536	---	1,113	---	37,550
South	43,302	23,054	21,666	44,258	198,288	---	330,568
Southeast	279	---	---	5,571	6,749	1,100	13,699
Sumatera							
North	11,547	38,052	8,804	69,476	100,666	11,971	240,516
South	8,400	---	---	9,631	---	128,823	146,854
West	22,979	56,693	30,937	47,452	28,407	---	186,468
Yogyakarta	1,200	11,775	15,187	22,262	14,039	---	64,463
Total	824,219	382,789	206,326	517,718	434,929	376,777	2,742,758

Source: Indonesia, Departemen Pertanian, unpublished data.

Table 8--Area of land with assured water supply suitable for intensified rice production programs, by province and type of irrigation, wet season 1978/79

Province	Public Works			Private Works	Rainfed Land	Other	Total
	Technical	Semitechnical	Simple				
				(hectares)			
Aceh	---	20,331	93,443	33,150	63,843	---	210,767
Bali	---	34,161	4,774	48,093	3,541	---	90,569
Bengkulu	8,689	15,039	34,713	4,659	---	---	63,100
Jakarta	---	---	---	---	---	---	---
Jambi	400	2,700	10,000	10,900	4,155	60,601	88,756
Java							
Central	311,449	98,460	26,344	163,511	296,733	---	896,497
East	551,400	123,000	93,350	163,815	42,000	---	973,565
West	498,703	178,671	126,727	198,742	161,485	---	1,164,328
Kalimantan							
Central	---	---	13,060	---	10,399	59,468	82,927
East	742	180	5,080	---	26,880	3,256	36,138
South	2,323	5,859	5,425	6,800	96,976	138,874	256,257
West	---	7,880	3,290	11,930	54,760	104,730	182,590
Lampung	57,315	---	1,457	16,822	22,810	2,336	100,740
Nusatenggara							
East	3,750	3,286	3,254	27,627	67,372	---	105,289
West	61,049	42,769	31,247	10,869	30,205	---	176,139
Riau	---	4,200	6,750	8,300	19,829	71,120	110,199
Sulawesi							
Central	2,725	8,442	6,515	40,647	692	---	59,021
North	4,082	20,819	11,536	8,029	1,113	---	45,579
South	80,491	15,597	21,739	55,094	109,360	---	282,281
Southeast	279	---	---	4,215	---	---	4,494
Sumatera							
North	12,828	50,996	18,857	94,219	87,833	11,063	275,796
South	18,717	9,594	14,563	31,555	24,314	42,113	140,876
West	24,706	70,281	43,593	55,075	36,115	---	229,770
Yogyakarta	1,200	23,166	32,032	4,200	45,009	---	105,607
Total	1,640,848	735,431	607,749	998,252	1,205,424	493,581	5,681,285

Source: Indonesia, Departemen Pertanian, unpublished data.

Table 9--Rice area harvested and yields under intensification and nonintensification programs, by province, dry season 1976 and wet season 1976/77

Province	Intensification				Nonintensification			
	1976		1976/77		1976		1976/77	
	Area (hectares)	Yield (kilograms)	Area (hectares)	Yield (kilograms)	Area (hectares)	Yield (kilograms)	Area (hectares)	Yield (kilograms)
Aceh	12,388	5,608	45,294	4,077	55,320	4,225	101,359	3,738
Bali	50,063	4,950	64,215	4,963	14,636	4,397	18,635	3,949
Bengkulu	3,793	4,196	11,900	3,237	18,253	3,493	20,591	2,957
Jambi	3,761	3,706	7,979	3,904	66,798	3,500	34,699	3,571
Java								
Central	234,566	5,638	584,665	4,306	111,778	3,793	218,474	3,389
East	233,068	5,270	715,101	5,056	75,958	3,879	200,950	3,470
West	472,463	4,848	701,149	4,288	181,635	3,613	261,362	3,515
Kalimantan								
Central	1,128	2,542	11,483	2,205	39,427	2,398	15,049	2,032
East	1,114	2,880	11,659	2,685	2,456	2,405	19,635	2,408
South	22,158	3,550	54,079	3,974	156,209	2,549	41,836	2,880
West	7,563	3,650	32,311	3,829	32,513	-3,210	121,104	2,602
Lampung	11,425	4,755	67,285	3,641	21,990	3,562	23,035	3,146
Nusatenggara								
East	498	3,376	8,868	3,323	25,798	2,753	10,003	2,822
West	13,575	3,387	45,663	3,796	9,505	2,999	105,247	3,029
Riau	5,120	2,884	10,725	2,946	6,457	2,895	68,287	2,847
Sulawesi								
Central	9,117	3,526	11,927	3,686	23,790	3,010	15,902	2,902
North	10,707	4,235	13,632	4,061	10,886	3,533	26,107	2,819
South	64,882	3,971	82,042	4,147	175,488	3,406	175,163	3,823
Southeast	452	3,708	540	2,911	6,663	2,205	2,375	2,364
Sumatera								
North	40,102	4,980	108,686	4,285	57,759	4,028	183,538	3,533
South	11,399	3,653	17,020	3,517	108,471	3,422	89,499	3,372
West	64,646	5,256	84,713	4,476	56,673	4,383	58,823	3,762
Yogyakarta	20,046	5,118	43,352	4,731	3,009	3,799	7,423	3,506
Total	1,294,034	---	2,725,420	---	1,261,472	---	1,819,096	---

Source: Indonesia, Biro Pusat Statistik, Kompilasi Data Pengolahan dan Penaksiran Produksi Padi Intensifikasi 1976/77 di Propinsi Kelompok A dan B, Maret 1978.

Regardless of the source of data, certain similarities are clear. Irrigated land is highly concentrated in Java. Java and Bali contain about 60 percent of the irrigated paddy lands, and the provinces of North and West Sumatera, Lampung, South Kalimantan, and South Sulawesi contain another 18 percent. These provinces comprise a group called "Kelompok A." They are the primary rice-producing provinces of Indonesia and typically have higher yields than other provinces.

Survey data are not available for 1978. However, the command areas for irrigation systems within the DPU imply that irrigated area increased about 200,000 hectares between 1976 and 1978. These figures appear to be inconsistent with the data on irrigation development. The irrigation development data indicate that the area irrigated by conventional gravity systems increased about 100,000 hectares, that the tidal/swamp areas increased by 117,000 hectares, and that 224,000 hectares were rehabilitated. It is possible that the command areas expanded more than the area actually developed, but the inconsistency in tidal/swamp irrigation remains unexplained.

Similarly, the increase of area with an assured water supply can partially be accounted for by newly developed areas and rehabilitated areas that now have assured water supplies. Individual provincial data for 1978 are not substantially different from the data for 1976.

3. RICE PRODUCTION

Between 1971 and 1978 wetland rice production increased 30 percent. Area, yield, and production data for 1978 are listed by provinces in Table 5. Production on Java increased by 26 percent, and production off Java increased by 37 percent. There are, basically, three factors that affect production: irrigated area (discussed earlier), cropping intensity, and yield.

CROPPING INTENSITY

The status and performance of the irrigation system can be inferred from cropping intensities and yields. The cropping intensities of a few projects are available, but project data usually refer to command areas, and cropping intensities often are not computed annually. The intensities are frequently computed only for pilot project areas and are not indicative of intensities in larger areas.

The lack of consistent data hampers the determination of change in cropping intensity. Data from the agricultural census should permit construction of statistics for rice and food cropping.

The rice-cropping intensity appears to have increased between 1963 and 1973, but most of the change occurred off Java and Bali. In 1963 the rice-cropping intensity on Java and Bali was 1.29. It was essentially the same in 1973. The rice-cropping index off Java and Bali was only 0.78 in 1963 and has increased considerably. The food-cropping intensities improved more than the rice-cropping intensities. The 1963 food-cropping intensity was 1.39 on Java and Bali and 0.74 off Java and Bali. The 1973 statistics for rice intensity, food crop intensity, and total cropping intensity are listed by province in Table 10.

The highest rice-cropping intensities are found on Java and Bali. Food-cropping intensity is also high on Java and Bali, as it is in Lampung, North Sulawesi, and East Nusatenggara. The total cropping intensity values overstate the true value. According to these data, 6.3 million hectares of tobacco and sugar were grown in 1973, which is about 15 times too great.

The rice-cropping intensities in Table 11 are developed from a Bureau of Census survey on the frequency of planting rice and on irrigation type. The data apply only to bunded fields or to those areas that can be irrigated. The statistics in the table are for rice only; they do not reflect the cropping intensities of other crops grown on irrigated land. Land irrigated by tides has a cropping intensity so close to 1.00 that statistics for it were not listed separately. High rice-cropping intensities are found on Java, Bali, and North Sulawesi. However, Bali and North Sulawesi do not contain large irrigated areas. Provinces such as North Sumatera and South Sulawesi have large irrigated areas but low rice-cropping intensities.

Table 10--Cropping intensities, by province, 1973

Province	Rice Harvesting Intensity[a]	Food Cropping Intensity[b]	Cropping Intensity[c]
Aceh	0.84	0.81	0.92
Bali	1.53	1.39	2.10
Bengkulu	0.96	1.03	1.45
Jambi	0.75	0.76	0.96
Java			
Central	1.23	1.58	2.50
East	1.11	1.63	2.68
West	1.28	1.25	1.53
Kalimantan			
Central	0.73	1.00	1.56
East	0.45	0.83	1.35
South	0.90	0.93	1.06
West	0.65	1.11	1.86
Lampung	1.03	1.66	2.98
Maluku	0.33	1.06	2.17
Nusatenggara			
East	0.78	2.00	3.93
West	1.00	1.22	1.81
Riau	0.47	0.61	1.03
Sulawesi			
Central	1.09	1.14	1.81
North	1.12	1.42	2.55
South	0.95	1.15	1.70
Southeast	0.63	1.12	1.99
Sumatera			
North	1.02	1.09	1.52
South	0.85	1.03	1.49
West	1.09	1.01	1.11
Yogyakarta	1.52	1.67	3.65

Source: Indonesia, Biro Pusat Statistik, Sensus Pertanian 1973.

a/This is the cropping intensity of rice-harvested area/paddy land.
b/This is the cropping intensity of harvested food-crop area/cultivated land.
c/This is the cropping intensity of harvested food-crop area plus harvested annual industrial-crop area/cultivated land.

In most provinces technically irrigated land has a high rice-cropping intensity. There are some exceptions, such as Riau and West Kalimantan, that produce little rice. Other minor rice-producing provinces, such as Central Kalimantan and Southeast Sulawesi, have very high rice-cropping intensities.

Table 11--Cropping intensities on sawah by type of irrigation, by province, 1976

Province	Technical Irrigation	Semi-technical Irrigation	Simple Irrigation	Rainfed Land	Total
Aceh	1.12	1.38	1.26	1.00	1.16
Bali	2.00	1.79	1.73	1.00	1.75
Bengkulu	1.22	1.70	1.11	1.22	1.28
Jambi	1.71	1.45	1.14	1.00	1.09
Java					
Central	1.73	1.65	1.55	1.17	1.49
East	1.57	1.45	1.28	1.03	1.38
West	1.86	1.71	1.70	1.09	1.60
Kalimantan					
Central	2.00	1.00	1.00	1.00	1.02
East	1.96	1.57	1.72	1.70	1.64
South	1.25	1.47	1.10	1.06	1.04
West	1.00	1.32	1.03	1.06	1.04
Lampung	1.47	1.58	1.40	1.24	1.37
Nusatenggara					
East	1.63	1.29	1.22	1.00	1.19
West	1.55	1.29	1.10	1.00	1.26
Riau	1.00	1.30	1.02	1.00	1.01
Sulawesi					
Central	1.82	1.45	1.57	1.13	1.47
North	1.93	1.88	1.70	1.19	1.72
South	1.68	1.44	1.32	1.02	1.28
Southeast	2.00	1.18	1.12	1.00	1.11
Sumatera					
North	1.73	1.69	1.40	1.02	1.28
South	1.05	1.15	1.24	1.02	1.04
West	1.99	1.79	1.49	1.02	1.43
Yogyakarta	1.89	1.75	1.63	1.04	1.60

Source: Indonesia, Biro Pusat Statistik, unpublished data.

As might be expected, rice-cropping intensity generally declines on land with less sophisticated irrigation systems. The overall rice-cropping intensity for Java and Bali is 1.50. It is only 1.16 for the rest of Indonesia. South Sulawesi, the major rice-producing province off Java, has a rice-cropping intensity of 1.28.

The above data can be supplemented for Java as adequate data exist to enable food-cropping intensities to be calculated. The planting and harvesting intensities of food crops on Java are as follows:

Province	Planting Intensity	Harvesting Intensity
West Java	1.77	1.63
Central Java	1.66	1.54
Yogyakarta	1.64	1.72
East Java	1.60	1.72

When other food crops are considered, the statistics are even more consistent. However, the statistics still understate the actual cropping intensity because some sugarcane, tobacco, and other industrial crops are produced on bunded land.

RICE YIELDS

Immediately after World War II, rice yields were lower on Java than on other islands. But more recently, because of rice intensification programs, rice yields became higher on Java than elsewhere. Between 1971 and 1978, yields on Java increased at an annual rate of 2.0 percent. Yields off Java increased at an annual rate of 2.3 percent. Thus the disparity is slowly being reduced. Provincial yields for 1976-78 are contained in Table 12. Yields on Java are 3,404 kilograms per hectare. Yields off Java are 2,844 kilograms per hectare. The potential for yield increases appears to be greater off Java.

Rice yields are typically highest during the months of January-April. However, when water control and management are good, differences between seasons disappear. Tables 13 and 14 indicate some of the differences in yields under alternative conditions. Of considerable interest are the yield increases off Java when chemical fertilizers are used and the land is technically irrigated. These data do not indicate how much chemical fertilizer is used.

The effect of water control is quite significant. Yields on Java are approximately 600 kilograms more where control irrigation systems exist and chemical fertilizer is used than in rainfed areas. The effect of fertilizer use by itself is also dramatic. Yields are about 700 kilograms greater where fertilizer is used on controlled irrigation areas than where it is not used. The yield differential is reduced to about 300 kilograms on rainfed areas. The effects of controlled irrigation and fertilizer use follow the same pattern off Java as on Java.

But, in general, where good water-control irrigation exists and fertilizer is used off Java, yields are greater than on Java. Average yields on Java under controlled irrigation and where fertilizer is used are about 3.75 tons per hectare. Off Java they are about 3.85 tons per hectare.

Table 12--Wetland rice yields, by province, 1976-78

Province	1976	1977	1978
	(kilograms per hectare)		
Java	3,254	3,236	3,404
Jakarta	2,355	2,571	2,576
West	3,149	3,092	3,157
Central	3,208	3,135	3,385
Yogyakarta	3,696	3,541	3,771
East	3,417	3,502	3,735
Bali	3,550	3,633	3,526
Sumatera	2,929	2,935	3,013
Aceh	3,054	3,068	2,968
North	3,260	3,060	3,245
West	3,000	3,204	3,318
Riau	2,195	2,157	2,086
Jambi	2,614	2,666	2,892
South	2,460	2,654	2,694
Bengkulu	2,652	2,679	2,825
Lampung	3,321	3,189	3,168
Kalimantan	1,773	1,718	2,129
West	1,767	1,683	2,175
Central	1,598	1,412	1,673
South	1,847	1,981	2,262
East	1,616	1,358	1,672
Sulawesi	2,733	2,851	2,908
North	2,718	2,711	2,928
Central	2,407	2,330	2,125
South	2,793	2,954	3,010
Southeast	1,860	1,757	1,772
Nusatenggara	2,805	2,600	2,842
West	2,918	2,789	3,053
East	2,332	2,211	2,108
Maluku	1,827	2,245	2,138
Irian Jaya	2,102	2,085	2,110
Maluku and Irian Jaya	1,944	2,178	2,126
Off Java	2,698	2,748	2,844
Total	3,072	3,028	3,171

Source: Indonesia, Biro Pusat Statistik, Produksi Tanaman Bahan Makanan di Indonesia: 1976; Indonesia, Biro Pusat Statistik, Produksi Tanaman Bahan Makanan di Indonesia: 1977; Indonesia, Biro Pusat Statistik, Produksi Tanaman Bahan Makanan di Indonesia: 1978.

Table 13--Rice yields with different types of irrigation, seasons, fertilizer usage, and locations

Season of Harvest/ Type of Irrigation	Java		Off Java	
	Chemical Fertilizer	No Fertilizer	Chemical Fertilizer	No Fertilizer
	(kilograms of dry paddy/hectare)			
January-April				
Technical	3,846	3,514	4,923	3,492
Semitechnical	3,888	2,980	3,366	2,779
Simple/village	3,659	2,965	3,220	2,998
Rainfed	3,052	2,760	3,126	2,366
Dry land/upland	1,363	1,363	1,246	1,246
May-August				
Technical	3,681	2,340	4,279	3,248
Semitechnical	3,511	2,591	3,543	2,800
Simple/village	3,310	2,491	3,517	2,932
Rainfed	2,456	2,172	2,767	2,637
September-December				
Technical	3,714	2,724	3,511	2,965
Semitechnical	3,670	2,512	4,082	3,391
Simple/village	3,412	2,516	3,326	2,666
Rainfed	3,004	2,574	2,986	2,547

Source: Indonesia, Biro Pusat Statistik, Rata-Rata Hasil Produksi Padi Sawah Setiap Hektar Menurut Luas Bidang, Jenis Intensifikasi, Irigasi, Pupuk, Obat-Obatan dan Serangan Hama di Indonesia, 1976, RTB78-33; Indonesia, Biro Pusat Statistik, Produksi Tanaman Bahan Makanan di Jawa Madura; Indonesia, Biro Pusat Statistik, Produksi Tanaman Bahan Makanan di Indonesia: 1976.

The response of yields to fertilizer use is shown in Table 15. The data are inconsistent because several variables were not controlled. However, they suggest that considerably higher yields are possible both on and off Java. Under fully controlled irrigation systems and where 150 kilograms or more urea is used within an intensification program, 4.5 tons per hectare are expected for Java. Where conditions are not intensive, about 4.0 tons are expected. Off Java, under similar intensive conditions, yields of 5.0 tons are expected. Inadequate data exist to estimate yields off Java where conditions are not intensive.

Table 14--Rice yields by variety, intensification, location, and type of irrigation, 1976

Location/Type of Irrigation	Bimas and Inmas		No Intensification	
	Improved Varieties	Local Varieties	Improved Varieties	Local Varieties
	(kilograms/hectare)			
Java-Madura				
Technical	4,490	3,825	3,781	2,995
Semitechnical	4,469	3,952	3,566	2,792
Sederhana	4,211	3,903	3,421	2,971
Irrigated	4,392	3,904	3,535	2,943
Rainfed	3,631	2,945	3,060	2,590
Off Java				
Technical	4,963	3,948	3,862	3,753
Semitechnical	4,488	3,806	3,354	3,300
Sederhana	4,282	3,675	3,634	3,212
Irrigated	4,449	3,708	3,568	3,262
Rainfed	3,182	3,098	3,463	2,871

Source: Indonesia, Biro Pusat Statistik, unpublished data.

Table 15--Rice yields by urea usage, type of irrigation, intensification, and location, 1976

Location/Type of Irrigation	Kilograms of Urea Used					
	0-49.9	50-99.9	100-149.9	150-199.9	200-249.9	250 or More
	(kilograms/hectare)					
Java-Madura						
Bimas and Inmas						
Technical	4,535	3,920	3,991	4,601	4,458	4,613
Semitechnical	42,135	4,069	3,995	4,270	4,547	4,637
Sederhana	3,797	3,901	3,932	4,067	4,282	4,466
Irrigated	4,139	3,953	3,965	4,265	4,418	4,580
Rainfed	3,176	2,937	3,404	3,137	3,637	3,681
No intensification						
Technical	2,970	3,489	3,935	3,940	4,582	4,104
Semitechnical	2,968	2,834	3,281	3,527	3,487	4,152
Sederhana	3,041	2,878	3,161	3,763	3,715	3,638
Irrigated	3,020	3,041	3,342	3,745	3,809	3,869
Rainfed	2,770	2,329	2,466	2,812	2,564	3,316
Off Java						
Bimas and Inmas						
Technical	4,583	4,718	4,319	4,815	5,530	5,056
Semitechnical	4,365	3,960	3,995	4,703	4,953	4,872
Sederhana	3,736	3,953	3,897	4,060	4,561	4,480
Irrigated	4,041	4,031	3,956	4,352	4,845	4,678
Rainfed	3,150	3,744[a]	2,930	3,373	2,920[a]	3,048
No intensification						
Technical	3,836	---	3,184[a]	---	3,546[a]	---
Semitechnical	3,314	3,696	3,555	2,896	2,906	---
Sederhana	3,341	3,727	3,648	3,091	3,917	2,890
Irrigated	3,376	3,716	3,592	3,060	3,389	2,890
Rainfed	2,962	3,723	4,067[a]	4,560[a]	4,443	3,675[a]

Source: Indonesia, Biro Pusat Statistik, unpublished data.

a/This figure is based on 10 or fewer observations.

4. WATER MANAGEMENT

For irrigation to be effective, water management must be efficient. The first and second five-year plans emphasized large-scale development of irrigation. They also included other water development schemes, such as flood control, to assist in food production. These proposed water development schemes were designed to supply water to irrigated paddy fields and to protect paddy fields against prolonged or excessive inundation.

EXISTING WATER MANAGEMENT

An irrigation project has three parts that must be integrated at all stages if it is to be productive: civil engineering, land and water management, and other supporting activities.

The responsibility for civil engineering and land and water management is divided among three ministries: Public Works, Home Affairs, and Agriculture. The responsibility for other supporting activities is held by several directorates of the Ministry of Agriculture. Unfortunately, these supporting activities are not being provided on the scale necessary for optimum intensive cropping.

Presidential Instruction No. 1/1969 directed the three ministries to coordinate irrigation water use and to define maintenance responsibilities for the canal networks. This instruction allowed divided authority and responsibility in the operation and maintenance of the irrigation system to continue.

The agencies of the Ministry of Public Works construct the civil engineering works on primary and secondary canals and the control outlets from secondary canals to the tertiary canals. The Ministry of Home Affairs organizes the construction of the tertiary canals. This component is often omitted from engineering design and consequently is not integrated into the overall design of the irrigation system. Programs such as INPRES Padat Karya and the Village Subsidy Programs are used to construct tertiary canals. However, tertiary development rehabilitation is still inadequate. Therefore, in fiscal year 1978/79, the Ministry of Public Works took responsibility for tertiary canal construction.

Traditional management and organization of the village (tertiary) irrigation system is in the hands of the village ulu-ulu pembagian on Java.

The ulu-ulu institution developed as a result of the 1,894 experiments in water management introduced under the Peraturan Pateguan and Peraturan Pekalen regulations. The Pateguan regulation is based on the principle that farmers should participate in the control and regulation of water distribution. The principle guiding the Pekalen regulation is that water usage should be as efficient as possible.

The concept of tertiary canals for water distribution to the fields developed under the Pekalen regulations. The efficiency criterion took precedence and the village head, through the ulu-ulu, placed the farmer's interest subservient to his. Through pressure from supra-village authorities, the irrigation benefits went primarily to the sugar industry.

The Provincial Works Department maintains all water structures, but the physical work is undertaken by its offices in the kabupatens. This office also distributes and manages irrigation water throughout the primary and secondary maintenance of canals. The tertiary canals are fully under the authority of the village heads. Under the village head, the ulu-ulu maintains the tertiary canals, coordinating with the Department of Agriculture and Public Works.

The comprehensive land and water use complex is thoroughly understood neither by farmers nor by many of the irrigation agencies in Indonesia. The system distributing water to farms is operated by the farmers without fixed control and measurement structures for distributing water to fields. A major fault of the system is that water is not released to the paddy fields in accordance with the water requirement of the crop.

There is strong evidence that irrigation water going to farms is not managed or used efficiently. A study conducted in the fully irrigated area of Klaten, Central Java, indicates that farmers usually receive and apply more irrigation water than is necessary to optimize production and maximize income. Specifically, irrigation water use is 50 percent greater than the crop requirements. By reallocating water, a significantly larger area could be irrigated in an average year.

Several factors affect irrigation efficiency. First, when farmers use irrigation water at no cost, they often use excessive amounts of water.

Second, much of the available surface water is wasted because diversion dams are ineffective and canals and related structures are weak. At least three consequences arise from this situation: the system is unable to allocate water appropriately even when there is no actual shortage, the timing of water release to the paddy field is made without regard for the requirements of the crop, and water is distributed unevenly between the upper and the lower part of the irrigation system.

The old rainfed paddy plot typically lacked storage facilities and ditches to provide subsurface drainage to the upper soil profile. In technical irrigation systems the surface is commonly drained by conveying excess water from plot to plot, which provides very poor drainage. Most systems do not control water sufficiently well in the tertiary system to meet the specific requirements of the modern rice varieties.

Third, uneven distribution of water among paddy fields is also caused by the institutional and social structure in the village. One study shows that the influence of officials at all levels helps determine how water is distributed. As long as the integrity of many officials is questionable, the effectiveness of water regulations will be limited. The sense of belonging is important. Where there are major social and economic differences between large and small farmers, no system of mutual help and consultation exists.

There is considerable potential for improved water management of both the main system and farm-level systems. Irrigation infrastructure generally is more developed in the main system than in tertiary systems, but inadequate management in the main system reduces the incentive for improvement of the management and infrastructure of tertiary systems.

IRRIGATION REHABILITATION AND PILOT TERTIARY PLOTS

The effectiveness of irrigation and the size of the area irrigated declined after independence. The quickest and most effective method of increasing agricultural production was irrigation rehabilitation. The World Bank estimated that before rehabilitation programs were initiated, the irrigation systems were in such disrepair that only 20 percent of their nominal command areas were serviced.

The government began the irrigation rehabilitation program in 1969. It was developed to improve the water transmission capacity of the primary and secondary canals of existing technical and semitechnical irrigation systems. This included the replacement of collapsed headworks, weirs, and other structures; desilting and reconstruction of primary and secondary canals and drains; repair and replacement of control structures; establishing an operation and maintenance organization; and strengthening agricultural support services. In addition, a water management system was to be developed to make continuous maintenance possible and to ensure efficient exploitation and equitable water use.

The rehabilitation efforts are managed by the Jatiluhur Authority as part of a multipurpose water resource development, and by Prosida, an agency of the Ministry of Public Works created to manage IDA-assisted irrigation rehabilitation projects. Since the First Five-Year Plan (1969), Prosida has rehabilitated canals servicing more than 700,000 hectares, and the Jatiluhur Authority has rehabilitated canals servicing 186,000 hectares.

Theoretically, the irrigation system should function properly after these projects are completed. However, proper functioning also depends on the tertiary system. Experience indicates that the tertiary and quarternary systems have not been developed well.

Crops are often inundated during the wet season, and irrigation water is distributed inequitably among the paddy plots in the command area during the dry season. Operational waste is very high. There is evidence that water is allocated inequitably, giving farmers upstream more water than farmers downstream. It is assumed that if the water is distributed more equitably, average yields will increase. As tertiary and quartenary canals have not been effectively developed by the farmers, the government has assumed the task of developing them. To help educate farmers about the advantages of improving irrigation efficiency and water management, the DPU developed several Pilot Tertiary Plots (PTP). The PTP are expected to serve as demonstration models of terminal water control and management.

Prosida has constructed 131 PTP units in seven irrigation project areas covering an area of 16,767 hectares. The first PTP was constructed in 1973/74. The PTP serves as "a demonstration plot" where

The PTP serves as "a demonstration plot" where farmers can learn proper water management, which is then related to the proper cropping pattern. It is expected that farmers from the neighboring areas will gain knowledge from the PTP and will develop and follow the design of the PTP. For this purpose all agencies are urged to work together to help farmers.

In addition to the PTP, the DPU began the Developed Tertiary Plot (PTD) program in 1977/78 to rehabilitate and renovate the tertiary plot. Within a year PTDs covered 69,178 hectares.

OPERATION AND MAINTENANCE

Responsibility for operating and maintaining irrigation systems in Indonesia is divided between the government and farming communities. The major irrigation systems, including intake structures, primary and secondary canals, and their related structures, have traditionally been the responsibility of provincial administrators. Maintaining the systems from the tertiary turnout to the farm ditches is the responsibility of the farming communities, under government guidance and supervision. Many Water User Associations (WUA) have been promoted by the government and developed in many areas. These are responsible for managing tertiary systems.

The WUA assume different names. In Central Java they are called Dharma Tirta, in West Java, Mitra Cai, in Bali, subak. Table 16 shows the number of WUA in several provinces. The WUA were established after 1970, except in Bali, where they have long been established.

In Bali the subak is a social organization that manages the irrigation systems. As it crosses village political boundaries, members of the subak are not necessarily from the same village. The subak area varies from 10 to 300 hectares, and the number of member farmers varies from 50 to 600.

The head of the subak is called pekaseh or klian subak. A subak is divided into tempek, each of which is headed by a klian tempek. The klian tempek is assisted by a kasinoman, who controls water distribution in the farm fields and maintains canals.

The members of the subak help maintain the canals and the dam, distribute water, and participate in religious ceremonies. The subak has its own rules and regulations, called awig-awig, which are strictly followed. These usually regulate the growing of rice and dry crops in rotation, resolution of disputes among members, and the performance of ceremonies.

In the Dharma Tirta system of Central Java, the village council, an organization of family members, is the highest authority. The Dharma Tirta is a customary law institution, and any new organization emerging from this institution can rely on member participation.

The DPU is responsible for water allocation in the primary and secondary canals, but the Dharma Tirta assumes responsibility for water distribution and canal maintenance at the tertiary level.

Presidential Instruction No. 1/1969 indicated that the cost of water distribution and maintenance of the irrigation networks must be borne by those obtaining the direct benefits from irrigation water.

Table 16--Water User Associations (WUA) in selected provinces, 1977/78

Province	Name of the WUA	Total Number of WUA	Total Member Farmers	Total Area (hectares)
Bali	Subak	1,262[a/]	n.a.	98,673
Java				
Central	Dharma Tirta	928	254,398	128,215
East	n.a.	1,358	n.a.	n.a.
West	Mitra Cai	2,568	138,081	171,460
Sulawesi				
South	n.a.	113	n.a.	n.a.

Note: Where n.a. appears, the figure was not available.

a/This figure is for 1979.

For this reason, the provincial governors are authorized to charge the landowners certain fees. But, by long-established custom, irrigation water is free. Thus the payments for operation and maintenance are regarded as farmer contributions for irrigation development. Part of the cost of operating and maintaining the main system is financed by a central government subsidy.

The presidential instruction has not been implemented effectively. In reality there is no charge for operation and maintenance. In most areas, however, farmers make "contributions." The contribution may be money, labor, or in kind. The payment is sometimes substantial, although none of it represents a direct contribution to the capital or recurrent costs of the main canal system. It is made to an ulu-ulu, the man in charge of village irrigation affairs, and is essentially a contribution to him. Table 17 shows the contribution by farmers to the ulu-ulu.

The general land tax, IPEDA, includes charges for irrigated paddy land, but the provincial administrator remits little of it for operating and maintaining the technical irrigation system. The IPEDA tax is levied at a 5 percent rate on the net annual income from land. Most of the proceeds go to the local kabupaten (regency) administration, which allocates it.

In theory, 10 percent of the IPEDA revenue is deducted as collection fees for the various officials involved. Seventy-five percent of the remainder should be used by the kabupaten administration for agricultural and rural development, including development of the irrigation infrastructure. However, Booth concluded from a 1972 survey of 35 sample kabupatens that an average of about 40 percent of the IPEDA revenue was allocated to economic infrastructure projects undertaken by kabupatens and a further 8 percent to projects undertaken by villages.1/

1/Anne Booth, "IPEDA--Indonesia's Land Tax," Bulletin of Indonesian Economic Studies 10 (March 1974).

Table 17--Payment by farmers for ulu-ulu services

Crop	Quoted August 1977[a]		Recorded 1973/74[b]	
	Amount (kilograms/ hectare)	Value (U.S. $/ hectare)	Amount (kilograms/ hectare)	Value (U.S. $/ hectare)
Wet season				
Rice	30-50	4.00-6.67	39.46	3.25
Dry season				
Rice	30-50	4.00-6.67	32.85	3.19
Maize	20	2.80	13.60	1.48
Soybeans	16-22	6.00-8.27	11.50	2.92
Tobacco	---	2.40-4.85	5.70	4.28

a/Anthony F. Bottral, personal communication.
b/Effendi Pasandaran and Donald Taylor, The Management of Irrigation Systems in the Pekalen Sampean Irrigation Project, Agro-Economic Survey, Research Note 01/76/RN, Jakarta, March 1976.

Another example of IPEDA tax revenue distribution is in the Krawang district to the east of Jakarta. The land tax for first-class paddy land under irrigation in wet and dry seasons is equivalent to U.S. $3.75. For marginal land within the same section of the Jatiluhur Irrigation Area, the land tax decreases to U.S. $2.40 per hectare. The average land tax levied on the entire irrigated paddy land in the Krawang district (83,817 hectares) amounted to U.S. $3.15 per hectare in the 1967/68 rice-growing year. This is equivalent to U.S. $253,012 of land tax collected in this irrigation section. Only U.S. $1,157 was remitted to the provincial Public Works Irrigation Section, or U.S. $0.15 per hectare. The actual unit cost for the proper operation and maintenance of this irrigation system was U.S. $15 per hectare.

It is useful to compare the cost of operation and maintenance with the cost of rehabilitation and PTP development. The basic capital expenditure for the construction of the canal system was incurred so long ago that it can be regarded as a sunk cost. Data from one irrigation project area (Pekalen Sampean) show that rehabilitation cost was just over U.S. $102 per hectare in 1973. Of this, U.S. $85 was for the rehabilitation of primary and secondary canals, U.S. $10 was for repairs of the dam, and U.S. $7 was for the construction of an additional inspection road. The cost of developing the PTPs is U.S. $355 per hectare. These costs are large compared to the annual operation and maintenance costs and illustrate the cost effectiveness of proper operation and maintenance.

PTPS AND DEVELOPMENT OF TERTIARY CANALS

Theoretically, tertiary canal development would help agricultural production in three ways. It would increase cropping intensity. It would improve water control and facilitate higher yields. And it would permit a greater portion of the command area to be irrigated. However, identifying how much of these improvements can be attributed to development of tertiary canals is difficult because of several interacting factors. Intensification programs containing an abnormal amount of supervision frequently accompany the development of tertiary canals. WUAs are also involved occasionally.

There is conflicting evidence on just how much tertiary development contributes to expanded production. The major problem is that the relatively brief period that has elapsed since tertiary canal rehabilitation has been under way prohibits an effective evaluation.

Studies conducted in the Pemali Comal, Cisadane, and Rentang irrigation project areas reported an increase in cropping intensities. However, a study in the Pekalen Sampean project area indicates that there is essentially no difference in the cropping intensities between areas with and without PTPs (Table 18). The difference between these areas appears to be the crop grown. Rice is grown on more land in areas with PTPs than in those without them. In addition, in areas without PTPs, some land is left fallow during the dry season. As more irrigation water becomes available, farmers switch from dry-land crops to rice.

In general, efficiency refers to the ratio between output and input. Irrigation water efficiency refers to the ratio between the amount of water actually used by the crops and the amount of water supplied to the field. Irrigation efficiency can be measured at any point in the system. Some studies, including some in the PTP areas, have focused on water loss.

Table 19 shows irrigation efficiency in four PTPs. Efficiency tends to decline as distances increase. Irrigation efficiency was high, over 90 percent on the main system, indicating a loss of less than 10 percent. However, the efficiency decreased to 70 percent on the tertiary and quarternary canals, a 30 percent loss. Certainly, efficiency is lower in areas without PTPs than in areas with them.

Some recent evidence suggests that tertiary development improves yields, but there is no indication that such development reduces yield variability. Recent Prosida reports have contained yield data from areas with PTPs and from areas without PTPs, with and without intensification programs.

In the 1977 dry season, samples were taken from seven Prosida subprojects. The samples were selected both near to and far from the tertiary headworks turnout. The yields in the dry season of 1977 are shown below.2/

2/Noertamtomo, Daryadi, "Tertiary Development Program under Prosida: Its Impact and Problems," seminar on the Institutional Aspect of Water Management in the Farmer's Field, Semarang, April 9-14, 1979.

Table 18--Cropping intensities in areas with and without PTPs, Pekalen Sampean, East Java

Season/Crop	Village A		Village B	
	No PTP	PTP	No PTP	PTP
Wet season				
Rice	100	100	100	100
Dry season	80	99	100	100
Rice	39	82	8	59
Soybeans	14	10	83	27
Maize	---	4	5	9
Tobacco	17	3	4	5
Other	---	---	---	---
Fallow	21	---	---	---
Total wet and dry season	180	199	200	200
Authorized dry-season rice area (as percent of total cropped area)[a/]	38	60	14	29

Source: Anthony F. Bottrall, personal communication.

a/This is authorized rice area for the dry season. However, much land is planted with unauthorized rice, as is apparent from the data in the third row of the table.

Table 19--Irrigation efficiency from selected irrigation project areas

Project Area	Irrigation Efficiency (percent)
Glapan Sedadi	
Primary Canal	99
Secondary Canal I	92
Secondary Canal II	93
Pemali Comal	
Primary Canal	99
Secondary Canal	92
PTP Way Saputih	
Tertiary Canal	85
Quarternary Canal	81
Pekalen Sampean	
Tertiary Canal	74
Quarternary Canal	71

	Far From Turnout	Near Turnout	Difference	Average
		(tons/hectare)		
Outside PTP	2.38	2.91	0.53	2.48
Within PTP	3.55	4.22	0.67	4.15
Difference	1.17	1.31	---	---
Average	2.97	3.56	---	---

The yield differences in areas located far from and near to turnouts were similar whether or not the area had a PTP. Areas located near the turnouts enjoyed a distinct advantage, presumably because more water was available. Their yields were one half to two thirds of a ton higher than the yields or areas far from the turnout. However, on average, areas with PTPs had yields 1.67 tons greater than areas without them.

For the 1977/78 wet season, more detailed data are available. A total of 329 samples was selected from the nine subproject areas. The data were further subdivided to include yields with and without intensification programs.3/ The resulting yields were as follows:

Relation to PTP	With Intensification			Without Intensification		
	Far From Turnout	Near Turnout	Average	Far From Turnout	Near Turnout	Average
			(tons/hectare)			
Outside PTP	3.14	3.55	3.35	2.16	2.16	2.16
Within PTP	4.04	4.67	4.35	2.79	2.79	2.79

The variability of the yields between project areas was quite large in all areas, with or without intensification or PTPs. There was no evidence that yields varied less in the areas with PTPs. These data suggested that areas near the turnout had higher yields where intensification programs were practiced, but yields were the same without the programs.

Yields within the areas with PTPs were consistently higher regardless of their location or the presence of an intensification program. However, this increase in yield was the effect of several inputs, such as fertilizer and pesticides, in addition to irrigation.

Although data from only one year cannot provide a basis for generalizations, it appears that development of tertiary canals will increase rice yields about 1 ton per hectare where intensification programs exist. The yields under such conditions average about 4.35 tons in the rainy season and about 200 kilograms less in the dry season. This implies, however, that the complementary inputs are also provided. Without intensification, the yield response caused by the development of tertiary canals is only 0.6 tons per hectare, providing yields of just under 2.8 tons per hectare.

3/Ibid.

These data are supported by data from a non-Prosida tertiary canal project in Mojokerto, East Java. Five years of data, covering periods before and after development, are presented below:

Year	Wet Season		Dry Season	
	PTPs	Other Sample Plots	PTPs	Other Sample Plots
	(tons/hectare)			
1973/74	6.6	5.80	4.6	4.60
1974/75	6.8	6.05	5.3	5.95
1975/76	6.6	5.85	4.5	5.95
1976/77 4/	0.0	1.75	7.5	5.85
1977/78	8.6	6.55	5.2	4.65

The pilot project for constructing tertiary canals was completed in August 1976. Before its completion the wet season yields were higher by about 0.8 tons in the areas that later became pilot areas. However, data from the next wet season show that the yield was over 2.0 tons greater in the pilot area. Before completion of the pilot project, dry-season yields were higher in the areas that were not pilot areas by approximately 0.8 tons. After completion, yields averaged 1.75 tons more in the pilot areas.

Yields in the pilot areas were significantly higher after development than before and were higher than yields in other areas. However, neither input use nor weather and other environmental factors influencing yields were controlled in the analysis, so differences in yields may not be fully attributable to the development of tertiary canals.

After the pilot projects were constructed, the development of tertiary canals was expanded into a large, nationwide program. Approximately 350,000 hectares were to be developed in 1980/81. The long-term target for the program is to develop 2 million hectares.5/ Despite this projected rapid growth, the tertiary development program has not been evaluated systematically.

4/In 1976/77, the rice crop was attacked by planthoppers during the wet season.

5/Anthony F. Bottrall, "Issues in Main System Management," paper presented at the Workshop on Investment Decisions to Further Development and Make Use of Southeast Asia's Irrigation Resources, Kasetsart University, Bangkok, 17-21 August 1981.

SEDERHANA SCHEMES

The sederhana irrigation schemes are small, run-of-the-river, diversion weir projects. Small is defined as a service area of less than 2,000 hectares. Thus the sederhana schemes are directed toward quick-yielding projects that are smaller than the other existing irrigation programs of the Ministry of Public Works. The average size of previous projects was 330 hectares. In addition to being small and capable of rapid execution, they are relatively inexpensive and simple to design and construct.

The sederhana program was begun in 1975, and 782 projects were programmed through fiscal year 1978/79. Some 132 of these projects have matured, and data on 517 have been analyzed.6/ These 517 projects are described below.

	Number of Crops of Irrigated Rice Each Year			Rainfed Rice	Total Rice	
	One	Two	Total		Actual Land Area	Gross Crop Area
	(thousand hectares)					
Before project	41	15	56	47	103	118
Project target	57	115	172	6	178	293
Project changes	16	100	116	-41	75	175

The 75,000 hectare increase in rice area includes 22,000 hectares converted from dry-land crops to paddy land and 53,000 hectares of newly developed crop areas.

The yield estimates of 3,800 kilograms for irrigated paddy and 3,050 kilograms of rainfed paddy show that the 517 projects have increased production by approximately 700,000 tons of rice. The benefits and costs of sederhana projects are completed for their assumed lifetime, 10 years. The social cost of capital for construction is assumed to be 15 percent, and another 15 percent is assumed to be necessary to maintain the structures for the 10-year period. Based on the above assumptions, the labor opportunity cost of production in these sederhana areas is Rp 460 per day. This has involved an implicit assumption that the average social cost of developing a hectare of paddy land is approximately U.S. $1,000.

6/Clive Gray, John Duewel, and Henry Gembala, Sederhana Evaluation, U.S. Agency for International Development, May 1978, Table IV-3.

5. ECONOMIC FEASIBILITY OF ALTERNATIVE TYPES OF IRRIGATION PROJECTS

Few of the theoretically feasible projects included in the inventory of potentially irrigable land have had their feasibility studied. Consequently, it is not possible to estimate costs project by project. However, some general rule-of-thumb guidelines have been developed by the International Bank for Reconstruction and Development (IBRD).7/

Only general information is available on soils in the areas for these potential projects and hydrological information is limited. Tidal irrigation is anticipated on a major scale, but a number of questions remain unanswered regarding soil and water management, soil suitability, drainage, cropping patterns, and crop management.

Within these unknowns, the IBRD undertook an economic evaluation of three synthetic irrigation projects involving water impoundment, run-of-the-river diversion, and tidal reclamation.

WATER IMPOUNDMENT

Several potential water impoundment sites have been identified on Java. Since Java is already highly irrigated during the rainy season, the development of an impoundment system would primarily expand dry-season production. Wet-season area would be expected to expand into areas not irrigated before, but that expansion would be slight. The impoundment would probably inundate some irrigated areas.

The simulated development of a water impoundment project on Java assumed a project area of 100,000 hectares, which involved rehabilitation of 80,000 hectares and the addition of 20,000 hectares. No assumptions were made regarding the inundation of productive land. The benefits were estimated on the assumption that only rice would be grown. It was also assumed that cropping intensity would increase from 1.25 to 2.00.

Using projected yields, prices, and costs, and assuming that a minimal acceptable rate of return was 15 percent, such an impoundment project would be economic if total costs remained below U.S. $3,700 per hectare. Engineering estimates suggest costs would be U.S. $3,000 to U.S. $3,500 per hectare. However, land acquisition, resettlement, and inundation of farmland would add to the costs and reduce the benefits. Hence, unless there were other benefits, such as electricity generation, such projects would not be economic. This

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7/International Bank for Reconstruction and Development, Indonesia -- Irrigation Program Survey 1977.

conclusion becomes more certain because the 15 percent economic rate of return threshold is quite sensitive to alternative assumptions. (For example, if the full benefits of development are delayed three years, the development costs must remain below U.S. $2,300 to permit an economic rate of return of 15 percent.)

RUN-OF-THE-RIVER DIVERSION

Sumatera has the largest potential for irrigation development. Hence, the second type of irrigation development synthesized was a 10,000 hectare run-of-the-river diversion system. The site was assumed to be remote, with low population density, little infrastructure, and an area designated for transmigration. Considerable land clearing and development would be necessary. Ninety-five percent of the benefits were assumed to come from irrigated rice cropped at an intensity of 1.50. The remaining benefits were assumed to come from the garden compound. Yields, prices, and costs are the IBRD's standard projections for similar areas. An eight-year development period was assumed.

The project benefits were discounted over 30 years, and it was assumed that rubber, forest products, and some rainfed rice were displaced. The 15 percent economic rate of return could be attained if the total cost of development did not exceed U.S. $3,900 per hectare. The simulated exercise suggested that the costs of development would be about U.S. $2,336 per hectare. If transmigration costs were included, they would be about U.S. $3,940 per hectare.

TIDAL RECLAMATION

While tidal reclamation contains the largest number of unknowns, it appears to offer greater economic returns. The model simulated 10,000 hectares of contiguous land in Sumatera located 100 kilometers downstream from the major city of Palembang (to facilitate pricing estimates). Standardized yields, crop budgets, prices, and costs were incorporated, and a seven-year development period was assumed.

The project benefits were for only one rice crop per year, discounted over a 30-year period. It was assumed that the project displaced some spontaneous agriculture and secondary-growth swamp forest. The combination of these activities was assumed to represent an opportunity cost of Rp 50,000 per hectare annually. The development cost break-even point for an economic rate of return of 15 percent was U.S. $2,460 per hectare. Estimated development costs are U.S. $1,130 per hectare or U.S. $1,950 per hectare, including the costs of transmigration.

The maximum development costs permitting a 15 percent economic rate of return and some sensitivity tests are presented below.8/

8/International Bank for Reconstruction and Development, Indonesia -- Irrigation Program Survey 1977, p. 21.

Basis for Estimates	Water Impoundment; on Java: 100,000 Hectares	Run-of-the-River Diversion; on Sumatera: 10,000 Hectares (U.S. $/hectare)	Tidal Reclamation; on Sumatera: 10,000 Hectares
Break-even point	3,660	3,900	2,460
Best estimate	---	2,300	1,130
Best estimate including transmigration cost	---	3,900	1,950
Benefits delayed three years	2,290	3,330	1,590
25 percent reduction in rice price	2,460	2,430	1,370
25 percent increase in rice price	4,580	4,890	3,070

Some of the additional assumptions used in the above synthesized models are the labor requirements per hectare of rice. Water impoundment on Java would require 230 man-days per hectare. Run-of-the-river diversion on Sumatera would require 155 man-days per hectare. Tidal reclamation on Sumatera would require 185 man-days per hectare.

The net impact these types of irrigation schemes would have on rice production is shown in Table 20.

SEDERHANA

The Sederhana II program is now under way on 410,000 hectares. Included are 210,000 hectares receiving new or improved major works. All of the 410,000 hectares receive irrigation/drainage systems. The new program is expected to cost U.S. $327.3 million. It will, however, have a longer life span than previous sederhana projects. The benefits to be generated by Sederhana II are shown in Tables 21 and 22.

The benefits were assumed to begin in the second year of the project and to reach maturity in the fourth. All costs are to be met by the end of the first year. The expected internal rate of return is 29 percent, considerably above the presumed social cost of capital, 15 percent. Discounting the costs and benefits yields a ratio of benefits to costs of 1.69:1.00 and a net present value of U.S. $300 million (at an exchange rate of Rp 415 = U.S. $1.00). The benefits are computed only for rice. The benefits accruing from other crops would increase the internal rate of return and the benefit/cost ratio.

The benefits from the Sederhana II program appear to be large. They apparently would be distributed most often to the farmers who had enjoyed a disproportionately small amount of the irrigation benefits.

Table 20--Rice production under alternative irrigation development systems

Irrigation Development Systems	With Project			Without Project		
	Area (hectares)	Yield (tons/hectare)	Production (1,000 tons)	Area (hectares)	Yield (tons/hectare)	Production (1,000 tons)
Water impoundment	200,000	4.5	900	125,000	3.87	484
Wet season						
Irrigated	100,000	4.5	450	80,000	4.5	360
Rainfed	---	---	---	20,000	2.0	40
Dry season						
Irrigated	100,000	4.5	450	25,000	4.2	84
Run-of-the river	15,000	4.0	60	1,300	1.8	2.34
Wet season						
Irrigated	10,000	4.0	40	---	---	---
Rainfed	---	---	---	1,300	1.8	2.34
Dry season						
Irrigated	5,000	4.0	20	---	---	---
Tidal	10,000	3.5	35	1,000	1.5	1.5
Wet season						
Irrigated	10,000	3.5	35	---	---	---
Rainfed	---	---	---	1,000	1.5	1.5

Source: International Bank for Reconstruction and Development, Indonesia -- Irrigation Program Survey 1977, Annex 10, Table 8.

Table 21--Yields generated by sederhana development

Previous Use of Land	Previous Yield	Expected Yield[a]	Yield Increase
	(kilograms of gabah)		
Village irrigated	3,825	4,193	368
Rainfed paddy	3,052	4,193	1,141
Upland paddy	2,739	4,193	1,454
Undeveloped land	0	4,193	4,193

Source: U.S. Agency for International Development, Indonesia--Sederhana Irrigation and Land Development II, AID/BAS-022, July 12, 1978, p. 46.

a/The yields after development are assumed to be equal to those of semi-technical irrigated land.

Table 22--Expansion of area and production generated by sederhana development

Condition of Land	Area: Without Sederhana Program	Area: With Sederhana Program	Production: Without Sederhana Program	Production: With Sederhana Program	Difference
	(1,000 hectares)		(1,000 tons)		
Area subject to major works and farm construction					
Irrigated paddy					
Double cropped	18	134	138	1,124	986
Single cropped	48	66	184	277	93
Rainfed paddy	54	---	165	---	-165
Upland rice	24	---	66	---	-66
Other	56	---	---	---	---
Area subject to farm construction only					
Irrigated paddy					
Double cropped	28	141	214	1,182	968
Single cropped	76	69	291	289	-2
Rainfed paddy	86	---	262	---	-262
Upland rice	11	---	30	---	-30
Forest	9	---	---	---	---
Total	---	---	1,350	2,872	1,552

Source: U.S. Agency for International Development, Indonesia--Sederhana Irrigation and Land Development II, AID/BAS-022, July 17, 1978, pp. 48, 49.

Unfortunately, the requirements for rapid execution, low costs, and a simple design reduce the number of areas suitable for such projects. There is little information on which to make estimates of areas that will fulfill the criteria of the sederhana projects. Therefore, this paper makes the arbitrary assumption that the areas programmed for Repelita III will exhaust the area available for such projects. Thus these projects are counted in projections of irrigation and its impact for 1990, but not for 2000.

DEVELOPMENT OF TERTIARY IRRIGATION

The development and rehabilitation of tertiary irrigation will be emphasized during the next several years. One of many projects involving tertiary irrigation is the Kali Progo project, which has a command area of 34,700 hectares.

This project is IBRD supported. A comprehensive analysis of its benefits and costs has been conducted. An economic rate of return of 21 percent was estimated based on a lifetime of 30 years. This rate of return altered only slightly under alternative assumptions. It would be 18 percent if construction costs increased 20 percent above estimates and 17 percent if total benefits decreased by 25 percent.

The analysis was made assuming that total capital costs were Rp 23.49 billion and incremental operation and maintenance costs were Rp 4,700 per hectare. The distribution of costs and the implementation schedule are shown in Table 23.

In estimating the benefits, the future production patterns were estimated with and without the project. It was assumed that projected yields would not be attained until five years after the project was completed. The fully developed, estimated production schedule is shown in Table 24.

Table 23--Implementation and cost schedule for tertiary canal development

Year	Area of Implementation	Capital Construction Costs	Incremental Operation and Maintenance Costs
	(hectares)	(Rp billion)	
1978	0	1.78	0.00
1979	5,000	5.01	0.00
1980	6,000	4.68	0.03
1981	6,000	4.72	0.06
1982	6,000	4.12	0.10
1983	6,000	2.06	0.13
1984	5,700	1.12	0.14
1985	---	---	0.16

Source: International Bank for Reconstruction and Development, Indonesia, Irrigation X, Appraisal Report, May 1, 1978.

Table 24--Production and income budget with and without tertiary development

Conditions	Area	Yield	Farm Price	Production: Gross Value	Production: Cost	Production: Net Value	Net Value of Production in Project Area
	(1,000 hectares)	(ton/ hectare)	(Rp 1,000/ ton)	(Rp 1,000/hectare)			(Rp 1,000)
Future without project							
Wet season							
Rainfed rice	4.2	2.0	104	208	43	165	693
Irrigated rice	30.5	3.8	104	395	72	323	9,852
Dry season							
Irrigated rice	14.1	3.8	104	395	67	328	4,625
Soybeans	12.5	0.6	195	117	13	104	1,300
Tobacco	0.6	0.4	800	320	76	244	146
Vegetables	6.0	17.0	20	340	101	239	1,434
Imputed labor cost							18,050
Net benefit in project area							1,633
Total							16,417
Future with project							
Wet season							
Irrigated rice	34.7	4.5	104	468	84	384	13,325
Dry season							
Irrigated rice	28.7	4.5	104	468	79	389	11,164
Soybeans	6.7	0.8	195	156	22	134	898
Tobacco	0.8	0.6	800	480	100	380	304
Vegetables	6.0	20.0	20	400	112	288	1,728
Imputed labor cost							27,419
Net benefit in project area							628
Total							8,741

Source: International Bank for Reconstruction and Development, Indonesia, Irrigation X, Appraisal Report, May 1, 1978.

6. IRRIGATED AREA AND RICE PRODUCTION PROJECTIONS

PROJECTIONS TO 1990

Several assumptions must be made when projecting future production. Many of the assumptions about yield are based on data from the fields and are, therefore, realistic, provided that the underlying conditions permitting current yields continue. But it is not certain that they will. The assumptions about the rehabilitation, development, and expansion of irrigation area are based on past accomplishments.

It is assumed that the planned irrigation development in the Third Five-Year Plan (1979/80-1983/84) will be accomplished and will mature to full yield potential by 1990. In all areas of irrigation development except rehabilitation, the current planned targets are double the area developed during the previous decade under earlier plans. A large pool of competent staff was developed during the past decade, and organizational and managerial skills were expanded. The nominal development budget for irrigation is more than double the amount spent in the first two development plans. However, inflation will erode most of the increased funds, and newer development projects will cost more per hectare because the projects to be initiated earlier were easier and cheaper. Therefore, the incremental area assumed to be available for rice production in 1990 will be the area planned for development over the next five years plus those systems being designed or under construction but that will not be completed during the Third Five-Year Plan. Table 25 is an inventory of systems being designed or under construction. The incremental difference between the list under "New Development" and the list under "New Area" in Table 26 is expected to be completed by 1990. All other listings in Table 25 are contained in the listings in Table 26.

There will also be some assumptions about technology that seem realistic but which may not be.

The 1990 inventory of irrigation systems, Projection A, is contained in Table 27.

All new developments are expected to be technically irrigated. This applies to land that is being upgraded from rainfed irrigation and to land that is developed from either dry cropland or land not cultivated before. Arbitrarily, the land being rehabilitated under sederhana schemes is assumed to be under semitechnical irrigation, as are half of the newly developed sederhana areas. The remaining half of the newly developed areas under sederhana schemes is assumed to be under simple irrigation. (There is little difference in the rice yields from the various categories of irrigation. Rice-cropping intensities do vary, however.)

Table 25--Inventory of systems being designed or under construction, October 1977

Province	Gravity Irrigated: New Development	Gravity Irrigated: Rehabilitation	Gravity Irrigated: Total	Swamp and Tidal Irrigation	Total
			(hectares)		
Java	265,506	330,968	596,474	---	595,474
DKI Jakarta	2,155	---	2,155	---	2,155
West	61,680	36,924	98,604	---	98,604
Jatiluhur	66,000[a]	18,243	84,243	---	84,243
Central	88,834	129,151	217,985	---	217,985
Yogyakarta	27,885	---	27,885	---	27,885
East	19,752	146,650	166,402	---	166,402
Bali	3,813	5,118	8,931	---	8,931
Sumatera	331,671	76,305	407,976	162,846	570,822
Aceh	59,725	33,150	92,875	---	92,875
North	24,694	14,500	39,194	3,000	42,194
West	41,762	6,840	48,602	12,000	60,602
Riau	13,589	1,650	15,239	51,626	66,865
Jambi	6,585	2,600	9,185	18,340	27,525
South	60,983	8,250	69,233	70,880	140,113
Bengkulu	31,572	8,800	40,372	---	40,372
Lampung	92,761	515	93,276	7,000	100,276
Kalimantan	24,532	1,600	26,132	62,114	88,246
West	3,600	---	3,600	26,630	29,230
Central	710	---	710	18,405	19,115
South	17,048	2,500	19,548	18,079	37,627
East	3,884	100	3,984	---	3,984
Sulawesi	143,964	72,573	216,537	---	216,527
North	25,704	4,886	30,590	---	30,590
Central	26,407	4,900	31,307	---	31,307
South	76,405	62,787	139,192	---	139,192
Southeast	15,448	---	15,448	---	15,448
Nusatenggara	31,272	12,070	43,342	---	43,342
West	22,941	7,890	30,831	---	30,831
East	8,331	4,180	12,511	---	12,511
Maluku	3,340	---	3,340	---	3,340
Total	804,808	499,634	1,304,442	224,960	1,529,402

Source: Directorate General of Water Resources Development, from International Bank for Reconstruction and Development, Indonesia--Irrigation Program Review.

Note: This inventory applies to service areas.

a/This includes 51,000 hectares of tertiary development.

Table 26--Planned irrigation development, 1979/80-1983/84

Province	Rehabil-itated	Tertiary	Tadah Hujan			Sederhana		Tidal Irrigation	Swamp Irrigation
			Rehabil-itated	Upgraded to Fully Irrigated	New Area	Rehabil-itated	New Area		
Aceh	12,700	16,000	12,050	7,584	12,748	750	4,500	---	13,000
Bali	7,200	20,000	800	1,872	1,918	350	2,100	---	---
Bengkulu	4,000	16,000	1,000	12,127	14,700	2,000	12,000	---	10,000
Irian Jaya	---	---	---	750	---	250	1,500	---	---
Jambi	3,000	16,000	5,000	8,046	2,496	2,500	15,000	45,000	5,000
Java									
Central	165,516	291,750	11,545	9,102	18,744	1,000	6,000	---	---
East	288,863	478,080	16,500	4,620	19,180	200	1,200	---	---
West	75,240	275,276	1,380	59,955	98,244	1,300	7,800	---	---
Kalimantan									
Central	---	---	---	3,900	2,100	1,000	6,000	42,000	10,000
East	1,200	12,000	300	3,478	2,516	800	4,800	---	10,000
South	2,100	12,000	400	8,332	10,348	1,300	7,800	43,000	15,000
West	---	6,000	---	5,100	3,500	1,200	1,200	55,000	11,000
Lampung	89,354	60,000	4,000	10,350	19,650	1,500	9,000	35,000	7,000
Maluku	---	2,000	---	1,519	1,796	250	1,500	---	---
Nusatenggara									
East	4,500	10,000	2,350	4,113	7,799	900	5,400	---	---
West	11,532	30,000	3,500	6,854	5,498	1,500	9,000	---	---
Riau	1,000	15,500	2,000	11,938	13,857	2,000	12,000	19,000	16,000
Sulawesi									
Central	3,500	20,000	2,500	7,839	8,296	1,500	9,000	---	---
North	5,000	20,000	3,000	9,102	11,240	1,500	9,000	---	---
South	30,443	137,710	11,200	17,836	49,619	1,500	9,000	---	---
Southeast	---	20,000	---	8,640	10,660	1,500	9,000	---	---
Sumatera									
North	55,712	24,000	11,000	8,850	9,400	1,750	10,500	21,000	12,000
South	10,000	20,000	3,000	8,670	6,230	2,000	12,000	140,000	13,000
West	24,000	30,000	4,000	14,632	40,643	2,500	15,000	---	13,000
Timor Timur	---	---	---	750	---	250	1,500	---	---
Yogyakarta	20,000	20,000	1,860	2,533	4,512	200	1,200	---	---
Total	814,860	1,452,316	97,385	238,492	375,694	31,500	189,000	400,000	135,000

Source: Indonesia, Departemen Pekerdjean Umum dan Taraga Listrik, Direktorat Jendral Pengairan, Rencana Pembangunan Lima Tahun ke III, Repelita III, 1979/80 s/d 1983/84.

Table 27--Inventory of irrigation systems in Indonesia projected to 1990, by province, Projection A

Province	Public Works				Rainfed Land	Tidal and Swamp Irrigation	Total
	Technical	Semitechnical	Simple	Total			
	(hectares)						
Aceh	59,725	25,703	93,321	178,749	55,959	13,000	247,708
Bali	3,813	48,041	7,482	59,336	1,669	---	61,005
Bengkulu	40,261	23,039	40,928	104,228	2,257	10,000	116,485
Jakarta	9,597	4,569	40	14,206	---	---	14,206
Jambi	11,217	15,096	26,728	53,041	4,155	78,080	135,276
Java							
Central	534,853	100,480	206,021	841,354	287,631	---	1,128,985
East	629,199	123,397	182,310	934,906	37,380	---	972,286
West	668,868	187,416	132,637	988,921	101,530	---	1,090,451
Kalimantan							
Central	6,000	4,000	3,000	13,000	6,499	106,729	126,228
East	7,161	4,414	32,573	44,148	23,402	168	67,718
South	22,180	17,834	6,354	46,368	88,644	109,859	244,871
West	8,600	13,020	2,850	24,470	49,660	88,856	162,986
Lampung	194,795	22,222	4,500	221,517	12,460	42,000	275,977
Nusatenggara							
East	11,912	13,403	16,560	41,875	63,259	---	105,134
West	56,320	77,612	56,264	190,196	23,351	---	213,547
Riau	25,795	29,260	14,430	69,485	7,891	123,290	200,666
Sulawesi							
Central	34,842	20,983	9,660	65,485	692	---	66,177
North	28,946	41,563	16,665	87,174	468	---	87,642
South	126,741	89,661	84,251	300,653	91,524	---	392,177
Southeast	26,974	19,440	4,500	50,914	610	---	51,524
Sumatera							
North	101,134	51,388	80,408	232,930	78,983	82,515	394,428
South	76,983	47,347	36,867	161,197	15,644	189,280	366,121
West	83,707	70,842	110,075	264,624	21,483	19,911	306,018
Yogyakarta	27,885	53,911	34,545	116,341	42,476	---	158,817
Other	4,840	3,000	2,250	10,090	---	---	10,090
Total	2,802,348	1,107,641	1,205,219	5,115,208	1,017,627	863,688	6,996,523

Sources: This inventory is developed from data in Tables 4, 8, 25, and 26. Rainfed irrigation is the column from Table 25 minus the area upgraded into a fully irrigated system.

The synthesized yield statistics are based on the assumptions that on Java and Bali 200-250 kilograms of urea will be used per hectare under Bimas/Inmas programs and 150-200 kilograms will be used on nonintensified production. On the other islands it is assumed that 150-200 kilograms of urea will be used per hectare under Bimas/Inmas programs and 100-150 kilograms will be used on nonintensified production. It is further assumed that the proportion of production on Java and Bali grown under intensified programs will increase from 75 to 80 percent and that the ratio of Bimas to Inmas production will not change. On the other islands it is assumed that the proportion of intensified production will increase from 30 percent to 50 percent and that the Bimas to Inmas production ratio will not change.

Using these assumptions, projected yields for 1990 are as listed below.

Type of Irrigation	Java and Bali	Other Islands
	(kilograms per hectare)	
Technical	3,701	3,400
Semitechnical	3,691	3,510
Sederhana	3,551	3,276
Rainfed	2,950	3,162
Tidal/swamp	---	2,975

Experimental/field data are not adequate for deriving yield estimates for tidal/swamp irrigated rice, which is why an estimate of 2,975 kilograms was used. This is 85 percent of the World Bank estimate.

The rice-cropping intensity is available by province and irrigation status for 1976.9/ The assumption is made that these cropping intensities will not change through 1990. They are:

Type of Irrigation	Java and Bali	Sumatera	Kalimantan	Sulawesi	Eastern Indonesia
Technical	1.70	1.47	1.78	1.69	1.55
Semitechnical	1.53	1.61	1.20	1.54	1.30
Sederhana	1.58	1.35	1.06	1.38	1.14
Rainfed	1.30	1.03	1.01	1.02	1.00

The rice-cropping intensity for tidal/swamp land is assumed to be 1.00 for all island groups.

The preceding data permit the derivation of production estimates. The projected area is multiplied by the projected yield, which in turn is multiplied by the rice-cropping ratio. The resulting statistics are projected production by island group and by irrigation status. The technology implications are entirely captured in the projected yields. The effects of rehabilitation and development of tertiary irrigation, plus the assumed fertilizer inputs, appear to justify the yield estimates.

9/Indonesia, Biro Pusat Statistik, unpublished data.

Projected production for 1990 (Projection A) is shown below.

Type of Irrigation	Java and Bali	Sumatera	Kalimantan	Sulawesi	Eastern Indonesia
			(1,000 tons)		
Technical	11,791	2,967	265	1,250	385
Semitechnical	2,924	1,610	165	927	428
Sederhana	3,158	1,801	156	520	257
Rainfed	1,805	648	537	301	274
Tidal/swamp	---	1,660	938	---	---
Total	19,678	8,686	2,061	2,998	1,344

The projections suggest that production will be approximately 34.79 million tons of dry paddy. Most production, 56 percent, is projected to be on Java and Bali. These projections ignore any contribution by groundwater development. Approximately 44,000 hectares are scheduled for development under groundwater projects. However, such development will only supplement gravity systems and cannot be considered "new" development areas.

The potential for error in the projected production figures is high. The basic assumptions may not be fulfilled and, as other crops might be more profitable, some of the developed areas may not produce rice. The production estimate of 34.77 million tons is dry paddy, which is 23.64 million tons when converted to rice. This implies a production growth rate of 3.3 percent from 1978 to 1990. In addition, approximately one million tons of rice could be expected from dry-land production, which is the amount currently produced.

An alternative projection (Projection B) was made using the 1976 irrigation survey data of the Biro Pusat Statistik.10/ To this base a 1990 area inventory was developed in the same manner as the inventory for Projection A. It is shown in Table 28. The base for Projection B, and the resulting 1990 inventory, was about 120,000 hectares less than Projection A. The difference in the base area was caused partly by the different base year, 1976, as opposed to 1978. However, more important than the discrepancy in total hectares irrigated is the composition of the irrigated hectares. The Projection B base indicates that 600,000 fewer hectares are technically or semitechnically irrigated and 500,000 more hectares are rainfed than the Projection A base shows.

Projection B indicates that 6.88 million hectares will be irrigated in 1990. They would be capable of producing 33.33 million tons of dry paddy or 22.66 million tons of rice.

10/Indonesia, Biro Pusat Statistik, Rata-Rata Hasil Produksi Padi Sawah Setiap Hektar Menurut Luas Bidang, Jenis Intensifikasi, Irigasi, Pupuk, Obat-Obatan dan Serangan Hama di Indonesia, 1976, RTB78-33.

Table 28--Inventory of irrigation systems in Indonesia projected to 1990, by province, Projection B

Province	Public Works				Rainfed Land	Tidal and Swamp Irrigation	Total
	Technical	Semitechnical	Simple	Total			
	(hectares)						
Aceh	72,618	34,504	75,432	182,554	64,469	16,074	263,097
Bali	6,051	44,272	75,690	126,013	1,669	---	127,682
Bengkulu	34,522	13,285	12,619	60,426	12,187	10,000	82,613
Jambi	10,970	14,542	18,500	44,012	1,555	50,747	96,314
Jakarta	4,903	2,148	109	7,160	4,442	---	11,602
Java							
Central	380,141	162,736	203,716	746,593	332,416	488	1,079,497
East	569,514	173,832	128,008	871,354	280,862	4,762	1,156,978
West	523,504	179,921	292,353	995,778	218,208	---	1,213,986
Kalimantan							
Central	7,784	8,801	40,885	57,470	5,051	63,829	126,350
East	6,639	3,376	6,209	16,224	38,384	2,595	57,203
South	18,880	7,520	10,652	37,052	89,685	143,987	270,724
West	9,116	3,987	17,313	30,416	69,339	105,768	205,523
Lampung	115,115	12,886	20,826	148,827	16,523	42,580	207,930
Nusatenggara							
East	13,162	14,480	17,196	44,838	5,489	885	51,212
West	76,263	53,398	33,114	162,775	23,687	45	186,507
Riau	26,130	11,109	9,732	46,971	11,469	78,757	137,197
Sulawesi							
Central	26,975	13,686	25,401	66,062	5,659	165	71,886
North	29,060	18,782	11,145	58,987	4,034	10,468	73,489
South	156,305	37,895	66,179	260,379	124,422	2,500	387,301
Southeast	19,965	6,975	11,331	38,271	5,458	610	44,339
Sumatera							
North	45,546	51,436	75,384	172,366	129,398	37,970	339,734
South	66,693	11,370	31,396	109,459	39,426	197,274	346,159
West	59,445	46,587	88,287	194,319	31,083	13,000	238,402
Yogyakarta	40,975	28,243	12,573	81,791	12,069	74	93,934
Other	4,840	1,200	4,500	10,540	---	---	10,540
Total	2,325,116	956,971	1,288,550	4,570,637	1,526,984	782,578	6,880,199

The estimates of area in Projection A are presumed to be more realistic. The 1978 base was the command area of the DPU's irrigation system. It may overstate irrigated area and some of the land within the command area may, in fact, be rainfed. However, many irrigation works have been rehabilitated and another 800,000 hectares are scheduled for rehabilitation in the current five-year plan. Furthermore, 1.45 million hectares are scheduled to have tertiary irrigation developed on them. These two activities should improve the water delivery capacity, although they are not designed to expand the command areas. Those areas that are defined as technically irrigated, but are not now functioning, should be functioning by 1990.

Therefore, assuming that technology makes it easier to attain the projected yields, the estimate of production under Projection B (shown below) should be considered a minimum, and Projection A should be considered as most probable.

Type of Irrigation	Java and Bali	Sumatera	Kalimantan	Sulawesi	Eastern Indonesia
			(1,000 tons)		
Technical	9,595	2,154	256	1,334	496
Semitechnical	3,339	1,106	99	417	314
Sederhana	3,997	1,469	260	515	205
Rainfed	3,259	997	646	450	92
Tidal/swamp	15	1,328	970	11	2
Total	20,205	7,054	2,232	2,727	1,109

PROJECTIONS TO 2000

The estimates of production after 1990 are based on several assumptions. Most change depends on assumed growth rates. This study estimates that irrigated area will expand 100,000 hectares per year between 1990 and 2000. This estimate is based on the premise that the addition of land will become increasingly difficult and expensive as the more readily accessible and easily convertible land will have been irrigated by 1990.

The inventory of potentially irrigable land is shown in Table 29. This listing is tentative and overstates the potentially irrigable land. The data are approximations of land that engineers believe could be irrigated. Not enough information is available to determine whether the soils are appropriate for irrigation or whether it would be economic to irrigate those lands. It is clear, however, that most additions to irrigated land will be on islands other than Java and Bali.

Table 29--Inventory of land area for potential irrigation development

Province	Conventional Gravity Irrigation			Tidal Irrigation	Swamp Irrigation	Total
	New Area	Rehabilitation	Total			
			(hectares)			
Aceh	251,912	22,256	274,168	---	55,000	329,168
Bali	13,628	300	13,928	---	---	13,928
Bengkulu	160,110	4,890	165,000	---	55,000	220,000
Jambi	181,031	6,469	187,500	---	---	187,500
Java						
Central	---	---	---	---	---	---
East	57,754	13,296	71,050	---	---	71,050
West	82,040	32,801	114,841	---	1,870	116,771
Kalimantan						
Central	352,110	4,885	356,995	---	25,449	382,444
East	143,650	1,350	145,000	55,000	40,790	240,790
South	6,660	240	6,900	19,000	253,800	279,700
West	181,200	17,800	199,000	180,000	45,000	424,000
Lampung	667,100	5,000	672,100	50,000	5,000	727,100
Nusatenggara						
East	---	---	---	---	---	---
West	---	---	---	---	---	---
Riau	687,978	20,022	708,000	250,800	43,000	1,001,800
Sulawesi						
Central	96,401	16,218	112,619	---	---	112,619
North	133,789	10,911	144,700	---	2,415	174,115
South	121,835	11,465	133,300	---	---	133,300
Southeast	6,975	2,925	9,900	---	---	9,900
Sumatera						
North	65,800	11,150	76,950	---	84,100	161,050
South	271,398	1,002	272,400	6,000	32,600	311,000
West	241,254	12,916	254,170	---	69,900	324,070
Yogyakarta	2,459	---	2,459	---	---	2,459
Total	3,725,484	195,896	3,920,980	560,800	713,924	5,195,704

Source: Indonesia, Departemen Pekerdjean Umum dan Taraga Listrik, Direktorat Jendral Pengairan, Inventarisasi Potensi Tanah Dataran, Maret 1978.

The additions to irrigated land are assumed to include 800,000 hectares of technically irrigated land and 200,000 hectares of tidal/swamp irrigated land. Most of this land is on Sumatera. It is assumed that 500,000 hectares of conventional gravity systems and 100,000 hectares of tidal/swamp land will be developed on that island:11/

Island	Technical Irrigation	Tidal Irrigation	Swamp Irrigation
Java and Bali	100,000	---	---
Sumatera	500,000	50,000	50,000
Kalimantan	100,000	50,000	50,000
Sulawesi	100,000	---	---

The continued and expanded use of fertilizers, insecticides, and credit-extension programs together with technological innovation will affect yields and cropping intensity. The uncertainties surrounding these factors are so numerous that a point projection seems inappropriate. Therefore, three different rates of change were assumed for yields between 1990 and 2000. The incremental increases assumed were 1.00, 0.75, and 0.50 tons (dry paddy) per hectare for fully irrigated (not rainfed) land. These increments were applied to the projected 1990 yields. Rainfed rice yields were assumed to increase to 3.25 tons per hectare for all islands, and tidal/swamp irrigated rice yields were assumed to be 3.5 tons per hectare. The incremental rate assumed most probable was 0.75 tons. Using this projection, yields on Java and Bali in 2000 would be similar to current yields on Taiwan. As Indonesia's yields historically have lagged behind Taiwan's by about 25 years, such a projection seems feasible. It should be noted that rice yields increased 1 quintal per year (1 ton per decade) during the past 10 years and the 1990 estimate implied annual yield changes of about 50 kilograms per year to 1990.

The rice-cropping intensity will also be affected by technology. Most of the increase will be caused by the new, shorter maturing rice varieties. This will permit more crops to be planted each season. Again, three alternative rates of change in the rice-cropping index were considered. Changes in the cropping indexes of 0.40, 0.30, and 0.20 over the 1990 values were considered for the fully irrigated (excluding rainfed) paddy. Rainfed paddy-cropping intensity was assumed to remain 1.30 on Java and Bali and 1.00 on other islands. An incremental change of 0.30 was assumed to be the most probable.

The implied rice-cropping intensity on irrigated land by 2000 is 1.85 for Java and Bali and 1.48 for the other islands. The newer, shorter maturing varieties, better water control and management, and two more decades of technological advances should permit such levels to be attained.

Rapid growth of the rice-cropping indexes needed to reach these levels is needed since all the change is assumed to take place in the last decade of this century. The rates required are 1.8 percent for Java and Bali and 2.3 percent for the other islands.

11/These figures are derived from Table 29.

The resulting projected production under the new alternatives is shown below:

Increase in Yield (tons)	Increase in Rice-Cropping Intensities 0.40	0.30	0.20
	(million tons of dry paddy)		
1.00	60.48	58.05	54.49
0.75	57.56	55.27	52.14
0.50	54.65	52.49	49.21

The projection for potential production is 55.27 million tons of dry paddy, equivalent to 37.5 million tons of rice.

It should be emphasized that the projections are based on assumed incremental changes. There are little data to substantiate these changes. They are, however, not beyond the technology and change now experienced in other countries.

It should also be emphasized that the entire 8.0 million irrigated hectares projected will not be planted exclusively with rice. They could be, but the resulting projection of 37.5 million tons of rice is far more than Indonesia needs (based on an estimated population of 207 million in 2000).

The minimum projection, assuming a cropping increase of only 0.2 and a yield increment of only 0.5 tons per hectare, would be 49.21 million tons of dry paddy or 33.4 million tons of rice.

LABOR ABSORPTION

The amount of incremental labor required to produce the incremental area was budgeted. Labor budgets for Java and Bali were based on current labor usage. This is 230 man-days for controlled irrigation and 179 man-days for rainfed paddy production per hectare, plus 25 man-days per ton harvested. The authors have little experience off Java, so they used IBRD labor budgets. These included both production and harvest in one figure. The labor values per hectare were 210 man-days for controlled irrigation, 190 man-days for rainfed paddy, and 185 man-days for tidal irrigation.

Using these labor budgets, the incremental labor required for the 1990 projected production was 150.1 million man-days for Java and Bali and 328.8 million man-days for the "Outer Islands." At 300 days per year, this translates to 1.6 million man-years of labor required for incremental production between 1978 and 1990. The labor budgets are subject to considerable error. On Java, where labor is plentiful, greater labor use can be expected. However, in areas off Java, labor may be limited and an optimum amount of labor may not be available. Nonetheless, 1.6 million man-years of additional labor could be absorbed in the incremental rice production with current technology.

Projecting the incremental use of labor in rice production between 1990 and 2000 requires assumptions with few facts to support them. The computations used here implicitly assume that technology would not alter and that production and harvesting would require the same quantity of labor used now. Despite the assumption that only 100,000 additional hectares of rice would be added on Java, 74 million additional man-days of labor were projected. The incremental requirement for labor off Java was projected to be 389 million man-years.

Therefore, the incremental labor requirement between 1990 and 2000 is about 1.5 million man-years. This is similar to the estimated differential between 1978 and 1990. In reality, technology would be expected to change, so that less labor would be required per hectare. Thus these statistics should be regarded as a maximum, but applicable only to rice. As the production of crops other than rice would also be expected to increase, additional labor would be absorbed producing them.

7. CONCLUSIONS

The irrigation infrastructure has many parts, all of which are important to the proper functioning of the system. Optimizing the allocation of resources to these parts requires that social issues as well as economic criteria be evaluated. There is not a single limiting factor in agricultural production or in the irrigation system, but several factors interact collectively to form a constraint. While there are logical sequences for investment, the complementary parts of the system must not be ignored or the decision criteria will be based on false assumptions. Attention was initially focused on rehabilitation of the main canal system. Later, new irrigation systems were developed on small and large scales, the smaller projects being developed for their relatively easy implementation and quick return. Development and rehabilitation of terminal canals followed. But the development of management and organization to use water more effectively has lagged. Similarly, the operation and maintenance of the entire canal system has not developed well enough to assure that capital invested in the canals will return the projected benefits. There are also serious questions regarding the quality of new and rehabilitated structures. Hence the projected life span of several investments will be considerably shortened. There is concern that the structures will require further rehabilitation because operation, maintenance, and initial rehabilitation have been inadequate.

The economic benefits of appropriate operation and maintenance and the costs and benefits of Water Users Associations or other parts of the organization and management infrastructure are difficult to measure. However, they probably have higher economic payoffs than any other form of investment. Similarly, more effort should be expended to ensure that the quality of construction on both rehabilitated and new structures is of the appropriate standard. Greater emphasis should be placed on routine maintenance activities to avoid or at least delay the need for rehabilitation.

In all of the projections in this report, it is assumed that repairs, operation, and maintenance will ensure that the systems are maintained, that service areas do not decline, and that the water is distributed equitably. Furthermore, it is assumed that additional expansion can occur and that efficiency will be improved. Therefore, to consolidate the gains obtained from irrigation investment, it is imperative that water management, organization, operation, and maintenance become effective.

Continued expansion of irrigated areas is necessary. It must occur primarily off Java. Run-of-the-river diversion weir systems and tidal/swamp irrigation will provide better investment opportunities than either impoundment or groundwater irrigation systems. Development of tertiary irrigation should continue to be a part of the conventional gravity system development. More emphasis will be required

on small-scale expansion programs. The large water sources and command areas soon will be fully exploited, thus necessarily relegating expansion to smaller water supplies and smaller command areas.

With efficient water management and appropriate operation and maintenance, the irrigation systems, when combined with existing and new technology, should help to increase rice production above consumption needs by 1990, assuming that per capita requirements are 125 kilograms. It can be expected that rice production will exceed 23 million tons by 1990. If it does, and irrigation technology continues to improve, area could be shifted to other food crops during the 1990s.

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