Irrigation Development and Management Strategies to Support Rice-Based Crop Diversification in Indonesia

Effendi Pasandaran
Director, Center for Agro-Socioeconomic Research
AARD, Ministry of Agriculture, Bogor, Indonesia

Soenarno
Director of Irrigation I, Directorate General of Water Resources Development
Ministry of Public Works, Jakarta, Indonesia

Suprodjo Pusposutardjo
Dean, Faculty of Agricultural Technology
Gadjah Mada University, Yogyakarta, Indonesia

INTRODUCTION

FOR THE LAST two decades, the Indonesian economy has been characterized by progressive structural changes and growth of the agricultural sector. One of the important sources of growth is rice production. A very remarkable progress has been achieved partly due to government policies involving investment in irrigation, research and extension programs in new technologies, and favorable input and output pricing policies.

The importance of irrigation development in the whole context of agricultural development is reflected in the increasing share of irrigation investment in the total government expenditure for the agricultural sector. During the third and fourth "five-year development" (*pelita*) periods, the government invested 43.1 percent and 49.1 percent, respectively, of the government budget in the agricultural sector. This high share of expenditure indicates the importance of rice in agricultural production. The impact of rice self-sufficiency is quite substantial, particularly in terms of labor absorption.

There are at least two challenges in the future development of irrigated agriculture: a) the need for new resources for agricultural growth to meet the increasing demand for food, and b) the sustainability of agricultural development. In the second long-term development plan of Indonesia, the agricultural sector is not simply a producer of raw materials, but also a complex contributor to achieving a number of desired outcomes. As a consequence of increased income, the demand for food will increase and shift toward greater consumption of protein and vitamins which require food crop diversification. Likewise, the various activities in producing food commodities in irrigated areas are continually expected to provide a significant share of labor absorption. The increasing need for sustainable development requires greater intersectoral linkages and greater participation of rural communities in various development processes.

The investment that has been made along with other policies such as research and extension of new technologies and inputs, and favorable input and output pricing policies, have undoubtedly contributed to an improved food situation, although the performance of many irrigation systems from both production and other economic perspectives have fallen short of expectation. As the expenditure per hectare of new investment increases and problems related to the performance of irrigation systems become more apparent, there is a growing need to improve investment and management strategies in supporting greater interest in food crop diversification in irrigated areas.

This paper provides a sense of the complexity of the issues and of the efforts being made to address them.

IRRIGATION INVESTMENT POLICIES

Since the colonial period, the development of irrigation systems has been designed to serve three major commodities: rice, sugar cane, and secondary food crops. In the later stage of development, greater emphasis has been given to the sustainable growth of rice production. As a consequence of the effort to achieve rice self-sufficiency, resource endowments were based toward rice.

In the last few years, however, there has been a considerable slowdown in the rate if growth of rice yield from over 5 percent in the early 1980s to below 2 percent in the late 1980s. There are several reasons for this declining trend. First is the reduction of the area in Java for intensified production which cannot be directly compensated by a corresponding area increase outside Java. Second, is the declining rates of input use.

PERFORMANCE OF IRRIGATION INVESTMENT

Four programs have been implemented since the first Five-Year Development Plan in 1969: a) rehabilitation of the existing irrigation systems, b) river training and flood control, c) development of new irrigated land, d) reclamation of tidal swamp ares. Table 1 shows that, except in the tidal swamp reclamation program, government expenditures per hectare increased substantially in the other programs. The annual expenditure for rehablitation, however, increased faster than that for new irrigation development. For example, annual expenditure per hectare for rehabilitation in the first Five-Year Development Plan was about 39 percent of that of new irrigation development. In the Fourth Five-Year Development plan, this increased to 74 percent. Additional new components in the rehabilitation program and a low maintenance cost are possible reasons for the faster rate of increase.

Over a two decade period, the government expenditure per hectare for the reclamation of tidal areas increased by only 11 percent in real terms. This implies that there are still plenty of tidal swamp areas available for extensive reclamation at a relatively low development cost. Efforts to protect agriculture and irrigation systems form external disturbances, as reflected by the annual expenditure on river training and flood control, become very costly due to the construction of large reservoirs in several river basins.

During the fourth FYDP (1984-89), 24 percent and 29 percent of the total government expenditure for the water resources subsector were allocated for rehabilitation, and river training and flood control programs, respectively. About 42 percent of the total expenditure was allocated for new irrgation development, and only 5 percent for tidal swamp reclamation. Even though the biggest portion of the government expenditure was allocated for new irrgation development, the performance of this program in terms of additional area irrigated has fallen short of expectation.

The food crop productivity of the new irrigated area is generally low. Most of the irrigation systems are in the early stage of development with relatively low irrigation efficiency. At this stage, production activities and suitable technologies that are available are limited. This situation is also true for the tidal swamps development program, although the experimental station results indicate quite a promising yield potential with proper soil water management.

Table 1 Average government expenditure for irrigation subsctor by type of development (US$), fixed price 1989.

Plan period	New construction	Tidal/ swamp	Irrigation rehabilitation	Flood control	Total of subsector
Pelita I	343 (259)	479 (363)	132 (100)	59 (44)	183 (138)
Pelita II	976 (739)	479 (363)	450 (340)	580 (439)	606 (459)
Pelita III	1,345 (1,019)	206 (156)	1,144 (866)	703 (533)	831 (629)
Pelita IV	2,731 (2,069)	535 (405)	2,027 (1,536)	1,443 (1,093)	1,766 (1,338)

Note: Value within brackets is the expenditure index relative to Pelita I rehabilitation expenditure (Pelita I = 100). Rate of conversion: US$1 = Rs 1,790.

Source: Central Bureau of Statistics.

While the major food crop production areas in Java and Sumatra have benefitted from irrigation development, the drier area in the eastern part of Indonesia where the scope for gravity irrigation is quite limited has not received its share of irrigation investment. Consequently, farm incomes in this part are significantly lower than those in the more intensely irrigated areas in Java and other parts of western Indonesia. An increased concern with eliminating poverty and reducing income gaps, combined with the recognition of the potential for rapid agricultural development through groundwater development for irrigation, has encouraged the government and donors to pursue programs to develop increased irrigation supplies through the introduction of pumps.

In general, where the government has taken the lead, the investment has involved large subsidies in capital and, in many cases, in operation and maintenance costs. In contrast, private investments by farmers have not involved any subsidies. This is also true for small-scale, run-of-the-river diversion systems developed by local communities.

There have been government interventions, however, both directly and indirectly, in farmer-managed irrigation systems. Direct interventions occurred when the government rehabilitated farmer- managed irrigation systems and then took over their administration through the public irrigation agency. In recent years, however, there has been increasing concern to turn over small-scale irrigation systems of less than 500 ha to the water users' associations.

Indirect government interventions were made when the village communities utilized the subsidies given by the central government to rehabilitate or upgrade their own irrigation systems without reducing financial and managerial autonomy. The village subsidy program is an example of the regional financing mechanism which has been used to induce small-scale irrigation system improvement and development. In 1979, a study of Indonesia's village subsidy program calculated investment inducement coefficients of 4.4 and 5.4 for two village irrigation systems based on the ratio of total investment to government subsidy (Hafid and Hayami). This study indicates that, of the locally mobilized resources, 64.8 percent and 74.7 percent were communal labor. In a 1985 study of data from 107 villages in Sukabumi, West Java, by Wirawan et al., it was found that the inducement coefficients varied from 1.8 to 2.2 between 1979 to 1983 and that mobilization of communal labor varied from 58.4 percent to 70.9 percent.

There has also been a growing concern on the part of NGOs to help farmers in the operation and maintenance of both gravity irrigation and pump irrigation systems, although, usually, there has been some implicit subsidy in the capital investment as well as in the services of the NGO staff.

In the present situation where financing irrigation investment is placing a large and increasing burden on agricultural sector expenditures, more rational investment policies need to be assessed. Food crop diversification in irrigated areas as a means of improving farmers' income has not been given due consideration nor has there been adequate attention given to investment in software development for design and irrigation management. A related issue is the institutional and organizational adjustment needed to link various processes such as design, physical construction, land development, irrigation management, and agricultural production.

MANAGEMENT POLICIES

A reorientation of management policies has been taking place during the past few years. These changes include a gradual turnover of government-managed, small-scale systems of less than 500 ha to water users, assessment of the funding for operation and maintenance, introduction of service fees, and institutional strengthening of both farmers and government support systems. While these policy instruments have to be tested properly prior to widespread implementation, they are conducive to promoting food crop diversification in irrigated areas.

Turning over of government systems to the local community will integrate the water allocation function of irrigation systems into community activities. By turning over small-scale systems to local water users' associations, the pressure on the government O&M budget is expected to be reduced and the performance of irrigation systems may be improved by assuming that farmers are financially and organizationally ready to assume ownership and/or management (Vermillion 1991). In addition, increased autonomy in management is expected to induce the farmers to choose irrigated crop mixtures suitable to their own decision-making criteria.

Introduction of irrigation service fees in large-scale government irrigation systems can be used to improve the performance of irrigation systems through a more efficient use of water. Since nonrice crops need much less water than rice, irrigation service fees can also be used as a policy instrument to promote food crop diversification. At present, however, due to limitations in physical facilities and arrangements in water delivery, such a policy is particularly designed to support its financial function, more specifically to meet the cost recovery for O&M. A report of the Ministry of Home Affairs on the Irrigation Service Fee (ISF) Pilot Project indicates that the key issue is to assess when a system is ready for ISF introduction from the standpoint of technical, administrative and socio-political factors. One of the criteria is that cropping arrangements and intensities should have no significant equity problems. Furthermore, as learned from experience, it is best to introduce ISF when special maintenance activities are almost completed, and the system is becoming efficient in operation and maintenance.

One of the policy issues related to institutional strengthening is whether there is a need to provide legal status to the existing water users' associations. This issue is particularly relevant to the implementation of other policies such as those on turnover and irrigation service fees, which are important in supporting food crop diversification in irrigated areas. However, those opposed to the idea of providing legal status to water users' associations argue that the latter's activities are only an integral part of the overall village activities.

Although this issue has not been resolved yet, there is a need to assess the performance of water users' associations in Indonesia in relation to the stage of irrigation development, to provide a stronger basis for the future direction of these associations.

PERFORMANCE OF FOOD CROP DIVERSIFICATION

Diversification can be narrowly defined as broadening the production of commodities other than rice. The expansion of nonrice crop production is expected to create new economic opportunities not only for the farm households but for rural areas as well. Agricultural diversification has been considered as one of the major efforts in implementing agricultural sector development in Indonesia. However, commodity-based programs such as rice intensification has weakened the process of diversification in irrigated areas.

In some irrigation systems in Java, diversified cropping has been practiced for quite some time supported by well-established water management rules and practices. The management tools used and the underlying principles are reported in the Proceedings of the IMCD Research Network of 1988. These include the management constraints to bridging the gap between systems at the early and advanced stages of development (Pasandaran et al. 1989).

There are at least three important constraints to diversified cropping in irrigation systems: a) system design, b) technical information, and c) production technologies. The system design of existing on-farm canals is inflexible and therefore unable to serve the seasonal changes in irrigating nonrice crops. The technical information available is inadequate to operate irrigation systems efficiently, so are the production technologies suitable for specific agro-ecological zones.

Suprodjo and Sunarno (1990) suggested minor improvements to enable irrigation systems to provide better services for nonrice crop cultivation. These include improvement of drainage facilities at the tertiary level, and improvement of data management related to hydro-meteorology and water requirement.

In addition to rice, five major food crops planted in irrigated areas are, corn, cassava, sweet potato, peanut, and soybean. These nonrice crops are generally planted during the dry season. Depending on the availability of water, these crops may be planted right after the rainy season rice crop or following the dry season rice crop. There are five patterns of crop diversification which reflect both the spatial and temporal dimensions of crops as related to water availability. A description of each pattern has been reported by Hutabarat and Pasandaran (1987).

Table 2 shows the harvested area of secondary crops in Indonesia from 1985 to 1989. The overall growth of area harvested was 2.47 percent annually, with an average harvested area of about 6.4 million ha. The rate of growth in areas outside Java is 5.5 percent with only 0.67 percent in Java. Of the total area planted to secondary crops, the share of the secondary crops planted in the wetland area is only 21.7 percent. In the last four years, outside Java, there has been a faster rate of growth of secondary crops planted in irrigated and wet land areas than in the dry land. In Java, however, there has been a negative rate of growth of secondary crops planted in irrigated areas, and only a slight increase in the area planted to secondary crops in the dry land.

The reduction of area planted to secondary crops in the irrigated area of Java was due to the reduction in the area for maize, with a reduction rate of about two percent annually (Table 3). There was also a reduction in the area for this crop outside Java at a rate of more than three percent a year (Table 4).

There has been a significant increase of the area planted to soybean particularly outside Java (more than 10 percent a year), both in dry and wet land areas. A special effort has been made by the government to promote the production of soybean in the last few years to reduce importation.

There has been a shift in the concentration of secondary crops from Java to other areas, with the irrigated and wet land areas marking the highest rate of shift (Table 5). This tendency is also true for rice where the harvested area increased by a rate of more than two percent a year outside Java (Table 6). Despite a significant increase in the area planted to secondary crops in other areas of the country, the share of Java is still more than 60 percent of the total area of secondary crops in Indonesia.

Table 2. Area of secondary crops in Java, 1985-89 ('000 ha).

Year	Maize	Cassava	Potato	Peanut	Soybean	Total
Dry land						
1985	1,404	767	59	246	239	2,714
	(51.7)	(28.3)	(2.2)	(9.1)	(8.8)	(100)
1986	1,366	743	54	259	339	2,762
	(49.5)	(26.9)	(2.0)	(9.4)	(12.3)	(100)
1987	1,413	472	48	233	281	2,448
	(57.7)	(19.3)	(2.0)	(9.5)	(11.5)	(100)
1988	1,502	809	59	241	295	2,906
	(51.7)	(27.9)	(2.0)	(8.3)	(10.1)	(100)
1989	1,442	770	53	276	296	2,836
	(50.8)	(27.1)	(1.9)	(9.7)	(10.4)	(100)
Average	1,425	712	55	251	290	2,733
	(52.1)	(26.1)	(2.0)	(9.2)	(10.6)	(100)
Growth (%)	0.67	0.10	-2.79	2.87	5.34	1.10
Wet land						
1985	542	26	40	124	379	1,110
	(48.8)	(2.3)	(3.6)	(11.1)	(34.1)	(100)
1986	553	27	42	133	407	1,162
	(47.6)	(2.3)	(3.6)	(11.4)	(35.0)	(100)
1987	322	25	39	119	281	786
	(41.0)	(3.2)	(35.0)	(15.1)	(35.7)	(100)
1988	615	14	46	117	371	1,163
	(52.8)	(1.2)	(4.0)	(10.1)	(31.9)	(100)
1989	499	30	40	130	393	1,092
	(45.7)	(2.7)	(3.7)	(11.9)	(36.0)	(100)
Average	506	24	42	125	366	1,063
	(47.6)	(2.3)	(3.9)	(11.7)	(34.5)	(100)
Growth (%)	-2.09	3.97	-0.09	1.28	0.94	-0.41

Note: The percentage of the total is given within brackets.

Source: Central Bureau of Statistics.

Table 3. Area of secondary crops outside Java, 1985-89 ('000 ha).

Year	Maize	Cassava	Sweet Potato	Peanut	Soybean	Total
Dry land						
1985	878 (47.7)	456 (24.8)	145 (7.9)	127 (6.9)	233 (12.7)	1,840 (100)
1986	1,062 (52.5)	385 (19.0)	135 (6.7)	147 (7.3)	293 (14.5)	2,023 (100)
1987	999 (47.5)	448 (21.3)	125 (6.0)	161 (7.7)	369 (17.6)	2,103 (100)
1988	1,142 (49.5)	507 (22.0)	118 (5.1)	164 (7.1)	375 (16.2)	2,307 (100)
1989	1,055 (46.4)	566 (24.9)	123 (5.4)	158 (7.0)	371 (16.3)	2,272 (100)
Average	1,027 (48.7)	473 (22.4)	129 (6.1)	152 (7.2)	328 (15.6)	2,109 (100)
Growth (%)	4.58	5.43	-4.24	5.46	11.58	5.28
Wet land						
1985	68 (31.7)	6 (2.6)	14 (6.6)	46 (21.4)	81 (37.7)	216 (100)
1986	81 (27.3)	9 (3.0)	19 (6.4)	60 (20.4)	127 (42.9)	296 (100)
1987	67 (26.3)	11 (4.2)	13 (4.9)	48 (18.7)	118 (45.9)	257 (100)
1988	90 (25.2)	17 (4.7)	32 (9.1)	71 (20.0)	146 (41.1)	356 (100)
1989	59 (20.6)	10 (3.3)	19 (6.7)	541 (18.6)	46 (50.7)	288 (100)
Average	73 (5.9)	10 (3.7)	19 (6.9)	56 (19.8)	124 (43.8)	282 (100)
Growth (%)	-3.52	13.77	7.70	3.77	14.71	7.27

Note: The percentage of the total is given within brackets.

Source: Central Bureau of Statistics.

Table 4. Area of secondary crops in and outside Java, 1985-89.

	Dry land ('000 ha)	(%)	Wet land ('000 ha)	(%)	Total ('000 ha)	(%)
Java						
1985	2,714	71.0	1,110	29.0	3,824	100.00
1986	2,762	70.4	1,162	29.6	3,924	100.00
1987	2,448	75.7	786	24.3	3,234	100.00
1988	2,906	71.4	1,163	28.6	4,069	100.00
1989	2,836	72.2	1,092	27.8	3,928	100.00
Average	2,733	72.0	1,063	28.0	3,796	100.00
Growth (%)	1.10		-0.41		0.67	
Outside Java						
1985	1,840	89.5	216	10.5	2,055	100.00
1986	2,023	87.2	296	12.8	2,318	100.00
1987	2,103	89.1	257	10.9	2,359	100.00
1988	2,307	86.6	356	13.4	2,662	100.00
1989	2,272	88.7	288	11.3	2,561	100.00
Average	2,109	88.2	282	11.8	2,391	100.00
Growth (%)	5.28		7.27		5.50	
Indonesia						
1985	4,553	77.5	1,326	22.5	5,879	100.00
1986	4,784	76.6	1,458	23.4	6,243	100.00
1987	4,551	81.4	1,042	18.6	5,593	100.00
1988	5,213	77.4	1,519	22.6	6,732	100.00
1989	5,108	78.7	1,380	21.3	6,489	100.00
Average	4,842	78.3	1,345	21.7	6,187	100.00
Growth (%)	2.87		1.01		2.47	

Source: Central Bureau of Statistics.

Table 5. Share in the total area of secondary crops harvested in and outside Java, 1985-89.

	Java ('000 ha)	(%)	Outside Java ('000 ha)	(%)	Indonesia ('000 ha)	(%)
Dry land						
1985	2,714	59.6	1,840	40.4	4,553	100.00
1986	2,762	57.7	2,023	42.3	4,784	100.00
1987	2,448	53.8	2,103	46.2	4,551	100.00
1988	2,906	55.8	2,307	44.2	5,213	100.00
1989	2,836	55.5	2,272	44.5	5,108	100.00
Average	2,733	56.4	2,109	43.6	4,842	100.00
Growth (%)	1.10		5.28		2.87	
Wet land						
1985	1,110	83.7	216	16.3	1,326	100.00
1986	1,162	79.7	296	20.3	1,458	100.00
1987	786	75.4	257	24.6	1,042	100.00
1988	1,163	76.6	356	23.4	1,519	100.00
1989	1,092	79.1	288	20.9	1,380	100.00
Average	1,063	79.0	282	21.0	1,345	100.00
Growth (%)	-0.41		7.27		1.01	
Indonesia						
1985	3,824	65.0	2,055	35.0	5,879	100.00
1986	3,924	62.9	2,318	37.1	6,243	100.00
1987	3,234	57.8	2,359	42.2	5,593	100.00
1988	4,069	60.5	2,662	39.5	6,732	100.00
1989	3,928	60.5	2,561	39.5	6,489	100.00
Average	3,796	61.4	2,391	38.6	6,187	100.00
Growth (%)	0.67		5.50		2.47	

Source: Central Bureau of Statistics.

Table 6. Harvested wet-land area of rice and yield of rice, 1969-87.

Year	Wet-land area ('000 ha)			Yield (mt/ha)		
	Java	Outside Java	Total	Java	Outside Java	Total
1969	3,933	2,611	6,544	2.57	1.88	2.25
1970	3,947	2,732	6,679	2.70	2.01	2.38
1971	4,037	2,856	6,893	2.81	1.99	2.42
1972	3,992	2,610	6,602	2.76	2.09	2.45
1973	4,226	2,838	7,064	2.86	2.20	2.56
1974	4,434	2,906	7,340	2.94	2.27	2.64
1975	4,379	2,955	7,334	2.95	2.24	2.63
1976	4,203	3,026	7,229	3.15	2.37	2.78
1977	4,115	3,087	7,202	3.00	2.57	2.79
1978	4,447	3,251	7,698	3.29	2.43	2.89
1979	4,393	3,282	7,675	3.40	2.53	2.99
1980	4,507	3,316	7,823	3.86	2.66	3.29
1981	4,763	3,428	8,191	4.07	2.83	3.49
1982	4,488	3,385	7,873	4.39	3.00	3.74
1983	4,479	3,508	7,987	4.53	3.12	3.85
1984	4,852	3,695	8,547	4.55	3.17	3.91
1985	4,965	3,704	8,669	4.59	3.50	4.08
1986	4,986	3,827	8,813	4.59	3.50	4.08
1987	4,971	3,866	8,837	4.73	3.24	4.04
Growth (%)	1.30	2.18	1.67	3.39	3.02	3.25

Information on the productivity of secondary crops across regions and agro-ecological zones, however, is quite limited. Some case studies indicated that the productivity of secondary crops in irrigated areas is higher than in dryland areas. The productivity of secondary crops in Java, as in the case of rice, is higher than that outside Java (Figures 1, 2, and 3).

The overall cropping intensity of food crops is higher in irrigated lands. Data from Table 7 indicate that only 29 percent of the total irrigated and wet-land area has been planted to secondary crops, and 62 percent to rice.

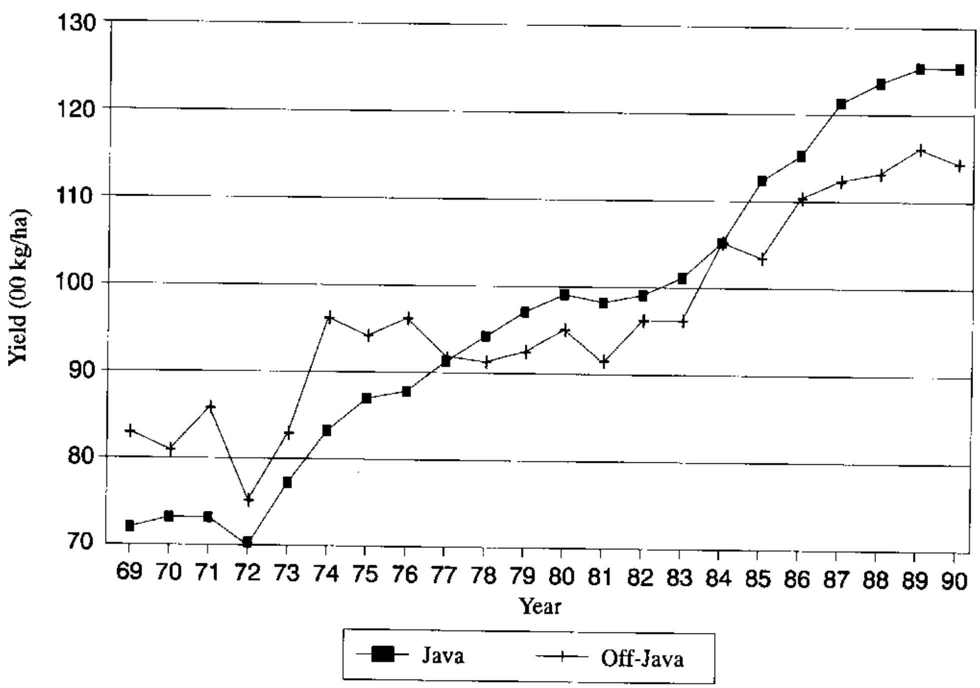
In response to the shift of concentration of secondary food crops in irrigated areas from Java to other areas, there is a need to identify irrigation management variables that have to be manipulated to improve the performance of food crop diversification both in terms of area and productivity. These management variables, however, have to be assessed as an integral part of the food crop diversification process in irrigated areas. Further steps are needed on institutional development of irrigation management in supporting food crop diversification.

Table 7. Gross area, harvested area and cropping intensity by type of land, 1985.

	Gross irrigated area ('000 ha)	Service area ('000 ha)	Rice harvest area ('000 ha)	Secondary crop harvest area ('000 ha)	Cropping intensity		
					Rice	Secondary crops	Total
Irrigated							
Technical	2,237	1,650	2,988	-	1.81	-	-
Semi-technical	1,202	850	1,434	-	1.69	-	-
Simple	974	584	929	-	1.59	-	-
Village	1,036	851	1,353	-	1.59	-	-
Total irrigated	5,449	3,935	6,704	-	1.70	-	-
Rain-fed	673	673	748	-	1.11	-	-
Total wet land	6,122	4,608	7,452	1,326	1.62	0.29	1.90
Tidal/swamp	-	1,167	1,217	-	1.04	-	-
Dry land	-	11,873	1,163	4,553	0.10	0.38	0.48
Total	6,122	17,648	9,832	5,879	0.56	0.33	0.89

Source: Rosegrant and Pasandaran (1990).

Figure 1. Yield of Cassava, 1969-1990.



Source of data: Central Bureau of Statistics.

Figure 2. Yield of Corn, 1969-1990.

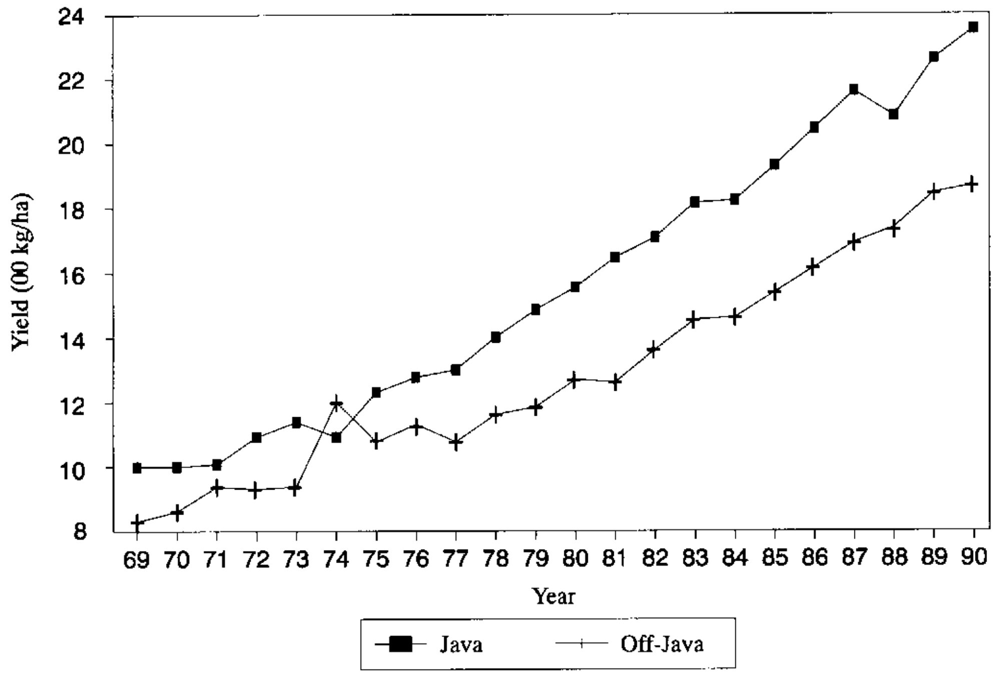
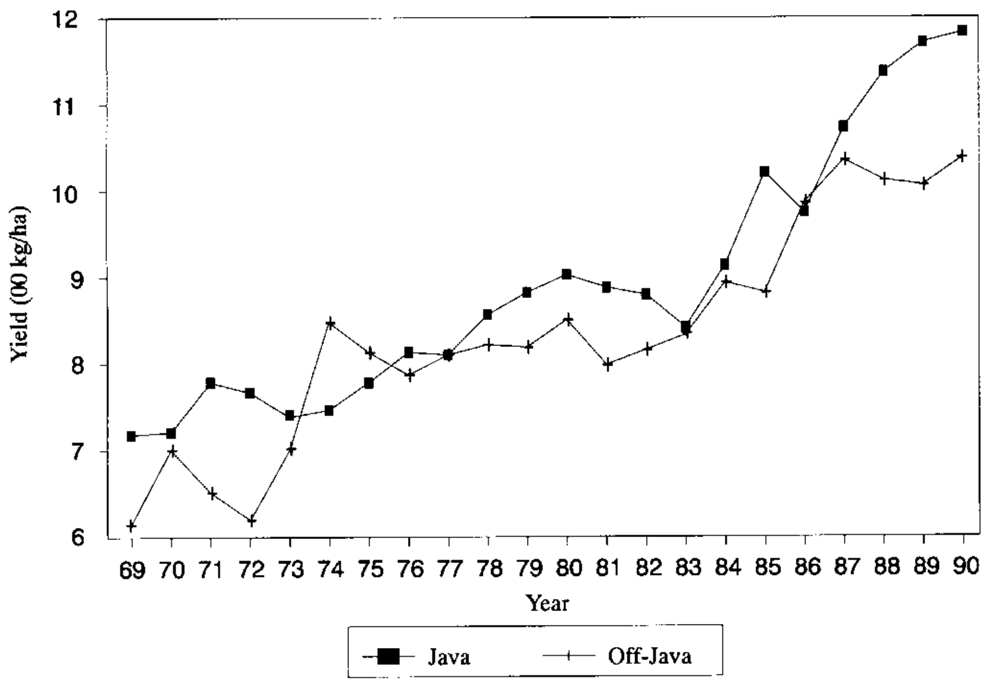


Figure 3. Yield of Soybean, 1969-1990.



Figures 2 and 3; source of data: Central Bureau of Statistics.

CONCLUSIONS

To expedite the process of food crop diversification in irrigated areas in Indonesia requires reorientation of irrigation investment strategies. Greater attention should be given to investment on software development to include improvement of system design, irrigation management and institutional adjustment, to link various activities from design to production.

The reorientation of management policies such as turning over of the small-scale irrigation systems to water users and introduction of irrigation service fees is expected to further induce the process of food crop diversification. Priority should be given to areas outside Java in relaxing various constraints to improve the capacity of irrigation systems and further induce the process of diversification.

There is a need to identify irrigation management variables to respond to the shift of concentration in the area of food crop diversification and the corresponding institutional development of irrigation management.

References

Euroconsult and Pusat Pengembangan Agribisnis: Irrigation Service Fee (ISF) Project Final Reporting Pilot Phase. Main Report. Ministry of Home Affairs, Republic of Indonesia. June 1991.

Hutabarat, B. and Pasandaran E. 1991. Reorientation of Indonesian Irrigation Management. Utilization Toward Crop Diversification. *In* Irrigation Management for Diversified Cropping. IIMI Colombo, Sri Lanka.

Pakpahan, A. et al. 1990. A Preliminary Study on Agricultural Diversification in Indonesia. Monograph Series No. 1. Center for Agro-Economic Research.

Pasandaran, E., B. Hutabarat, and D. Soekarso. 1989. Irrigation Management to Support Crop Diversification in Indonesia. Research Network on Irrigation Management for Diversified Cropping in Rice-Based Systems. IIMI.

Rosegrant, M. and E. Pasandaran. Irrigation Investment in Indonesia: Trends and Determinants. International Food Policy Research Institute and Center for Agro-Socioeconomic Research. (Forthcoming.)

Suprodjo P. and Soenarno. 1990. Management Arrangements for Diversifying Rice Irrigation Systems in Indonesia. Paper presented at the First Progress Review Coordination Workshop on Management Arrangement for Accommodating Nonrice Crops in Rice-Based System. Quezon City, the Philippines. 10-14 December.

Vermillion, D.L. 1991. The Turnover and Self-Management of Irrigation Institutions in Developing Countries. IIMI, Colombo, Sri Lanka. June.