IRRIGATION AND THE PERFORMANCE OF THE IMPROVED RICE TECHNOLOGY

A CASE STUDY IN WEST SUMATRA INDONESIA

by

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DECLARATION

Except where otherwise indicated this thesis represents the original research of the author.

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ABSTRACT

This thesis attempts to provide a better understanding of the nature of performance of improved rice technology, particularly in relation to irrigation. It shows that field water conditions not only affect yields directly, but also influence the crop response to fertilizer and the level of fertilizer use. The efficiency of irrigation water utilization is shown to depend not only upon the supply and distribution of the irrigation water, but also and more importantly on the way farmers utilize it. It thus highlights the importance of farm water management in the application of the improved rice technology.

Factors affecting farm water management are analysed, and performances of groups of farmers are compared, not only in terms of yield and profit, but also in terms of the technical, price and economic efficiencies of farmers. This study also assesses the distribution of benefits of rice cultivation among farmers, and compares them with those of farm size, per capita incomes, and of technical and price efficiencies. Policy implications of the study findings are given and directions are suggested for further research to increase yields and profits and to improve these distributions.

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CHAPTER 1

INTRODUCTION

Rice in Indonesia's Economy

Rice is very important in Indonesia's economy because it is the strongly preferred staple of nearly the entire population and because about 69 per cent of its family households grow it in sawah or wet paddy fields (BPS 1976). The price of rice is a barometer for other commodity prices, especially when it rises. Thus, because of its paramount importance in the national economy, rice is called upon to play dual roles, those of a staple food and of a price stabilizer (Afiff and Timmer 1971).

Over the last 50 years, Indonesia has been transformed from a leading rice exporter to the world's largest importer of both commercial and concessional rice (Timmer 1975). This is due to the fact that the growth rate of rice production has been lower than that of population and domestic supply has lagged behind demand. Although Indonesia imports rice, other basic carbohydrates are exported, indicating not only how important rice is to the population, but also how difficult it is for most of the population to shift from rice to another staple. In the last three decades (1950-1979), Indonesia had imported 22.8 million mt (metric tons) of rice, at an average of 0.76 million mt yearly and with a range from 0.13 million mt in 1955 to 2.6 million mt in 1977 (Table 1.1).[1]

Since independence, the government of Indonesia has consistently pursued the goal of national self-sufficiency in rice production

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[1] According to an FAO expert, the marketable surplus of rice in international markets in 1977 was about 4.5 million mt. Indonesia's rice imports in that year were more than 50 per cent of this international marketable surplus (Majalah Tempo, Jakarta, November 5, 1977, p.6).

Table 1.1 Indonesia's rice production, imports and consumption, 1950-79 (million mt milled rice)

Year	Production	Yield (mt/ha)	Imports	Population (million)	Availability per capita (kg/capita)[a/]
1950	5.79	1.06	0.33	77.2	75
51	5.98	1.07	0.53	78.7	78
52	6.39	1.09	0.77	80.3	84
53	7.03	1.13	0.34	81.9	85
54	7.53	1.18	0.26	83.7	88
55	7.22	1.14	0.13	85.4	84
56	7.30	1.13	0.77	87.3	87
57	7.63	1.12	0.83	89.2	90
58	7.98	1.14	0.71	91.1	90
59	8.29	1.16	0.61	93.2	90
60	8.76	1.20	0.89	95.3	96
61	8.27	1.21	1.01	97.5	91
62	8.89	1.22	1.01	99.3	94
63	7.93	1.18	1.07	101.2	84
64	8.42	1.22	1.02	103.3	86
65	8.84	1.16	0.14	105.4	80
66	9.14	1.21	0.24	107.6	82
67	9.32	1.22	0.35	109.9	83
68	11.67	1.45	0.48	112.4	102
69	12.25	1.54	0.24	114.9	102
70	13.14	1.62	0.32	117.5	108
71	13.72	1.65	0.12	120.1	108
72	13.18	1.67	0.34	123.1	103
73	14.61	1.74	1.86	126.0	124
74	15.28	1.81	1.13	129.1	120
75	15.19	1.80	0.69	132.1	113
76	15.85	1.89	1.28	135.2	120
77	15.94	1.90	2.60	138.3	125
78	17.53	2.01	1.30	141.6	125
79	17.90	2.08	0.75	145.0	128

a/ Availability per capita = (net production + import)/population. Net production = 0.94 x production (it is estimated that six per cent of production is for seed and losses).

Source: 1950-67 from Mubyarto (1975), 1968 from IRRI (1977), 1969-77 from Nota Keuangan dan RAPBN Indonesia 1979/80, and 1978-79 from Harian Kompas Jakarta, 30 January 1979 (estimated figure) and Bratamidjaja (1980).

and has implemented programs of rice production intensification, both because of the significance of rice to Indonesia and in recognition of the fact that the surplus marketed internationally may not always be sufficient to meet the gap in the country's needs. According to Burki and Goering (1977), there may be a gap by 1985 between domestic food production and the food needs of 45-70 million mt in the low income developing countries.

Government aims of increasing rice production through intensification programs were first set out in 1952 within Kasimo Welfare Plan. This plan set a target for Indonesia of self-sufficiency in rice production by 1956. In pursuit of this, a number of Balai Pendidikan Masyarakat Desa (BPMD) or Village Community Education Centres were established, particularly in rice production areas. Good farming techniques were demonstrated at these BPMD in the hope that they would gradually spread from there through the farming community. This pattern of extension was the same as the olie vlek or oil spot method used in the early Dutch colonial program. Progress achieved was very slow and the target of self-sufficiency in rice production was not reached.[2] With a slow increase in rice production between 1952 and 1958, imports of rice increased, particularly in the 1956 to 1958 period (Table 1.1).

From 1959 to 1962, the government undertook another rice intensification program called Padi Sentra or Paddy Centre. It was the first attempt by the government to organize the supply of inputs on a large scale (especially fertilizers) to rice farmers in Java (Sajogyo and Collier 1973). Each Padi Sentra was responsible for coordinating rice production intensification on about 1,000 hectares, and the aim was to include about 1.5 million hectares in the program by 1964. Unfortunately, the program had proved a failure by 1962 and lost about two billion rupiahs. Causes of failure included:

(a) Farmers' very unfavourable reaction to the strong centralization of the program in general and to low rice price in

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[2] For further discussion of the Kasimo Welfare Plan and the Padi Sentra program and its ultimate failure, see: Higgins (1957), Soedarsono (1971), Bulog (1971), Afiff and Timmer (1971), Rukasah and Penny (1967), and Timmer (1975).

particular;

(b) The abuse of credit by officials distributing it and by the farmers receiving it;

(c) Most of the Padi Sentras, which were set up at short notice, were seriously under-staffed with competent technicians (Timmer 1975).

The Padi Sentra organization was abandoned in early 1963, and the failure of the program caused a significant decrease in rice production in that year, and higher imports, exceeding one million mt annually during 1961-4 (Table 1.1).

A new approach to rice extension was then introduced, which originated from the Bogor Institute of Agriculture in the 1962/63 rice season in Java and was expanded to a national scale in 1964/65 season. In this program farmers were provided with adequate credit in kind and cash with a complete demonstration in the field, and direct guidance on how to adopt new inputs and improved rice technology. This program was called BIMAS.[3] The area under the program increased substantially (though with fluctuations) until 1975 (Table 1.2). Reductions in area coverage after 1975 were due partly to poor repayment of credit by the farmers, to the limited area of irrigated sawah which could be included in the intensification program, and to a lack of supporting institutions at the village level (Teken and Kuntjoro 1978).

It is obvious, however, that the program increased rice production substantially (Table 1.1), for area coverage under the intensification programs (Bimas + Inmas) reached about 50 per cent of total rice harvested area in 1977 (Table 1.2).

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3 BIMAS is an acronym for Bimbingan Massal or Mass Guidance or extension. It is an agricultural intensification program providing farmers with a package of inputs including fertilizer, extension services and official credit. Until 1967, the direct guidance was given by students of agricultural faculties of most universities in Indonesia. These students lived in the villages during the rice season. In 1969, the Bimas was called Bimas Gotong Royong or mutual self-help program in which the government contracted with several foreign companies to provide credit for the program. Since 1969 there has also been INMAS (Intensifikasi Massal or Mass Intensification) similar to Bimas but without the provision of official credit. Since the introduction of IRV (international rice varieties) there have been the programs of Bimas Baru (using IRV) and Bimas Biasa (using non IRV).

Table 1.2 Harvested rice area, Indonesia, 1964-77, ('000 hectares)

Year	Bimas	Inmas	Bimas + Inmas	Non intensification	Total
1964	0.1	-	0.1	6,979.9	6,980
65	9.8	-	9.8	7,318.2	7,328
66	340.6	-	340.6	7,350.4	7,691
67	522.0	-	522.0	6,994.0	7,516
68	1,596.2	-	1,596.2	6,367.8	7,964
69	1,309.0	821	2,130.0	5,884.0	8,014
70	1,248.0	905	2,153.0	5,982.0	8,135
71	1,396.0	1,392	2,788.0	5,536.0	8,324
72	1,203.0	1,966	3,169.0	4,729.0	7,898
73	1,832.0	2,156	3,988.0	4,415.0	8,403
74	2,676.0	1,048	3,724.0	4,785.0	8,509
75	2,683.0	954	3,637.0	4,858.0	8,495
76	2,424.0	1,189	3,613.0	4,756.0	8,369
77	2,056.0	2,173	4,229.0	4,159.0	8,388

Sources: 1964-8 from Afiff and Timmer (1971) and Statistical Pocket Book of Indonesia, 1968-9, BPS Jakarta; and 1969-77 from Nota Keuangan dan RAPBN Republik Indonesia 1979/80.

Encouraged, perhaps, by these good results the government again set the target of self-sufficiency in rice production for the end of Repelita I (The First Five Year Development Plan, 1969-73), but again this target was not met. Indeed in 1973, rice imports were the highest ever, at 1.86 million mt (Table 1.1). During Repelita II, 1974-78, highest priority was again given to increasing rice production but results were still unsatisfactory, with production and yields both below targets.

Table 1.3 Harvested area and average yields on areas of intentisification of rice production and national average yields, 1963-78 (yields in milled rice).

Year	Area of intensi-fication ('000 ha)	Yield of intensi-fied area (mt/ha)	Average national yields (mt/ha)	Differences
1963	0.1	3.45	1.15	2.30
1964-68	2,468.7	2.86	1.26	1.60
1969-73	14,228.0	2.13	1.64	0.49
1974-78	15,203.0	2.29	1.85	0.44

Sources: Afiff and Timmer (1971), Nota Keuangan dan RAPBN Republik Indonesia 1979/80, Buku Repelita II 1974-78, and draft Buku Repelita III 1979-83.

Comparison of total areas under intensification programs and average rice yields on these areas over time show a generally inverse relation (Table 1.3). Yields in the early years on small areas of intensification were high, particularly in relation to national averages. With time and an expansion of intensification, yields on these intensified areas dropped by one third or more, whilst the national average yield rose 61 per cent, thus greatly narrowing the difference between the two.

Reasons offered for this have been that with intensification, management becomes more difficult as the area expands, the lack of personnel to give direct guidance to farmers on these areas becomes more acute, and inclusion of a number of poorly irrigated areas in the projects to achieve area targets for the intensification areas as planned in the Repelita I and II.[4]

This decline in yield on areas of intensification is all the more

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4 Readers interested in Bimas programs, see for further discussion: Rukasah and Penny (1967), Mears and Afiff (1968), Rieffel (1969), Soedarsono (1971), Hansen (1971), Franke (1972), Collier (1972), Truc (1975), Birowo (1975), Soewardi (1976).

important since the average yield nationally for Indonesia is low compared with those of more developed countries in Asia and the Pacific (Table 1.4). In 1975, Indonesia ranked sixth and its average yield was less than one-half that of the Republic of Korea and was 37 per cent of average yield of Japan. Its absolute and relative position was even worse in terms of per capita availability of rice.

Table 1.4 Rice yield, population and availability per capita of rice in some Asia and Pacific Countries, 1975.

Country	Rice yield[a/] (mt/ha)	Population[b/] Number	Population Ranking	Availability[c/] per capita Number	Availability per capita Ranking
Japan	4.76	111.6	4	118	7
Korea, Rep. of	3.83	35.3	9	132	4
China, P.R.	3.29	838.8	1	139	3
Australia	2.66	13.5	12	29	14
Malaysia	1.98	9.9	13	119	6
Indonesia	1.81	130.6	3	118	7
Taiwan	1.64	16.1	11	80	10
Philippines	1.60	42.5	7	69	11
Pakistan	1.44	70.3	6	33	13
Bangladesh	1.40	76.8	5	129	5
India	1.06	598.1	2	67	12
Thailand	0.95	41.9	8	190	1
Burma	0.94	30.2	10	159	2
Kampuchea	0.74	8.1	14	96	8

a/ in milled rice, except for Japan in brown rice.
b/ in million people.
c/ in kg rice/capita.

Sources: Rice yields from IRRI (1977), Constraints to high yield on Asian rice farms: An interim report, for Bangladesh, Indonesia, Philippines, Taiwan and for Thailand; for other countries, from Statistical Yearbook for Asia and the Pacific 1976, United Nations. Population from the Statistical Yearbook (ibid.), and from China Yearbook 1978, China Publishing Co., Taipei, Taiwan (for Taiwan only).

The Problem

Past experience with these various attempts to increase rice production in Indonesia have revealed various constraints that have limited the growth rate of the rice production - biological, technological, socio-economic and infrastructural. These are interrelated and complex, and thus are difficult to remove, requiring research to provide a basis for policies and planning decisions for the further development of rice production.

One of the most important constraints on achieving high rice production levels and yields is availability of irrigation water and its control at field level. With ample water, the command area of an irrigation system can be cultivated twice or three times a year, but frequently supplies restrict cultivation to only one crop a year. With good water control at field level, the yield response of a rice crop to inputs such as chemical fertilizers will substantially exceed those from traditional distribution systems.

The importance of water control in the implementation of improved rice technology or the Green Revolution (using IRV, chemical fertilizers, and pesticides) has been stressed specifically by many writers.[5] The term 'Blue Revolution' has been used to dramatize the need for such improved water control. Blue and Green Revolutions are clearly needed concurrently.

As suggested above, there are two important aspects to irrigation water management. First, the requirement of adequate quantities of water for the irrigation area,[6] and second, efficient utilization of irrigation water is needed at field level, e.g. with controlled water depth and duration in rice fields, as appropriate to particular stages

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5 See for example: Wharton (1969), Johnston (1969), Falcon (1970), Barker (1971), FAO (1972), Shand (1973), Herdt and Wickham (1975), PEO-ANU (1976), Palmer (1976), Taylor (1976), Mears (1976), APO (1977), and Taylor and Wickham (1979).

6 According to APO (1977, p.13), only two per cent of the 80 million hectares of rice land in 16 countries are adequately irrigated, 33 per cent inadequately, and the remaining 65 per cent are rainfed.

of rice cultivation.

With regard to the first aspect, water supplies can be augmented in many ways: '(1) pumped from underground sources by means of wells, (2) drawn from the natural flow of streams, (3) obtained by damming or otherwise regulating the flow of streams. It may be applied to the crop by flooding, by channels, or by spray.' (Clark, 1970, p.1). In Indonesia most of the water supply for rice cultivation is obtained from rivers by gravity flow irrigation systems (about 65 per cent of total rice land); some of the rice land (about 17 per cent of the total) is still unirrigated (dry land paddy and rainfed sawah); and a small proportion comprises tidal and swampy areas (Table 1.5).

In the beginning of the Repelita I, emphasis was given to large scale rehabilitation programs. Experience showed that development of large scale irrigation systems[7] required considerable capital and time. This experience along with an increasing concern for equity issues in development process, induced a reorientation of government policy in terms of scale and location of irrigation construction. In 1974, the Indonesian government introduced "Program Irigasi Sederhana" (Simple Irrigation Scheme) in which small scale irrigation schemes, of approximately 2,000 ha, were built by labour intensive methods, with locations outside Java (e.g. Sumatra and Sulawesi) designated as priority areas (Sinaga and Hafid 1979).

Future development of irrigation in Indonesia will be concentrated on more intensive system rehabilitation, including the construction of tertiaries, development of a number of new large to medium scale dams designed to increase the water supply to existing systems, and investigation of the hydrology of areas with ground water resources to determine the magnitude of the reserves, their response to water withdrawal, water quality and the sources of replenishment. (World Bank, 1978, pp.17-20). It is interesting to note that Taylor and Tantigate (1979) in their Malaysia study showed that the larger the irrigation

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[7] For example, Jatiluhur (260,000 ha), Pekalen Sampean (238,000 ha), Pemali Comal (127,000 ha), and Madium (140,000 ha), all in Java (Bratamidjaja 1980).

Table 1.5 Riceland arranged by irrigation types, harvested area and rice production, Indonesia 1974-78 (Unit: 000 ha for area and 000 mt milled rice for production).

Year	Gravity irrigation		Unirrigated and Dry land	Tidal and swampy area	Total rice land	Total harvested area	Total rice production
	Government[a/]	Village[b/]					
1974	2,628	1,028	1,990	587	6,233	8,509	15,275
75	2,721	1,036	1,561	658	5,976	8,495	15,185
76	2,811	1,033	1,414	651	5,871	8,369	15,845
77	2,832	1,110	1,528	808	6,278	8,388	15,941
78	2,904	1,114	1,421	875	6,314	8,701*	17,213*

a/ Government irrigation includes technical and semi-technical irrigation as defined in Chapter 4 below.

b/ Village irrigation includes simple irrigation as defined in Chapter 4 below.

* Estimated.

Source: Bratamidjaja, Otje S.R. (1980), 'Indonesia', in APO (1980), Farm-level water management in selected Asian countries, Asian Productivity Organization, Tokyo, pp.68-75.

scheme, the lower the cost of construction per hectare, except for very large schemes, where the construction cost per hectare was higher. They also showed that larger schemes have higher annual yields than smaller schemes, and that construction costs per hectare for pumping schemes were higher than those for gravity-diversion schemes. Thus, the question of whether to develop large or small scale irrigation schemes, depends upon the policy objectives underlying irrigation development. In Indonesia, as shown above, large-, medium-, and small-scale irrigation systems have been developed simultaneously.

The aspect of efficient utilization of irrigation water revolves very much around the ways in which rice farmers themselves utilize the water on their farms. Without knowledge of management practices appropriate to needs at various stages, water utilization by rice farmers will be inefficient. Extension work is thus needed to stress not only technological aspects of rice cultivation, but also management practices for efficient utilization of irrigation water at field level. Field data in this study indicated a serious deficiency in this latter respect.

These latter observations of course merely introduce issues relevant to efficiency of irrigation water use. The important questions are included in the following study objectives.

Study Objectives and Definitions

In the light of the above problems, the objectives of this study are to analyse:

1. The nature and extent of variations in the equity of water distribution and the efficiency of use of irrigation water by rice farmers within an irrigation command area, and the underlying factors explaining both types of variations;
2. The impact of variations in water availability on farmer decisions regarding the use of production inputs;
3. The organization of irrigation water supply and distribution, the problems that farmers experience in controlling irrigation

water supplies, and possible ways of overcoming these; and

4. Constraints on the adoption of the improved rice technology.

The improved rice technology is defined as one which utilizes Modern Rice Varieties (MRV)[8], chemical fertilizers, pesticides, and irrigation water. The performance of the improved rice technology is measured in terms of yields and profits per hectare.

In irrigation, a stress day is a condition in which there is no free water on the soil surface of a rice farm, i.e., the water level is zero on that day.

The field efficiency of irrigation water use is defined as the ratio of the amount of water actually applied to the amount of water necessary for rice crop cultivation. In mathematical form it can be written as,

$$E_{fi} = \frac{W_a}{W_n} (100) \qquad (1.1)$$

where: E_{fi} is the field efficiency of irrigation water; W_a is the amount of water actually applied over a certain period of time during a crop season; and W_n is the amount of water deemed necessary for cultivation of a rice crop over a specified period of time during the crop season.

Actual applications (W_a) were obtained by regularly measuring the depth of water on rice fields from the day of transplanting until 15 days before harvest (DBH). Data on water requirements (W_n) for the study area were not available, so data from secondary sources were used, e.g. research findings from the Philippines or other sources.[9] Since it is assumed that water requirements (W_n) for all

8 MRVs include IRVs (International Rice Varieties) produced by IRRI, NIVs (National Improved Varieties) produced by the Central Agricultural Research Station in Bogor (e.g. Pelita I/1 and Pelita I/2), and LIVs (Local Improved Varieties) produced by local farmers (e.g. Dalin variety in this study area).

9 See for example, data in FAO (1972) or in APO (1977).

sample farmers in the study area are the same, the field efficiency of irrigation water use (E_{fi}) will be determined solely by actual application of irrigation water (W_a).

Study Hypotheses

It is hypothesized in this study that:

1. In the command area of a lateral irrigation distribution system, rice yields and profits per hectare vary inversely with the distance from the main outlet, i.e., they are highest in the head section and lowest in the tail section of the command area. This hypothesis is based on the findings of an IRRI study of an irrigation system in the Philippines where it was reported that the amount of water available to farms was inversely related to the distance from the beginning of the major canal to farm sites (IRRI 1974 and Herdt and Wickham 1978).

2. There is a negative relationship between the number of stress days and rice yields. This is a logical hypothesis since it is assumed that the stress days significantly influence the yield of rice.

3. Application levels of chemical fertilizer (especially nitrogenous fertilizer) are inversely related to the number of stress days.

4. The level of modern inputs (especially fertilizer) used per hectare has typically been suboptimal for maximum profit per hectare.

5. Rice farms which receive irrigation water directly from an irrigation channel obtain higher average yields than those which receive it indirectly through other rice farms (plot-to-plot system). This hypothesis is based on an assumption that the availability of irrigation water is greater for the former than for the latter.

General Analytical Framework

There are several analytical approaches that can be used to analyse the relationship between irrigation and the performance of improved rice technology. With the use of irrigation water held constant, yields from the improved rice technology can be compared with those obtained from the old rice cultivation practices. Or, holding cultivation practices constant, yields and profits per hectare can be compared in areas with good and poor irrigation facilities. This type of analysis implicitly assumes that maximum yield is compatible with maximum profit, and therefore, that output and input prices are constant. Such an assumption of fixed market prices both of output and input is unrealistic and would give a fallacious relationship between inputs and output.

A second approach would be to calculate the benefit-cost ratio of input use. Although an improvement on the first approach, this type of analysis has limitations in application. It employs the mean value of production response, and thus does not show the optimum level of input use with changes in input and output prices. Nor does it indicate the rate of substitution between inputs required for calculation of minimum costs.

A third approach and the one chosen for this study, involves the use of production and profit functions, and of regression analysis to estimate demand functions for certain inputs (especially for labour, fertilizer and irrigation water).

Parameters of average production functions were estimated with the Ordinary Least Square (OLS) method, and a Linear Programming (LP) method, as used by Timmer (1971), was used to estimate frontier production functions. An estimated average production function will indicate the contribution of each input (including irrigation water) to output and its marginal productivity, the marginal rate of substitution between inputs, the optimum levels of input use, and the changes in input combinations for higher levels of output or for minimum costs. By including prices of inputs and output, the allocative or price efficiency of farmers can be identified. With a frontier production function, technical efficiency ratings of each farmer can be estimated, and from these, technical efficiency ratings of farmer groups can be compared. Profit function analysis enables us to compare relative economic efficiency of groups of farmers.[10] These functions will be used to test our above hypotheses.

Other objectives of this study which cannot be met with quantitative analysis will be attempted with either qualitative or descriptive analysis.

Review of Previous Studies

A recent bibliography on socio-economic aspects of Asian irrigation, published by IRRI and A/D/C (1976), clearly shows that literature on irrigation in Indonesia is very sparse. Few attempts have been made to assess the specific impact of irrigation on the performance of improved rice technology in the country.

Studies on irrigation in Indonesia[11] to date can be classified as: (1) Economic analysis of design and construction of irrigation systems (e.g., IDA, 1973), (2) Operation and management of irrigation systems (e.g., Mohan 1969, Grader 1970, ADB 1972, IRP 1973, Indonesia 1973, Pasandran and Taylor 1976), (3) Irrigation policy and planning (e.g., Schophuys 1970, Hanna 1972, and IPB 1974), (4) Economic analysis of irrigation performance (e.g., IPB 1970 and 1972, Teken 1972, LPMA 1973, RISS 1973, and Pajajaran University 1973), (5) Water charge rates (e.g., Teken 1972 and 1973), (6) Social and institutional factors in irrigation (e.g., Clason n.d., Geertz 1959, 1967 and 1972, Indonesia 1959 and 1969; Jay 1969, Liefrinck 1969, RISS 1970, Universitas Satya Watjana 1971, Birkelbach 1973, and Pasandaran and Harmoni 1975), and (7) General analysis (e.g. Booth 1977).

There has been no measurement of the relative importance of the water control variable on rice yields using production function analysis, so water production function analysis has not been used to project future rice production in Indonesia. Mears (1976) has rightly pointed out that the parameters for water control, improved seed and plant protection need much further examination for Indonesia.

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10 The analytical framework and techniques are discussed in detail in Chapter 3.

11 This review is based on IRRI and A/D/C (1976), Booth (1977), and Prabowo (1977).

Teken (1962), Nazir (1974), and Nurdin (1974) estimated rice production functions for Demak (Central Java), West Java and West Sumatra, respectively, without including an irrigation water variable. They assumed that quality and efficiency of irrigation water at field level in each of their study areas was uniform, as each had good irrigation facilities. It will be shown later, with findings of this and other studies, that this assumption might be misleading.

Using Cobb-Douglas, log and log-inverse, and transcendental production function models, Desai (1973) investigated the ecomomics of resource use on sample farms in central Gujarat, India. His study area was stratified into two regions, one more and one less developed. In the more developed region, rainfall was higher and more evenly distributed over the monsoon period, and farms had a more reliable source of irrigation water than in the less developed region. In the more developed region, with adequate and more reliable irrigation water, sample farmers maximized net returns over all inputs.

Also in India, Kumar (1974) investigated the impact of availability of irrigation field channels on rice yields and incomes of rice farmers using cost-benefit analysis. His study area was divided into two sub-areas, in which villages respectively did and did not have field channels. It was found that those villages with channels had much higher average yields and farm incomes and that the channels made an important contribution to water availability at field level.

An International Rice Research Institute (IRRI 1974) study in the Philippines, found that the amount of water available to farms from an irrigation system was inversely related to distance from the beginning of the major canal to farm sites. This implies that the efficiency of irrigation water at farm level should similarly vary with distance from the major canal, since other factors are assumed constant.

Rosegrant (1976), in a study very similar to the present one, examined the impact of irrigation on the yields of modern varieties (MRV) in the Philippines using multiple regression analysis. Stress days were used as the irrigation variable, and were estimated with a 'water balance' model developed by Wickham (1971). These were not measured in the field, but by simulation, using weekly average data of rainfall, irrigation water flow, evapotranspiration, seepage and percolation. The study demonstrated the critical complementarity between irrigation and nitrogen use for MRV, and concluded that lack of irrigation, and the typically poor quality of irrigation, drastically reduced the yield benefits from modern nitrogen-responsive rice varieties.

A study of constraints on high yields of Asia rice farms by IRRI (1977) showed that in Indonesia (Kulon Progo, Yogjakarta), fertilizer was the dominant factor explaining the yield gap in both dry and wet seasons. The study indicated that farmers who experienced water problems tended to apply less fertilizers to MRV than those without these problems, thus pointing to the need for study of the water control variable.

A macro study of irrigation in Indonesia by Booth (1977) showed, as might be expected, positive correlations between the ratio of irrigated sawah to total sawah and rice yields, and between cropping intensity and the irrigation ratio. A negative correlation was found between farm size and cropping intensity. Again irrigation was shown to be a crucial factor for increasing both yield and planted area.

Sadeghi (1978) examined the economic impact of increased water supply on small rice farms in Iran. He fitted a Cobb-Douglas production function to estimate the production function coefficients of rice in two regions, before and after the construction of a dam. The study showed an upward shift of the production function after the construction of the dam, indicating an increase in the productivity coefficients and the value of the intercept, which again demonstrated the importance of irrigation for rice yields and production.

Problems of water management were discussed in a FAO/UNDP seminar in Manila in 1970 (FAO 1972) and in an Asian Productivity Organization symposium in Tokyo in 1976 (APO 1977). At the Manila seminar it was concluded:

> "...the final goal of water development is to provide farmers with adequate water supplies at the farm level, farmers

themselves should attempt to make the best use of water and complementary inputs. It was fully agreed that the transmission of knowledge to the farmers plays a crucial role in attaining economic and social benefits from any water development project...." (FAO 1972 p.10).

"It was recognized that further research work on the physical conditions of water management at the field should be carried out, ..., as well as the need for diversified and intensified agriculture. For this purpose, regional coöperation is considered to be essential and received the fullest support of the session." (FAO 1972 p.11).

The Tokyo symposium stressed that:

"The solution to critical institutional and organizational problems of the terminal unit level is dependent, in part, upon the outcomes of increased and sustained research efforts on these issues. A broad program of research on irrigation organization would include the following dimentions: i) analysis of indigenous systems of irrigation and water management; ii) analysis of patterns and relationships in government-managed systems; and iii) implementation of action research activities. Action research moves beyond the identification and analysis of existing forms of irrigation organization, either indigenous or government-managed systems, to activities in which new or modified organizational arrangements are designed and tested for their performance in actual field situations." (APO 1977 p.13).

From the above discussion, it is clear that research on irrigation problems at field level is essential for obtaining solutions, since it is at this level that farmers themselves must make the decisions as to the best use of water and complementary inputs.

Organization of the Study

The following chapter discusses selection of the study area, the sampling method, the data collection, and the socio-economic conditions of the selected study area.

Quantitative analytical approaches and techniques are surveyed in Chapter 3. Production and profit function models are selected, together with variables for these models and the methods for statistical analysis and testing of the model. The three kinds of efficiency (technical, allocative or price, and economic efficiencies) are defined and the distinctions between them are discussed along with the techniques of measuring them.

The theory of the role of irrigation in increasing yields and production of rice is presented in Chapter 4. Types of irrigation are defined and special attention is given to defining the concept of irrigation efficiency, and to the problem of measuring efficiency.

Irrigation performance in the study area is discussed in Chapter 5. Consideration is given to farm water management and organization, factors affecting the depth of water at field level, the number of stress days, and the timing of farm drainage before harvest. The relationships between yields and irrigation variables (depth of water, number of stress days, and the time of draining farms) are also discussed in this chapter.

The technological performance of sample rice farmers is analysed in Chapter 6. Empirical estimates of rice production functions are made for the study area, using both average and frontier production functions. These are used to conduct tests between groups of farmers, and to estimate the technical efficiency of individual sample farmers and of farmer groups. Factors affecting technical efficiency of farmers, and those influencing yield differentials between farmer groups are also analysed.

Chapter 7 discusses the economic performance of sample farmers, with an analysis of allocative or price efficiency, and of the economic rationality of sample farmers. Optimum levels of inputs for maximizing profits are calculated and used to estimate potential gains from achieving technical and price efficiencies. Factors influencing the demand for labour and fertilizer are analysed. Empirical profit functions are estimated and used to assess the relative economic efficiency and relative profits of groups of farmers.

A summary, conclusions, policy implications of study findings, and suggestions for further research are given in Chapter 8.

CHAPTER 2

THE STUDY AREA, SAMPLE AND DATA COLLECTION

The Selection of a Study Area

There are 27 provinces in Indonesia, of which 22 produce rice. According to the Central Bureau of Statistics (BPS, 1975, p.viii), there are only 10 provinces which have a major potential for rice production, while the Agro Economic Survey (AES) of Indonesia (Sajogyo and Collier 1973) reported only 8 provinces, with relatively good irrigation, marketing facilities and machine processing, and relatively good contacts with town and city markets, as having high potential. These eight were North Sumatra, West Sumatra, Lampung, West Java, Central Java (including Yogyakarta), East Java, Bali and South Sulawesi.[1]

West Sumatra was selected for this study because:

1. Rice is a key commodity in the West Sumatra's economy. About 90 per cent of farm households grow paddy in sawah, and about 26 per cent of West Sumatra's regional income in 1972 came from rice production. These proportions were the highest among the eight provinces in the early 1970s (Table 2.1).

2. Since 1969, West Sumatra has changed from a rice importing to a rice exporting province. This has been due partly to the successful introduction of improved rice technology, and partly to irrigation development. Before Repelita I, in 1966, the sawah area with technical and semi-technical irrigation systems was only 16.6 per cent of total sawah area. At the end of the Repelita I in 1973, this had increased to 36 per cent, and at the end of Repelita II in 1978, the proportion had grown to 46 per cent (UNAND, 1975, p.139; and BAPPEDA, 1978, p.319).

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[1] Geertz (1963, pp.14-15) and Booth (1977) also mentioned that these provinces had relatively good irrigation and great potential for rice production.

Table 2.1 Rice farming indicators in eight provinces of Indonesia, 1973.

Province	Total sawah ('000 ha)	Ratio of irrigated to total sawah	Sawah yield (mt/ha of milled rice)	Ratio of rice farmers to total farmers	Rice contribution to regional income 1972 (%)	Ratio of IRV area to total lowland rice area (%)
North Sumatra	299	0.27	2.220	75.4	18.0	n.a.
West Sumatra	204	0.46	1.919	90.1	25.9	89.0
Lampung	89	0.44	1.752	38.3	14.8	27.9
West Java	839	0.89	1.955	88.0	22.3	15.0
Central Java	809	0.43	2.049	71.4	18.7	16.0
East Java	932	0.85	2.096	64.5	11.2	21.2
Bali	82	0.41	2.382	62.3	23.9	14.0
South Sulawesi	330	0.25	1.778	71.0	21.0	47.1

Sources: 1973 Agricultural Census, Vol.1; Statistical Pocketbook of Indonesia 1974/75; Sumatera Barat Dalam Angka tahun 1977, BAPPEDA Sumatera Barat 1978; Booth (1977); AES (1972), 'Agricultural Census in Thirty Three Villages Located in the Major Rice Producing Areas of Indonesia', Research Notes No.6, April 1972; Kelompok Penelitian Pendapatan Regional, Fakultas Ekonomi, Universitas Indonesia, Jakarta, 1974, Perhitungan Pendapatan Regional di Indonesia 1968-1972.

3. The government of West Sumatra has made continuous efforts to improve the existing irrigation systems (Table 2.2) and to construct new systems (Table 2.3).

Table 2.2 Irrigated Sawah areas in West Sumatra 1976 ('000 ha)

Kabupaten/ Kotamadya	Technical irrigation	Semi technical irrigation	Simple irrigation	Rainfed	Total
Agam/Bukittinggi	0.6	7.8	2.5	2.7	13.6
Pasaman	5.4	17.2	6.8	1.7	31.1
Limapulah Kota	4.0	6.8	1.9	3.8	16.5
Tanah Datar	2.3	4.4	3.0	9.4	19.1
Padang-Pariaman	5.5	13.7	15.1	15.5	49.8
Pesisir Selatan	4.8	7.3	10.0	7.8	29.9
Solok	5.0	9.2	6.2	11.1	31.5
Sawahlunto Sijunjung	0.7	1.3	0.1	3.6	5.7
West Sumatra	28.3	67.7	45.6	55.6	197.2

Source: DPU Sumatera Barat (1976)

As Table 2.2 shows, there are still some 55,600 ha of sawah areas without irrigation systems, and more without channels. Completion of plans for new irrigated sawah area would nearly double the total area of sawah in West Sumatra. These new irrigated areas are intended especially for local and national transmigration.

4. Comprehensive studies of the improved rice technology, and of the impact of irrigation on its performance, have not been undertaken in West Sumatra to date.

The Badenah Gunung Nago Irrigation System

The area that was selected purposively for this study is the command area of the Badenah Gunung Nago technical irrigation system

Table 2.3 New irrigated areas planned for West Sumatra 1978

Irrigation project	Area ('000 ha)	Location (Kabupaten)	Stage
Dataran Anai	14	Padang-Pariaman	under survey
Tongar	10	Pasaman	under survey
Panti-Rao	20	Pasaman	under construction
Batang Masang	50	Pasaman	under survey
Batang Hari	27	Sijunjung	under survey
Batahan	6	Pasaman	under survey
Lunang-Silaut	10	Pesisir Selatan	under survey
Kapur IX	15	Limapuluh Kota	under survey
Total	152		

Source: UNAND (1975, p.138)

currently the largest irrigation system in West Sumatra.[2] It covers about 4,000 ha of sawah area located on the Kuranji river in Kabupaten Padang-Pariaman in the eastern part of Padang municipality (Figure 2.1).

The area was selected for study not only because of its potential for rice production and the reported condition of its irrigation system, but also because of a number of local factors: farmers practised the improved rice technology, the people were prepared to cooperate for the period of the study, local leaders were sympathetic to the objectives of the study, there was scope for adequate supervision of enumerators and assistants to measure the depth of water on rice fields, and the area was accessible throughout the year.

The Badenah irrigation project is actually a rehabilitation project in which a new weir and a distribution system from secondary to tertiary

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2 According to the government of West Sumatra, it is the best irrigation system in West Sumatra, particularly in terms of construction, irrigation channel networks and water control from the headwork to tertiary canals.

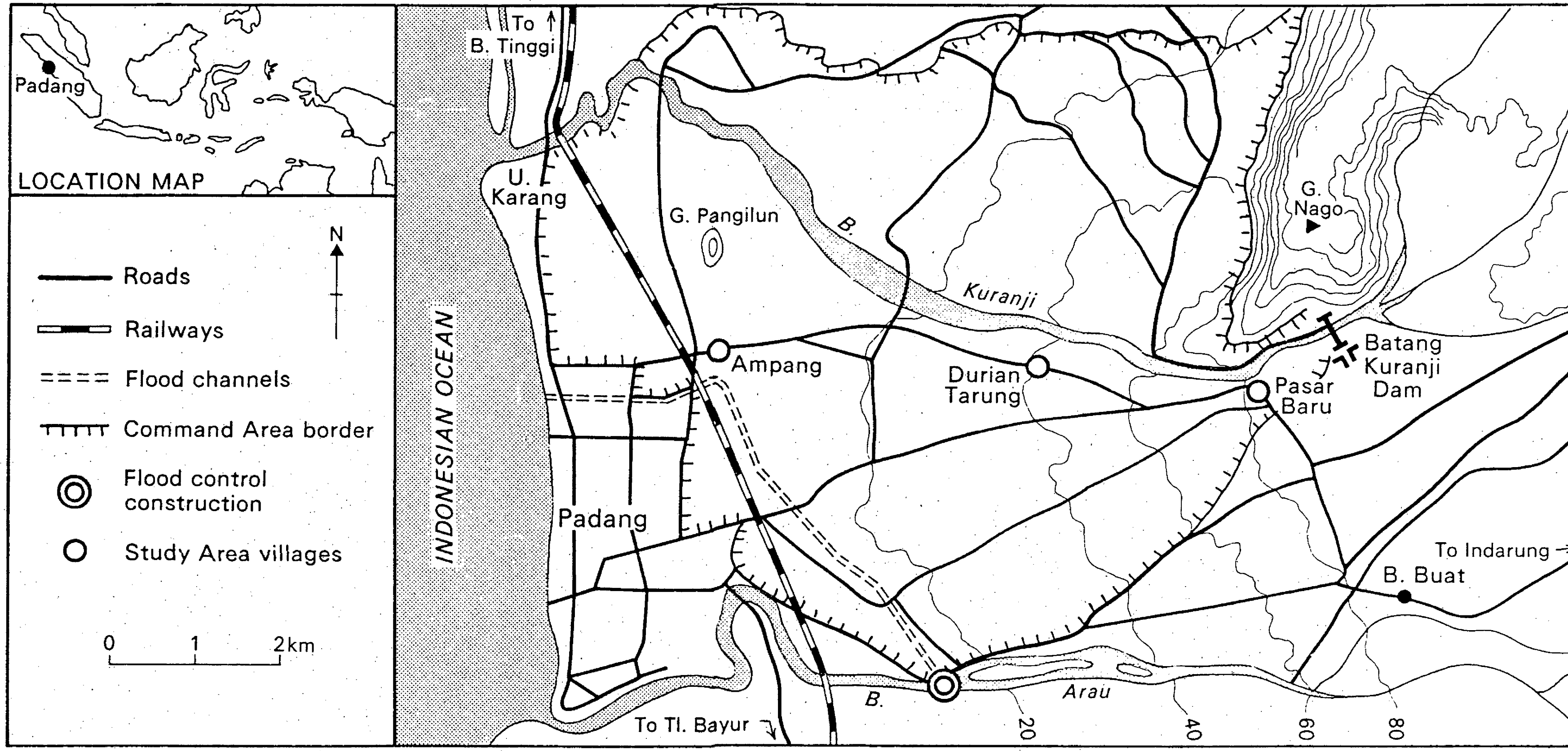

Figure 2.1. The Badenah irrigation system command area, West Sumatra, Indonesia.

channels were added to the existing irrigation channels. Before rehabilitation, there were nine simple and independent irrigation constructions along the Kuranji river. The water supply and distribution were not adequate nor sufficiently controlled for the needs of two rice crops a year, and farmers grew only one rice crop during the wet season. With rehabilitation, the nine irrigation constructions were reduced to one, the major technical construction at Gunung Nago. This enabled the supply and distribution of irrigation water to be controlled at the headworks, and at the distribution points from primary to secondary canals and from secondary to tertiary channels. Farmers in the command area have planted rice at least twice a year since the rehabilitation project was nearly completed in 1975.

The rehabilitation project was initiated in 1969, in the first year of Repelita I and completed in 1977, the third year of the Repelita II. Total cost of the project was about 300 million rupiahs or about 0.75 million US dollars.[3] Maintenance and operating costs of the project are about three thousand rupiahs per hectare per year or about eight US dollars/ha/year.[4]

The detailed plan of the irrigation project (Figure 2.2) shows that the command area of the Badenah system consists of two major sections, the Badenah I section with 2,500 hectares of sawah and the Badenah II section with 1,500 hectares of sawah. There are four lateral distribution systems in the Badenah I section: the Lubuk Begalung (BLb1-BLb6); the Andalas (BAn1-BAn4); the Lubuk Lintah (BLL1-BLL2); and the Kampung Kelawi (BKK1-BKK5), together with the Pasar Baru main canal (BPbI-BPbIV). In the Badenah II section, there are three lateral distribution systems and the Kuranji main canal (BKI-BKII). The lateral systems are: the Kalumbuk (BKL1-BKL3), the Nanggalo (BN1-BN3), and the Balimbing (BB1-BB3). The layout of the Badenah system is reported in Figure 2.3

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[3] The exchange rates for the US dollar were US$1 = Rp326 for 1967-71, and US$1 = Rp415 for 1971-78, and since 1978 (November) US$1 = Rp625.

[4] See, Departemen PUTL Ditjen Pengairan Direktorat Irigasi, <u>Bendung Batang Kuranji Gunung Nago Padang 4,000 Ha</u>, no date.

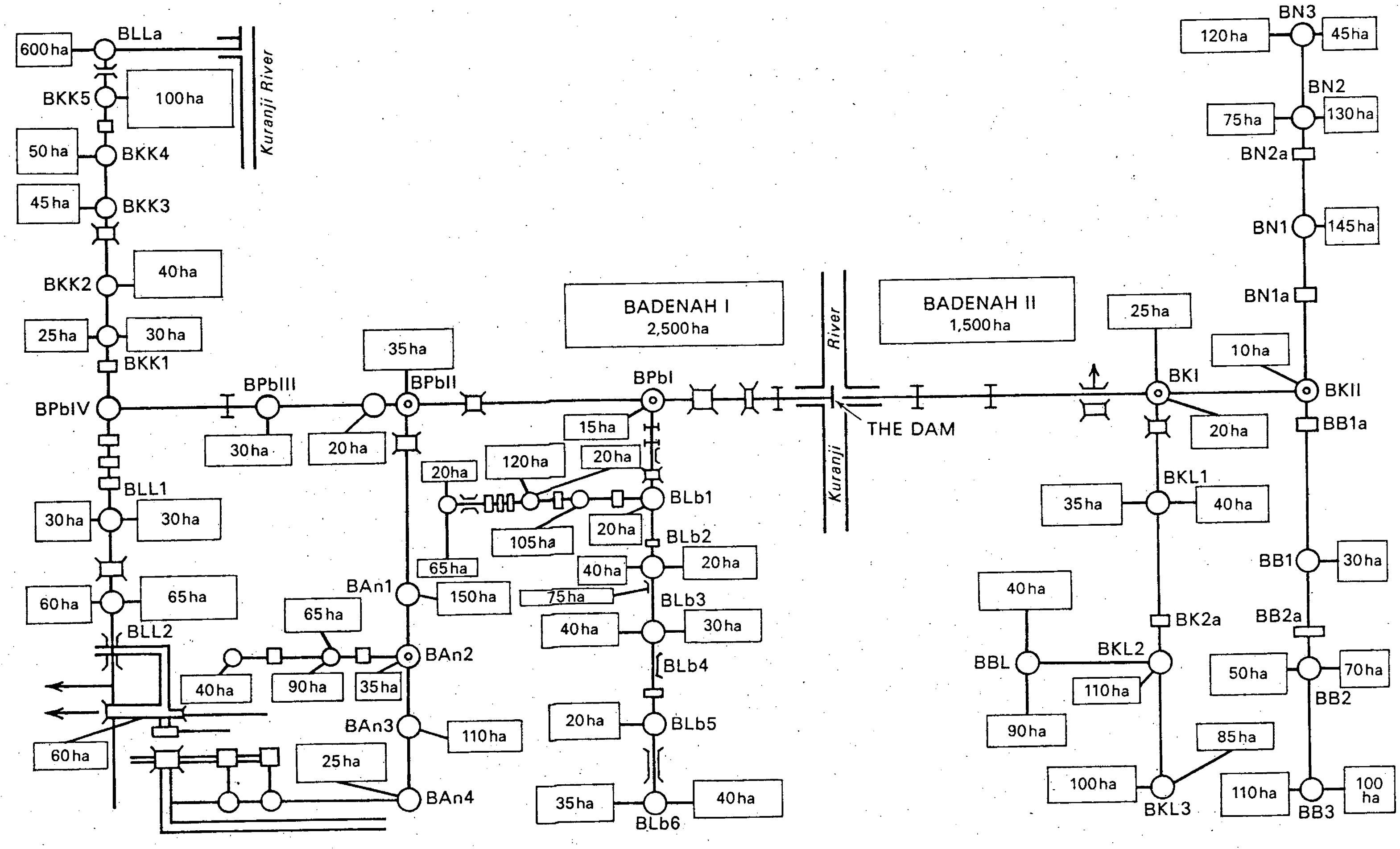

Figure 2.2. The Badenah irrigation scheme.

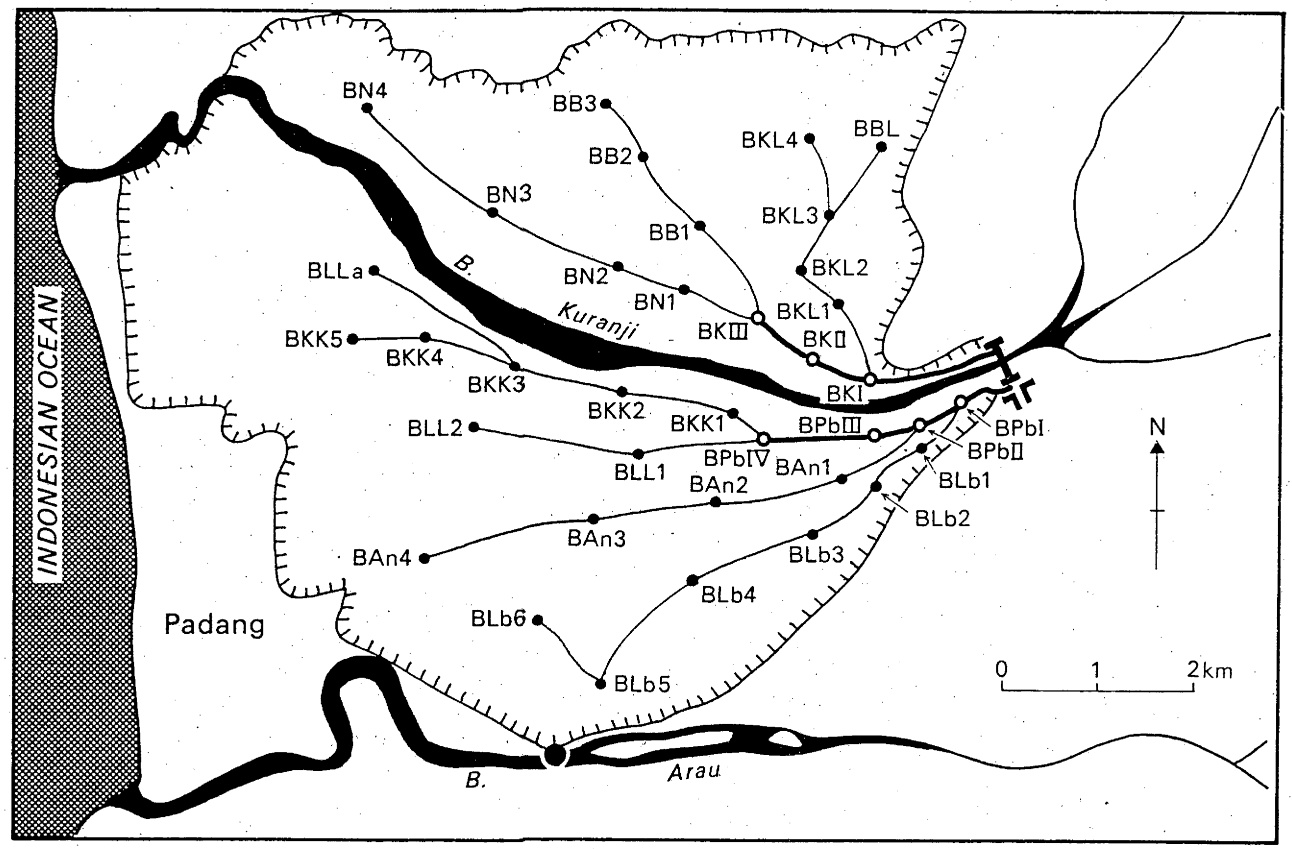

Figure 2.3. Layout of the Badenah irrigation system

After visiting the command area of the system in December 1977, and taking into account local factors and the objectives of this study, the study area was selected along the main canal of Pasar Baru (BPbI-BPbIV) and the BKK lateral system (BKK1-BKK5). This area is located in two villages, Pauh V and Pauh IX, of Kecamatan Pauh in Kabupaten Padang- Pariaman, and in some eastern parts of Padang municipality.

The length of the irrigation channel (primary and secondary channels) from the headwork or weir to the BKK5 distribution gate is about eight kilometres. Both canals and ditches are mostly earthen except for the main canal which is lined. These and other characteristics affect the availability of water from the head to the tail sections of the channels as will be discussed in Chapters 4 and 5.

Climate and Soil Types

The climate and soil type of the study area do not vary

Table 2.4 Distribution of average monthly precipitation, air temperature and humidity of the study area 1971-77.

Month	Precipitation (mm)	Temperature (centigrade)	Humidity (%)
January	243	25.3	80.8
February	267	25.3	90.8
March	230	25.6	82.3
April	369	26.3	83.8
May	342	26.4	82.7
June	293	26.0	81.8
July	249	25.7	81.7
August	322	25.6	82.5
September	369	25.5	83.9
October	405	25.6	83.6
November	513	25.9	83.1
December	363	25.6	83.7

Source: UNAND (1978, p.163).

significantly from the head to the tail sections. The climate is defined as humid, with an average annual rainfall of between 3034 and 4091 mm, and an average temperature of between 25.6^{o} and 26.1^{o} centigrade. The distributions of average monthly precipitation, air temperature and humidity in the study area between 1971 and 1977 show little monthly variation (Table 2.4), and therefore no significant difference between wet and dry seasons.

Table 2.5 Distribution of monthly precipitation, rainydays and hours of sunshine in the study area, 1978.

Month	Precipitation (mm)		Rainydays (day)		Sunshine (hours)	
	G. Nago	Tabing	G. Nago	Tabing	G. Nago	Tabing
January	686	493	12	13	161	n.a.*)
February	252	341	13	15	162	n.a.
March	478	312	16	24	174	n.a.
April	341	207	11	13	205	n.a.
May	459	388	19	17	190	n.a.
June	303	387	12	14	188	n.a.
July	496	467	13	18	219	n.a.
August	342	364	13	19	182	n.a.
September	481	398	14	16	174	n.a.
October	399	685	18	24	153	n.a.
November	296	247	23	21	161	n.a.
December	424	417	19	20	173	n.a.
Total	4957	4703	183	214	2142	
Mean	413.1	391.9	15.3	17.8	178.5	
S. Dev.	118.6	123.3	3.7	3.9	19.6	

*) n.a. = not available

Sources: Tabing station of meteorology and Gunung Nago irrigation project office station.

Monthly data for precipitation, rainy days and sunshine (Table 2.5 and Figure 2.4) during the survey period in 1978 for two stations (Gunung Nago and Tabing in the head and tail section respectively) show no significant differences in precipitation or rainy days. Data on sunshine were not available for Tabing station, but given these other data, an assumption that there is no significant difference between sunny days in the head and tail sections seems reasonable.

It is difficult to differentiate between wet and dry seasons in terms of precipitation and the number of rainy days, as there is no apparent contrast (Figure 2.4). However the distribution of sunshine during 1978 suggests that there are more sunny-times in April-September than in October-March. This supports the view of West Sumatra's Department of Agriculture (Dinas Pertanian Rakyat) that the wet season is from October to March, and the dry season from April to September.

The soil type is uniform, yellowish-brown alluvial from the head to the tail sections of the study area. Its texture does vary a little, from light in the head to medium in the body and to slightly heavy in the tail section. The natural drainage conditions reflect this, and are more satisfactory in the head and body sections than in the tail section. Soil fertility can be gauged from the chemical content, organic ingredients, and its pH. The C-organic and nitrogen content of the soil are relatively low, but the soil is fairly high in phosphorous and high in other elements such as iron and aluminium (Table 2.6).

The low content of C-organic and nitrogen are caused by intensive land preparation causing frequent oxidation, and because intensive cultivation of the land takes a lot of the nitrogen (N) content. The high P content is explained by the alluvial origin of the soil, and also because of good irrigation water supplies. The impact of the irrigation water on soil fertility is to add chemical elements such as Na, Ca, Mg, K, Al, Fe, Mn and SO_4.

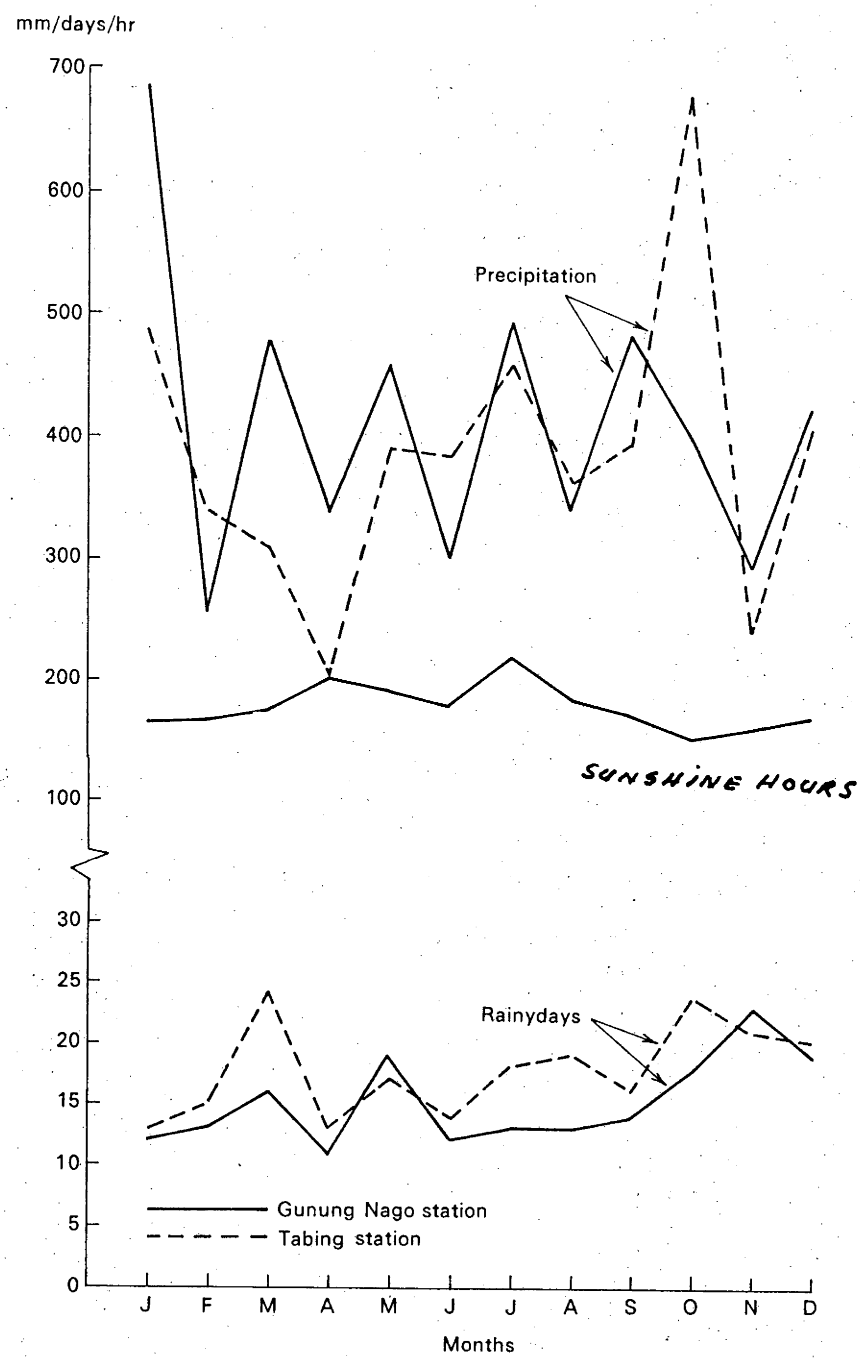

Figure 2.4. Monthly distribution of precipitation, rainy days and sunshine hours in the study area, 1978.

Table 2.6 Chemical element content of the study area soil.

Elements	Unit	Average	Range	Categories
C-organic	%	2.4	0.4-12.7	low
N	%	0.2	0.1-0.5	low
P	ppm	14	6-27	medium to high
Na	meq/100g	0.4	0.2-0.8	high enough
Ca	idem	7.4	1-3-41.4	idem
Mg	idem	2.1	0.2-5.7	idem
K	idem	0.3	0.1-0.9	idem
Al	ppm	121	n.a.	high
Fe	ppm	178	n.a.	high
Mn	ppm	0.2	0.1-0.9	very low
SO_4	ppm	155	n.a.	medium

Source: UNAND (1978, pp.54-56)

The acidity (pH) of the soil is low, ranging from 3.7 to 6.6 with an average of 4.3. This may be due to the sulphur content (SO_4).

The quality of land for agriculture is determined by a number of factors such as the effective soil depth, extent of erosion and the organic matter and stone content. On the basis of these factors, eight classes of land quality have been recognized. The UNAND (1978) study placed the land quality of the study area in the second class, and is thus relatively good. The effective depth of the soil is around 50 cm, its slope is between three to eight per cent, its stone or gravel content is between 0 and 15%, its erosion level is low and its chemical content is relatively good.

The quality of irrigation water in the study area, which comes from the Kuranji river, is also good. The levels of dangerous elements for crops such as sodium and boron are low and can be tolerated by crops.[5]

Socio-economic Conditions

The study area comprises two villages, Pauh V and Pauh IX of Kecamatan Pauh. The head section is located in Pauh V, while the body and the tail sections are located in Pauh IX. Pauh V is classified as Desa Swakarya or underdeveloped, and Pauh IX as Desa Swambada or developed (Table 2.7).

As a desa swakarya village, Pauh V's economy is still dominated by agriculture, particularly by rice. About 65 per cent of the total land in use is sawah, and 76.5 per cent of its total labour force works in the agricultural sector. Its population density is high, with more than 300 persons per square kilometre, so that average farm size is small. About 35 per cent of farmers have less than 0.5 ha rice farm land, and only about nine per cent have more

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5 Detailed analysis of the water of the Kuranji river can be studied in UNAND (1978, pp.17-29).

Table 2.7 Socio-economic conditions of the study area, 1978.

Items	Unit	Pauh V	Pauh IX	Total
Total used land	ha	1,357	3,311	4,668
Land Use:				
1. Sawah land	ha	893	2,118	3,011
2. Dry land	ha	38	148	186
3. Cashcrops land	ha	92	254	346
4. Housing and yards	ha	143	451	594
5. Fishponds	ha	4	75	79
6. Others	ha	187	265	452
Population:				
1. Total	person	14,297	42,182	56,479
2. Male	%	48.7	48.5	48.6
3. Less than 15 yrs	%	53.9	49.6	50.7
4. Density/sq km	person	>300	>300	>300
5. Growth rate/year	%	2.8	3.0	2.9
Employment:				
1. Labour force	person (%)	5,847 (40.9)	22,876 (54.2)	28,723 (50.9)
2. Agriculture	%	78.1	74.9	76.5
3. Non-agriculture	%	9.7	14.5	12.1
4. Unemployment	%	12.2	10.6	11.4
Education:				
1. Primary school graduate and up	% of total pop.	<30	30-60	n.a.
2. No. of Kindergarten	unit	3	0	3
3. No. of Primary school	unit	11	26	37
4. No. of Junior high school	unit	2	5	7
Health facilities:				
1. Health centres	unit	1	1	2
2. BKIA	unit	2	1	3
3. Medical clinics	unit	2	1	3
Economic facilities:				
1. Huller	unit	9	11	20
2. Kincir or water rice mills	unit	58	84	142
3. Village unit banks	unit	1	2	3
4. PPL or field extension worker	person	1	3	4

Source: Kantor Wali Nagari (Village Head Office) Pauh V and Pauh IX.

than one hectare. About 16 per cent of land is privately owned, 55 per cent is communally owned, (or 'tanah suku'[6]), about 26 per cent is share cropped, only about two per cent is leased out, and the remaining one per cent is under mortgaged land ownership.

Because most of the agricultural land, including sawah, is under communal ownership, it is mostly operated rotationally among members of the community, e.g., within a 'kaum' or group of families of the same 'suku' or clan. The member of the community who cultivates the sawah land gives one third of total production to the leader of the community who holds the 'adat' or customary title to the land, and who is usually the oldest in the 'kaum'. In that sense it is share cropped, so the percentage of share cropped land actually becomes much higher. Indeed 58 percent of sample farmers in this study were under this share cropping tenurial system. (Appendix 2.1).

The unemployment[7] level in the study area is relatively high, and in 1978 was about 11 per cent of the labour force. This is due not only to high population density and growth rates but also to the fact that job opportunities are very limited relative to demand, both in the two villages and in Padang municipality. The high population growth rate (2.9%) is due to high natural growth rates and more especially to the high rate of immigration in this area.

The overall infrastructure (physical, social and economic) is quite well developed. For example, the average density of village roads is 0.45 km per sq km, while the density of district roads in the study area is about 1.4 km per sq km, though the quality of those roads needs improvement. There are more than 500 kiosks for fertilizer distribution, 20 hullers and 142 water mills for rice processing. Each village in the study area has one health centre

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6 'Tanah suku' is land ownership which is based on traditional law of the Minangkabau community.

7 An unemployed person is defined here as a person who does not have a permanent job.

with a doctor (general practitioner), and has at least one medical clinic and one mother and children health centre (BKIA). There are three village unit banks to disburse credit to farmers, especially to those participating in the Bimas program. The number of schools, including buildings, teachers and pupils or students is satisfactory.

The education level of the people in the study area is low. Only about 40 per cent of the population have graduated from primary school or higher levels, and more than 10 per cent of adults (aged 15 years and above) are illiterate. Comparatively, Pauh IX village is more progressive, possibly because of the higher educational level of its population. The incomes of Pauh V and IX villages, in 1971, were medium (between 50 and 100 million rupiahs/year) and high (more than 100 million rupiahs/year) respectively (PMD 1972).

The main problems facing the study area are how to raise production and income of the area, and how to reduce the level of unemployment.

Sampling Method

Effective measurement of the impact of irrigation on the performance of improved rice technology in West Sumatra requires: (1) Definition of irrigation utilization efficiency; (2) accurate foreknowledge of the variations in the availability of irrigation water to farms and the principal factors affecting the variations; and (3) minimization of the effect of other environmental variables on production. Selection of an appropriate sample is possible provided requirements (1) and (2) above are met.

Irrigation utilization efficiency was defined in the preceding chapter, and the second requirement has been met by IRRI study findings also referred to in Chapter 1. The third required consideration of alternative approaches as focusses for the study. One possibility was to test the vailidity of the common view in Indonesia that a technical irrigation system[8] is the most efficient and a simple irrigation system is the least efficient, while a semi-technical irrigation system holds an intermediate position.

There is a range of environmental variables that affect rice output, such as soil type, topography, and rainfall, that can confound a comparison of these three types of irrigation. Since the three irrigation types are seldom found contiguously, or even near each other, there is a strong likelihood of substantial differences between the three in terms of environmental conditions. Consequently, there would be major difficulties in isolating the effects of differences in irrigation efficiency from these other factors.

It was also felt that such a study would be testing the obvious, and if the popular view about the relative efficiency of the three systems was confirmed, few new policy implications would emerge. In preference it was decided to focus the study on another important issue, that of variations in irrigation use efficiency within an irrigation system and its effects on productivity. For this, a technical system was chosen since it was thought that, being allegedly the most efficient system of the three, it would be the type upon which most reliance would be placed for successful introduction of the improved technology for rice. The Badenah technical system fitted these criteria and was selected for study. Preliminary survey work suggested that production conditions were fairly homogeneous within the system so far as the above environmental variables were concerned, thus facilitating the measurement of variations in irrigation efficiency.

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[8] The technical irrigation system comprises a weir with full water measurement and control facilities, including the construction of canal/ditches up to the secondary distribution system. The semi-technical irrigation system has a weir and gates at the turn-outs to control the flow of water but has no measuring devices. The simple irrigation system refers to all other types of irrigation systems (more detail of these definitions is given in Chapter 4).

It is difficult to assess how to select a technical system representative for West Sumatra or for Indonesia. But since the scope of this study would allow examination of only one scheme, this effectively became a case study of a technical system. For this reason a combination of probability and non-probability sampling methods could be used (Kearl 1976, Chapter III). For sample selection within the scheme, a stratified multi-stage technique was chosen, in which the sampling method combines purposive and probability sampling.

Following the selection of the Badenah technical irrigation system, the second stage was the selection of a study area within it. It was decided that areas served by the main canal of Pasar Baru (BPbI-BPbIV) and the Kampung Kelawi distribution system (BKK1-BKK5) were appropriate[9] (see Figure 2.2). The third stage was to select areas along this irrigation water route, stratified according to distance from the headworks of the Badenah irrigation system.[10] The final stage was to draw a sample of rice farms, the basic unit, at random in each location stratum.

The first stratum chosen in the study area was in the head section, located near the headworks, i.e. sawah areas around the BPbI-BPbII, located in Pasar Baru sub-village area of Pauh V village. This section was between 135 and 1,048 metres from the headworks with a sawah area of about 60 hectares. The second stratum, chosen as the body section, was around BKK1-BKK2, located in the Durian Tarung sub-village area of Pauh IX village. This section was about 1,551-1,836 metres from the head section, with about 70 hectares of sawah. The third stratum, the tail section,

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9 This was done purposively because the lateral distribution systems were not homogenous. Some (e.g. BLL, BAn and BLb) had not been completed with distribution gates in the tail areas, and some others (e.g. BKL, BB and BN) in Badenah II were difficult to reach by vehicle owing to very bad road conditions. Hence the Badenah I section was preferred.

10 This was also carried out purposively, given that each BKK supplies irrigation water to certain sawah areas, i.e. tertiary block areas.

Figure 2.5. Monthly harvested area and precipitation for the whole irrigation command area and for study area only, 1977.

was around BKK5, in the Ampang sub-village area of Pauh IX village, with a sawah area of about 65 hectares. This was about 2,658 metres from the body section.

It was found that the timing of rice planting in each season was not simultaneous within the study area (Figure 2.5). Some transplanting had already occurred when the survey began. Since it was intended to measure the depth of water on rice fields regularly from the day of transplanting up to 15 days prior to harvest, the sampling universe became those rice farms which had not commenced transplanting at the start of the survey.[11]

The number of such farms in the study area was not available at that time from village records, so the universe of farms in each stratum had to be found directly in the field. With the help of knowledgeable local assistants, all rice farmers in each stratum were identified: 63 in the head section, 79 in the body section, and 61 in the tail section.

The maximum size of sample was determined by the limited survey funds available and the survey plan. The latter was to visit each sample farmer at least once a month during a full year of the survey, to record the rice farm practices for two seasons of rice planting and socio-economic characteristics of the households. Thus, time and cost input per sample household was high.

Calculation of sample size was based on Neyman optimum allocation (Som, 1976, p.137):

$$n = (C - C_o)/\bar{C} \qquad (2.1)$$

where:

n = total sample size

C = the predetermined total cost

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11 Land preparation, however, had started.

C_o = the overhead cost

$\bar{C}$ = the average cost per unit

This gave a total sample size for this study of about 90 rice farmers. The optimum allocation of a fixed total cost is as follows:

$$n_h = (C - C_o) \frac{N_h \sqrt{(V_h/C_h)}}{\Sigma N_h \sqrt{(V_h/C_h)}} \qquad (2.2)$$

where:

n_h = sample size of stratum h

N_h = total number of elementary units in stratum h

V_h = universe variance of the most important characteristics of the elementary unit in stratum h

C_h = the average cost per unit of sample in stratum h

Since the average cost per unit in all strata is the same, the equation (2.2) can be written as:

$$n_h = \frac{nN_h \sqrt{V_h}}{\Sigma N_h \sqrt{V_h}} \qquad (2.3)$$

where n is the sample size for the whole study area, namely, 90 rice farmers.

The most important characteristic of the farm unit is the size of holding, since the area of sawah is widely used as the appropriate indicator of the socio-economic status of farmers in West Sumatra (Nurdin 1975).

The value of V_h was not known in advance, therefore, estimates had to be obtained from previous surveys relating to sawah size. In the absence of any information on the deviation of the universe, the range of values of sawah size was substituted for V_h in equation

(2.3). Data on rice farms in the study area, collected by the Fakultas Pertanian of Universitas Andalas in 1976, showed clearly that the standard deviation estimators of sawah size for the three strata in the study area would not be significantly different (Table 2.8). Therefore, the optimum allocation was 30 sample rice farmers for each stratum. The selection of the 30 sample units for each stratum was carried out by the simple random sampling method using a random numbers table.

Table 2.8 Optimum allocation of total sample size of 90 rice farmers into different strata

Stratum (h)	N_h	S_h a/	$N_h \times S_h$	n_h
Head	63	.2447	15.4161	29.8
Body	79	.1957	15.4603	29.8
Tail	61	.2569	15.6709	30.3
Total	203		46.5473	89.9

a/ This standard deviation of farm size was calculated from data for UNAND (1976).

Where the total cost of the survey is not given, total sample size is usually determined by setting up the desired coefficient of variation of the sample estimator (e), in which:

$$n = \frac{(\text{CV per unit in universe})^2}{e^2} \qquad (2.4)$$

and where CV is the coefficient of variation. Because the CV per unit of the universe is unknown, it can be estimated by using the CV per unit of sample, in which:

$$CV_y = \frac{S_y}{\bar{Y}} \qquad (2.5)$$

where:

CV_y = the CV per unit of sample estimator

S_y = the standard deviation of sample estimator

$\overline{Y}$ = the mean of the sample estimator

Since n was determined (90 sample units) the desired CV of the sample estimator can now be calculated. From the equation (2.4) we can write:

$$e^2 = \frac{(CV)^2}{n} \tag{2.6}$$

or

$$e = \frac{CV}{\sqrt{n}} \tag{2.7}$$

The mean of rice farm sizes of the 90 sample units in this study was 0.4688 hectare with a standard deviation of about 0.25497 hectare. Hence the coefficient of variation of the sample units was 0.25497/0.4688 = 0.5437 or about 54 per cent. Therefore, the desired CV of the sample estimator, e, was about 0.5437/9.4868 = 0.0573 or about 6 per cent. This value of e was not high, which means the size of the sample is quite representative.

Data Collection

Data were collected from farmers and from Government sources at village, district and provincial levels. Data at farm level were collected for two rice crop seasons, the 1978 dry season and the 1978/79 wet season. A set of structured and pre-coded questionnaires was prepared which included questions on rice farming practices, and other socio-economic characteristics of rice farmers (Appendix 2.2). The questionnaire was pre-tested in December 1977 and modified as needed, in time for the start of the first season's survey in January 1978.

Data for the irrigation variable were collected directly, from the day of transplanting until 15 days before the harvest, by measuring the depth of water on rice fields. This measurement also provided the number of stress days for each sample farm during the period. The density of field channels in the study area was calculated by measuring the length of the network of irrigation channels to the farm ditches for each stratum of the study area. Simple maps of the networks were used.

Data collection was carried out by the author and five assistants. Two assistants were graduate students of the Faculty of Agriculture, Andalas University, and worked full time interviewing sample farmers. Three people from the study area assisted by measuring the depth of water on rice fields every second day during the survey period.

One of the problems in data collection was the lack of data on farm sizes. This was solved by taking a sample of farm size in each stratum. Five farmers were selected at random from the 30 sample farms, and were measured for size directly in the field. The quantity of seed used was also collected directly from each of the five operators. There was no significant interfarm variation within a section, so it was assumed to be the same in each section of the study area. This sample showed that the average farmer used an average of about 57 kg paddy seed per hectare in the study area.

In order to get reliable data from sample farmers, a meeting was held between local government officials, the author, the sample farmers and assistants prior to survey, to assure them that data collected would be treated as confidential, would be used only for the study and that the survey had no connection with any form of tax calculation. Sample farmers agreed to cooperate and, as far as possible, to provide reliable data.

CHAPTER 3

ANALYTICAL FRAMEWORK AND TECHNIQUES

One approach to irrigation policy issues is to compare rice cultivation performances with and without irrigation. For this, the effects of irrigation on yields and rate of returns are calculated by applying cost-benefit analysis. But yields do not depend on irrigation alone, but also on the way irrigation facilities are utilized. Therefore, in considering whether to build a new irrigation system or not, we must compare the impact of such new irrigation facilities with the effects of policies to improve the use of existing irrigation facilities.

The present study is a study of efficiency of use of existing irrigation facilities. This was done by examining the head, body, and tail of the Badenah irrigation system in West Sumatra.[1] Comparisons were also made of different tenurial systems (owner, fixed-rent, and share-cropping operators), rice varieties in use (IRV , NIV, and LIV), and irrigation water application systems (direct from channels or plot-to-plot system). A set of hypotheses were set out in Chapter 1 to provide a basis for the study of the impact of irrigation water utilization efficiency on the performance of improved rice technology.

The performance of rice farms can be analysed in two ways:

a. Their technological performances can be judged from output or yields, as determined solely by physical input-output relationships.

b. Their economic performances can be evaluated from profits, and this depends both on the physical relationships and on prices of inputs and output.

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1 See Chapter 2 for a detailed classification of the Badenah irrigation system.

These performances (technological and economic) depend upon the decision-making process of rice farmers. This can be identified by considering three kinds of efficiency: technical efficiency; price or allocative efficiency; and economic efficiency. The following discussion defines and measures these three kinds of efficiency in the three parts of the Badenah irrigation system.

Analytical Framework

The three kinds of efficiency are first defined and illustrated.

Technical efficiency is defined as the capacity of farmers to maximize output or yields from a given set of inputs. If, for example, the yield of farm A is higher than that of farm B (using the same set of inputs), farmer A is said to be more efficient technically than farmer B. Input and output prices are not included in the analysis of technical efficiency.

Price efficiency or allocative efficiency is the capacity of farmers to use inputs so as to maximize profits. A farmer is said to be price efficient in using an input, if the marginal value product of the input is equal to the price of the input. Price efficiency measurement involves prices of inputs and output.

Another way to measure price efficiency of farmers is to use the concept of Wise and Yotopoulos, as condensed in Yotopoulos and Nugent (1976, pp.83-93), referred to as economic rationality. Rationality means 'the ability of firms to successfully apply the profit maximizing rule of behaviour'. The concept measures the economic rationality of a group of farmers using an index calculated from the simple correlation coefficient between capital and labour applied by the farmer group, with special techniques as discussed below.

Economic efficiency is the combined effect of the technical efficiency and price efficiency as defined above. A group of farmers can be economically more efficient than another group owing greater to price efficiency and/or technical efficiency.[2]

These three types of efficiency and their relationships can be illustrated diagramatically (Figure 3.1). Suppose, for simplicity, there are only two factors X_1 and X_2 used and a product Y. The Y_oY_o curve is the unit isoquant for inputs X_1 and X_2, i.e. it represents combinations of inputs X_1 and X_2 that yield one unit of output Y. In production function theory, this isoquant depicts the minimal combinations of inputs required to produce the unit of output, or alternatively, the isoquant shows the maximum quantity of output that can be produced with any combination of the inputs. The PP line is a price or isocost line which shows the minimum cost of producing a unit of output Y at given prices.

Suppose farms A, B, C and D use different combinations of inputs X_1 and X_2 to produce one unit of output Y. The input combination of farm A lies outside isoquant Y_oY_o and also outside the PP price line, so farm A is said to be technically and price inefficient. Farm B combines inputs in such a way as to be located on the unit isoquant Y_oY_o but outside the PP price line, and is therefore technically efficient but price inefficient. The combination selected by farm C places it on a price line (P'P') which is parallel to the PP price line, assuming constant prices. Farm C is thus price efficient but not technically efficient. The input combination of farm D places it at the point of tangency of the isoquant Y_oY_o and the PP price line. It is thus both technically and price efficient and therefore is economically efficient.

Both farm B and farm D are 100 per cent efficient technically. Farm A is inefficient technically, and the degree of its efficiency is measured by the ratio OB/OA which is less than unity. Therefore all farms have a technical efficiency rating between zero and one. Farm D is 100 per cent price and technically efficient, while farm

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[2] Yotopoulos, P.A. and J.B. Nugent (1976), Economic of Development: Empirical Investigations, Harper and Row, New York, p.88.

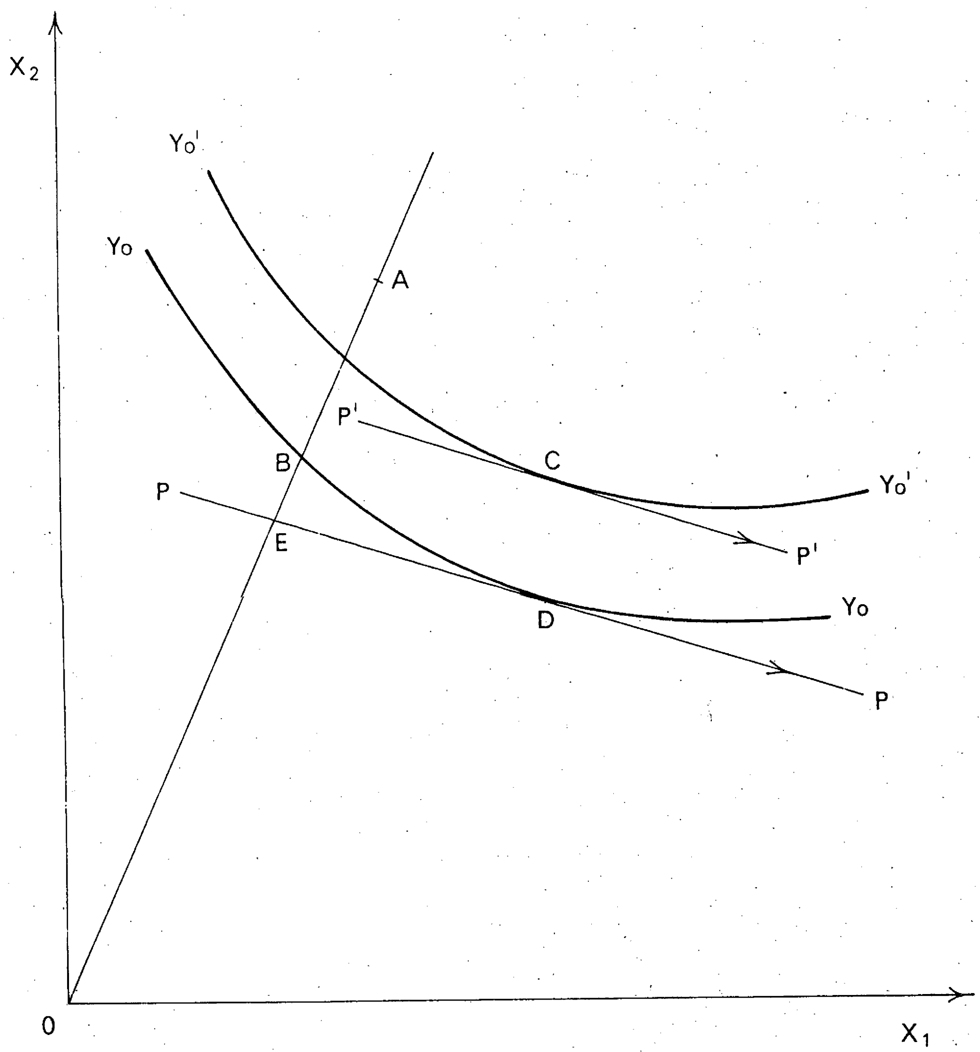

Figure 3.1. Technical efficiency, price efficiency, and economic efficiency.

B is 100 per cent efficient technically but is not price efficient. Farm B spent OB, while farm D spent only OE, thus, the price efficiency rating of farm B is the ratio OE/OB which is also less than unity, and therefore all farms have also a price efficiency rating between zero and one.

This approach (Figure 3.1) is due particularly to Farrell (1957) and has been summarized by Timmer.[3] Farrell was able to measure technical and price efficiencies separately. In another approach, Yotopoulos and colleagues[4] showed how to distinguish between technical and price efficiencies, using the profit function derived from the production function.
<u>Production function</u>: Output = function (of inputs).
<u>Profit function</u>: Profit = function (of prices of inputs relative to output price).

The production function does not take account of how inputs are chosen and their dependence upon prices, which is necessary in considering price efficiency. The profit function shows the technical relation between output and a given set of inputs (technical efficiency) and the effect of the way in which inputs are chosen (price efficiency).

In Yotopoulos and Lau's (1973) method of measuring technical efficiency (TE), interfarm differences in TE within a group are assumed to be negligible; therefore we cannot calculate the TE of each farm, and we cannot estimate the maximum feasible yields under farm conditions. An alternative less limiting approach is therefore used in this study. Moreover, the above test of equal price efficiency (PE) with the profit function does not give the overall

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3 Timmer, C.P. (1971), 'Using a Probabilistic Frontier Production Function to Measure Technical Efficiency', <u>Journal of Political Economy</u>, Vol.79, No.4, pp.776-794.

4 Lau, L.J. and P.A. Yotopoulos (1972), 'Profit, Supply and Factor Demand Functions', <u>American Journal of Agricultural Economics</u>, Vol. 54, No.1, pp.11-18; Yotopoulos, P.A. and L.J. Lau (1973), 'A Test for Relative Economic Efficiency: Some Further Results', <u>American Economic Review</u>, Vol.63, No.1, pp.214-223; and Yotopoulos and Nugent (1976), op.cit.

picture of profit maximization behaviour of the farmer groups for the inputs as a whole. To test this behaviour of farmers in the study area, an alternative approach was used as developed by Wise and Yotopoulos, and condensed in Yotopoulos and Nugent (1976, pp.88-93), that is, a test for economic rationality. The relative economic efficiency of groups of sample farmers was measured by the profit function approach above.

Analytical Techniques

Production Function Analysis

Production function analysis deals with input-output relationships. It is based on the physical and biological sciences, but was developed and used mainly by economists as a tool for economic analysis, as mentioned in an earlier chapter. Input-output relationships can be written:

$$Y = f\,(X_1, X_2 \,\ldots\ldots\ldots, X_n) \qquad (3.1)$$

where Y is output and X_i $(i = 1, 2, \ldots., n)$ is the ith input. For a useful production function estimate, the following assumptions are needed:

a. Sample farms are selected randomly.[5] They attempt to maximize profit based on anticipated output.[6]

b. Farmers are price takers, and both output and input prices are fixed competitively.

c. Farmers have different endowments of fixed factors of

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[5] This is a cross section production function since the farmers are observed at one time.

[6] With this assumption, the production function process can be explained by a single equation model (Walters 1963).

production (e.g. farm size), and varying levels of input applications.

d. Within the study area, all farmers have access to the same information on improved rice technology.[7]

Three important aspects need to be considered prior to estimating a production function:

(a) Model specification, i.e. the choice of an appropriate mathematical model for the production function.

(b) Variable selection and specification, i.e. the choice of variables to be included in the selected production function model, and the form in which they are to be included.

(c) Choice of techniques for estimating the coefficients or parameters of the selected variables.

(a) <u>Model Specification</u>

There are numerous alternative algebraic models that can be used as production functions. Selection should be based on economic theory, it can be suggested from previous investigation; it should have logical implications which guide preferment, and should satisfy the assumptions in the context of the empirical data.

According to production theory, the shape of the production curve depends on the complementarity and substitutability of factors of production. Three possible cases are indicated by Ott (1962):

(i) Complementary factors of production with fixed proportions.

(ii) Complementary factors of production with variable proportions.

(iii) Full substitutability between factors of production.

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7 This is a realistic assumption since the study area is compact.

Types (ii) and (iii) have a high likelihood in the agricultural production process. For this process, two production function models can be associated: the Cobb-Douglas (CD) and Transcendental (Trans) functions. From the viewpoint of production theory, the Trans might be thought preferable because it incorporates all three stages of the neo-classical function (Halter et al. 1957). However, theory also says that the economic optimum level of production lies only in the second stage of the production function. Thus the CD function can provide a direct test of the existence of rational production behaviour (Desai 1973).

These two functional models, however, do not include interaction between the inputs, and the functions need all the inputs to form output. These restrictions can be solved by fitting other models, such as the Quadratic and Translog models.[8] The algebraic models of these production functions are as follows:[9]

Cobb-Douglas

$$Y_i = a\, X_{1i}^{b_1}\, X_{2i}^{b_2}\, u_i \tag{3.2}$$

Transcendental

$$Y_i = a\, X_{1i}^{b_1}\, e^{c_1 X_{1i}}\, X_{2i}^{b_2}\, e^{c_2 X_{2i}}\, u_i \tag{3.3}$$

Translog[10]

$$\ln Y_i = \ln a + b_1 \ln X_{1i} + b_2 \ln X_{2i} + b_3(\ln X_{1i} \ln X_{2i}) + u_i \tag{3.4}$$

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8 Detailed discussions of various production function models for agriculture can be found in Heady and Dillon (1961, pp.73-107), Ahmad (1972, pp.57-68), and Dillon (1968).

9 For simplicity, there are only two factors of production used in these equations.

10 Another model of the translog was used by Ranade and Herdt (1978) where $b_3(\ln X_{1i} \ln X_{2i})$ was replaced by $b_3(\ln X_{1i} - \ln X_{2i})^2$. See also Kmenta (1971, p.463) for linearized CES functions. If b_3 in this equation is not significantly different from zero, we would reject the CES model in favour of the CD model.

Quadratic

$$Y_i = a + b_1X_{1i} + b_2X_{2i} + b_3X_{1i}X_{2i} + b_4X_{1i}^2 + b_5X_{2i}^2 + u_i \tag{3.5}$$

where Y_i = output or yield of farm i (i = 1, 2,....,n; n = sample size); X_1 and X_2 are factors of production; a, b, and c are parameters to be estimated; u_i is a stochastic disturbance; and the ln are natural logarithms.

The above functional models have distinctive features with respect to production elasticities. In the CD function, production elasticities of inputs are constant, while in the transcendental, translog and quadratic functions, they vary with input application levels. The transcendental and translog become a CD function when parameters c_1 and c_2 (in Trans) and b_3 (in Translog) are not significantly different from zero.

The CD model is the most widely used in farm and general economic production function studies. It is almost universally acceptable and extensively applied as it:

a. conforms with economic theory,

b. provides a compromise between an adequate fit of the data, computational feasibility and sufficient unused degrees of freedom to allow statistical testing, and

c. the relative ease of interpretation of the estimated parameters.

Regarding the Cobb-Douglas model, Timmer (1970) wrote: 'The Cobb-Douglas Function is the standard for the profession. Although some of its secondary characteristics are disturbing...., its primary characteristics - ease of handling and generally good fit - continue to recommend it to economists.'

When the above models were applied it was found that the Cobb-

Douglas function gave the best fit.[11] The F-test (to test the overall significance of the regression), and the maximum number of significant estimates of the production function parameters of the CD model, were much higher than those of the other three models. The problem of multicollinearity was not serious in the CD model, while it was for the other three models. For the transcendental and quadratic models, the correlation between an input and its logarithm, and between pairs of variables including quadratic terms was high, so there was a serious problem of multicollinearity.[12]

With the above considerations in mind, the Cobb-Douglas production function model was chosen for the further analysis in this study.

(b) Variable Selection and Specification

Selection of variables for the functional model is very important. On one hand, ignoring relevant variables will bias the estimates of the regression coefficients; on the other, the inclusion of an irrelevant variable will enlarge the variance, reduce the degrees of freedom, increase the possiblity of multicollinearity, lead to imprecise estimates of parameters, and possibly induce autocorrelated residuals (Nurdin 1974). These implications were taken into account in selecting the variables in this study.

With a careful selection of variables and with the above mentioned assumptions, the production function for rice cultivation in the Badenah irrigation command area for the analysis was:

$$\ln Y = \ln a + b_1 \ln W + b_2 \ln N + b_3 \ln L + b_4 \ln D + b_5 \ln C + c_1 T + c_2 M + c_3 E + \ln u \qquad (3.6)$$

where Y = yield of rice farms, measured in kg grain paddy per hectare

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[11] In terms of F-test values (see Tables 3.1-3.4).

[12] Discussion of the problem of multicollinearity will be given below.

Table 3.1 Estimated Cobb-Douglas production function for sample rice farms in the Badenah irrigation system, 1978 dry season.

Variable	Parameter		t_b
	b	Beta	
ln Y (yield, dependent)			
ln a (constant)	2.6799		
T (tenure dummy)	0.3219***	0.2940	3.49
ln L (labour/ha)	0.3505***	0.2723	3.09
ln W (water depth)	0.2759**	0.2205	2.33
ln N (kg N/ha)	0.1409**	0.1886	1.93
M (migration dummy)	0.1715**	0.1616	1.95
ln C (other costs/ha)	0.1886*	0.1508	1.53
ln D (crop damage)	-0.0561*	-0.1437	-1.51
E (education dummy)	0.1181	0.0863	1.03
Degrees of freedom	8/80		
R	0.71		
Adjusted R^2	0.45		
F-test	10.05***		
S.E. of lnY	0.3816		

Notes:

Y = yield (kg paddy/ha), T = tenure dummy (T = 1 for non-owner operators, and zero otherwise), L = labour used (manday/ha) not including harvesting labour, W = average water depth from transplanting to 15 days prior to harvest (mm/day), N = nitrogenous fertilizer used (kg N/ha), M = migration dummy (M = 1 for those who had migration experience, and zero otherwise, C = other variable costs (Rp/ha), D = crop damage caused by pests and diseases (% of crop area), E = education dummy (E = 1 for those who had education more than 6 years, and zero otherwise).

* Significant at the 10 per cent level.
** Significant at the 5 per cent level.
*** Significant at the 1 per cent level.

b = coefficients of variables.

Beta = coefficients of variables which show the relative importance of each variable to variations of yields. Beta parameters are adjusted parameters of b. The higher the absolute value of the Beta, the more important is its variable.

Table 3.2 Estimated Transcendental production function for sample rice farms in the Badenah irrigation system, 1978 dry season.

Variable	Parameter b	Parameter Beta	t_b
ln Y (dependent variable)			
ln a (constant)	5.0452		
D	-0.0105**	-0.4131	-2.48
ln N	0.2582*	0.3458	1.64
T	0.2904***	0.2652	2.89
L	0.0026	0.2255	0.73
ln D	0.0814	0.2085	1.19
M	0.1761**	0.1660	2.01
C	0.00002*	0.1684	1.62
N	-0.0031	-0.1645	-0.71
ln W	0.1512	0.1208	0.35
W	0.0078	0.1005	0.28
ln L	0.0793	0.0616	0.19
E	0.0812	0.0593	0.71
ln C	....	0.0095	0.03
Degrees of freedom	12/76		
R	0.74		
Adjusted R^2	0.55		
F-test	7.64***		
S.E. of lnY	0.3733		

Notes:

Variables are the same as in Table 3.1 where ln = natural logarithm, and all notes in Table 3.1 apply to this table.

.... F-level insufficient for further computation.

S.E. of lnY = standard error of estimated yield.

Table 3.3 Estimated Translog production function for sample rice farms in the Badenah irrigation system, 1978 dry season.

Variable	Parameter b	Parameter Beta	t_b
ln Y (dependent variable)			
ln a (constant)	18.4449		
ln D	-1.4225*	-3.6411	-1.82
LO (lnL x ln C)	0.3570	3.2728	1.01
NO (lnL x ln C)	-0.1819	-2.5676	-1.12
ln L	-0.3284	-2.5512	-1.06
Ln N	1.3693	1.8338	0.89
DO (lnD x ln C)	0.0720	1.7125	0.78
WN (lnW x lnN)	0.2804	1.4912	1.17
ln W	-1.8382	-1.4689	0.93
WD (lnW x lnD)	0.1419*	0.9395	1.51
LD (lnL x lnD)	0.0661	0.7645	0.63
ln C	-0.9288	-0.7427	-0.56
WL (lnW x lnL)	0.1535	0.7037	0.37
T	0.3124***	0.2853	3.24
NL (lnN x lnL)	-0.0678	-0.5084	-0.29
M	0.1757**	0.1656	1.95
E	0.1598*	0.1168	1.34
WO (lnW x ln C)	....	1.1093	0.33
ND (lnN x lnD)	....	-0.0327	0.05
Degrees of freedom	16/72		
R	0.74		
Adjusted R^2	0.45		
F-test	5.47***		
S.E. of lnY	0.3827		

Notes:

All notes in Table 3.1 and 3.2 apply to this table.

LO, NO, DO, WN, WD, LD, WL, NL, WO, and ND are interaction variables.

Table 3.4 Estimated Quadratic production function for sample rice farms in the Badenah irrigation system, 1978 dry season.

Variable	Parameter b	Parameter Beta	t_b
Y (yield, dependent variable)			
Constant	6.7147		
Crop damage (D)	-52.1743**	-1.1744	-2.35
N x N	-0.2423**	-0.8998	-2.13
L x C	-0.6882	-0.7698	-0.73
Other costs (C)	0.1046	0.6061	0.99
N x C	0.7506	0.5325	0.86
N x L	0.1040	0.5261	0.88
Labour (L)	10.6196	0.5238	1.07
W x D	1.5103**	0.4740	1.89
D x D	0.2788*	0.4552	1.76
L x W	-0.3163	-0.4362	-0.75
W x C	-2.2543	-0.3544	-0.58
Tenure dummy (T)	604.583***	0.3196	3.62
L x D	0.0687	0.1816	0.49
Nitrogen (N)	-5.8563	-0.1786	-0.39
W x W	0.6039	0.1687	0.48
C x C	0.7860	0.1524	0.20
Education dummy (E)	246.923	0.1034	1.09
D x C	0.3229	0.0875	0.22
L x L	0.0063	0.0867	0.19
Migration dummy (M)	156.666	0.0846	0.98
N x W	0.9578*	0.7755	1.63
Waterdepth (W)	....	-0.0576	0.08
N x D	....	-0.0009	0.00
Degrees of freedom	21/67		
R	0.78		
Adjusted R^2	0.48		
F-test	4.94***		
S.E. of Y	645.6		

Notes:

All notes in Tables 3.1-3.3 apply to this table.

as reported by the sample farmers. It is assumed that output is homogeneous without quality differentials among the sample farms.[13]

W is the water or irrigation variable, measured as the average depth of water per day at farm level (in mm) from 1 DAT (days after transplanting) to 15 DBH (days before harvest). The depth of water was measured directly every second day on all sample farms during the survey period, as described in Chapter 2.

N is the nitrogenous fertilizer variable, measured in kg N/ha. Nitrogen was chosen as a specific variable rather than a broader fertilizer variable because the soil in the study area was low in nitrogen (as outlined in Chapter 2), and also because agronomic studies indicated that nitrogen was a more important additive than phosphatic fertilizer in rice cultivation (Roumasset 1976, pp.155-6). The types of fertilizer used in the study area were:

a. Urea which contains 0.46 kg N per kg urea;

b. TSP (Triple super phosphate) , which contains 0.46 kg P_2O_5 per kg TSP; and

c. DAP, which contains 0.18 kg N and 0.46 kg P_2O_5 per kg DAP.

Sample farmers all applied nitrogenous fertilizer either as urea or DAP, but not all sample farmers used phosphatic fertilizer.[14] The inclusion of phosphatic fertilizer as a variable in the Cobb-Douglas function would introduce a number of zero values which would result

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13 Because data on farm size were not available, the amount of seed used/ha was used to estimate the size of the sample farms. Our field observations indicated that the amount of seed used/ha was homogeneous with a section, but differed slightly between the sections. The average seed dosage/ha in the head, body and tail sections were 60.6, 57.3 and 53.1 kg/ha respectively. These figures were used to estimate the size of sample farms in each section.

14 This situation showed that farmers in the study area also considered that nitrogen was a more important additive than phosphatic fertilizer.

in unsatisfactory estimates of its coefficient.

L is the labour input measured in mandays (7 hours a day). It measures the total amount of pre-harvest labour used/ha by a farm during a rice crop season. Categories of labour were:

a. Bullocks and operators for land preparation;

b. Hired labour, both male and female; and

c. Family labour, also male and female.

Bullocks and their operators were calculated in mandays by using weighting techniques used by Yotopoulos and Nugent (1976), that is, by comparing the cost of a bullock and its operator with the wage of male hired labour per hour.[15]

Thus,

$$1 \text{ bullock day and its operator} = r \text{ mandays} \qquad (3.7)$$

where r is the ratio of wages per bullock/operator hour to male hired labour. The value of r varied among the sample farms. A weight of 1 womanday = 0.8 manday[16] was used, which was consistent with the differential in the average male labour wage (Rp750/day) to that of the female labour wage (Rp600/day). The number of working hours per day was the same for males and females, and the quality of labour was also homogeneous. Thus, total labour used was the sum of bullock/operator days, and hired and family labour in mandays. Not all sample farmers used bullocks for land preparation. About 47 per cent were still using hoes for land preparation, so bullocks could not be entered as a single variable in the CD production function.

D is a crop damage variable, measured as a percentage of the

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15 A bullock and its operator worked 5 hours a day in the study area, while male and female labourers worked an average of 7 hours a day. The wage of the bullock and its operator was about Rp750/day, while the average wage of the male was Rp750/day and of female was about Rp600/day. Thus wages per hour of the bullock and its operator, female and male were Rp300, Rp86 and Rp107 respectively.

16 This technique was also used by Nurdin (1974).

farm crop area. Damage was caused by pests, diseases or by both. Thus if D = 10, it means that 10 per cent of the farm rice crop was damaged by pests and/or diseases. Measurement was based on farmers' opinions during interviews.

C is other variable costs, measured in rupiahs/ha. It includes phosphatic fertilizer, pest control, seed and other items. This aggregation was made because not all sample farmers applied phosphatic fertilizer and took pest control measures, but all sample farmers used seed.

T is a dummy variable for the tenurial system where T = 1 for non-owner operators and is zero otherwise.

M is a dummy variable for merantau (migration) experience, where M = 1 for those who had merantau experience (i.e. had been outside West Sumatra) and is zero for those who had not.

E is a dummy variable for education. E = 1 for those who had more than 6 years education, and is zero otherwise.

u is a stochastic disturbance terms, and the ln are natural logarithms.

(c) Choice of Techniques for Estimating Parameters

Our CD production function model is a single equation linear in logarithms, so multiple linear regression analysis was used, and the ordinary least square (OLS) method was applied to estimate the parameters. It is always assumed in estimating production functions empirically that discrepancies exist between estimated and observed output. These are called a "disturbance term" in the theory of estimation,[17] and assumptions about the structure and distribution of the disturbance term are needed to ensure that the estimation of

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[17] Cramer (1969) stresses that the random disturbance term must be added to allow for the effect of all variables ignored in the analysis.

the parameters is unbiased.

The general model for multiple linear regression is:

$$Y_i = b_o X_{oi} + b_1 X_{1i} + \dots + b_j X_{ji} + u_i \qquad (3.8)$$

where Y_i is the output of farm i, X_{ji} is use of factor X_j (j = 0, 1, 2, ..., k; k = number of factors of production) by farm i (i = 1, 2, ..., n; n = sample size or number of observations), b_j are the parameters to be estimated,[18] and u_i is a random disturbance term for farm i.

The estimates of the parameters will be the best linear unbiased estimation (BLUE) if the following assumptions hold:

(i) Y is a random variable and it has a conditional distribution with respect to each given X, and the Y's are not interdependent.

(ii) X's are sets of fixed numbers and are independent of each other. This assumption deals with the problem of multicollinearity which will be discussed below.

(iii) The expected value of u_i on each occasion is equal to zero, i.e., $E(u_i) = 0$.

(iv) u_i is independent of time so there is no serial correlation among disturbances, i.e.:

$$E(u_i u_j) = 0 \quad \text{for } i \neq j\text{, but}$$
$$E(u_i u_j) = \sigma^2 \quad \text{for } i = j\text{, and}$$
$$\text{Cov } (u_i u_j) = \text{Cov } (Y_i Y_j) = 0 \ (i \neq j)$$

This means that variance of u_i should be the same from sample to sample and equal to the variance of Y_i, i.e. σ_y^2. The covariance of u_i and Y_i should be zero.

(v) If X's are considered as random variables, then they

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18 The variable X_o is a vector of ones to allow for an intercept.

have independent joint distributions with u, namely:

$$E(X_i u_i) = 0$$

(vi) The disturbance term (u_i) is distributed normally as $N(0,\sigma^2)$.

With these assumptions, the OLS method can be applied to estimate the parameters by minimizing the sum of square of the disturbances between the observed and estimated values.

Equation (3.8) can be written in matrix notation as:

$$Y = Xb + u \qquad (3.9)$$

where Y is an (n x 1) column vector, X is a matrix of fixed numbers of order (n x k) with rank (k x n), b is a column vector of order (k x 1), u is a column vector (n x 1) of disturbances with $E(u) = 0$, and $E(uu') = \sigma^2 In$.

Suppose $\hat{b}$ denotes a column vector of estimates of b, and e is the column vector of n residuals (Y-Xb), we can write:

$$Y = X\hat{b} + e \qquad (3.10)$$

$$e_i^2 = e'e$$

$$= (Y-X\hat{b})'(Y-X\hat{b})$$

$$= (Y'Y-Y'X\hat{b}-\hat{b}'X'Y + \hat{b}'X'X\hat{b}) \qquad (3.11)$$

By using partial derivatives of equation (3.11) with respect to $\hat{b}$, and by equating to zero, $\hat{b}$'s are obtained.

$$\frac{\delta e'e}{\delta \hat{b}} = -2X'Y + 2X'X\hat{b} = 0 \qquad (3.12)$$

Therefore:

$$\hat{b} = (X'X)^{-1} X'Y \qquad (3.13)$$

Production Function Estimation Problems

With regard to the above assumptions of multiple regression, our estimation could be confronted with the following problems:

(a) multicollinearity

(b) simultaneous equation bias

(c) management bias

(d) risk.

(a) Multicollinearity

One of the most important conditions for application of the least square estimation method is that the independent variables are not perfectly linearly correlated with each other, namely:

$$r_{x_i x_j} \neq 1 \tag{3.14}$$

where $r_{x_i x_j}$ is the correlation coefficient between X_i and X_j. Multicollinearity is a condition where there are linear relationships among independent variables. If the correlation coefficient between two independent variables is equal to unity, the parameters of these variables become undefined (Nie et al., 1975, p.329) or indeterminate. At the other extreme, where the independent variables are not inter-correlated with each other, i.e., where:

$$r_{x_i x_j} = 0 \tag{3.15}$$

these variables are called orthogonal and there are no problems of multicollinearity in the estimates of the coefficients.

In practice, these two extreme cases are seldom found, the question is rather one of the extent of the inter-correlation among the independent variables, a serious problem in estimating parameters.

'The effect of collinearity is uncertain. The evidence from the theoretical econometric studies (with controlled data) as well as from applied research is controversial and by no means conclusive' (Koutsoyiannis, 1977, p.236). Conflicting views have been given by different scholars on this matter. Koutsoyiannis (1977, pp.237-8) shows that according to Theil, in a model with more than two independent variables, even small intercorrelations between variables lead to non-significance owing to the increase in standard errors. On the other hand, Frisch showed that standard errors are not always large when multicollinearity is present. Klein argues that collinearity is harmful if the simple correlation between any two independent variables is greater than or equal to the multiple correlation of the relationships:

$$r^2_{x_i x_j} \geq R^2_{y, x_1 x_2, \ldots, x_k} \qquad (3.16)$$

Heady and Dillon (1961, p.136), Yotopoulos and Nugent (1976, p.69) conclude that if the correlation between a pair of independent variables is greater than 0.8 the problem of multicollinearity may arise.

A combination of the above criteria, as suggested by Koutsoyiannis, is used in this study to help the detection of multicollinearity. The dependent variable is regressed on each one of the independent variables separately. Thus we obtain all elementary regressions, and we examine these results on the basis of <u>a priori</u> and statistical criteria. The elementary regression which appears to give the most plausible results was chosen for inclusion in the production function. Additional variables are then inserted step by step and their effects are examined on the individual coefficients, on their standard errors, and on the overall R^2. A new variable is classified as useful, superfluous or detrimental, as follows:

"(1) If the new variable improves R^2 without rendering the individual coefficients unacceptable ('wrong') on <u>a priori</u> considerations, the variable is considered useful and is retained as an explanatory variable.

(2) If the new variable does not improve R^2 and does not affect to any considerable extent the values of the individual coefficients, it is considered as superfluous and is rejected (i.e. is not included among the explanatory variables).

(3) If the new variable affects considerably the signs or the values of the coefficients, it is considered as detrimental. If the individual coefficients are affected in such a way as to become unacceptable on theoretical, a priori, considerations, then we may say that this is a warning that multicollinearity is a serious problem". (Koutsoyiannis, 1977, p.239).

This procedure was carried out by using a computer regression package program, i.e., the SPSS (Statistical Package for the Social Sciences) program.[19]

(b) Simultaneous Equation Bias

As noted above, in estimating parameters of a production function, disturbance terms should be included.

$$Y = aX_1^{b_1}X_2^{b_2}u \qquad (3.17)$$

where Y is output, X_1 and X_2 are factors of production. And a, b_1 and b_2 are parameters to be estimated, and u is the disturbance term.

The condition for profit maximization is that the marginal productivities of inputs should be equal to their respective prices, so that from the above equation (3.17):

$$\begin{aligned} MP_{x_1} &= b_1 \frac{Y}{X_1} u = P_1 \\ MP_{x_2} &= b_2 \frac{Y}{X_2} u = P_2 \end{aligned} \qquad (3.18)$$

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[19] The detail of this package program can be found in: Nie, Norman H. et al. (1975), Statistical Package for the Social Sciences, SPSS, second edition, McGraw Hill Book Company, New York, pp.320-94.

where MP_{x_1} and MP_{x_2} are marginal productivities of inputs X_1 and X_2 respectively; P_1 and P_2 are ratios of input-output prices of inputs X_1 and X_2 respectively.
From equation (3.18) we can write:

$$\begin{aligned} X_1 &= (b_1/P_1)(Y\ u) = (b_1/P_1)(aX_1^{b_1}X_2^{b_2}u) \\ X_2 &= (b_2/P_2)(Y\ u) = (b_2/P_2)(aX_1^{b_1}X_2^{b_2}u) \end{aligned} \tag{3.19}$$

Equations 3.19 show that X_1 and X_2 are not only dependent on their respective input-output price ratio and other inputs, but also on the disturbance terms, so that we cannot get unbiased estimators of the equation 3.17 above.[20] This problem can be solved by making an assumption that output never occurs as anticipated, so that X_1 and X_2 become random variables (Hoch 1962). This means that where farmers make their decisions they consider their anticipated output, but in fact the actual output seldom equals their anticipations. Thus, anticipated output is

$$aX_1^{b_1}X_2^{b_2}$$

instead of

$$aX_1^{b_1}X_2^{b_2}u$$

and the marginal productivities of the inputs to achieve maximum profit become:

$$\begin{aligned} MP_1 &= (b_1/X_1)(aX_1^{b_1}X_2^{b_2}) = P_1 \\ MP_2 &= (b_2/X_2)(aX_1^{b_1}X_2^{b_2}) = P_2 \end{aligned} \tag{3.20}$$

With the above assumption, simultaneous equation bias is avoided, since the disturbance term u does not enter into this equation.

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[20] We have already noted that the independent variables are assumed to be independent of the disturbance terms. This assumption seems to be violated in this situation (Yotopoulos and Nugent 1976, pp.84-85).

(c) Management Bias

Management is recognized as an important factor of production. It is however difficult to quantify, and despite numerous efforts, few studies have included a management input (Ahmad 1972, p.73). Its exclusion will bias estimates if the variable has an effect on the magnitudes of the parameter estimates. A positive correlation will give an over-estimated coefficient, and if negatively correlated, the coefficient will be under-estimated (Griliches 1957).

Three different approaches to the problem were identified by Heady and Dillon (1961, p.224):

a. attempting to restrict the farm sample to a group relatively homogeneous with respect to management, e.g., to good or poor managers on some subjective rating scale;

b. attempting to select a farm sample that minimizes correlation between management and other factors;

c. introducing some measure of management into production function analysis.

With regard to a., observations can be classified into different groups of management capability based on subjective reasoning, and production functions can be estimated according to these groups (Massell 1967a). The weakness of this approach is the subjective factor in determining the managerial skill of the sample farmers.

The second approach seems impossible as management affects all farm activities, directly or indirectly or both. It can however be attempted by constructing an index of management, either as a weighted score based on selected criteria (Taib 1976), or as a single proxy variable, such as education of the farmer (Griliches 1957, 1964), or education of the farm family (Yotopoulos and Nugent 1976). Massell (1967) used a multiplicative index of farm efficiency or management ability as a management variable. To make estimates consistent, Mundlak (1961) and Hoch (1962) suggested pooling time series and cross section data and using analysis of covariance.

These attempts have three major disadvantages: (i) they may not adequately distinguish between knowledge and entrepreneurial logic, (ii) the management index may reflect managerial potential rather than actual management input over the period studied, and (iii) such indexes suffer from the fact that they incorporate subjective elements (Heady and Dillon 1961, p.225).

In the third approach, the differences between estimated and observed production are used as the management variable (Heady 1946). The problem there, however, is that the residuals may not be related to management but to other factors of production (Heady and Dillon 1961, p.225), or, there may be serious multicollinearity between the management variable and other factors of production which may also bias estimates. It has been argued that since management changes output indirectly, through other factors, so the relationship between management and output should be examined indirectly too (Johnson 1967), but the method for this has not been clearly evolved.

Another question is whether the management variable affects the intercept or the slope of the production curves, or both (Etherington 1973). If both, we will face the problem of degrees of freedom.

Our study does not include a management variable directly in estimating the production function. Some proxy variables such as education, merantau (outmigration) experience and tenurial systems are included in the production function model, as also used by Moock (1976) for estimating the production function of maize in Kenya.

(d) Risk

Neo-classical theory of agricultural production does not include risk in analysis (e.g. Heady and Dillon 1961). Attempts have been made to blend riskless neo-classical theory with concepts of decision theory in order to show that risk generally has a significant impact on resource allocation in decision-making (e.g. Anderson, Dillon and

Hardaker 1977, Chapter Six, and Roumasset 1975). If a farmer is risk averse, risk acts as a friction on production and induces a lower level of resource use than would otherwise prevail. If a farmer prefers risk, the reverse occurs.

In agriculture, risk can broadly be divided into output and price risks. Usually, 'price risks for both inputs and outputs are ignored for two reasons: (i) price risk is generally small in comparison to yield risk; and (ii) even when there is considerable variation in rice prices, as there has been, for example, since the introduction of MRVs in 1966, the high covariance between the prices of different rice varieties, with the high elasticity of substitution on the demand side, reduces the role of price variability in choice of techniques'. (Roumasset 1975, p.53).

In this study area the price of rice and of key inputs (e.g. fertilizer, seed and pesticides) are controlled by government and are therefore not uncertain. Hence, price risk is very small and can be ignored in this analysis.

Output risks arise from input variability that is outside the farmer's control. They are stochastic with values unknown at the time of farmers' decisions about input variables that are under their control. These include, for example, climatic conditions, pest and disease damage. Climatic risk, from monsoon and other weather conditions has been minimized in the study area since the completion of the Badenah irrigation project. However, the rice crop was subject to attack by rodents, and our field observations indicated that farmers took preventive measures by draining rice farms earlier than was recommended. Variations in choice of timing of draining farms could perhaps be interpreted as indicating risk preference differentials among the farmers. Alternatively, they could reflect differences in farmers' prediction of the likelihood or timing of rat attacks. However, as will be shown in Chapter 5, this was a complex calculation as time of drainage and rodent attack had counterbalancing effects on rice yield. Our field observations indicated that risks other than from rat damage in the study area were low. In the circumstances, risk was not taken into account directly in this analysis. Special attention is, however, given in the analysis below to the questions of time of draining and rodent damage as factors in determining output.

Measurement of Technical Efficiency

There are, however, two ways in which the CD production function model (equation 3.6) can be estimated. If we wish to find the average production function, i.e. the production function for all the farmers in the sample, the parameters of the equation are estimated by the method of Ordinary Least Square (OLS) using the data of all the farmers. But when we wish to find the maximum feasible yields under farm conditions, and to measure TE of each farmer, we have to calculate a frontier production function. Many methods have been suggested for this purpose. This analysis uses the method of Timmer (1970,1971) to estimate a CD frontier production function by the method of Linear Programming (LP).

The basic concepts of the Farrell techniques were used by Timmer (1971) with a number of important differences. For instance, Farrell's assumption of a linear homogeneous production function was relaxed and a CD production function was specified. The frontier function is estimated in input-output space (in Timmer techniques) rather than input-input space (in Farrell techniques).

The general model of the Cobb-Douglas production function is

$$Y_i = A\, X_{1i}^{b_1}\, X_{2i}^{b_2} \ldots\ldots X_{ji}^{b_j}\, E_i \qquad (3.21)$$

or in logarithms (with lower case letters),

$$y_i = a + \sum_{j=1}^{m} b_j x_{ji} + e_i \qquad (3.22)$$

where Y_i = yield of farm i, X_{ji} = use of factor j by farm i, A = a constant or intercept, b_j = factor elasticities, and E_i = a random error term that contains a systematic efficiency term as well.

If all e_i in equation (3.22) are constrained to one side of the estimated production surface the resulting function is an envelope or frontier function. To make the frontier efficient, equation (3.22) should be estimated as

$$\hat{a} + \sum_{j=1}^{m} \hat{b}_j x_{ji} = \hat{y}_i \geq y_i \tag{3.23}$$

By setting all $e_i \geq 0$, equation (3.23) can be written as an equality:

$$\hat{a} + \sum_{j=1}^{m} \hat{b}_j x_{ji} - \hat{e}_i = y_i \tag{3.24}$$

The technique of estimation is then to minimize $\sum_{i=1}^{n} e_i$ subject to

$$\hat{a} + \sum_{j=1}^{m} \hat{b}_j x_{ji} \geq y_i$$

and

$$a \text{ and } b_j \geq 0$$

For a solution by linear programming, $\sum_{i=1}^{n} \hat{e}_i$ must be expressed as a linear function of a, b_j and x_{ji}. By summing the equation (3.24) over i and then solving for $\sum_{i=1}^{n} \hat{e}_i$, we get:

$$\sum_{i=1}^{n} \hat{e}_i = \sum_{i=1}^{n} \sum_{j=1}^{m} (\hat{a} + \hat{b}_j x_{ji}) - \sum_{i=1}^{n} y_i \tag{3.25}$$

For any particular data set, $(-\sum_{i=1}^{n} y_i)$ is a constant, so it can be dropped from equation (3.25) without consequences. The remainder is suitable as a linear programming objective function. For computational purpose, the arithmetic mean of the observations on the jth input ($\bar{x}_j$) is used instead of the total. Thus, our linear programming problem is to minimize:

$$a + b_1\bar{x}_1 + \dots + b_j\bar{x}_j \tag{3.26}$$

subject to:

$$\begin{array}{l} a + b_1 X_{11} + \dots\dots\dots + b_m x_{m1} \geq y_1 \\ \vdots \qquad\qquad\qquad\qquad \vdots \qquad \vdots \\ a + b_1 x_{1n} + \dots\dots\dots + b_m x_{mn} \geq y_n \end{array} \tag{3.27}$$

and

$$a \geq 0; \quad b_j \geq 0 \tag{3.28}$$

This can be solved with any linear programming package.

In order to avoid the problem of spurious errors in the extreme observations, Timmer suggests fitting a probabilistic frontier, in which equation (3.23) must be translated into a probability statement, i.e.,

$$\Pr\left[(a + \sum_{j=1}^{m} b_j x_{ji}) \geq y_i\right] > P \tag{3.29}$$

where P is an externally specified probability (e.g. 98 per cent), for which the inequality is to hold (Aigner and Chu 1968). The value of P will be obtained by deleting a percentage of observations on the assumption that they were affected by statistical errors, e.g. by deleting 3 per cent of observations which are most efficient (Timmer 1971).

Technical efficiency of each sample farmer was measured with the probabilistic frontier production function. The ratio of the actual yield of farm i (Y_i) to the estimated yield of farm i ($\hat{Y}_i$) from the frontier function estimates, gives the technical efficiency rating of farmer i. Or, in equation form,

$$TER_i = Y_i/\hat{Y}_i \tag{3.30}$$

where TER_i is the technical efficiency rating of farm i. The degree of technical efficiency between groups of the farmers was calculated by using formula,

$$TER_g = \frac{1}{m} \sum_{j=1}^{m} (Y_j/\hat{Y}_j) \tag{3.31}$$

TER_g is the average technical efficiency rating of farms in group g; m is the number of farms in that group; Y_j and $\hat{Y}_j$ are the actual and the estimated yields of farm j of group g, where j=1, 2, ..., m.

Measurement of Yield Gap Factors

There are two important factors that cause variations in yields of rice farms:

a. Differences in the amount of inputs used per hectare; and/or

b. Differentials in the technical efficiency among the rice farmers, i.e. differences in the output farmers would get from the same inputs.

These differentials are quite distinct aspects of agricultural efficiency; they vary considerably among farmers and sometimes in different directions. Therefore, it is useful to find a quantitative measure of each.

Suppose Y_a and Y_b are the production functions of the A and B groups of rice farmers respectively; and let x_a and x_b be the actual average inputs applied by these two groups. Then $Y_a(x_a)$ is the average yield that the A group would get using its input levels, and $Y_a(x_b)$ is the average yield that the A group would have got using the input levels of the B group. Similarly, $Y_b(x_b)$ is the average yield that the B group would get with its input levels, and $Y_b(x_a)$ is the average yield that the B group would have got using the input levels of the A group. All of these average yields can be calculated from the production function estimates of the two groups, Y_a and Y_b. Then, a convenient decomposition of the difference in average yields into those due to the two factors is given by the following formula:

$$Y_a(x_a) - Y_b(x_b) =$$

$$\tfrac{1}{2}\left[Y_a(x_a) - Y_b(x_a) + Y_a(x_b) - Y_b(x_b)\right] \quad \text{due to differences in technical efficiency}$$

$$+ \tfrac{1}{2}\left[Y_a(x_a) - Y_a(x_b) + Y_b(x_a) - Y_b(x_b)\right] \quad \text{due to differences in inputs applied levels} \tag{3.32}$$

This decomposition can be applied to any two groups with different production functions. Thus, the values needed in the equation (3.32) can be calculated only if the production functions of each group have been identified, and the levels of inputs applied by each group are given.

If the production functions of each group are unknown, but the average technical efficiency of each group can be calculated with the equation (3.31), there will be another way to calculate the values needed in the equation (3.32). The values of $Y_a(x_a)$ and $Y_b(x_b)$ can be taken from the data of actual average yields of the two groups of farmers. The values of $Y_a(x_b)$ and $Y_b(x_a)$ can be calculated by the following formula.

$$\begin{aligned} Y_a(x_b) &= Y_b(x_b)\,\frac{TER_a}{TER_b} \\ Y_b(x_a) &= Y_a(x_a)\,\frac{TER_b}{TER_a} \end{aligned} \tag{3.33}$$

where TER_a and TER_b are the average technical efficiency ratings of the A and B groups respectively, calculated by the equation (3.31).

This alternative approach was applied in this study to the differences of average yields between farmers in the head, body, and tail sections; and also to those between the owner, fixed-rent and share-cropping operators groups of the sample farmers.

Measurement of Allocative Efficiency

The condition for profit maximization, as discussed above, is that the marginal value product of an input is equal to the unit price of the input. In the CD production function case, the marginal product of an input is,

$$MP_j = b_j\left(\frac{Y}{X_j}\right) \tag{3.34}$$

where:

MP_j = the marginal product of input j.

b_j = the production elasticity of input j.

Y/X_j = the average product of input j.

Thus, the condition for maximum profit is,

$$b_j(Y/X_j)P_y = P_j$$

or (3.35)

$$b_j(Y/X_j)(P_y/P_j) = 1$$

where P_y and P_j are prices of output and input j respectively.

The left hand side of equation (3.35) is the allocative or price efficiency index of the rice farms for input j, viz.,

$$AEI_j = b_j(Y/X_j)(P_y/P_j) \tag{3.36}$$

where AEI_j is the allocative efficiency index of the farmers for input j.

The AEI_j of each group of sample farms was estimated by substituting the geometric mean values of the output and inputs and the arithmetic mean values of the prices of inputs and output. Thus, the AEI_j for a group g for input j is,

$$AEI_{jg} = b_{jg}(\bar{Y}_g/\bar{X}_{jg})(\bar{P}_{yg}/\bar{P}_{jg}) \qquad (3.37)$$

where g stands for the farmer groups.

A group of farmers is said to be price efficient for input j if the AEI_{jg} is not significantly different from unity. If the AEI_{jg} is greater than one, it means that the level of the input j applied is below the level for maximum profit. Conversely, if it is less than unity, it indicates that the level of the input applied exceeds the level for profit maximization.

To test whether AEI_{jg} significantly differs from unity or not, the variance of AEI_{jg} is computed by the following formula,

$$\text{Var}\,(AEI_{jg}) = (AEI_{jg}/b_{jg})^2 \text{ var } (b_{jg}) \qquad (3.38)$$

where var (b_{jg}) can be calculated from the Standard error of b_j.[21]

Measurement of Economic Rationality

Farmer efficiency in allocating inputs to maximize profits can be tested by assessing their economic rationality. For this study, the technique of Wise and Yotopoulos, as condensed in Yotopoulos and Nugent (1976, pp.88-93), was used.

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[21] Yotopoulos, Pan A. (1967), "Allocative Efficiency in Economic Development", Research Monograph Series, No.18, Center of Planning and Economic Research, Athens, p.194. It is assumed that in the equation (3.38) that the yield is held constant. This is not true in our case because it is derived on the basis of b_{jg}, which is only an estimate of the true population elasticity. Thus, it will vary over alternative samples. However, since it is estimated with the inputs held at their geometric mean levels, the equation (3.38) causes only a negligible bias in the variance estimates (Heady and Dillon, 1961, p.231).

This is a model comprising a Cobb-Douglas production function with two factors of production (capital and labour), constant elasticity supply functions for inputs, and constant elasticity demand functions for output.

$$Y_i = A_i K_i^{\alpha} L_i^{\beta} \tag{3.39}$$

$$K_i = kP_{ki}^{\eta} \quad \text{or} \quad P_{ki} = (K_i/k)^{1/\eta} \tag{3.40}$$

$$L_i = lP_{li}^{\varepsilon} \quad \text{or} \quad P_{li} = (L_i/l)^{1/\varepsilon} \tag{3.41}$$

$$Y_i = qP_{yi}^{-\lambda} \quad \text{or} \quad P_{yi} = (Y_i/q)^{-1/\lambda} \tag{3.42}$$

where Y_i, K_i and L_i are physical output, capital and labour, respectively, for farm i; P_{ki}, P_{li} and P_{yi} are the prices of capital, labour and output, respectively, for farm i; A_i is the technical efficiency parameter which varies from farm to farm; α and β are the elasticity coefficients of production and are assumed constant across farms; η and ε are the price elasticities of supply for capital and labour, respectively; and λ is the demand elasticity for output, and these elasticities are presumed constant across the farms.

Total revenue of farm i from output Y is

$$R_i = P_{yi}Y_i = (Y_i/q)^{-1/\lambda} Y_i = q^{1/\lambda} Y_i^{(1-1/\lambda)} \tag{3.43}$$

By assuming that the market is cleared (demand = supply), we can substitute equation (3.39) into equation (3.43), and total revenue of farm i becomes

$$R_i = q^{1/\lambda}(A_i K_i^{\alpha} L_i^{\beta})^{(1-1/\lambda)}$$

and by supposing

$$A_{oi} = q^{1/\lambda} A_i^{(1-1/\lambda)}$$

we can write total revenue as

$$R_i = A_{oi}K_i^{\alpha(1-1/\lambda)}L_i^{\beta(1-1/\lambda)} \tag{3.44}$$

where A_{oi} is the technical efficiency parameter that represents exogenously determined inter-farm variations in the volume and quality of the fixed factors of production (e.g. farm size and management).

The total cost of capital and labour can be drawn from equation (3.40) and (3.41), respectively, i.e.

$$C_{ki} = P_{ki}K_i = (1/k)^{1/\eta}K_i^{(1 + 1/\eta)} \tag{3.45}$$

$$C_{li} = P_{li}L_i = (1/l)^{1/\varepsilon}L_i^{(1 + 1/\varepsilon)} \tag{3.46}$$

The total profit of farm i under the assumption of constant returns to scale is

$$\Pi_i = R_i - C_{ki} - C_{li} \tag{3.47}$$

so by substituting equations (3.44) to (3.46) into equation (3.47), the total profit of farm i becomes

$$\Pi_i = A_{oi}K_i^{\alpha(1-1/\lambda)}L_i^{\beta(1-1/\lambda)} - (1/k)^{1/\eta}K_i^{(1 + 1/\eta)} - (1/l)^{1/\varepsilon}L_i^{(1 + 1/\varepsilon)} \tag{3.48}$$

It has been assumed that farmers have knowledge of their production and return functions. The hypothesis of economic rationality is that farms maximize profits if

$$\frac{\delta\Pi_i}{\delta K_i} = 0 \quad \text{and} \quad \frac{\delta\Pi_i}{\delta L_i} = 0 \tag{3.49}$$

The profit maximization condition for capital inputs (whether or not labour inputs are at their correct levels) becomes

$$\frac{\delta\Pi_i}{\delta K_i} = \alpha(1 - 1/\lambda)\frac{R_i}{K_i} - (1 + 1/\eta)(1/k)^{1/\eta}K_i^{\ 1/\eta} = 0 \qquad (3.50)$$

which can be written as

$$\frac{R_i}{K_i} = \frac{(1 + 1/\eta)}{\alpha(1 - 1/\lambda)}(1/k)^{1/\eta}K_i^{\ 1/\eta} \qquad (3.51)$$

or

$$\text{Log } R_i = a + (1 + 1/\eta)\log K_i \qquad (3.52)$$

where,

$$a = \log\frac{(1 + 1/\eta)}{\alpha(1 - 1/\lambda)}(1/k)^{1/\eta}$$

With the same approach, the maximization condition for labour inputs (whether or not capital inputs are at their correct levels) is

$$\text{Log } R_i = b + (1 + 1/\varepsilon)\log L_i \qquad (3.53)$$

where,

$$b = \log\frac{(1 + 1/\varepsilon)}{\beta(1 - 1/\lambda)}(1/l)^{1/\varepsilon}$$

From equations (3.52) and (3.53), we find

$$\text{Log } K_i = \frac{(b - a)}{(1 + 1/\eta)} + \frac{(1 + 1/\varepsilon)}{(1 + 1/\eta)}\log L_i \qquad (3.54)$$

Since a and b are constants, equations (3.52), (3.53) and (3.54) represent linear relationships between log R_i and log K_i, log R_i and log L_i, and between log K_i and log L_i, respectively.

The economic interpretation of these linear relationships is that

(a) Equation (3.52) describes the maximizing behaviour of the farmer who can control the quantity of capital he employs by holding the quantity of labour constant.

(b) Equation (3.53) describes the maximizing behaviour that can control the quantity of labour use by holding the amount of capital constant.

(c) Equation (3.54) implies that the two variable factors (K and L) have been combined in such a way as to minimize the cost of achieving a specified level of revenue (R).

The model does allow for systematic variation in the profit maximizing inputs and output of the individual farm, since it is assumed that the technical efficiency term (A_i) is an exogenous variable that varies from farm to farm.

If we combine equations (3.52) and (3.53) with the production function we form a system of simultaneous equations in which log K_i, log L_i and log R_i are linear functions of A_{oi} (see Yotopoulos and Nugent, 1976, p.90).

The system of simultaneous equations is

$$\begin{aligned}\log A_{oi} + \text{constant} &= \left[(1+1/\eta) - \alpha(1-1/\lambda)\right] \log K_i - \beta(1-1/\lambda)\log L_i \\ \log A_{oi} + \text{constant} &= -\alpha(1-1/\lambda)\log K_i + \left[(1+1/\varepsilon) - \beta(1-1/\lambda)\right] \log L_i\end{aligned} \tag{3.55}$$

The solution of this system gives

$$\log K_i = \frac{g}{(1 + 1/\eta)} \log A_{oi} + \text{constant} \tag{3.56}$$

$$\log L_i = \frac{g}{(1 + 1/\varepsilon)} \log A_{oi} + \text{constant} \tag{3.57}$$

where

$$g = \frac{1}{1 - \dfrac{\alpha(1 - 1/\lambda)}{(1 + 1/\eta)} - \dfrac{\beta(1 - 1/\lambda)}{(1 + 1/\varepsilon)}}$$

And by substituting equations (3.56) and (3.57) into equations (3.52) and (3.53) respectively we get

$$\log R_i = g \log A_{oi} + \text{constant} \tag{3.58}$$

The above equation systems (3.52-3.54) and (3.56-3.58) are in terms of profit maximizing variables, so their variables are non-observable. To be observable, they should be formulated in a stochastic model that also allows for random variation. The observable equations are

$$\log K_i = X_{1i} = x_{1i} - u_{1i} \tag{3.59a}$$

$$\log L_i = X_{2i} = x_{2i} - u_{2i} \tag{3.59b}$$

$$\log R_i = X_{oi} = x_{oi} - v_i \tag{3.59c}$$

$$\log A_{oi} = Z_i \tag{3.59d}$$

where X_{1i}, X_{2i}, and X_{oi} are the systematic and non-observable variables of capital, labour, and output, respectively; x_{1i}, x_{2i} and x_{oi} are the observable actual amounts of inputs used and outputs produced (in logs), while u_{1i}, u_{2i} and v_i are stochastic deviations from profit maximizing terms of the respective variables x_{1i}, x_{2i} and x_{oi}. It is assumed in these equations that the errors are entirely due to deviations from maximizing behaviour.

Yotopoulos and Nugent then proceed to define the index of economic rationality, i.e., the proportions of the variance (in the logs) of the observed quantities of farm inputs of labour and capital which are caused by the variations in the observed systematic profit maximizing component of these inputs. Thus

$$P = \frac{\text{var } X_{1i}}{\text{var } x_{1i}} = \frac{\text{var } X_{2i}}{\text{var } x_{2i}}$$

or

$$P = \frac{\text{var } x_{1i}}{\text{var } x_{2i}} = \frac{\text{var } X_{1i}}{\text{var } X_{2i}} \qquad (3.60)$$

where P is the index of economic rationality and other notations are as above. Yotopoulos and Nugent (1976, pp.105-6) proved that the index of economic rationality (P) is the simple correlation coefficient of equation (3.54) after it is transformed into a stochastic equation. Similarly, the slope coefficients of the equations (3.52) and (3.53), after they are transformed into stochastic equations, will give estimates of the elasticities of the supply of capital (η) and of labour (ε), and are obtained by calculating the ratio of the standard deviations of the observed variables ($\hat{\sigma}_1/\hat{\sigma}_2$).

It should be noted that with regard to the error terms above (u_{1i}, u_{2i}, and v_i), it was assumed that:

(a) $E\ (u_{1i}) = E\ (u_{2i}) = 0$

(b) $\text{cov}\ (u_{1i}, Z_i) = \text{cov}\ (u_{2i}, Z_i) = 0$

(c) $\text{cov}\ (v_i, Z_i) = 0$

(d) $\text{cov}\ (u_{1i}, u_{2i}) = 0$

(e) $E\ (v_i) = 0$

Assumption (a) means that the values of the two inputs are those that maximize profit. This assumption, although common, is not necessary for the errors-in-variables model (Klein, 1953, p.285). A more general alternative assumption is that $E\ (u_{1i})$ and $E\ (u_{2i})$ are constant.

Assumption (b) means that the errors in the inputs are not correlated with the errors in the exogenous variables. This assumption is necessary for estimates of both the slope parameters and the index of economic rationality (P).

Assumption (c) is similar to assumption (b) which is used in the estimation of the slope parameters. Assumption (d) means that the errors in the capital and labour inputs are not correlated with each other. This is used for the measurement of P but it is not required for the estimation of the slope parameters. Assumption (e) is not crucial for statistical analysis of this model, so that it is permissible for E (v_i) = constant, i.e., there is a systematic bias in the efficiency parameter across farms.

By substituting definitions in equations (3.59a-3.59d), equations (3.52) to (3.54) can be written as

$$x_{oi} - v_i = a + (1 + 1/\eta)(x_{1i} - u_{1i}) \qquad (3.61a)$$

$$x_{oi} - v_i = b + (1 + 1/\varepsilon)(x_{2i} - u_{2i}) \qquad (3.61b)$$

$$x_{1i} - u_{1i} = \frac{(b - a)}{(1 + 1/\eta)} + \frac{(1 + 1/\varepsilon)}{(1 + 1/\eta)}(x_{2i} - u_{2i}) \qquad (3.61c)$$

These equations (3.61a-3.61c) are in terms of observables so they can be estimated directly.

Similarly, by employing the definitions in equations (3.59a-3.59d), equations (3.56) through (3.58) can be written as

$$x_{1i} = \frac{g}{(1 + 1/\eta)} Z_i + u_{1i} + \text{constant} = X_{1i} + u_{1i} \qquad (3.62a)$$

$$x_{2i} = \frac{g}{(1 + 1/\varepsilon)} Z_i + u_{2i} + \text{constant} = X_{2i} + u_{2i} \qquad (3.62b)$$

$$x_{oi} = gZ_i + v_i + \text{constant} = X_{oi} + v_i \qquad (3.26c)$$

And by substituting var X_{1i} and var X_{2i} from equations (3.62a-

3.62c) into equation (3.60), we can write

$$\text{var } X_{1i} = \frac{g^2}{(1 + 1/\eta)^2} \text{ var } Z_i$$

$$\text{var } X_{2i} = \frac{g^2}{(1 + 1/\varepsilon)^2} \text{ var } Z_i$$

or

$$\frac{\text{var } X_{1i}}{\text{var } X_{2i}} = \frac{\text{var } x_{1i}}{\text{var } x_{2i}} = \frac{(1 + 1/\varepsilon)^2}{(1 + 1/\eta)^2}$$

or

$$\frac{(1 + 1/\varepsilon)}{(1 + 1/\eta)} = (\text{var } x_{1i}/\text{var } x_{2i})^{\frac{1}{2}} \tag{3.63}$$

The expression in equation (3.63) is the diagonal regression coefficient relating x_{1i} and x_{2i}, and the index of economic rationality (P) is the simple correlation between x_{1i} and x_{2i} (Yotopoulos and Nugent 1976, pp.105-6).

Since the model is the errors-in-variables type, the appropriate estimates of $(1 + 1/\eta)$, $(1 + 1/\varepsilon)$, and $(1 + 1/\varepsilon)/(1 + 1/\eta)$ in equations (3.61a-3.61c) are the diagonal regression estimates, namely, by using the equation (3.64),

$$\beta_{12} = \rho_{12}(\sigma_1/\sigma_2) \tag{3.64}$$

where 1 and 2 are the dependent and the independent variables, respectively, in the least square estimation. Since the diagonal regression coefficient is $\frac{\sigma_1}{\sigma_2}$ sign ρ_{12}, it can be estimated by β_{12}/ρ_{12}. The standard errors of the coefficients are obtained by assuming var (b/r) = (var $b)/r^2$. This implies that cov (b,r) and var (r) are neglected because they have opposite signs. Thus, the standard errors of the diagonal regression coefficients are (var $b)/r^2$, and from the coefficient estimates, we can compute the elasticity of supply of capital (η) and of labour (ε).

Relative Economic Efficiency Measurements

The relative economic efficiency between two groups of farmers was measured by the profit function approach. This approach is mainly due to Yotopoulos and his colleagues.

(a) Requirements

Yotopoulos and Nugent (1976, pp.93-94) identify three minimum requirements to make the concept of economic efficiency useful: (i) farms may have differences in technical efficiency (TE); (ii) farmers may have differences in price or allocative efficiency (PE); and (iii) farms may operate at different sets of market prices.

These three requirements can be encompassed in a single concept of economic efficiency by using the profit function. Yotopoulos and Nugent show that the relationship between the production function and the profit function is as 'a set of dual transformation relations that connect the profit function and the production function' (ibid., p.96).

The most important difference between the production function and the profit function is that the production function does not consider how far the levels of inputs use depend upon their prices, which is necessary for considering price efficiency. But the profit function shows the effect both of the output obtained from given sets of input (TE) and the effect of the input prices on the way the input levels are chosen (PE).

(b) The Profit Function

Lau and Yotopoulos (1972) demonstrate how to calculate the profit function from the production function. Profit is defined as the difference between total revenue and total variable cost.

$$P = p_y F(X_j,\ Z) - \sum_{j=1}^{m} p_j X_j \tag{3.65}$$

where P is profit; p_y is price of output; $F(X_j,\ Z)$ is the production function $Y = F(X_j, Z)$; P_j is price of variable input j; X_j is the quantity of variable input j; Z is the quantity of the fixed factor of production; m is the number of variable inputs. The condition for profit maximization is,

$$P_y \frac{\delta F}{\delta X_j} = P_j$$

or

$$\frac{\delta F}{\delta X_j} = p_j/p_y = h_j \qquad (3.66)$$

where h_j is the normalized price of input j, that is the price ratio between the unit prices of variable input and output.

Similarly, when we divide profits in equation (3.65) with the price of output p_y, we get the normalized profit equation,

$$P^* = \frac{P}{P_y} = F(X_j, Z) - \sum_{j=1}^{m} h_j X_j \qquad (3.67)$$

where P* is the normalized profit.

From equation (3.66), the optimal quantities of variable inputs can be calculated, denoted by X_j^*, which is a function of the normalized prices of the variable inputs h_j, and fixed factors Z.

$$X_j^* = f_j(h, Z) \qquad (3.68)$$

where h and Z are the vectors of normalized input prices and quantities of fixed inputs respectively.

By substituting equation (3.68) into equation (3.67), we can write the normalized profit function as

$$P^* = G(h_j, Z) \qquad (3.69)$$

The normalized profit function is also called the UOP (Unit Output

Price) profit function (Yotopoulos and Lau (1973).

In terms of the UOP profit function above, the demand function for a variable input that was given in equation (3.68) can be written as,

$$X_j^* = \frac{\delta P^*(h,\ Z)}{\delta h_j} \tag{3.70}$$

By substituting equation (3.70) into equation (3.67), the output supply function is obtained,

$$Y^* = P(h,\ Z) - \sum_{j=1}^{m} \frac{\delta P(h,\ Z)}{\delta h_j} h_j \tag{3.71}$$

where Y^* = output of maximum profit, and other notations are as before.

(c) Measurements

The profit function above does not consider possible differences in technical efficiency and price efficiency between groups of farms. To distinguish TE and PE, Lau and Yotopoulos (1973) suppose there are two groups of farms with production functions as;

$$Y^1 = A^1F(X^1,\ Z^1);\ Y^2 = A^2F(X^2,\ Z^2) \tag{3.72}$$

where subscripts identify the groups of farms. The conditions for profit maximization are,

$$\begin{aligned} \frac{\delta A^1F(X^1,\ Z^1)}{\delta X_j^1} &= k_j^1 h_j^1 \\ \frac{\delta A^2F(X^2,\ Z^2)}{\delta X_j^2} &= k_j^2 h_j^2 \end{aligned} \tag{3.73}$$

$$k_j^1 \geq 0; \quad k_j^2 \geq 0 \quad j=1,\ 2,\ \ldots.,\ m$$

where A^1 and A^2 are technical efficiency parameters for groups 1 and 2 respectively; k_j^1 and k_j^2 are price efficiency parameters of groups 1 and 2 for input X_j respectively. The right hand side of equation (3.73) is interpreted as the effective prices facing the two groups of farms. These effective prices are introduced into the profit function. Thus the profit functions of the two groups are,

$$P_b^1 = A^1 G^*\left(\frac{k_1^1 h_1^1}{A^1}, \ldots\ldots, \frac{k_m^1 h_m^1}{A^1}; Z_1^1, \ldots\ldots, Z_n^1\right)$$

$$P_b^2 = A^2 G^*\left(\frac{k_1^2 h_1^2}{A^2}, \ldots\ldots, \frac{k_m^2 h_m^2}{A^2}; Z_1^2, \ldots\ldots, Z_n^2\right) \qquad (3.74)$$

This profit function is called the behavioural normalized profit function (P_b) because it represents profit maximization subject to imperfect profit maximization because of the effective prices (Yotopoulos and Nugent 1976, p.98).

Partially differentiating equation (3.74) with respect to the effective prices $k_j^i h_m^i$ (i = 1, 2, the two groups of farms), the demand function for variable inputs is,

$$X_j^i = -A^i \frac{\delta G^*\left(\frac{k^i h^i}{A^i}, Z^i\right)}{\delta k_j^i h_j^i}$$

$$= \frac{-A^i}{k_j^i} \frac{\delta G^*\left(\frac{k^i h^i}{A^i}, Z^i\right)}{\delta h_j^i} \qquad (3.75)$$

where i = 1, 2 group of farms; j = 1, ..., m variable inputs. And the supply function of the output is,

$$Y^i = A^i G^* \left(\frac{k^i h^i}{A^i}, Z^i\right) - A^i \sum_{j=1}^{m} k_j^i h_j^i \frac{\delta G^* \left(\frac{k^i h^i}{A^i}, Z^i\right)}{\delta k_j^i h_j^i}$$

or,

$$Y^i = A^i G^* \left(\frac{k^i h^i}{A^i}, Z^i\right) - A^i \sum_{j=1}^{m} h_j^i \frac{\delta G^* \left(\frac{k^i h^i}{A^i}, Z^i\right)}{\delta h_j^i} \tag{3.76}$$

where $i = 1, 2$ group of farms; $j = 1, \ldots, m$ variable inputs. Equations (3.75) and (3.76) are corresponding to equations (3.70) and (3.71) respectively.

Solving equation (3.71) for P (profit) and substituting from equations (3.75) and (3.76), the actual profit function is obtained as,

$$P_a^i = Y^i - \sum_{j=1}^{m} h_j^i X_j^i$$

$$= A^i G^* \left(\frac{k^i h^i}{A^i}, Z^i\right) + A^i \sum_{j=1}^{m} \frac{(1 - k_j^i)\, h_j^i}{k_j^i} \frac{\delta G^* \left(\frac{k^i h^i}{A^i}, Z^i\right)}{\delta h_j^i} \tag{3.77}$$

where $i = 1, 2$ group of farms.

In equation (3.77), A^i and k^i are group specific variables, and h_j and Z_j are farm specific variables. When the observable variable h_j and Z_j are controlled, the difference between the actual profit functions of the two groups is limited to the extent that $k^1 \neq k^2$ or $A^1 \neq A^2$. Therefore, the equal relative economic efficiency between the two groups can be tested with the null hypothesis, by comparing the actual UOP profit functions of the two groups when appropriate forms are specified for G*. This approach was used in the present study by applying the Cobb-Douglas profit function.

(d) The Cobb-Douglas Profit Function

Suppose a Cobb-Douglas production function is given as,

$$Y = A\prod_{j=1}^{m} X_j^{b_j} \prod_{j=1}^{n} Z_j^{c_j} \tag{3.78}$$

where the sum of the coefficients, b_j, is restricted to less than one, since constant or increasing returns in the variable inputs are inconsistent with profit maximization (Yotopoulos and Nugent, 1976, p.99).

The normalized restricted or UOP profit function is given as,

$$P^* = A^{(1-w)^{-1}} (1-w) \left[\prod_{j=1}^{m} (h_j/b_j)^{-b_j(1-w)^{-1}} \right] \left[\prod_{j=1}^{n} Z_j^{c_j(1-w)^{-1}} \right] \tag{3.79}$$

where $w = \sum_{j=1}^{m} b_j < 1$ and h_j = normalized price of input j.

By direct computation, the actual UOP profit function for the Cobb-Douglas production function for farm i, with efficiency parameters A^i and k^i is,

$$P_a^i = A^{i(1-w)^{-1}} \left[1 - \sum_{j=1}^{m} b_j/k_j \right] \left[\prod_{j=1}^{m} (k_j^i)^{-b_j(1-w)^{-1}} \right]$$

$$\left[\prod_{j=1}^{m} b_j^{b_j(1-w)^{-1}} \right] \left[\prod_{j=1}^{m} (h_j^i)^{-b_j(1-w)^{-1}} \right]$$

$$\left[\prod_{j=1}^{n} (Z_j^i)^{c_j(1-w)^{-1}} \right] \qquad i = 1,\ 2 \text{ group of farms.} \qquad (3.80)$$

Suppose,

$$A_*^i = A^{i(1-w)^{-1}} \left[1 - \sum_{j=1}^{m} b_j/k_j \right] \left[\prod_{j=1}^{m} (k_j^i)^{-b_j(1-w)^{-1}} \right]$$

$$\left[\prod_{j=1}^{m} b_j^{b_j(1-w)^{-1}} \right] \qquad (3.81)$$

and the equation (3.80) can be written as,

$$P_a^i = (A_*^i) \left[\prod_{j=1}^{m} (h_j^i)^{-b_j(1-w)^{-1}} \right] \left[\prod_{j=1}^{n} (Z_j^i)^{c_j(1-w)^{-1}} \right] \qquad (3.82)$$

By writing A_*^1 and A_*^2 for group 1 and 2 respectively, and taking the ratio of A_*^2 to A_*^1, we find

$$\frac{A_*^2}{A_*^1} = (A^2/A^1)^{(1-w)^{-1}} \frac{\left(1 - \sum_{j=1}^{m} b_j/k_j^2 \right)}{\left(1 - \sum_{j=1}^{m} b_j/k_j^1 \right)}$$

$$\left(\prod_{j=1}^{m} (k_j^2/k_j^1)^{-b_j(1-w)^{-1}} \right) \qquad (3.83)$$

Thus, the actual UOP profit function for each group is,

$$P_a^1 = A_*^1 \left[\prod_{j=1}^{m} (h_j^1)^{-b_j(1-w)^{-1}} \right] \left[\prod_{j=1}^{n} (Z_j^1)^{c_j(1-w)^{-1}} \right] \quad (3.84)$$

$$P_a^2 = A_*^1 \, (A_*^2/A_*^1) \left[\prod_{j=1}^{m} (h_j^2)^{-b_j(1-w)^{-1}} \right] \left[\prod_{j=1}^{n} (Z_j^2)^{c_j(1-w)^{-1}} \right] \quad (3.85)$$

Suppose further,

$$b_j^* = -b_j(1-w)^{-1} \qquad \text{and} \qquad c_j^* = c_j(1-w)^{-1} \quad (3.86)$$

and taking natural logarithms of equations (3.84) and (3.85), we find,

$$\ln P_a^1 = \ln A_*^1 + \sum_{j=1}^{m} b_j^* \ln h_j^1 + \sum_{j=1}^{n} c_j^* \ln Z_j^1 \quad (3.87)$$

$$\ln P_a^2 = \ln A_*^1 + \ln (A_*^2/A_*^1) + \sum_{j=1}^{m} b_j^* \ln h_j^2$$

$$+ \sum_{j=1}^{n} c_j^* \ln Z_j^2 \quad (3.88)$$

Yotopoulos and Nugent (1976, p.100) note that if $A^1 = A^2$ and $k^1 = k^2$, then $A_*^1 = A_*^2$, and thus the two profit functions P_a^1 and P_a^2 should be identical, which implies that $\ln(A_*^2/A_*^1) = 0$. Therefore, the relative economic efficiency between the two groups can be tested by utilizing a farm dummy variable in the logarithmic UOP profit function and examining whether its coefficient is equal to zero or not.

(e) <u>Empirical Profit Function</u>

Based on our production function (equation 3.6) above, the estimating UOP profit function for the present study is,

$$\ln P = \ln A^* + \sum_{j=1}^{7} a_j^* D_j + b_1^* \ln W_L + b_2^* \ln N_p + b_3^* \ln C_p + b_4^* \ln F \qquad (3.89)$$

where:

P = the UOP profit (Rp)

W_L = normalized wage for hired labour (manday) and is calculated by dividing the total wage paid to hired labour by the total number of hired labour and then dividing this ratio by the unit price of paddy.

N_p = normalized price of nitrogen and is computed by dividing the total expenditure on nitrogenous fertilizer by the total amount of nitrogen used (in kg N) and normalizing the ratio by UOP.

C_p = price of other variable costs and is worked out by dividing the total expenditure on other variable inputs by the total amount of other variable inputs (in kg/litre) and normalizing the ratio by UOP.

F = farm size as a fixed factor (in Ha).

D_1 = 1 for the body section, and zero otherwise.

D_2 = 1 for the tail section, and zero otherwise.

D_3 = 1 for the owner operator, and zero otherwise.

D_4 = 1 for the fixed-rent operator, and zero otherwise.

D_5 = 1 for the IRV, and zero otherwise.

D_6 = 1 for the NIV, and zero otherwise.

D_7 = 1 for farms that receive water directly from irrigation channels, and zero otherwise.

CHAPTER 4

IRRIGATION: IRRIGATION EFFICIENCY AND MEASUREMENT

Types of Irrigation

In Indonesia, irrigation water is obtained mostly by diversion methods from rivers, with dams or weirs or other regulatory means, and is then channelled to crops, especially to rice. There are three types of irrigation systems in Indonesia: (1) technical, (2) semi-technical, and (3) non-technical or simple irrigation systems.

A technical irrigation system comprises a weir with full water measurement and control facilities and a distribution system of primary and secondary canals. The construction and maintenance of the system, to the end of the secondary canals, is the responsibility of the Public Works Department, while the system of tertiary channels to rice fields is the responsibility of the rural community and local government.[1]

A semi-technical irrigation system has a weir and gates at turnouts to control the flow of water, but has no measuring devices. Only headworks are constructed by the national or provincial governments and the construction of all canals is carried out by the rural community and local government.

A non-technical or simple irrigation system refers to all other types of irrigation systems and includes the traditional techniques of irrigation. All such works and maintenance are financed by the rural community and local government on a 'gotong royong' or mutual

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[1] In Repelita III, 1979-83, the Indonesian government plans to finance the construction of tertiary channels. Priority will be given to rice producing areas which already have irrigation systems, but which lack tertiary channels.

help basis.[2]

The above classification is based on the technology of headworks construction, but as mentioned in Chapter 2, these three types of irrigation do not necessarily denote the quality of irrigation. We cannot, for example, generally assume that technical irrigation is the best, and that the semi-technical irrigation is better than the simple irrigation. There are, however, size differences. A technical irrigation system covers the largest area of some thousands of hectares, and a simple irrigation system covers only a small area.

The Asian Productivity Organization (APO) classified irrigation differently, using the criterion of the condition or situation of the terminal unit of the irrigation system. With this method, irrigated paddy fields may be divided into three classes according to the stage of development of irrigation and drainage facilities. First class (Class A) paddy fields have separate ditches for irrigation and drainage, which enable delivery and withdrawal of water to and from every plot. Second class (Class B) paddy fields do not have special drainage ditches, and plots are irrigated and drained through the same field channel. Third class (Class C) paddy fields depend on plot-to-plot irrigation (APO, 1977, p.159). Most irrigation in Indonesia, and in this study area, is transitional from Class C to B. The APO reported that the Republic of China (Taiwan) is the only Asian country in which virtually all paddy fields belong to Class A. In Japan they belong to Class A or B, while in other countries (Indonesia, Pakistan, the Philippines and Thailand) Class C fields predominate.

In 1972/73, the average paddy yield per hectare in APO survey areas was highest in Japan, followed by the Republic of China, Indonesia, Thailand, the Philippines and Pakistan (APO, 1977,

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2 These definitions are adopted from FAO (1972, p.25).

p.164).[3] This strongly suggests that, ceteris paribus, the average yields per hectare of Class A and B fields are higher than those of Class C.

Most rice fields in Indonesia are still Class C because of lack of farm ditch networks. In some, the field channel density is quite high but because the channels are unevenly distributed, most of them remain dependent upon plot-to-plot irrigation.

Irrigation and Development Stages of Rice Technology

As mentioned in Chapter 1, the importance of irrigation in the Green Revolution has been stressed specifically by many writers. However the role or importance, and the existing problems, of irrigation still need thorough study.

On the question of the importance of irrigation for rice cultivation, two interesting models have been proposed. The first, the Takase Model was introduced by Takase and Kano (1969). The second, introduced by Ishikawa, is called the Ishikawa Model. Both models show a correlation between yield and rice production technology throughout all stages of rice technology development, and within rice production technology, irrigation plays a key role.[4]

The Takase Model

The Takase model shows four stages in the development of rice production technology (Figure 4.1). In stage I, water is not controlled; in stage II it is controlled through irrigation; in stage III modern inputs are applied; and in stage IV diversification and mechanization is adopted.

The model implies that water control at farm level determines

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[3] In 1975, Japan still showed the highest yield amongst some Asian and Pacific countries, but the Republic of China (Taiwan) was below Indonesia (see Table 1.4).

[4] The discussion of these two models is based particularly on APO (1977).

the level of rice cultivation technology. In stage I where irrigation is not known or available, the technology of rice production ranges from primitive (e.g. shifting cultivation) to simple (e.g. sedentary rainfed sawah or flooded field). In this stage, rice cropping intensity is lowest with a maximum of only one crop a year in the rainy season. The average yield is also lowest, at less than one metric ton of paddy per hectare (Figure 4.1). Water is not controllable and modern inputs (MRV, chemical fertilizer and pesticides) are not used.

In stage II, irrigation is known and available, and water for rice production is controlled. In this stage, cropping intensity can be increased to two crops a year, and the average yield, though modern inputs are still not used, is substantially higher, at between 1.0 and 2.5 mt paddy per hectare. Most Asian countries are in this stage (Figure 4.1).[5]

In stage III, the adoption of modern inputs commences. Notably and correctly, modern inputs are ideally introduced when sufficient controlled water is available, since modern rice varieties need high levels of fertilizer and need more water than traditional rice varieties to realize their high yield potential. In this stage, average yields may reach between 2.5 and 3.5 mt paddy per hectare, and by adopting early maturing varieties, cropping intensity can be increased with two crop seasons for paddy and one for a third crop.

Stage IV of the model involves diversification and mechanization, as has occurred in Japan, Korea and Taiwan, with high paddy yields (Figure 4.1). Why is farm mechanization and diversification associated with high yields? From a technical viewpoint, mechanization alone cannot affect yields. The relationship between mechanization and high yields is a function of intensive management practices (e.g. judicious application of fertilizer, pesticides, weeding, etc.)

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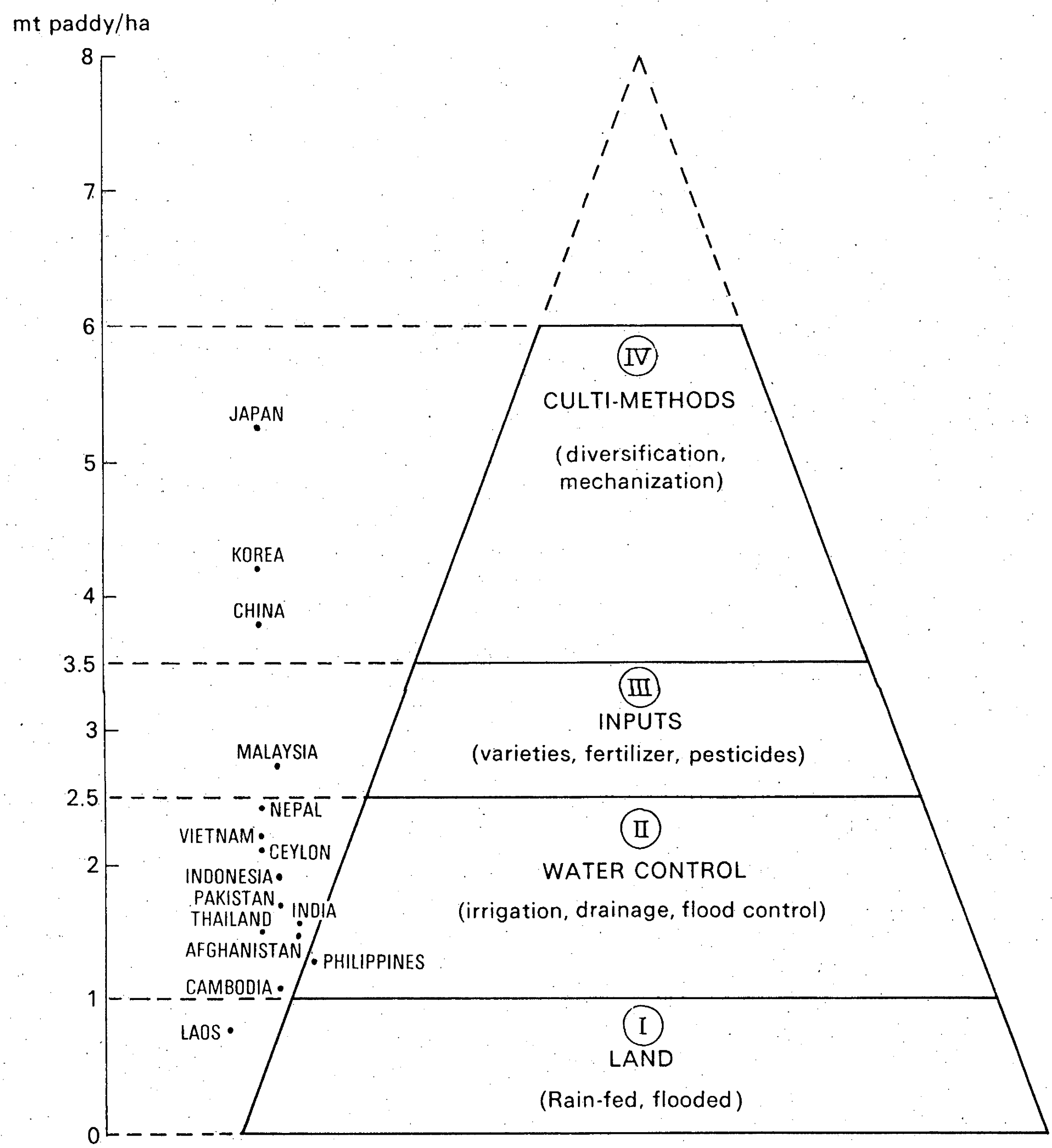
[5] Data in Fig. 4.1 refer to the 1960s. In the 1970s, some of the countries (e.g. Indonesia, the Philippines, India, Pakistan) moved from stage II to stage III.



<u>Figure 4.1.</u> Takase model for development stages of rice production technology.

<u>Source</u>: APO (1977, p.31), and see also K. Takase and T. Kano, '<u>Development Strategy of Irrigation and Drainage</u>', Asian Development Bank, Asian Agricultural Survey (1969).

in addition to land levelling and improvement of irrigation and drainage canals, all of which are necessary for farm mechanization and crop diversification (Kanazawa, 1977). While mechanization will not have a direct yield effect, it may influence yields indirectly. Most importantly it reduces the time needed for land preparation, harvesting, weeding, etc., so cropping intensity can be raised.

Ishikawa Model

The relationship between irrigation and rice production technology was described by Ishikawa,[6] using a production function approach (Figure 4.2)

Ishikawa distinguishes three stages in the development of rice production technology, namely:

Stage I : Flood dependent irrigation and/or rainfed.

Stage II : Irrigation based on flood control and aimed at supplementing rainfall, and

Stage III: Intensive cultivation based on irrigation and use of improved varieties and heavy application of fertilizer.

Ishikawa sets the output of rice (O) as a function of inputs (L = land, N = labour, IR = irrigation, FER = fertilizer, and E = other factors), or

$$O = f\ (L, N, IR, FER, E) \qquad (4.1)$$

The f (I_i), $f(II_i)$ and $f(III_i)$ curves in Figure 4.2 are the production functions for the three stages of rice cultivation technology in which all inputs except fertilizer (FER) are kept constant, while f(I), f(II) and f(III) are their aggregations. The differences among aggregated production functions come from

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6 The discussion of the Ishikawa model draws heavily on a paper by Suzuki (in APO, 1977, pp.97-112).

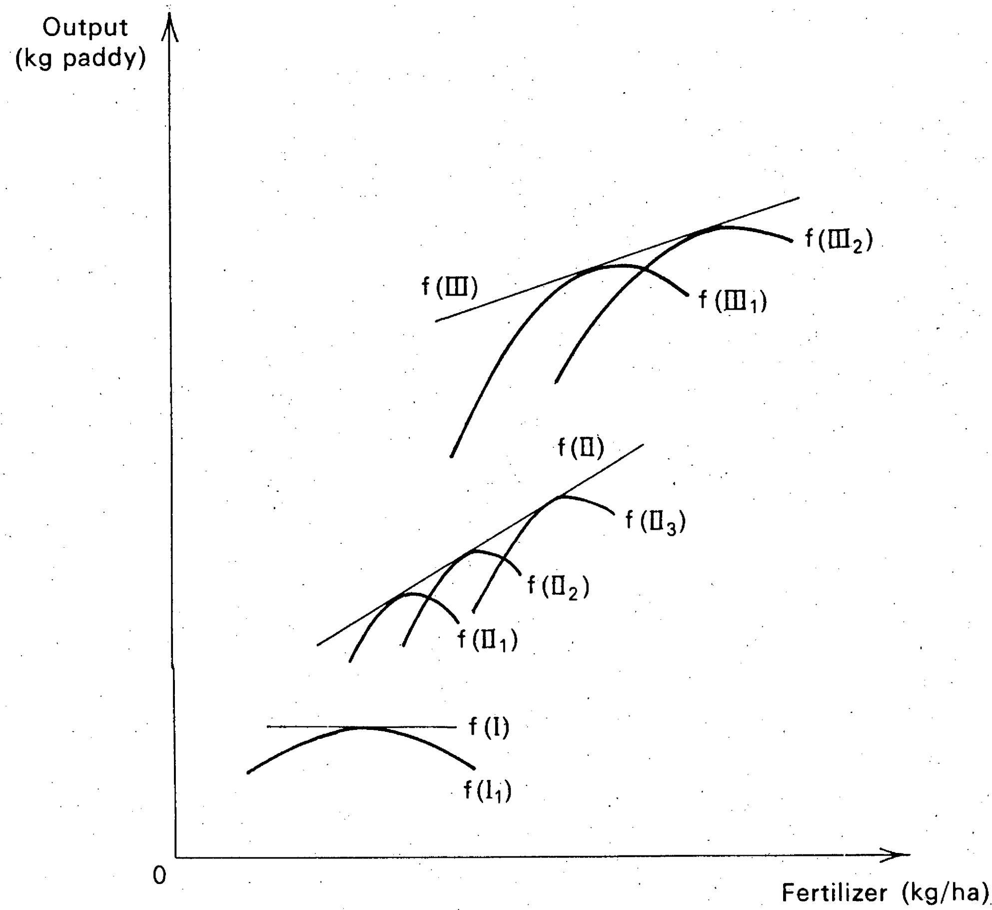


Figure 4.2. Input (irrigation and fertilizer) - output (paddy) relationships.

Source: Suzuki, F., Water Management Problems in Paddy Cultivation Practices, in APO (1977, pp.97-112).

differences in the level of irrigation (IR) which was previously assumed to be constant along with other inputs, except fertilizer. For example, the ratio between irrigated land and cultivated land is larger for f(II) than for f(I). Therefore, the aggregation curves show the locus of the maximum possible point of production which fertilizer inputs can achieve with the help of increased inputs of irrigation. The shifts from f(I) to f(II), and from f(II) to f(III) show the technological advance which takes place with the advent of irrigation, increased irrigation inputs or its technical improvement.

In stage I, water for rice cultivation is not controlled and crops depend entirely on rainfall during the rainy season, or on flood water spills from rivers in addition to rainfall. The production method is dependent on the natural flow of water. Cultivated land is close to its natural state, without capital structures, apart from possible investment in reclamation. Production tools are also relatively simple, requiring only minimal investment. Labour inputs for rice cultivation in this stage range from 40 to 80 mandays per hectare, and average yields range from 1.1 to 1.6 mt paddy per hectare.

In stage II, there are irrigation facilities in which floods and water delivery can be controlled in a traditional way. This extends to supplementing rainfall in times of shortage, and avoiding a delay in planting time because of late onset of the rainy season - the primary cause of harvest time variation in stage I. Irrigation at field level is by plot-to-plot flow. Production methods are basically similar to those in stage I. The significant differences are irrigation facilities comprising weirs, ditches, etc., which are mostly built with farmers' own labour and with materials readily available locally. Maintenance and repair of these facilities and water management become the additional components of rice cultivation activities. Average yields increase to a maximum of 2.5 mt paddy per hectare. The rice production function shifts from f(I) to f(II) as a consequence of the change from rainfed to irrigated rice cultivation technology. With the technological change, capital structures are added to land mainly as the direct product of labour. Labour inputs in this stage, therefore, are substantially larger than in stage I, at between 80 and 100 mandays per hectare.

In stage III, there is an improvement in irrigation and drainage facilities. The irrigation method changes from plot-to-plot irrigation to water delivery to, and drainage from, each plot, i.e. the irrigation system is in Class B or A. These conditions make the use of biological innovation feasible, such as modern high yielding and early maturing rice varieties, chemical fertilizer, pesticides and herbicides. In this stage, production methods appropriate to the new technology require high levels of labour and other current inputs, a variety of farm implements and machines and advanced cultivation practices. Rice cropping intensity increases to at least two crops a year. The average yield per harvest can exceed 6 mt paddy per hectare, as it did in Japan, for example, in 1975. For this stage, the production function in Figure 4.2 shifts from f(II) to f(III), and labour inputs increase to approximately 300 mandays per hectare.

Stage I and II technologies are currently used in the southern parts of Asia, and stage III technology is applied in the northern parts of Asia.

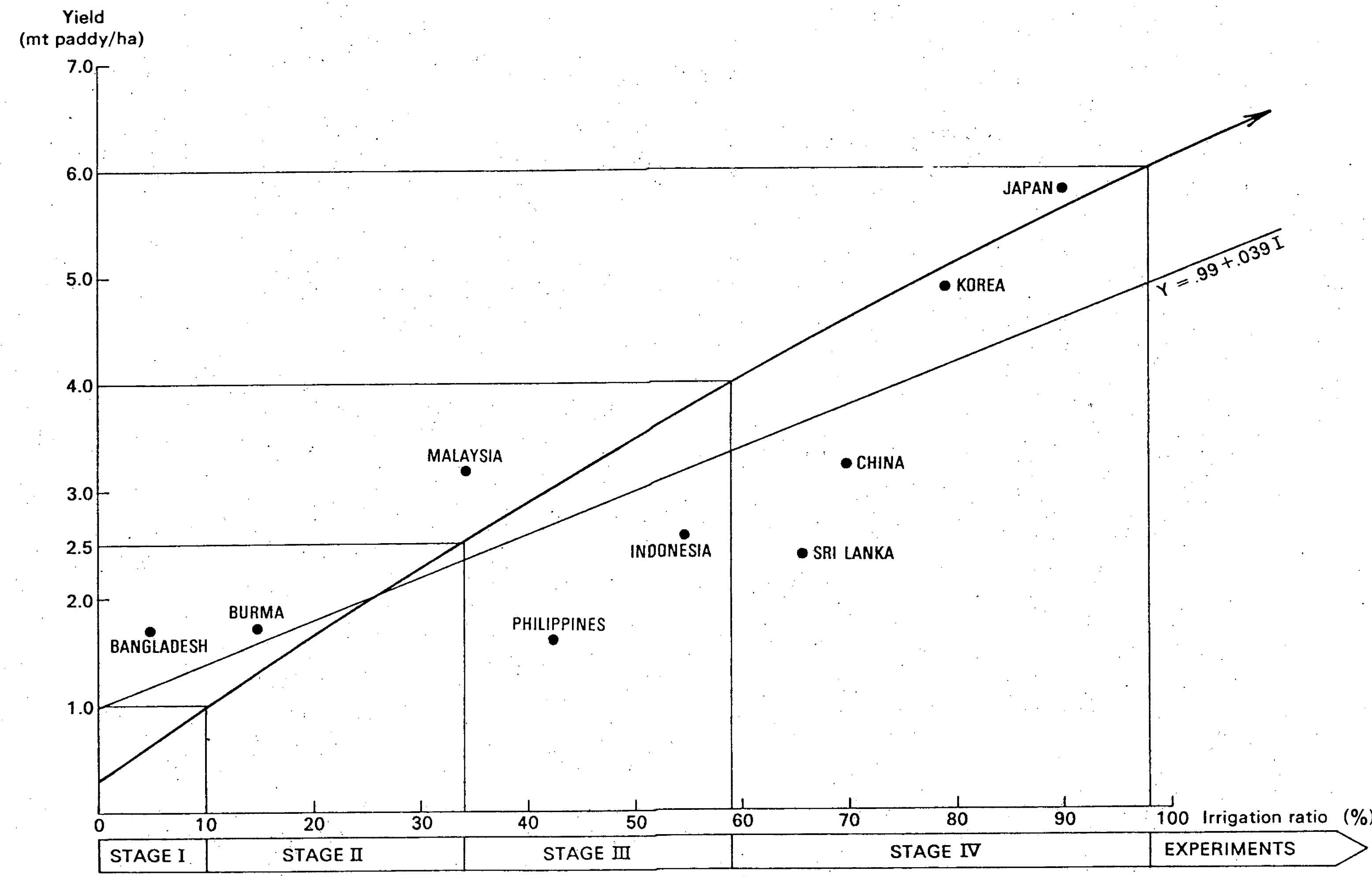
These two models are basically similar, though the Takase model does not take into account the level of labour inputs in the mix of rice cultivation technology and irrigation intensity. The Ishikawa model, which does, shows that as rice cultivation technology advances, labour requirements increase. Thus, the improved rice technology not only increases yield and cropping intensity, but also creates more employment opportunities. Both models show clearly that the stage of development of rice production technology is highly dependent upon the development of irrigation. However, the development of rice production technology and irrigation facilities involves not only the shift from one stage to another and infrastructure conditions, but also the endowment of resources from rice production such as land, water, solar energy, etc. Development of rice production technology also requires the knowledge and skill of rice farmers be raised through extension or education to levels appropriate to the needs of the technological changes. If not, the development of irrigation will be less effective and beneficial, for in the final analysis, the most important factor in the success or failure of the development of rice production technology is the rice farmer himself who adopts the technical changes.

Both models imply a relationship between stages of rice production technology development and rice yields (Figure 4.3). The stage of rice production technology (horizontal axis) is particularly determined both quantitatively and qualitatively, by the levels of water management and of modern input use.

Figure 4.3 shows that, at the macro level, the relationship between the irrigation ratio and yield is not always positive. For example, the irrigation ratio of Sri Lanka (66 percent) is much higher than that of Malaysia (36 percent), but the latter's paddy yield (3.02 mt paddy/ha) is much higher than that of Sri Lanka (2.4 mt paddy/ha). This may be due to differences in the levels of modern inputs used, particularly chemical fertilizer, or to differences in local factors such as climate, soil fertility, farmers' skills and education. However, in general, the correlation between the irrigation (I) and paddy yield (Y) is positive, as is shown in the equation:

$$Y = 0.99 + 0.039\ I \qquad (4.2)$$

where its R^2 (coefficient of determination) is 0.64. This means that the correlation between the irrigation ratio (I) and yield (Y) is positive and significant statistically, and about 64 percent of yield variations between countries is caused by the variations in the irrigation ratio. Hence, irrigation is one of



Source: Park (1977). Figure 4.3. Relationship between yield and irrigation ratio and the stage of rice cultivation technology development.

the most important factors in increasing rice yields, and in shifting rice cultivation technology from stage I through to stages III and IV.

Irrigation Efficiency

The efficiency of irrigation has two components: (1) efficiency of irrigation water distribution, and (2) efficiency of irrigation water utilization.

Irrigation water distribution efficiency comprises:[7]

(i) Conveyance efficiency (E_c), i.e. the ratio of water received at the inlet to a block of fields, to that released at the project headworks;

(ii) Field canal efficiency (E_b), is the ratio of water received at the field inlet to that received at the inlet of the block of fields;

(iii) Field application efficiency (E_a), is the ratio of water directly available to the crop, to that received at the field inlet.

Conveyance and field canal efficiency are sometimes combined as distribution efficiency (E_d), in which:

$$E_d = E_c \times E_b \qquad (4.3)$$

Field canal and application efficiencies are sometimes collectively called farm efficiency (E_f) where:

$$E_f = E_b \times E_a \qquad (4.4)$$

Irrigation project efficiency is the ratio of water made

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[7] These definitions are taken from Doorenbos and Pruitt (1977), Crop Water Requirements, FAO, Rome, 1977, pp.76-80.

directly available to the crop, to that released at headworks, or:

$$E_p = E_a \times E_b \times E_c \tag{4.5}$$

Field irrigation water utilization (E_u), is the ratio of the amount of water actually applied (W_a) to a particular crop to the amount of water necessary (W_n) for that crop cultivation:[8]

$$E_u = \frac{W_a}{W_n} (100) \tag{4.6}$$

Factors affecting conveyance efficiency (E_c) include area irrigated, size of rotational unit, number and types of crop, canal lining, and technical and management facilities of water control. Field canal efficiency (E_b) is affected primarily by the method and control of operation, the type of soil in respect of seepage losses, length of field canals, size of the irrigation block and the fields. As can be expected, distribution efficiency (E_d) has been shown to be particularly sensitive to quality of technical procedures as well as operational organization. Farm efficiency (E_f) is much dictated by the operation of the main supply system in meeting the actual field supply requirements as well as the irrigation skill of the farmers (Doorenbos and Pruitt, 1977).

Field application efficiency (E_a) is much lower than conveyance efficiency (E_c) and field canal efficiency (E_f) as shown in Table 4.1. This is because water losses can be high during field application when the rate of application exceeds the infiltration rate and excess is lost by runoff, and when the depth of water applied exceeds the storage capacity of the root zone and the excess is lost by deep drainage. With surface irrigation, field layout and land grading is most essential, and uneven distribution of water will cause drainage losses in one part and possibly inadequate irrigation in another part of the field, resulting in very low efficiency. Field application efficiency may vary during the growing season with

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8 This definition is adapted from Bower (1968).

Table 4.1 Conveyance, field canal, distribution and field application efficiency *).

Types of Efficiency		Efficiency
Conveyance efficiency (E_c)		
Continuous supply with no substantial change in flow		0.9
Rotational supply in projects of 3,000-7,000 ha and rotational areas of 70-300 ha, with effective management		0.8
Rotational supply in large schemes (larger than 10,000 ha) and small schemes (less than 1,000 ha) with respective problematic communication and less effective management:		
	based on predetermined schedule	0.7
	based on advance request	0.65
Field canal efficiency (E_b)		
Block larger than 20 ha:	unlined	0.8
	lined or piped	0.9
Block up to 20 ha:	unlined	0.7
	lined or piped	0.8
Distribution efficiency ($E_d = E_c.E_b$)		
Average for rotational supply with management and communication	adequate	0.65
	sufficient	0.55
	insufficient	0.40
	poor	0.30
Field application efficiency (E_a)		
Surface methods:	light soils	0.55
	medium soils	0.70
	heavy soils	0.60
	graded border	0.53
	basin and level border	0.58
	contour ditch	0.55
	furrow	0.57
	corrugation	0.60
Subsurface method		0.80
Sprinkler,	hot dry climate	0.60
	moderate climate	0.70
	humid and cool	0.80
Rice		0.32

*) Based on recent comprehensive survey by ICID/ILRI, and USDA and US(SCS) sources, and quoted in Doorenbos and Pruitt (1977).

highest efficiency during peak water use periods.

Because of these factors, the amount of water available to farms from an irrigation system is inversely related to distance from the beginning of the major canal to the farm sites (IRRI 1974). The problem of water distribution within irrigation systems is primarily related to the inequitable movement of water (Taylor 1976). Along the primary canal (Figure 4.4)[9] actual quantities of water received per hectare in earlier secondaries such as S-1 are higher than those in later secondaries like S-5. The same applies along secondaries like T-1 and T-3, and in tertiaries for farmers at the head end (HE) and tail end (TE) (Figure 4.5). Again for plots of land on individual farms (Figure 4.6), actual quantities received on the plots nearby (NB) the tertiaries are greater than those on plots far from (FF) them. Thus, the distribution efficiency of irrigation water on rice farms within an irrigation system varies inversely with distance of plots from : (1) headworks, (2) primary, (3) secondary, (4) tertiary canals of the irrigation system, and (5) overland flow of the irrigation water.

Unequal distribution of irrigation water is not only caused by the location factor on rice farms. Tabbal and Wickham (1978) distinguish some other factors:

"1. Unscheduled checking, frequently done at night, which farmers in the upper sections resort to during periods of water scarcity;

2. Lack of control gates at the substantial headworks and on turnouts, which cause water to flow freely through those openings even though their service areas may already have been oversupplied;

3. Presence of numerous unauthorized turnouts along the lateral and sublateral canals, which divert considerable quantities of water, especially in conjunction with unregulated checking. Their number greatly exceeds that of the authorized ones;

4. Partial silting of canal beds, which results in overflows at embankments of upstream sections, but only moderate flows and depths downstream;

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9 Figures 4.4-4.6 are taken from Taylor (1976).

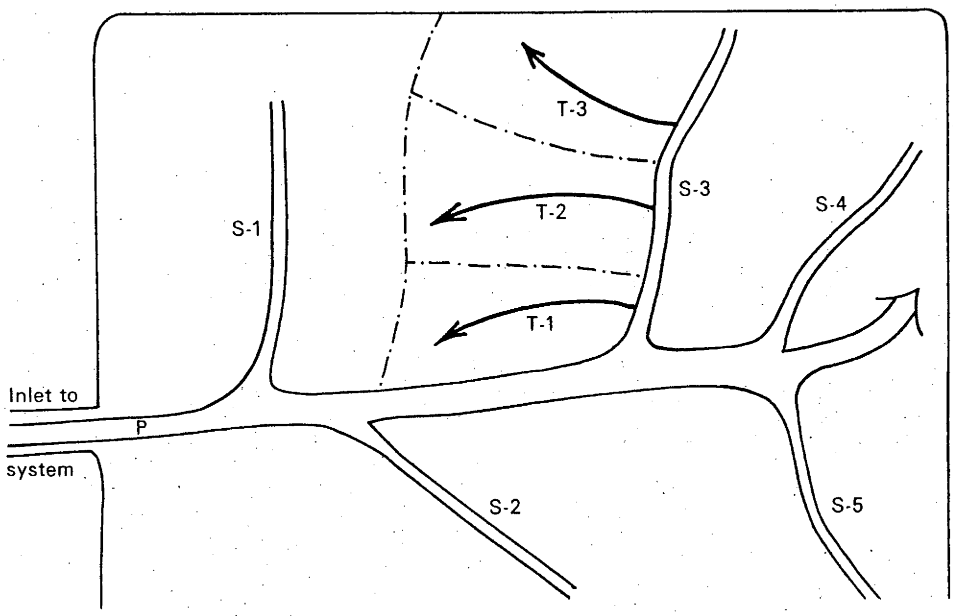

Figure 4.4. Layout of primary, secondary and tertiary canals of an irrigation system.

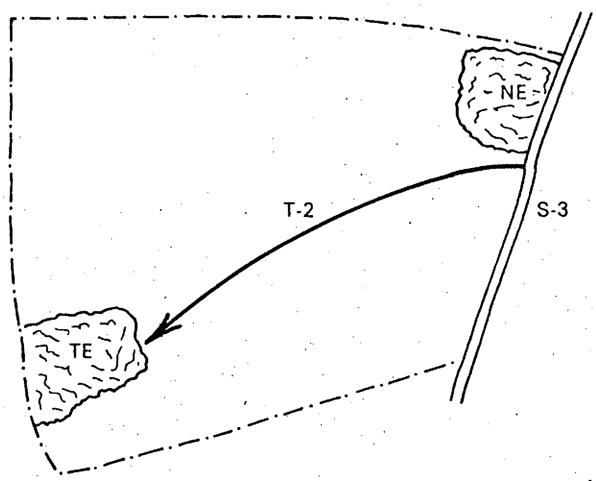

Figure 4.5. Farms at Head End (HE) and Tail End (TE) of a tertiary block.

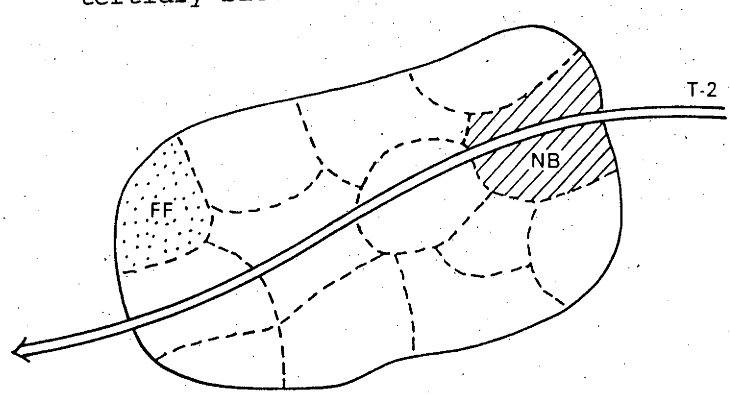

Figure 4.6. Plots of land on a farm nearby (NB) and far from (FF) a tertiary canal.

5. Presence of numerous pumps drawing water from the first two sections of the lateral to irrigate adjacent rain-fed areas, which further reduces the water available to downstream reaches of the canal;
6. Better control over water by farmers nearer the turnout than by those farther away. In times of scarcity, the farmer nearer the turnout may not allow the farmer next to him to receive water until his own needs have first been satisfied;
7. Water losses through surface drainage, seepage, and percolation, which are largely due to irrigation over-supply; and
8. Paddy-to-paddy water movement on irregular topography which tends to result in water lost as surface drainage."

With the exception of the fifth, all the above factors were relevant in this present study area, and another should be added, the number and quality of farm ditches.

As mentioned above, the two elements which determine the level of efficiency of field water utilization are the amount of water necessary for rice cultivation, and the amount of irrigation water actually applied to rice fields. The amount actually applied will vary from farm to farm with variation in distribution efficiency within an irrigation system. Thus, if we assume that the amount of water necessary for rice cultivation is the same for all rice farms within an irrigation system area, and water management practices used by both ditchtenders and farmers are uniform, the efficiency of irrigation water utilization will vary from farm to farm with irrigation water distribution efficiency. The most important question then is the relationship between variations in irrigation water utilization efficiency and rice yields.

<u>Water Requirement for Rice Cultivation</u>

Crop water requirements are defined as "the depth of water needed to meet the water loss through evapotranspiration (ET crop) of a disease-free crop, growing in large fields under non-restricting soil conditions including soil water and fertility and achieving full production potential under the given growing environment"

(Doorenbos and Pruitt, 1977)

Owing to the difficulty in obtaining accurate field measurements, crop water requirements are typically estimated with prediction methods, or in experiments. Doorenbos and Pruitt estimated crop water requirements with the equation:

$$\text{ET crop} = \text{kc.ETo} \tag{4.7}$$

where ETo represents evapotranspiration observations, and kc is a crop coefficient. The value of ETo is influenced by many factors such as climate, crop characteristics, local conditions and agricultural practices.

$$\text{ETo} = \text{c.p.}\ (0.46T + 8)\ \text{mm/day} \tag{4.8}$$

where:

c = adjustment factor which depends on minumum relative humidity, sunshine hours and daytime wind estimates.

p = mean daily percentage of total annual daytime hours obtained from observation data for a given month and latitude.

T = mean daily temperature in $^{\circ}$C over the month considered.

Using the prediction method,[10] they estimated the approximate range of seasonal ET crop for various crops. For rice, the range was 500 to 950 mm per rice crop season. If the length of the growing season from transplanting to two weeks prior to harvest is assumed to be 100 days, the average depth of water during the growing season will need to be between 5.0 and 9.5 mm per day.

The results of a three year study by IRRI on their Philippine experimental farm during the 1969, 1970 and 1971 dry seasons (Figure 4.7) indicate that the optimum daily water application

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[10] For detail of prediction methods, see Doorenbos and Pruitt (1977, pp.1-54).

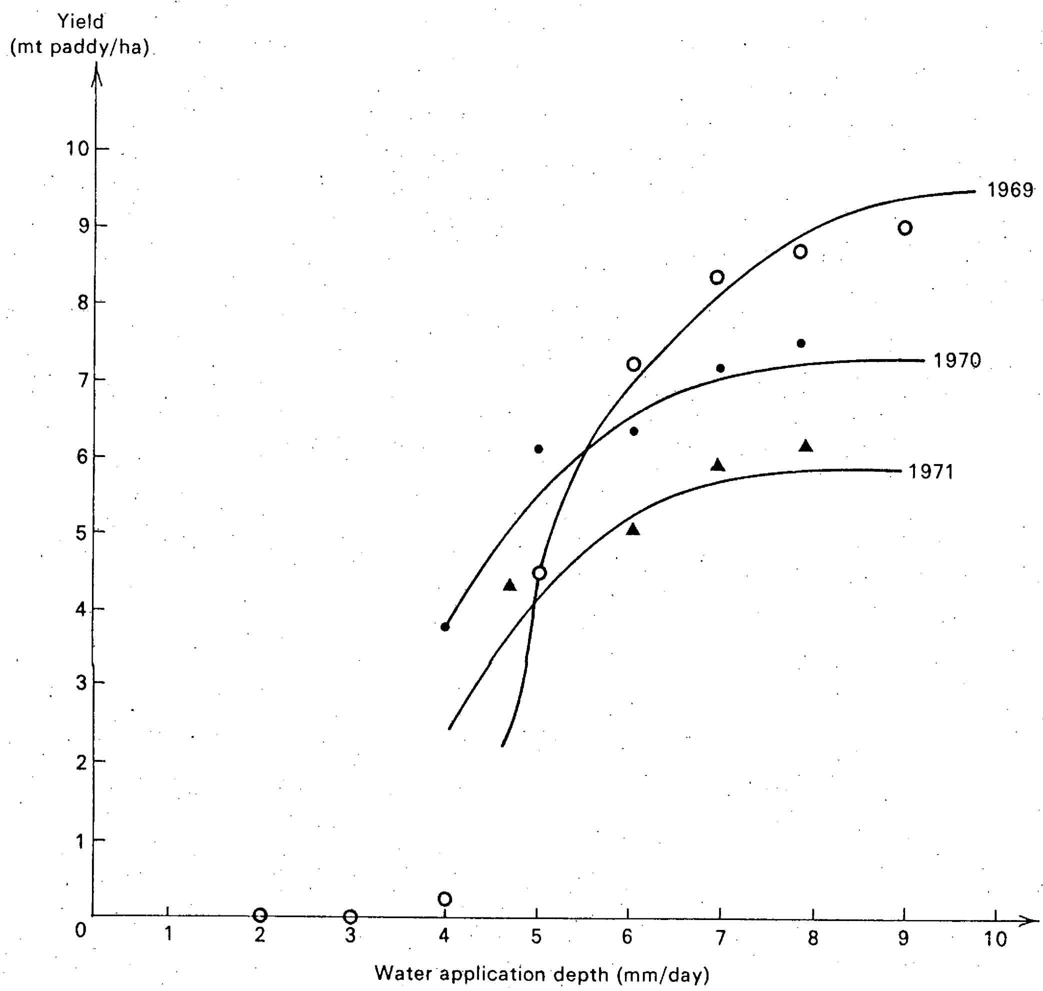

Figure 4.7. Rice yields and water application intensity, 1969, 1970 and 1971 dry seasons (IR-8), Philippines

Source: Reyes, R.D., 'An analysis of some factors affecting rice yield response to water', in: IRRI (1973), Water Management in Philippine Irrigation Systems: Research and Operations, pp.34-52.

depth for rice cultivation is less than 10 mm,[11] which is not much different from the Doorenbos and Pruitt predictions above.

Hitoshi Isozaki, as quoted in Hsu (1970), reported that for Japan in 1956, a daily depth of from 15 to 25 mm was recommended as optimum with heavy fertilizer dosages. In that range, rice yields would be maximized (Figure 4.8).

A water level higher than actual crop requirements is needed because much is lost through percolation. Experiments have shown that an optimum daily rate of percolation is from 15 to 25 mm depending upon soil properties and the moisture gradient. At this rate, subsoil percolation can leach away toxic substances and supply oxygen, which makes a favourable environment for rice root development (Hsu 1970). The rate of percolation is also determined by the quality of land levelling. If the latter is poor, water losses will be substantial.

Water requirements for paddy vary with the growth stages of the crop. Seedlings require little because water consumption is low at this stage. During the vegetative phase, from transplanting to maximum tillering (50-60 days after transplanting), the requirements are heavy, especially during the early part. Depth can be shallower later, and drainage helps to promote the establishment of tillers. A large volume of water is consumed during the generative period, from maximum tillering to fully flowering (15-20 days prior to harvest), during which time water deficiencies will cause a serious decrease in yield.[12] More specifically,

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[11] R.D. Reyes, 'Experiments on the Economics of Water Distribution', in: UP and IRRI (1969), Seminar on economics of rice production in the Philippines, pp.(8-1)-(8-65).

[12] Peter Kung, Water Management for Paddy Fields in Tropical Asia, a technical report presented to Symposium of Water Management in Rice Fields, Tropical Agriculture Research Centre, Tokyo, Japan, 1975.

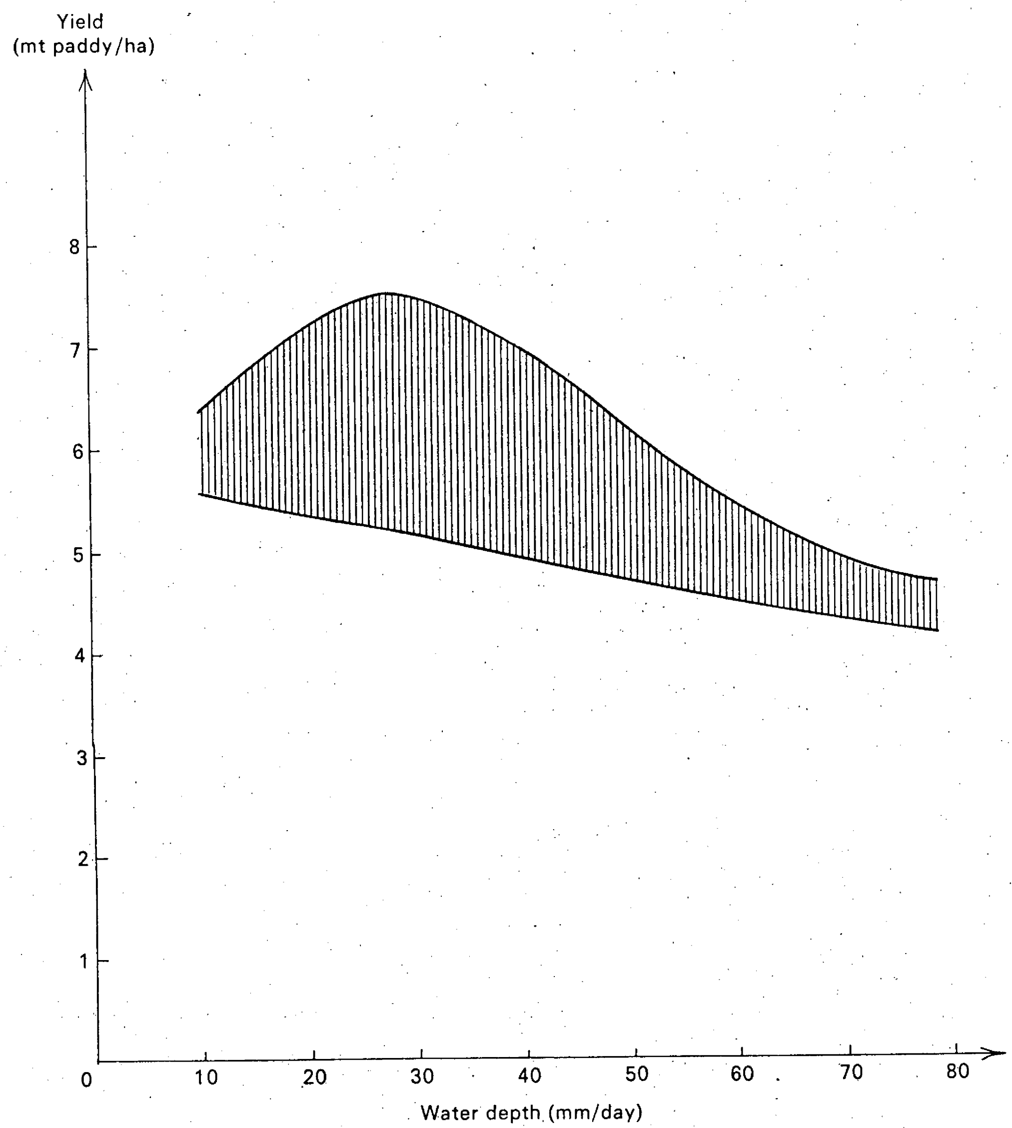

Figure 4.8. Relationship between water depth and rice yields, Japan 1956.

Source: Yuh Piau Hsu, Water management in paddy field, a paper presented at the Short Training Course sponsored by ASPAC Food and Fertilizer Technology Center, October 5-22, 1970, Taipei (Mimeo.).

Tsutsui (1972) recommended specific water depths for different growth stages under continuous flooding (as in the present study area), as follows:

> "During transplantation: the puddled field is covered with water to about 2-3 cm. Deep water may not be desirable....
>
> After transplanting: to secure healthy growth of transplanted seedlings a considerable depth (5-10 cm) of water is to be kept for a period of about 8 weeks.
>
> Tilling stage: water depth should be maintained as shallow as possible and mid-season drainage takes place at the beginning of the maximum tilling stage.
>
> Panicle formation stage: abundant water supply is desirable as severe drought damage usually occurs during this period. Water depth of 5-8 cm is desirable.
>
> After full flowering: fields should be drained gradually 2-3 weeks after full flowering stage. Late drainage will make it difficult to conduct efficient harvest."

There are a number of reasons why rice is usually grown in flooded soil:[13] i) weed growth is drastically reduced under flooded conditions; ii) nutrient availability is generally higher in flooded soil than non-flooded soil; and iii) there is a higher efficiency of fertilizer utilization under flooded conditions. Thus, variations in water depth will influence yields.

An experiment in California showed that grain yield was 53 per cent lower under non-flooded conditions. Non-flooded conditions delayed flowering, led to a high percentage of sterility and consequently to a low yield. Another experiment in Japan found that rice is most sensitive to water stress from 20 days before to 10 days after heading (De Datta et al. 1973).

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13 See De Datta, S.K., H.K. Krupp, E.I. Alvarez and S.C. Modgal, 'Water Management Practices in Flooded Tropical Rice', in IRRI (1973), Water Management in Philippine Irrigation Systems: Research and Operation, Laguna, Los Banos, Philippines, pp.1-18.

Measuring Irrigation Efficiency

Measurement of irrigation efficiency involves both distribution and utilization efficiency. The former can be assessed by comparing water flow at the intake gate or headworks with that in other channels (secondary or tertiary) and in farm ditches. Expressed as ratios, these give water distribution efficiency. Measurement of water utilization efficiency is not as easy, since data on water depth in farm fields are not readily available. Such measurement on a daily basis requires sizeable manpower resources and is costly for any more than a limited number of rice farms.

Water Balance Model

To tackle the problem of measuring water depth on rice fields, Wickham (1971, 1973) developed a 'water balance' model. It accounts for water movements into and out of fields according to a simplified equation:

$$NI + RN = SP + ET + SD \tag{4.9}$$

where NI = net irrigation water into the fields, RN = rainfall, SP = seepage and percolation, ET = evapotranspiration, and SD = surface drainage.
Thus, the depth of water in fields is the total amount of water received from irrigation and rainfall minus total losses from seepage, percolation, evapotranspiration and surface drainage.

With this model, Wickham then developed a dynamic balance model to estimate the depth of water available on rice fields on a daily basis, as represented by the following equation:

$$WD_t = WD_{t-1} + RN_t + NI_t - ET_t - SP_t - SD_t \tag{4.10}$$

where WD_t is water depth on day t, and other variables are as above.

Suppose the initial value of WD for each site of a study area can be specified, and RN and NI data are available from the offices of the irrigation project and meteorology department. The daily values of ET are calculated according to the following equation

$$ET_t = a + b\ EV_t \tag{4.11}$$

where EV = the evaporation of a rice crop that can be estimated from experiment results; a and b are parameters whose values vary slightly for different seasons and for different stages of crop growth. The daily values of SP are also computed as a linear function of WD_t, where fifty per cent of the maximum SP value for a site is assumed to occur when $WD_t = 0$.

Surface drainage (SD) is calculated with the equation

$$SD_t = WD_t - WD_{cr} \tag{4.12}$$

where WD_{cr} is critical water depth, i.e. when WD = 0, WD_{cr} = WD = 0. Thus, if WD_t is equal to or less than WD_{cr}, SD_t becomes zero.

With this model, Wickham calculated the depth of water on a daily basis and the total number of stress days on each farm in each crop season. Further, with yield measurement on sample farms from crop cutting at harvest time, Wickham was able to measure the relationship between rice yields and the number of stress days, using regression analysis.

In the present study this model was not used because the input data needed were not available. Instead, water depth was measured directly on each sample rice farm, and a management variable was included, to enable investigation of factors affecting the depth of water or/and the number of stress days.

CHAPTER 5

IRRIGATION PERFORMANCE IN THE BADENAH IRRIGATION SYSTEM

Farm Water Management and Organization

There are three ministries involved in irrigation activities in Indonesia: Public Works which is responsible for construction and administration; Home Affairs responsible for operation and maintenance; and Agriculture which is concerned with utilization and extension of irrigation water (Figure 5.1).

Under these arrangements, the Ministry of Public Works has delegated responsibility for the construction work, including the initial investment for the main system, to the Directorate General of Water Resources Development (DGWRD). The operation and maintenance (O&M) activities which follow have become the responsibility of provincial governments and farmers. The provincial governments assign the work to the local public work ministry agencies. The farmer is totally responsible for the terminal system, from construction to O&M.

The Directorate General of Food Crop Agriculture (DGFCA) is concerned with the utilization of irrigation water for agriculture on behalf of the Ministry of Agriculture. The DGFCA assists and supervises farmers in the development of terminal systems and water management activities including simple irrigation, to achieve efficient water use. Its activities also include farmers' training in irrigation and water management, pilot schemes, establishment and development of water user associations (P3A), and trials of water use and water requirements. Most of these activities are carried out with the cooperation of the Sub-Directorate of Land and Water Conservation of the DGFCA, and the Agriculture Services (Dinas Pertanian Rakyat) of the DGFCA at the provincial level.

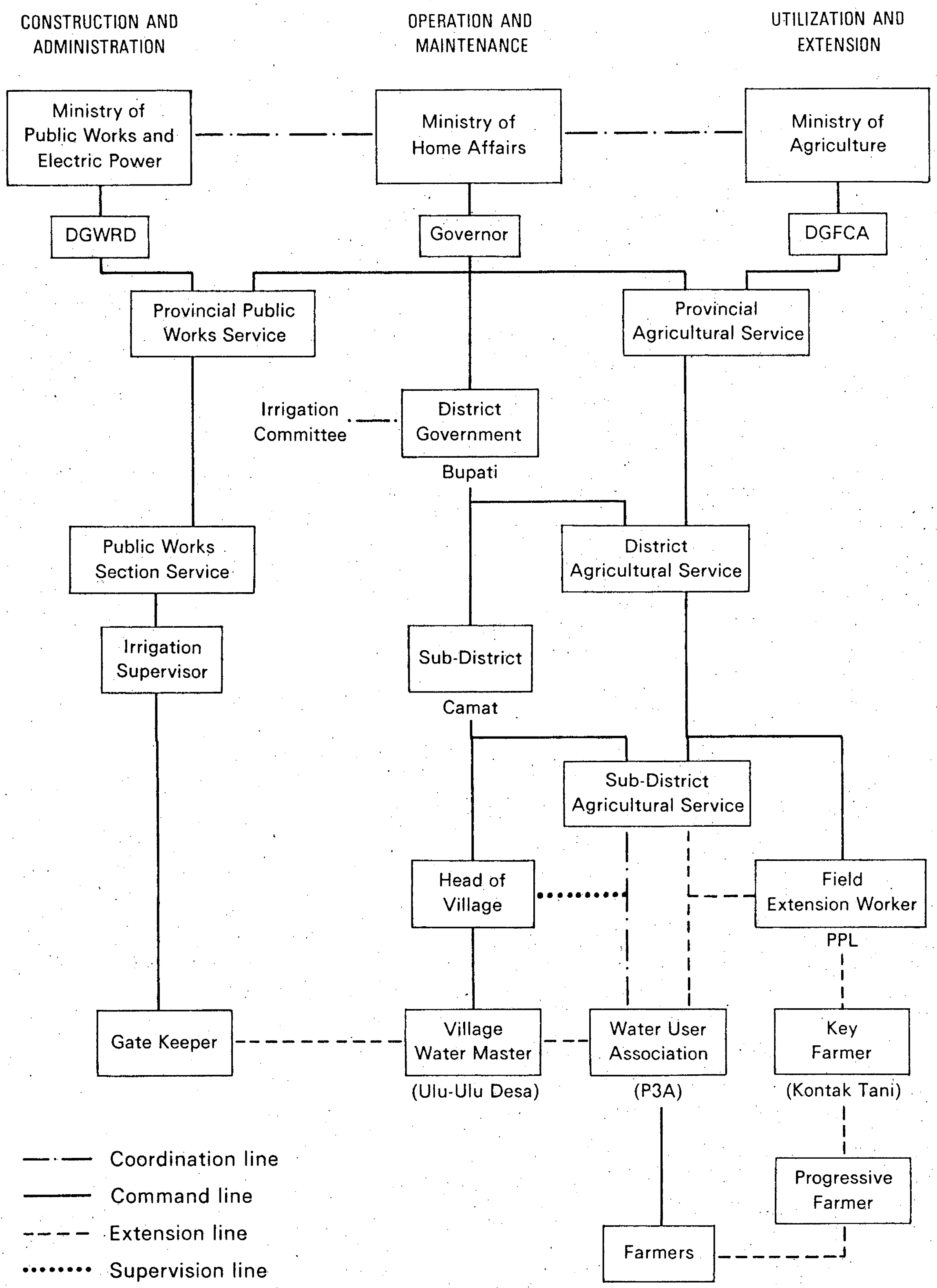

Figure 5.1. Irrigation management and organization in Indonesia.

Source: Bratamidjaja, 1977.

Finally, the Directorate General of Rural Community Development (PMD) is given responsibility under the Ministry of Home Affairs, primarily for village development plans, including rural irrigation.[1]

The above structure shows that water management at farm level depends heavily upon the activities of rice farmers themselves. One of the most important of these is the construction of field channel networks, and their development is one test of farmer involvement. In the Badenah scheme selected for this study, field channel networks have not been fully established, but their condition was better than those of the average Wet Sumatra's field channel networks. The existing networks in the study area (Figures 5.2.A-5.2.C) were found to be unevenly distributed, and their quality was inadequate. While some parts of fields were adequately served with farm ditches, other parts had very few. Uneven distribution of farm ditches was found both in the head and body sections, with an average farm ditch density higher in the former (63 m/ha) than in the latter (45 m/ha). The distribution of networks in the tail section was relatively good, and the density of field channels was highest there (80.3 m/ha).[2] Nevertheless the supply of water from the sub-secondary canals to farms has not been controlled in the tail section because one of the two outlets from the secondary canal was still a simple construction (without control and measurement devices), so at times farmers experienced shortages of water. During the survey period, however, the supply of water in this section was not a serious problem, as discussed above.

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1 Bratamidjaja, O.S.R. (1977), 'Indonesia', in Asian Productivity Organization, APO, Farm Water Management for Rice Cultivation, Tokyo, Japan, pp.238-247.

2 The length of field channel networks in the study area was measured directly in the field, and Figures 5.2.A-5.2.C were drawn on the basis of field data. It should be noted that in computing the length of field channels, the length of tertiary canals was included.

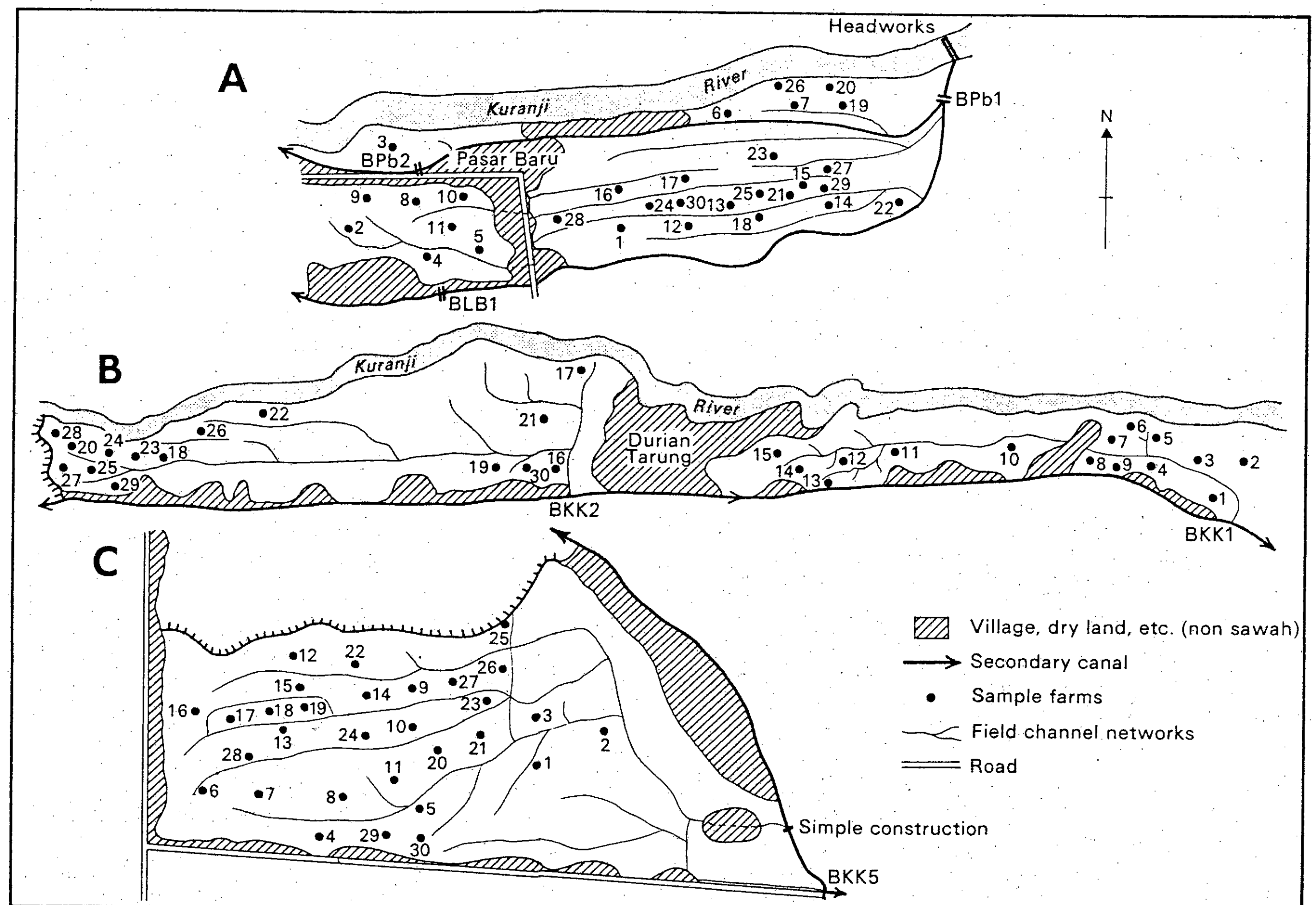

Figure 5.2. Field channel networks of the head (A), body (B) and tail (C) sections.

Most of the existing channels in the study area were established many years ago by the community in gotong-royong manner under the leadership of adat leaders. Variations in length and networks of field channels in the study area were a function of the activity levels of the rural communities within the command area, and this depended much upon the concern of local government and community leaders. Field channel development was adequate only where local government and community leaders gave leadership[3] high priority to irrigation, and encouraged farmers to establish and develop their irrigation networks at field level.

Our field observations indicated that formal leadership (village government) and informal leadership (community leaders) were very important in encouraging farmers to adopt improved rice technology and to improve farm water management. The leaders of Pasar Baru sub-village (the head section) showed less leadership capacity than those of Durian Tarung (the body section) and Ampang (the tail section) sub-villages. The formal leaders in Pasar Baru performed traditional functional roles similar to those within the old social structure wherein little attention was given to the organization of farm water management. There has been no Kelompok Tani (farmer's group) or water user organization (P3A) established in Pasar Baru. In contrast, the leaders of Durian Tarung and Ampang sub-villages were characterized by their plural roles. They organized farmers in a variety of farmer groups, e.g., a pest control group, a young farmer's group (Kelompok Pemuda Tani), a woman farmer's group (Kelompok wanita tani), a rural broadcast listener's group (Kelompok pendengar siaran pedesaan), and an irrigation group

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3 In the Adat Minangkabau structure, each Nagari (village) has a special leader who is responsible for irrigation water management at field level. This institution is called tuo banda (village water master). A tuo banda has responsibility and authority to encourage his community to develop and to clean irrigation channels regularly, and to determine rice planting times. However, since the Sumatran rebellion (1958), this institution has become inactive, following the change in rural government structure. At the moment, the government of West Sumatra is trying to reactivate this institution.

(<u>kelompok pengairan</u>), and acted as liaison officers between the rural community and the government agencies. These contributions were additional to their roles in village government and tasks on their own farms.

The difference in leadership between the sub-villages was reflected in the fact that farmers in Durian Tarung and Ampang were more progressive than those in Pasar Baru, and there were more rural development projects in these former two sub-villages. Water user associations (P3A) were established in Durian Tarung (in 1976) and Ampang (early 1978) by the rice farmers who had been previously organized into various farmer groups in 1971. It seems that the P3A was very important for the improvement of farm water management and for the development of rice cultivation in that area. The success of the P3A will, however, depend much again upon the continued activity and the leadership of the association managers.

The area of a P3A is based on the irrigation distribution systems (Figure 5.3), which is appropriate since the goal of the association is to improve farm water management.[4] Our survey observations revealed that the activity of the P3A in Durian Tarung and Ampang sub-villages had a significant positive effect on water distribution to rice farms. The association established 14 distribution constructions on various tertiary canals in <u>gotong royong</u> manner, with the financial support of the provincial government. It also constructed a building in Durian Tarung by <u>gotong royong</u>, which is used as the association's office and place for regular meetings of members to discuss questions of irrigation water distribution and utilization, rice cultivation techniques, and other problems. The discussions are held under the guidance of the local PPL (field extension workers). The local agriculture service is also regularly given some training courses which relate

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4 For a detailed discussion of the importance of the role and problems of local farmer's group associations, see Taylor (1976), Hutapea et al. (1979), and Sinaga and Hafid (1979).

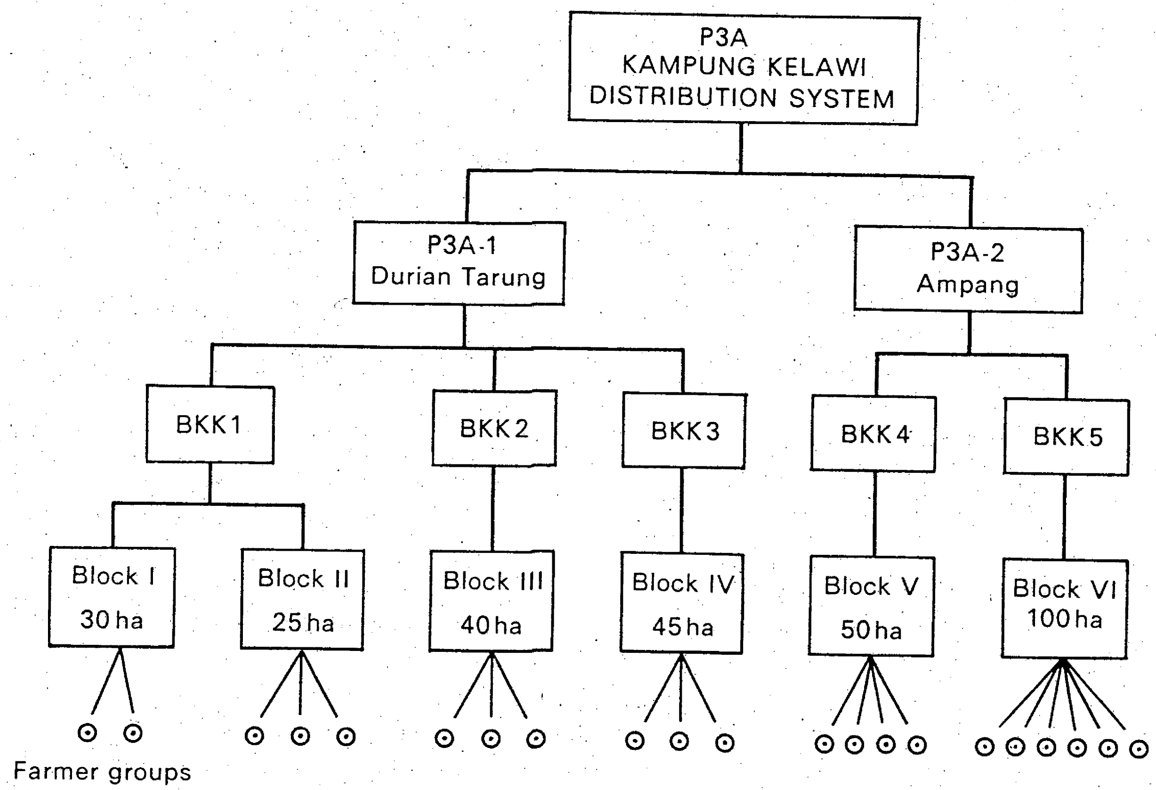

Figure 5.3. The structure of the P3A association in the study area.

to rice farming activities. Every planting season, members are all obliged to clean tertiary canals in gotong royong manner, and the chairman of each farmer's group is responsible for encouraging his members to do so. In 1977, the chairman of the association visited some irrigation projects in Java under government sponsorship, and in 1978, the vice chairman of the association visited Bali to investigate the management and organization and the factors contributing to their success.[5] Study tours like this are very useful in encouraging the development of leadership potential for managing the association.

Irrigation Performance in the Study Area

Water distribution in primary and secondary canals was not a problem in the study area because the irrigation scheme is relatively new: canals have not silted up and the control structures in the canals were operating properly. However, the distribution efficiency of irrigation water at each distribution point was different (Table 5.1).

Thus, the irrigation water available at each distribution point varied inversely with the distance from the headworks of the irrigation system. Water available to each tertiary block and to each farm in each block could not be calculated because data on field canal and field application efficiencies for each block were not available. However, by using the field canal and field application efficiencies of 0.8 and 0.32 respectively in Table 5.1, water availability for the rice crop in each section was estimated (Table 5.2).

The average water requirement for a rice crop depends upon

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[5] According to Taylor (1976), Bali's subak is perhaps the most successful traditional irrigation organization in Indonesia. More information about subak, see Hutapea et al. (1979), and Birkelbach (1973).

Table 5.1 Irrigation distribution efficiency in the study area, 1977.

Distribution points[a)]	Distance from weir (m)	Distribution efficiency[b)]
BPbI	135	0.98
BPbII	1048	0.72
BPbIII	1388	0.57
BPbIV	2291	0.55
BKK1	2599	0.52
BKK2	3884	0.46
BKK3	4401	0.41
BKK4	4918	0.37
BKK5	5418	0.35

a) See Figure 2.2, for the detail of the scheme.

b) Distribution efficiency at each distribution point is ratio of water available at that point to that released at the headworks of the irrigation system.

Source: The Badenah irrigation project office.

soil type, topography and the size of an irrigation block.[6] Light soils (e.g. sandy loam) require a larger amount of water than heavy soils (e.g. light clay soil). Plain topography (e.g. low-land wet paddy fields) requires less water than hilly land (e.g. upland wet paddy fields). Larger irrigation blocks require less water per hectare than smaller irrigation blocks. Based on these characteristics, water requirements for the study area were about 1.0-1.75 litres/sec/ha, or about 8.5-15.0 mm water depth per day. The head section required larger amounts of water (light soil, hilly topography, and smaller irrigation block) than the body

6 See, L.T. Chin, 'Modification and Renovation of Old Canal Systems', in: FAO (1972), Farm Water Management Seminar Manila, pp.165-72; Ahmadi Partowijoto et al. (1976), Teknik Tanah dan Air, Departemen Mekanisasi, IPB, Bogor.

Table 5.2 Estimated water availability for the rice crop in the study area, 1978 dry season and 1978/79 wet season.

Sections	Rice field[a] area (ha)	Conveyance[b] efficiency	Field canal[c] efficiency	Field application[c] efficiency	Water available[d] (litre/sec/ha)
Head	70	0.85	0.80	0.32	7.7
Body	95	0.50	0.80	0.32	4.1
Tail	100	0.35	0.80	0.32	2.7

a) Total area of ricefields in each section irrigated through BPbI and BPbII (for head section), BKK1 and BKK2 (for the body sections), and BKK5 (for the tail section), and see Figure 2.2 for detail.

b) Calculated from Table 4.1.

c) These figures are taken from Table 4.1 by assuming that field canal efficiency and field application efficiency are the same for each section of the study area.

d) The average water released from the head works of the Badenah irrigation system for Badenah I is about 3,000 litre/sec/day. The water available for the rice crop is calculated by the following equation:

$$W_a = \left[S_w \times E_c \times E_b \times E_a\right]/I_a$$

where: W_a is water available for rice crop (litre/sec/ha), E_c is the conveyance efficiency, E_b is field canal efficiency, E_a is field application efficiency, and S_w is the amount of water released from the headworks (litre/sec), and I_a is the area of rice fields (ha).

section. Even with these variations, actual supplies of irrigation water in all sections of the study area were more than adequate (Table 5.2).

Although there was more irrigation water available to rice farms in the head section than in the body and tail sections (Table 5.2), the average depth of water in the body section was higher than in the head section in both seasons (Table 5.3). This finding shows clearly that the level of irrigation water utilization was not only determined by the availability of water, but was heavily dependent upon natural conditions and farm water management.

Our survey observations indicated that the majority of sample farmers considered that supply of water for their farms was more important during the vegetative period than in the generative period because, much water is needed for good rooting and for rapid development of tillers, and water shortage or drought during the vegetative period will lower yields. This consideration was reflected in the fact that the average depth of water in the vegetative period (W_1) was much higher than that in the generative period (W_2) in both seasons, and also in the very much lower number of stress days in the vegetative period ($S_1 < S_2$) in both seasons (Table 5.3). Some farmers thought that the supply of water was equally important in the two periods, but few farmers considered the depth of water should be higher in the generative period than in the vegetative period.

For sample rice farmers, the management factor was manifest principally in the choice of timing for draining their farms prior to harvest (TD). Table 5.3 shows clearly the positive relationship between TD and S_2, and the negative relationship between TD and W_2. It also shows that the average depths of water (W_1 and W_2) in both seasons were much greater in the body section than those in the head and tail sections. The number of stress days[7] (S_1 and S_2)

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[7] A stress day is defined here as a condition where the depth of water in the field on that day was zero mm.

Table 5.3 Indicators of irrigation performance within the Badenah irrigation system during the 1978 dry season and the 1978/79 wet season.

Categories	1978 dry season								1978/79 wet season							
	n	TD	W_1	W_2	S_1	S_2	N	yield	n	TD	W_1	W_2	S_1	S_2	N	yield
Section:																
Head	28	16	14	9	5	7	53	1757	27	49	13	4	7	24	44	1671
Body	30	12	30	15	1	5	62	2567	30	30	25	7	3	18	61	2029
Tail	30	45	20	2	6	26	26	1448	30	54	22	2	6	34	17	1500
Land Tenure:																
Owner operator	29	23	22	8	4	11	53	1698	28	42	21	4	4	23	45	1666
Fixed-rent	8	18	30	13	1	5	66	3028	7	33	23	6	5	16	48	2168
Share-cropping	51	27	20	7	4	15	41	1921	52	46	19	4	6	28	37	1715
Rice varieties:																
IRRI	51	31	22	7	5	17	44	1806	57	45	21	4	5	26	38	1746
National	17	14	30	12	2	6	50	2218	9	29	23	4	5	19	54	1711
Local	20	16	20	10	3	9	52	2080	21	47	19	4	6	26	41	1718
Water sources:																
From channels	69	24	22	9	3	12	46	1981	67	42	20	4	5	25	41	1731
Plot-to-plot	19	25	19	8	6	15	51	1826	20	48	19	3	7	28	40	1752

Notes: n = the number of observations; TD = average time of draining farms (DBH); W_1 = average depth of water per day in mm from transplanting to 60 DAT; W_2 = average depth of water per day in mm from 60 DAT to 15 DBH; S_1 and S_2 are the average number of stress days during W_1 and W_2 periods respectively; N = the amount of nitrogen used (kg N/ha), and yield is in kg paddy/ha.

in both seasons were much lower in the body than in the head and tail sections. The highest number of stress days in both seasons were recorded in the tail section. The lowest W_1 in both seasons was in the head section, while the lowest W_2 in both seasons was in the tail section. The earliest timing of draining farms (TD) in both seasons was also in the tail section, and the latest was in the body section.

The question now is what factors affect the average depth of water and the number of stress days from transplanting to 15 days prior to harvest? For this, multiple regression analysis was used with the average depth of water (W) and the number of stress days (S) from transplanting to 15 days before harvest as dependent variables.

Factors Affecting Average Water Depths

Factors affecting the average depth of water from one day after transplanting to 15 days prior to harvest (W) were found to be different for each section in both seasons as shown by Beta parameter (Tables 5.4 and 5.5). In the dry season, the most important factor was the distance variable[8] for the head and body sections, while for the tail section, it was the timing of draining farms.[9]

It is generally assumed that the coefficient of the distance

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8 The distance variable is the distance of a farm from the secondary outlet, measured in meters. The distances were measured directly in the field on the basis of the length of irrigation channels from the outlet to the farm.

9 These are indicated by the highest absolute values of their Beta coefficients. The SPSS package program for regression, besides giving coefficients of variable (b) also gives the adjusted coefficients (Beta). Parameter Beta is the adjusted parameter (b) for the same unit. Thus, Beta parameters indicate the relative importance of independent variables in influencing the dependent variable (for detail see, Nie, N.H. et al., 1975, pp.326-327).

Table 5.4 Regression coefficients of factors affecting the average depth of water per day from transplanting to 15 days prior to harvest (W), 1978 dry season.

Variable	Parameter b	Beta	t_b	Mean	S. Dev.
		Head section			
W				11.74	3.60
Constant	5.6312				
Distance	0.0099***	0.5762	3.29	365.21	208.72
Tenurial dummy	2.4343**	0.3383	1.91	0.45	0.51
Time of draining	-0.1109*	-0.3103	-1.80	15.93	10.16
Water source dummy	1.4610	0.1825	0.95	0.76	0.44
Farm size	2.6985	0.1708	0.94	0.39	0.23
Experience	0.0451	0.1578	0.89	23.10	12.59
Variety dummy	-0.2289	-0.0319	-0.16	0.41	0.50
Education	-	-	-	4.17	3.85
Degrees of freedom	7/21				
R	0.69				
Adjusted R^2	0.30				
F-statistic	2.68**				
		Body section			
W				24.74	3.78
Constant	24.1012				
Distance	-0.0038**	-0.4246	-2.25	704.40	416.56
Farm size	4.0266*	0.2486	1.40	0.45	0.23
Tenurial dummy	1.4659	0.1861	1.09	0.33	0.48
Water source dummy	1.5377	0.1751	0.94	0.77	0.43
Time of draining	-0.0557	-0.0973	-0.46	11.93	6.60
Education	0.0666	0.0748	0.45	5.73	4.24
Variety dummy	0.3588	0.0479	0.28	0.43	0.50
Degrees of freedom	7/22				
R	0.68				
Adjusted R^2	0.30				
F-statistic	2.75**				
		Tail section			
W				14.13	2.91
Constant	20.14				
Time of draining	-0.1310***	-0.4973	-2.89	45.17	11.05
Experience	0.0987**	0.4968	2.69	24.20	14.64
Distance	-0.0014	-0.1700	-1.04	1692.13	366.18
Farm size	2.0488	0.1549	0.94	0.54	0.22
Variety dummy	-1.4608	-0.1532	-0.93	0.90	0.31
Tenurial dummy	-0.9931	-0.1469	-0.82	0.23	0.43
Education	0.1289	0.1112	0.59	4.30	2.51
Water source dummy	-0.3780	-0.0493	-0.29	0.83	0.38
Degrees of freedom	8/21				
R	0.72				
Adjusted R^2	0.51				
F-statistic	2.78**				

Table 5.4 (Cont'd.)

Notes:

Water source dummy = 1 for farms whose water comes directly from channels, and it is zero otherwise.
Variety dummy = 1 for IRRI varieties and zero otherwise.
Tenurial dummy = 1 for owner operators and zero otherwise.

*	significant at the 10 per cent level.
**	significant at the 5 per cent level.
***	significant at the 1 per cent level.
without *	non-significant at the 10 per cent level or less, except for constant, because the SPSS program does not give the standard error of constant term.

Table 5.5 Regression coefficients of factors affecting the average depth of water (W), 1978/79 wet season.

Variable	Parameter b	Beta	t_b	Mean	S. Dev.
			Head section		
W				10.02	3.60
Constant	7.9213				
Time of draining	-0.0976***	-0.5734	-4.45	48.44	21.14
Distance	0.0072***	0.3945	3.46	344.70	197.84
Tenurial dummy	2.2497**	0.3131	2.64	0.41	0.50
Farm size	3.9795**	0.2385	2.11	0.42	0.22
Experience	0.0511*	0.1766	1.41	20.81	12.43
Education	0.0937	0.0991	0.82	4.59	3.81
Water source dummy	0.5093	0.0659	0.54	0.70	0.47
Variety dummy	-0.1533	-0.0217	-0.19	0.48	0.50
Degrees of freedom	8/18				
R	0.91				
Adjusted R^2	0.74				
F-statistic	10.34***				
			Body section		
W				20.94	11.11
Constant	27.0496				
Time of draining	-0.3753**	-0.4605	-2.61	29.53	13.63
Tenurial dummy	9.0659**	0.4001	2.17	0.37	0.49
Experience	-0.2056	-0.2375	-1.29	15.47	12.83
Education	0.5927	0.1839	1.02	5.70	3.39
Variety dummy	2.2799	0.0984	0.52	0.67	0.48
Water source dummy	-1.8682	-0.0724	-0.45	0.77	0.43
Farm size	2.8911	0.0669	0.37	0.47	0.26
Degrees of freedom	7/22				
R	0.67				
Adjusted R^2	0.28				
F-statistic	2.58**				
			Tail section		
W				14.68	3.48
Constant	24.9101				
Time of draining	-0.1688***	-0.7999	-7.80	54.13	16.50
Education	0.3278**	0.2527	2.57	3.63	2.68
Variety dummy	-1.2463	-0.1456	-1.29	0.80	0.41
Experience	-0.0315*	-0.1377	-1.42	23.23	15.24
Farm size	-2.1035*	-0.1306	-1.32	0.52	0.22
Distance	0.0002	0.0261	0.26	1692.10	366.18
Water source	0.1549	0.0189	0.16	0.83	0.38
Degrees of freedom	2/22				
R	0.91				
Adjusted R^2	0.76				
F-statistic	14.34***				

Notes: All notes in Tables 5.4 and 5.6 apply to this Table.

variable should be negative, indicating that rice farms far from their water source are at a disadvantage compared with those near the canal, because water supply diminishes as it passes over the nearer fields, and the possibility of obstruction or diversion of flow by farmers who have received enough water increases (Wickham and Valera 1979). However, in our case, the coefficients of the distance variable for the head section regression in both seasons (Tables 5.4 and 5.5) were positive and significant at the 1.0 per cent level, so farms in this section that were far from their water source had better average water depth (W) than those near their water source. This finding may have occurred because, in the head section, topography was hilly. Elevations varied between farms by location and there was, in fact, a negative correlation between distance from water source and elevation. And soil texture was lighter on farms near the water source and it has been observed that farms at lower elevations usually have somewhat heavier soils, and often have a higher water table, than those at higher elevations (Wickham and Valera 1979). These two factors could have caused water movement from upstream farms to those at lower elevations, which more than counterbalanced the normal relation between the distance and water depth (W).

In the body section the coefficient of the distance variable was negative as generally expected. This would have been influenced by the fact that the topography of this section was flat compared to the head section,[10] and the soil texture was medium. Thus, there was no counterbalance to the normal negative influence of distance on water depth (W). In the tail section the coefficient of the distance variable was also negative but was not significant at the 10 per cent level.

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10 The elevations of the head section were between 90 and 68 m above sea level with length of about 910 m. The elevations of the body section were between 55 and 40 m above sea level with distance of about 1,280 m from the upstream to downstream. The elevations of the tail section were between 17 and 9 m above sea level with length of about 2,600 m.

Other factors[11] affecting the average depth of water (W) in the dry season were the time of draining farms (TD) in the head and tail sections, the tenurial system in the head section, farm size in the body section, and rice farming experience in the tail section. The coefficient of TD was negative as expected, which means that the earlier the timing of drainage, the lower was the average depth of water (W) and vice versa. The positive coefficient of the tenurial dummy means that the average depth of water (W) of owner operators was greater than that of non-owner operators (i.e. share-croppers and fixed-rent operators). The farm size coefficient was also positive in the body section, and this implies that W was positively correlated with farm size, though farm size in this section was generally small, with a mean of 0.45 ha and a standard deviation of 0.23. In the tail section, the coefficient for experience was positive which means that farmers with more experience in rice farming had a greater average depth of water.

In the wet season, the most important factor affecting W in all sections of the study area was TD. The coefficients of TD, as in the dry season, were also negative, and so had the same meaning as above (Table 5.5). In the head section, distance, tenurial system, farm size and farming experience all had positive (as in the dry season) and significant coefficients in the wet season. In the body section, the tenurial system had a positive and significant coefficient, as it had in the dry season. In the tail section, other significant factors were education, experience, and farm size. The coefficient for education was positive which meant that the level of farmer education varied directly with the average depth of water. In contrast to the dry season, the coefficient for experience was negative and significant and thus was not consistent between seasons in this section.

Comparison of the constant terms of the section regressions (Tables 5.4 and 5.5) show the highest values in the body section,

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11 These are only factors for which coefficients were significant at the 10 per cent level.

and the lowest values in the head section for both seasons mean that the water at farm level was most adequate in the body section and was least adequate in the head section. This in turn could be explained by natural (e.g. soil texture and topography) and field water management factors. It has been mentioned above that the topography of the head section is hilly relative to that of the body and tail sections, and soil texture varies from light in the head to slightly heavy in the tail section. These natural factors could affect field water conditions in these sections. In the body and tail sections, farmers are members of their own water users organization (P3A). If the supply of water is not sufficient for their farms, they will complain to the irrigation officer through their organization. There was no such organization in the head section. Relatedly, farmers in the body and tail sections cleaned their irrigation channels every rice crop season which, as mentioned before, did not happen in the head section. Also, the leaders (formal and informal leaders) in the body and tail sections paid more attention to the problem of rice production, including irrigation problems, than those in the head section.

Number of Stress Days

The most important factor affecting the number of stress days from transplanting to 15 days prior to harvest (S) for the three sections of the study area in both seasons was the time of draining farms (TD) as shown in Tables 5.6 and 5.7. The coefficients of this variable were positive and significant, which means the earlier the farm drainage time, the higher the number of stress days.

Other factors affecting S in the dry season were the water source and variety dummy variables in the head section, and experience in rice farming in the tail section. These factors were significant statistically (Table 5.6). The coefficient of the water source dummy was negative, which, as expected, indicates that farms that received their water directly from channels had fewer stress days than those who received their water on a plot-to-plot system. The positive coefficient of the variety dummy variable implies that

Table 5.6 Regression coefficients of factors affecting the number of stress days from transplanting to 15 days prior to harvest (S), 1978 dry season.

Variable	Parameter b	Beta	t_b	Mean	S. Dev.
		Head section			
S				11.24	11.32
Constant	6.9805				
Time of draining	0.5919***	0.5314	3.29		
Water source dummy	-8.1043*	-0.3119	-1.86		
Variety dummy	6.1971*	0.2745	1.61		
Education	-0.2730	-0.0928	-0.58		
Distance	-0.0018	-0.0331	-0.21		
Tenurial dummy	0.4706	0.0211	0.13		
Degrees of freedom	6/22				
R	0.72				
Adjusted R^2	0.39				
F-statistic	3.99***				
		Body section			
S				5.20	5.75
Constant	-2.7526				
Time of draining	0.7938***	0.9106	9.22		
Water source dummy	-1.0299	-0.0771	-0.85		
Tenurial dummy	-0.8147	-0.0679	-0.81		
Variety dummy	-0.6079	-0.0533	-0.64		
Experience	-0.0093	-0.0179	-0.20		
Education	-0.0159	-0.0118	-0.13		
Farm size	0.3403	0.0138	0.16		
Distance	-0.0001	-0.0095	-0.10		
Degrees of freedom	8/21				
R	0.94				
Adjusted R^2	0.85				
F-statistic	20.84***				
		Tail section			
S				32.00	13.96
Constant	8.4003				
Time of draining	0.9755***	0.7721	5.61		
Experience	-0.2399*	-0.2516	-1.73		
Water source dummy	-6.0197	-0.1635	-1.19		
Education	-0.6923	-0.1244	-0.84		
Variety dummy	-4.1172	-0.0900	-0.68		
Distance	-0.0017	-0.0445	-0.34		
Tenurial dummy	0.4883	0.0151	0.10		
Degrees of freedom	7/22				
R	0.82				
Adjusted R^2	0.57				
F-statistic	6.43***				

Table 5.6 (Cont'd.)

Notes:

Water source dummy = 1 for farms whose water comes directly from channels, and it is zero otherwise.
Variety dummy = 1 for IRRI varieties and zero otherwise.
Tenurial dummy = 1 for owner operators and zero otherwise.

*	significant at the 10 per cent level.
**	significant at the 5 per cent level.
***	significant at the 1 per cent level.
without *	non-significant at the 10 per cent level or less, except for constant, because the SPSS program does not give the standard error of constant term.

Table 5.7 Regression coefficients of factors affecting the number of stress days (S), 1978/79 wet season.

Variable	Parameter b	Beta	t_b	Mean	S. Dev.
		Head section			
S				31.22	16.68
Constant	9.9556				
Time of draining	0.6698***	0.8487	8.62		
Tenurial dummy	-5.3852*	-0.1616	-1.72		
Experience	-0.1520	-0.1132	-1.21		
Farm size	-8.1173	-0.1049	-1.13		
Variety dummy	-1.3780	-0.0421	-0.46		
Distance	-0.0031	-0.0367	-0.39		
Water source dummy	-1.0046	-0.0280	-0.29		
Degrees of freedom	7/19				
R	0.93				
Adjusted R^2	0.82				
F-statistic	18.23***				
		Body section			
S				21.07	11.89
Constant	4.2595				
Time of draining	0.5884***	0.6744	3.79		
Experience	0.2252	0.2430	1.29		
Tenurial dummy	-5.1621	-0.2127	-1.18		
Education	-0.3817	-0.1086	-0.60		
Water source dummy	-2.5617	-0.0927	-0.62		
Distance	0.0024	0.0858	0.48		
Variety dummy	-1.7952	-0.0724	-0.42		
Farm size	3.0649	0.0662	0.38		
Degrees of freedom	8/21				
R	0.74				
Adjusted R^2	0.38				
F-statistic	3.23***				
		Tail section			
S				40.13	15.09
Constant	8.1736				
Time of draining	0.8933***	0.9765	16.91		
Tenurial dummy	2.8648*	0.0772	1.34		
Variety dummy	-2.2788	-0.0614	-0.98		
Water source dummy	1.7057	0.0428	0.68		
Experience	0.0203	0.0205	0.36		
Degrees of freedom	6/23				
R	0.97				
Adjusted R^2	0.92				
F-statistic	56.37***				

Notes: All notes in Tables 5.4 and 5.6 apply to this Table.

those farms that were planted with IRV had fewer stress days than those with NIV and LIV. In the tail section, the negative coefficient for experience suggested a reduction in stress days with greater experience.

In the wet season, apart from time of draining, the tenurial system also affected the number of stress days. However, the coefficient of this factor was not consistent between sections. Therefore, we cannot make a general conclusion for the effect of this factor on S.

The constant terms of the section regressions (Tables 5.6 and 5.7) indicate the lowest values in the body section for both seasons. This implies again that field water conditions were most adequate in the body section. The reasons for this are as discussed above.

In conclusion, variations in the average depth of water (W) among the sections were due partly to natural factors such as differentials in topography and soil texture, and partly to the way in which rice farmers utilized the irrigation facilities, particularly in the choice of the timing of farm drainage prior to harvest. The number of stress days (S) was heavily determined by the farm water management factor, i.e. the time of draining farms, rather than the natural factors.

<u>The Timing of Draining Farms</u>

The proportion of farmers who chose to drain their farms earlier than the recommended 20 days prior to harvest were 36, 17 and 100 per cent in the head, body, and tail sections respectively. Survey questions revealed two reasons for this practice.

First, there was a taboo against killing rats, and to protect their crops from rat attacks, farmers drained their farms earlier, rather than applying rodenticides. They believed that earlier draining toughened the rice stem, making it more difficult for rats to cut it, and easier for predators to catch the rats.

A second reason, given by most sample farmers in the tail section, was that their rice farm land was 'tanah rawang' or swampy land, and to facilitate harvesting, it must be drained much earlier than usual. Our field observations confirmed that a lot of rice fields in the tail section were on swampy ground.

As we can see later in Chapter 6 below, damage caused by rats was much higher in the head section than in the body section. This could be one reason why farmers in the head section drained their farms earlier than those in the body section. However, the action seemed to be ineffective, for if early draining farms was effective, the damage should be reduced.

Irrigation and Yields

The impact of irrigation on rice yields can be tested using a production function specifically including an irrigation variable. The foregoing discussion provides three possible variables that can be used to represent the irrigation, viz: i) the average depth of water per day from transplanting to 15 days prior to harvest (W), measured in mm/day; ii) the number of stress days from transplanting to 15 days prior to harvest (S); and iii) the timing of draining farms (TD) measured in the number of days before harvest.

Application of the Cobb-Douglas production function model in the dry season showed the impact of W on rice yield to be positive, and negative for S and TD (Table 5.8).

The positive effects of the average depth of water (W) on rice fields in the dry season can be attributed to a number of factors. On days when the depth of water was zero, the lack of water would have reduced rice yields directly. The larger the consecutive sequence of zero water depth, the more severe the drought would be, and so too the yield reduction. Second, weed growth flourishes in the absence of, or with limited, water. Third, nutrient availability is generally higher in flooded soil than in non-flooded soil, so there is a higher efficiency of fertilizer utilization under flooded

Table 5.8 Estimated Cobb-Douglas production functions for sample rice farms in the Badenah irrigation system, 1978 dry season.

Variable	Parameter		
	Model A	Model B	Model C
Constant (ln a)	3.3003*** (2.95)	4.2303*** (3.90)	4.1533*** (3.80)
Labour (ln L)	0.3966*** (3.29)	0.3745*** (3.03)	0.3811*** (3.05)
Water depth (ln W)	0.2712** (2.15)	-	-
Stress days (ln S)	-	-0.0172* (-1.34)	-
Time of draining farms (ln TD)	-	-	-0.0113 ns (-0.37)
Nitrogen (ln N)	0.1392** (1.83)	0.1530** (1.95)	0.1651** (2.07)
Crop damage (ln D)	-0.0676** (-1.71)	-0.1097*** (-3.13)	-0.1105*** (-3.12)
Other costs (ln C)	0.1359 ns (1.05)	0.1357 ns (1.02)	0.1360 ns (1.02)
Number of observations	89	89	89
R^2	0.41	0.38	0.37
F-test	11.29***	10.17***	9.87***

Notes:

Model A applying W as an irrigation variable.
Model B applying S as an irrigation variable.
Model C applying TD as an irrigation variable.
*** Significant at the 1.0 per cent level.
** Significant at the 5.0 per cent level.
* Significant at the 10 per cent level.
ns Not significant at the 10 per cent level.

Figures in brackets are respective t-values of parameters.

conditions. The coefficient of W in the dry season was 0.2759 which means that raising or lowering the average water depth one per cent, with other variables constant, will raise or lower yields by about 0.28 per cent.

The impact of an increasing number of stress days (S) on rice yields was negative, i.e. it reduced yields. This is due to the same factors as influence yield through water depth but in an inverse direction. With increasing stress days, crop response to nitrogen is inhibited; there is greater competition between weed and rice crop for the available soil nutrients; total nutrient availability is lower and at a certain point, drought conditions are induced which reduce crop roots ability to absorb nutrient from soil. A sustained drought period will be fatal to the crop.

The sign of the coefficient of TD was also negative but the coefficient was not statistically significant. So variations in TD apparently do not affect yields. This could be because the highest figure for TD in the dry season (i.e. earliest timing of draining) was in the tail section (Table 5.3) where the reason given by farmers for draining farms early was that their farm land was swampy. Thus, early TD there may not automatically reduce soil below saturation level even though the depth of water was zero.

In the wet season (Table 5.9), the coefficients of the irrigation variables (W, S and TD) were not significant at the 10 per cent level or less. This implies that variations in W, S and TD did not affect rice yields. This may be because, during this season, water supplies are not such a problem as in the dry season because the number of rainy days is higher. Therefore, although the number of stress days was higher in the wet season (Table 5.3), their impact on soil moisture was not significant and could be ignored.

The following multiple regression equations show clearly the impact of irrigation variables (W, S, and TD) on rice crop response to nitrogen.

Table 5.9 Estimated Cobb-Douglas production functions for sample rice farms in the Badenah irrigation system, 1978/79 wet season.

Variable	Parameter		
	Model A	Model B	Model C
Constant (ln a)	5.4843*** (5.13)	5.4278*** (5.71)	5.2407*** (5.23)
Labour (ln L)	0.1827* (1.31)	0.2180* (1.54)	0.1861* (1.33)
Water depth (ln W)	-0.0423^{ns} (-0.37)	-	-
Stress days (ln S)	-	-0.0266^{ns} (-0.98)	-
Time of draining farms (ln TD)	-	-	0.0152^{ns} (0.18)
Nitrogen (ln N)	0.2132*** (2.80)	0.2124*** (2.82)	0.2133*** (2.74)
Crop damage (ln D)	-0.2025*** (-4.75)	-0.2026*** (-5.84)	-0.2002*** (-5.73)
Other costs (ln C)	0.1040^{ns} (0.91)	0.0895^{ns} (0.78)	0.1099^{ns} (0.97)
Number of observations	87	87	87
R^2	0.44	0.44	0.44
F-test	12.69***	12.99***	12.65***

Notes:

All notes in Table 5.8 apply to this Table.

$$Y = -69.7859 + \underset{(6.73)}{0.5142^{***}}\,NW + \underset{(2.90)}{621.4762^{***}}\,T + \underset{(2.26)}{398.5110^{**}}\,M$$

$$- \underset{(-1.86)}{289.5317^{**}}\,V + \underset{(1.80)}{396.4499^{**}}\,WS - \underset{(-0.45)}{0.0987^{ns}}\,N^2 + \underset{(1.31)}{15.5600^{*}}\,N$$

$$+ \underset{(0.63)}{41.5395^{ns}}\,W - \underset{(-0.44)}{0.7688^{ns}}\,W^2 \qquad (5.1)$$

($R^2 = 0.46$; F-test = 7.56***; n = 89)

$$Y = 409.0583 + \underset{(5.73)}{29.8486^{***}}\,N - \underset{(-3.76)}{0.4131^{***}}\,NS + \underset{(2.98)}{635.6982^{***}}\,T$$

$$+ \underset{(2.62)}{409.1279^{**}}\,M - \underset{(-1.17)}{0.0969^{ns}}\,N^2 + \underset{(0.96)}{230.4408^{ns}}\,WS - \underset{(-0.72)}{120.0567^{ns}}\,V$$

($R^2 = 0.45$; F-test = 9.32***; n = 89) (5.2)

$$Y = 279.2687 + \underset{(5.48)}{29.0588^{***}}\,N + \underset{(2.78)}{628.779^{**}}\,T - \underset{(-2.47)}{0.2868^{**}}\,NTD$$

$$+ \underset{(2.57)}{424.3166^{**}}\,M + \underset{(1.38)}{367.1140^{*}}\,WS - \underset{(-1.08)}{177.4742^{ns}}\,V$$

$$- \underset{(-0.79)}{0.0751}\,N^2 + \underset{(0.17)}{1.9115}\,TD \qquad (5.3)$$

($R^2 = 0.40$; F-test = 6.77^{***}; n = 89)

where Y = yield (kg paddy/ha); N = nitrogen used (kg N/ha); NW = interaction between W and N (N x W); NS = interaction between N and S (N x S); NTD = interaction between N and TD (N x TD); N^2 is a squared N; W^2 is a squared W; W, S, and TD are as defined above; T, V, and WS are dummy variables as defined in Table 5.4 above; M is a dummy variable for merantau experience (M = 1 for those who had migration experience, and others M = 0). Figures in brackets are respective t-values of the coefficients.

The coefficient of NW was positive and highly significant at the 1.0 per cent level. This implies that a deeper average depth of water improves the rice crop response to nitrogenous fertilizer (5.1). On hand

the other, the coefficient of NS was negative and also significant at the 1.0 per cent level. This indicates that an increasing number of stress days reduces the rice crop response to nitrogen (5.2). The interaction term between nitrogen and time of draining (NTD) was also negative and significant at the 5.0 per cent level. This shows that draining farms earlier inhibits the crop response to nitrogen by increasing the number of stress days (5.3).

It should be noted that these findings, especially the sign of the interaction term NS, corresponds with those in a study by Rosegrant (1976). It does, however, differ with those in another study by Wickham (1973). Wickham found that the interaction term NS had positive coefficients. Wickham argued that the positive NS interaction term indicated that a greater incidence of stress days was accompanied by more nitrogen use. He claimed that the positive interaction between N and S could be expected for two reasons: 'First, higher nitrogen levels encourage greater root development which expands the volume of soil from which the plant can attempt to extract moisture. Second, extensive losses of soil nitrogen have been documented in puddled soils which have been allowed to dry out, and then flooded again. When nitrogen is lost this way the crop's subsequent requirement can only be met by additional application'.

Thus, the sign of the interaction coefficient between N and S is still controversial. However, to this writer, the negative sign allows a more logical relationship than that suggested by the positive sign, since the negative coefficient indicates that stress days inhibit the crop response to nitrogen use. As Table 5.3 shows the amount of N used was inversely related to the number of stress days in both seasons.

Equations (5.1) to (5.3) were fitted by using the dry season data. When we fit the multiple regression model to the wet season data, the results were not satisfactory. All coefficients of the irrigation variables (W, S, and TD) were non significant at the 10 per cent level or less, and some of their signs were not as expected. The coefficients of NW, NS, and NTD were non significant at the 10 per cent level or less, but all of their signs were correct as expected. This is consistent with the results of the CD production function for the wet season above (Table 5.7), where the coefficients of W, S, and TD were non significant either at the 10 per cent level. And this, as mentioned above, was due to the fact that, during the wet season, water supplies were not such a problem as in the dry season because the number of rainfall and rainy days were higher in the wet season. Therefore, variations in NW, NS, and NTD did not affect significantly the crop response to nitrogen in the wet season, because the impact of S on soil moisture was not significant and could be ignored.

Conclusions

The foregoing analysis allows the following conclusions:

1. Water availability for the rice crop within the Badenah irrigation command area was inversely related to the distance of the farm from the headworks of the irrigation system (Tables 5.1 and 5.2). However, even with these variations, actual supplies of irrigation water in all sections, as reported by sample farmers and our rough calculations, were more than adequate (Table 5.2).

2. Farm water conditions were most adequate in the body section and were least adequate in the tail section in both seasons (Tables 5.4 and 5.5), which implied that the condition of water at the field level did not only depend upon the supplies of irrigation water, but also and importantly, on the way in which farmers used the irrigation facilities and upon natural factors such as topography and soil texture differentials (Tables 5.4-5.7).

3. Variations in farm water conditions significantly affected rice yields, especially in the dry season (Table 5.8). In the wet season they did not affect yields significantly because in the wet season water was plentiful owing to a high number of rainfall and

rainy days (Table 5.9).

4. The rice crop response to nitrogen was significantly influenced by farm water conditions. The interaction between the average depth of water and nitrogen was positively correlated which meant that deeper water encouraged higher crop response to nitrogen. Conversely, stress and early draining of farms inhibited the crop response to nitrogen (Equations 5.1-5.3). These findings are consistent with the Ishikawa model discussed in Chapter 4 above, and the study finding of Rosegrant (1976).

5. The levels of nitrogen applied were also determined by water conditions at field level. Up to a certain point, the higher the average depth of water the higher was the level of nitrogen applied. Conversely, the higher the number of stress days, the lower was the level of nitrogen applied (Table 5.3).

6. There was no significant difference in the efficiency of water utilization between farms which took water directly from channels and those which received it from other farms (plot-to-plot system)(Tables 5.1-5.7). This implies that water conditions at field level are heavily determined by the availability of water supplied rather than by the density of field channels. This finding is consistent with the results of other studies by Tabbal and Wickham (1979), and Priyono (1980).

CHAPTER 6

TECHNOLOGICAL PERFORMANCE

This chapter considers the technological performances of sample rice farmers (as defined in Chapter 3) by means of comparison of these farmers grouped by:

a. location, i.e., the head, body and the tail sections;[1]

b. tenurial system, i.e., owner, fixed-rent and share-crop operators;[2]

c. rice variety, i.e., international varieties (IRV), national improved varieties (NIV), and local improved varieties (LIV);[3] and,

d. water source, i.e., between rice farms which take irrigation water directly from channels and those which receive it indirectly through other farms (plot-to-plot irrigation system).[4]

The comparisons are made by analysing the relationships between irrigation and other inputs and output, using the Cobb-Douglas production function model. Information on these relationships can

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1 Based on an IRRI finding (IRRI, 1974), it was hypothesized that yields are highest in the head section and lowest in the tail section.

2 Theoretically, different tenurial systems do not imply different efficiencies of resource use as long as these systems are themselves aspects of private property rights (Cheung, 1969, p.4).

3 It was hypothesized that the average yields of IRV are higher than those of NIV and LIV.

4 It was hypothesized that the average yields of farms which receive irrigation water directly from irrigation channels are higher than those of farms with a plot-to-plot irrigation system.

be used in reaching decisions on the allocation of irrigation water among rice farms in the command area of an irrigation system, and of factors of production among individual farm units or geographic areas.[5]

There is a general belief among scientists concerned with rice in developing countries that few farmers are fully exploiting the potential of rice production technology, and therefore, that yields of rice farms are far below their potential.[6] There are two kinds of yield gaps: i) between experiment station and potential farm yield, and ii) between potential and actual farm yield. The first can be caused either by non-transferable technology, by environmental differences, or by both. The second, of principal concern in this study, can be caused by biological constraints (e.g., variety, water, soil fertility, pests and diseases) and/or socioeconomic constraints (e.g., on profit, credit facilities, tradition, input availability, institutions, and attitudes).[7]

Falcon (1970) summarised the general problems of usage and impact of new high yielding varieties in terms of three categories of problems. The first category arises with the adoption of the new technology. In this, one of the most severe constraints is lack of adequate and controllable water supplies; another is the inadequacy of pesticide programs. The second category involves the problem of marketing, markets and resource allocation. The third category includes socioeconomic problems and problems of risk and uncertainty.

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[5] See Headley, J.C. and V.W. Ruttan (1966), 'Regional differences in the impact of irrigation on farm output', in Smith, S.C. and E.N. Castle (eds.), Economic and public policy in water resource development, Iowa State University Press, 1966, pp.127-149.

[6] Barker, R., Kauffman, H.E., and R.W. Herdt (1975), Production constaints and priorities for research, a paper presented at an IRRI conference, Los Banos, April 21-25.

[7] IRRI (1977), Constraints to high yields on Asian rice farms: an interim report, Los Banos, Philippines, pp.1-2.

A number of studies of these problems have been carried out to find the specific nature and magnitude of constraints on high rice yields in a number of rice producing countries, and in regions within these countries.[8] The findings showed that problems of adoption of the new rice technology differed between countries, between regions within a country, and indeed between areas within a region. The analysis that follows here examines these adoption problems within the Badenah irrigation system in West Sumatra, Indonesia.

Yield Performance of Sample Farms

General Performance

Average yields of sample farms (1.96 mt paddy/ha in the dry season and 1.74 in the wet season)[9] were much lower than the 1977 average yields officially reported for the Badenah irrigation command area (5.1 mt paddy/ha),[10] for West Sumatra's wet paddy fields (3.7 mt paddy/ha),[11] and for the Bandar Buat experiment Station in 1975

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[8] See for example in: Shand, R.T., Ed. (1973), Technical change in Asian agriculture, Australian National University Press, Canberra; International Rice Research Institute, IRRI (1975), Changes in rice farming in selected areas of Asia, Los Banos, Philippines; IRRI (1977), Constraints to high yields on Asian rice farms: an interim report, Los Banos, Philippines; IRRI (1978), Interpretive analysis of selected papers from changes in rice farming in selected areas of Asia, Los Banos, Philippines; IRRI (1978), Economic consequences of the new rice technology, Los Banos, Philippines.

For water management problems see, e.g.: Asian Productivity Organization, APO (1977), Farm water management for rice cultivation, Tokyo, Japan; Taylor, D.C. and T.H. Wickham, Eds. (1979), Irrigation policy and management in Southeast Asia, The Agricultural Development Council, Inc., Bangkok.

[9] See Table 6.1.

[10] Suhatman Aziz (1978), Laporan khusus exploitasi dan pemeliharaan irigasi Badenah I/II Gunung Nago, Dinas Pekerjaan Umum Daerah Sumatera Barat Selatan, Padang.

[11] BAPPEDA SUMBAR (1978), Sumatera Barat Dalam Angka 1977, Padang p.287.

Table 6.1 Average yields and inputs used per hectare by sample farm groups, Badenah irrigation system, 1978 dry and 1978/79 wet seasons.

Categories	1978 dry season											
	n	yield	CD	AWD	NSD	TD	N	P	PC	TL	FL	FS
All farms	89	1.96	29.6	17	16	24	47	27	3.0	106	70	0.46
Section												
Head	29	1.84[a]	34.8[a]	12[a]	11[a]	16[a]	53[a]	32[a]	3.2	107[a]	69	0.39
Body	30	2.57[b]	9.9[b]	25[b]	5[b]	12[b]	62[b]	31[a]	3.9	123[b]	77	0.45
Tail	30	1.48[c]	17.6[c]	14[a]	32[c]	45[b]	27[c]	17[b]	1.9	87[c]	65	0.54
Land tenure status												
Owner operator	30	1.75[a]	26.4[a]	17[a]	15[a]	23	53[a]	29	3.8[a]	109	76	0.40
Fixed-rent operator	8	3.03[b]	11.6[b]	24[b]	6[b]	18	66[b]	35	5.2[b]	117	85	0.51
Share-cropping	51	1.92[a]	18.6[c]	16[a]	19[a]	27	41[a]	24	2.2[c]	102	65	0.49
Rice variety												
IRV (international)	52	1.83	18.9	16	21[a]	31[a]	44	22[a]	3.0	99	67	0.50[a]
NIV (national)	17	2.22	22.7	19	8[b]	14[b]	50	27[b]	3.3	128	76	0.34[b]
LIV (local)	20	2.08	23.2	16	11[c]	16[b]	52	39[c]	2.6	103	74	0.45[a]
Water source												
From channels	68	1.99	20.0	17	15	24	46	27	3.1	109	71	0.47
Plot-to-plot	21	1.83	22.7	16	20	25	51	26	2.9	92	66	0.44

Notes: yield = mt paddy/ha, CD = crop damage (% crop area), AWD = average water depth/day from transplanting to 15 days prior to harvest (in mm), NSD = number stress days from transplanting to 15 days prior to harvest, TD = time of draining farms (days before harvest), N = nitrogen applied (kg N/ha), P = phosphorous (kg P_2O_5/ha), PC = pest control (Rp '000/ha), TL = total labour used (mandays/ha), FL = family labour used (mandays/ha), FS = farm size (in ha), and n = sample size.

Table 6.1 (cont'd)

Categories	1978/79 wet season										
	n	yield	CD	AWD	NSD	TD	N	P	PC	TL	FL
All farms	87	1.74	28.6	15	31	44	42	23	2.5	97	66
Section											
Head	27	1.67^{a}	35.3^{a}	10^{a}	31^{a}	48^{a}	45^{a}	33^{a}	3.1	96^{a}	65
Body	30	2.03^{b}	23.1^{b}	21^{b}	21^{b}	30^{b}	61^{b}	23^{b}	2.2	111^{b}	76
Tail	30	1.50^{c}	28.0^{a}	15^{a}	40^{c}	54^{a}	20^{c}	13^{c}	2.2	85^{c}	58
Land tenure											
Owner operator	28	1.67^{a}	27.6^{a}	17	27^{a}	42^{a}	46^{a}	22	3.7^{a}	98	72
Fixed-rent	7	2.17^{b}	38.1^{b}	18	21^{a}	33^{b}	48^{a}	27	4.1^{b}	98	54
Share-cropping	52	1.71^{a}	27.8^{a}	14	34^{b}	46^{a}	39^{b}	22	1.7^{c}	97	64
Rice variety											
IRV (international)	57	1.75	29.1	16	31^{a}	45^{a}	40	21	2.8^{a}	94^{a}	64
NIV (national)	9	1.71	24.7	17	20^{b}	29^{b}	54	23	1.4^{b}	127^{b}	102
LIV (local)	21	1.72	28.9	13	34^{a}	47^{a}	42	27	2.1^{a}	93^{a}	59
Water source											
From channels	67	1.73	30.1	16	30	43	42	23	2.7	100	67
Plot-to-plot	20	1.75	23.6	14	35	48	41	22	1.8	88	64

Notes: Values for groups within a category with the same superscript letters within a column indicates differences between the values are not significant, and vice versa.

(3.3 mt paddy/ha).[12]

One reason for the yield differentials was the difference in methods of collecting yield data. Average yields of sample farms in this study were based on production as reported by sample farmers. Those of the Badenah irrigation command area were based on crop cutting sample as reported by the irrigation office. Calculations of the average yields of West Sumatra were also based on a crop cutting sample in each rice producing Kecamatan (sub-district) in the province. The average yields on the experiment station were total harvest measurements, which are only possible on such small areas.

A study in Kulon Progo, Yogyakarta, Indonesia, by Widodo et al.[13] showed that the average yields from survey data (2.68 mt paddy/ha) were also much lower than those obtained by crop cutting (5.62 mt/ha) and from experimental (3.15 mt/ha) data. In a study in the Philippines, Wickham[14] also obtained that average yields from survey data were 30 per cent lower than those from crop cutting data.

These yield differentials could be due to the methods of calculating yields. Yields from survey data were calculated by dividing farm output, as reported by the farmer, by area cropped. Yields from crop cutting were obtained by measuring the output of a crop area of 10 x 10 metres, and then from which yields per hectare were obtained by multiplying by one hundred.

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[12] Yusuf, M. (1976), Percobaan pemupukan N secara individual pada tanaman padi sawah, Dinas Pertanian Rakyat Sumatera Barat, Padang (Mimeo). The location of the Bandar Buat Experiment Station was only about 4 km south-east of the study area.

[13] Widodo, S. et al. (1977), "Indonesia", in IRRI (1977), Constraints to high yields on Asian rice farms: an interim report, Los Banos, Philippines, pp.45-114.

[14] As explained by Dr. T.H. Wickham to the author in a private communication in December 1979.

Yield differentials in this study area could be also due to the high percentage of pest and disease damage during the survey period, i.e. around 30 per cent of the total crop area (Table 6.1) as reported by sample farmers. Data for all sample farms indicate that crop damage reduced average yields by as much as 0.47 and 0.66 mt paddy per hectare in the dry and wet seasons respectively. With crop damage excluded, the average adjusted yields of the study area are much higher than the actual average yields (Table 6.2). The average adjusted yields were still highest in the body section among location groups, and for the fixed-rent system among tenure groups. Thus, the high yields in the body section and in the fixed-rent system were due not only to lower levels of crop damage, but also owing to other factors discussed below.

Both actual and adjusted yields were higher in the dry than in the wet season, except for the tail section and plot-to-plot irrigation groups. This could have been due to the higher level of solar radiation in the dry season.[15]

Group Performances

Average yields, both actual and adjusted between groups of farmers differed significantly only within location and tenure categories (Tables 6.1 and 6.2).

Amongst locations, the highest average yields were found in the body section in both dry and wet seasons (Table 6.2). This finding is at variance with the common hypothesis that the best performance will be found in the head section in accordance with availability of irrigation water. This finding does not necessarily contradict IRRI's results referred to above (IRRI 1974, and Herdt and Wickham 1978), for as in the IRRI study, our field observations

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15 See Montano, C.B. and R. Barker (1971), 'The Economic Significance of the Relationship Between Rice Yield, Nitrogen Input and Solar Energy', in IRRI (1971), Rice Policy Conference: Current Papers for the Department of Agricultural Economics, Los Banos, Philippines.

Table 6.2 Actual and adjusted yields by groups of sample rice farmers in the Badenah irrigation area, 1978 dry and 1978/79 wet seasons.

Categories	Actual yield		Adjusted yield*)	
	Dry season	Wet season	Dry season	Wet season
All farms	1.96 (0.78)	1.74 (0.79)	2.43 (1.02)	2.40 (0.87)
Section				
Head	1.84[a] (0.84)	1.67[a] (0.65)	2.61[a] (0.96)	2.41[a] (0.84)
Body	2.57[b] (0.96)	2.03[b] (0.88)	2.91[b] (1.17)	2.76[b] (1.00)
Tail	1.48[c] (0.46)	1.50[c] (0.81)	1.79[c] (0.47)	2.03[c] (0.73)
Tenure				
Owner operator	1.75[a] (0.83)	1.67[a] (0.70)	2.19[a] (0.84)	2.31[a] (0.86)
Fixed-rent	3.03[b] (1.01)	2.17[b] (1.38)	3.53[b] (1.37)	3.35[b] (1.50)
Share-cropping	1.92[a] (0.82)	1.71[a] (0.77)	2.41[c] (0.97)	2.32[a] (0.78)
Variety				
IRV	1.83 (0.88)	1.75 (0.86)	2.22[a] (0.96)	2.36 (0.96)
NIV	2.22 (0.99)	1.71 (0.89)	2.72 (1.08)	2.29 (0.64)
LIV	2.08 (0.83)	1.72 (0.66)	2.75 (1.04)	2.56 (0.89)
Water source				
From channels	1.99 (0.95)	1.73 (0.88)	2.45 (1.06)	2.37 (0.94)
Plot-to-plot	1.83 (0.69)	1.75 (0.52)	2.39 (0.88)	2.49 (0.82)

Notes: Yield is measured in mt paddy/ha. Figures in brackets are standard deviations of yields. Values between groups within a category with different letters within a column, indicate difference between the two values are significant at the 10 per cent level.

*) Adjusted yields were calculated by using the following formula,

$$Y_a = Y/(1-D)$$

where Y_a is the adjusted yield, Y is the actual yield, and D is the percentage of crop area damage caused by pests and diseases within total crop area.

and calculations showed that the amount of water available along the lateral distribution system was inversely related to distance from the headworks of the irrigation system. It does, however, suggest that farm water availability depends not only on the amount of water made available to it, but also and importantly, on natural factors and farm water management as discussed in Chapter 5 above. The highest average yield in the body section is also consistent with the fact that sample farmers there applied the highest average levels of irrigation water (AWD), nitrogenous fertilizer (N), and labour inputs (TL) (Table 6.1). Also, the average number of stress days were lowest in the body section.

Amongst tenure groups, the best performance was recorded by the fixed-rent farmer, and the average yield of the share-cropper was higher than that of the owner operator in both seasons (Table 6.2). The performance of the fixed-rent operator also coincided with the highest levels of input applications, and the lowest number of stress days. However, as discussed below, average yield variations between the tenurial groups depended not only upon differentials in levels of input applications but also upon differences in technical efficiency.

Average yields of rice varieties did not differ significantly, except for the average adjusted yield in the dry season (Table 6.2). The principal superiority of IRV over other varietal groups (NIV and LIV), emphasized by rice scientists, is the greater yield response of the former to fertilizers. The response in this study was positively related to water conditions in the field (as discussed in Chapter 5). In the study area, the level of nitrogen applications to IRV was lower than that to NIV and LIV (Table 6.1), and the number of stress days was higher for the IRV than for the NIV and LIV. Thus the lower yield of IRV in the study area could be due to water availability problems.

There was no significant difference in average yields between farmers grouped by water sources in either season. Neither did the level of input applications in the two groups vary significantly. Thus, differences in water sources did not affect rice yields in the study area, which means that variations in field channel density did not affect yield significantly. This finding corroborates the results of a study in the Philippines by Tabbal and Wickham (1979) and another study in Indonesia by Priyono (1980).

Identifying Yield Variations

Three possible factors were responsible for yield variations among groups of farmers:

a. differences in the levels of average input applications, with identicical technical efficiencies;

b. technical efficiency variations with the same average level of input applications; and

c. differentials in both technical efficiency and average levels of input applications.

The following analysis below will show the contributions of these factors to yield variations in the study area.

Production Function Analysis

The Cobb-Douglas (CD) production function model (equation (3.6) in Chapter 3) was fitted to the data of all sample farms. The results, without including dummy variables, with four different irrigation variables, are reported in Table 6.3. The average depth of water (W), the number of stress days (S), the timing of draining farms (TD), and the ratio of W to S (I) were applied in equations I, II, III and IV respectively as the irrigation variable.

The Selection of Irrigation Variable

The results show that equations I and IV gave the best fit (values of adjusted R^2 and F-test) and were almost the same. Their superior fit over equations II and III is consistent with the fact

Table 6.3 Estimated average Cobb-Douglas production functions for sample rice farms in the Badenah irrigation system, 1978 dry season.

Variable	Equations			
	I	II	III	IV
Constant (ln a)	3.3004	4.3430	4.1532	4.1527
ln W	0.2711*** (4.08)	-	-	-
ln S	-	-0.0643** (-1.79)	-	-
ln TD	-	-	-0.0133^{ns} (-0.38)	-
ln I	-	-	-	0.0636*** (3.70)
ln N	0.1392** (2.55)	0.1226*** (3.38)	0.1651*** (3.27)	0.1151** (2.30)
ln L	0.3967*** (5.55)	0.3623*** (5.55)	0.3810*** (5.37)	0.3647*** (5.55)
ln D	-0.0676* (-1.64)	-0.1035*** (-3.12)	-0.1105*** (-3.02)	-0.0938** (-2.50)
ln C	0.1359^{ns} (1.06)	0.1514^{ns} (1.18)	0.1360^{ns} (0.99)	0.1521^{ns} (1.19)
No. of observations	89	89	89	89
R^2	0.40	0.40	0.37	0.40
Adjusted R^2	0.37	0.36	0.34	0.37
F-test	11.29***	10.85***	9.87***	11.19***

Notes: Equation I had the water depth (w) variable; equation II had the number of stress days (S) variable; equation III had the time of draining farms (TD) variable; and equation IV had the I (W/S) variable.

*** Significant at the 1.0 per cent level.
** Significant at the 5.0 per cent level.
* Significant at the 10 per cent level.
ns Not significant at the 10 per cent level.
Figures in brackets are respective t-values.

that variations in TD (equation III) did not affect yields directly (the coefficient of TD was not significant), but indirectly through S and W variables. Variations in S (equation II) did affect yields significantly but they did not include the effects of variations in the average depth of water per day. On the other hand variations in W were affected both by S (i.e. when W = 0) and TD and significantly influenced yields. W is therefore a much more sensitive irrigation variable than S and TD. But, W has a weakness, because it is possible for the values of W for two farms to be the same whilst the numbers of stress days (S) vary significantly, and the latter factor can result in differences in yields. The best irrigation variable was given by the ratio between the average depth of water (W) and the number of stress days (S), i.e. I variable, and this was used as the irrigation variable in the further analysis with the CD function in this study.

Production Function Tests Between Groups of Farmers

Our Cobb-Douglas production function model can be written as,

$$\ln Y = \ln a + b_1 \ln I + b_2 \ln N + b_3 \ln L + b_4 \ln D + b_5 \ln C \qquad (6.1)$$

where I is the irrigation variable (W/S) and other notations are the same as in the equation (3.6).[16] This model was fitted to data arranged by location, i.e., head, body and tail sections, and a production function was estimated for each section (Table 6.4).

The analysis then tested whether the three estimated functions varied significantly or not, and whether the production elasticities of the inputs differed between locations. The following F-test,

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Variables Y (yield), L (labour), N (nitrogen), and C (other variable costs) are on per hectare basis; and variable D is the percentage damage of the crop area of a farm.

Table 6.4 OLS estimated Cobb-Douglas production functions for sample farms arranged by location, 1978 dry season.

Variable	Parameter				
(1)	All farms (2)	Head+Body (3)	Head (4)	Body (5)	Tail (6)
Constant (ln a)	4.1527	3.7986	1.5655	4.1230	4.4314
Irrigation (ln I)	0.0636***	0.0812**	0.1274**	....	....
	(3.70)	(2.61)	(1.73)		
Nitrogen (ln N)	0.1151**	0.0889^{ns}	-0.0524^{ns}	0.2254*	0.1538**
	(2.30)	(0.052	(-0.19)	(1.57)	(2.40)
Labour (ln L)	0.3647***	0.3961***	0.2833**	0.4114***	0.3817**
	(5.55)	(3.82)	(2.29)	(2.83)	(2.22)
Crop damage (ln D)	-0.0938**	-0.0801*	-0.3029**	-0.0277^{ns}	-0.1115***
	(-2.50)	(-1.38)	(-1.98)	(-0.47)	(-3.47)
Other costs (ln C)	0.1521^{ns}	0.1787*	0.6060*	0.0807^{ns}	0.1012^{ns}
	(1.18)	(1.41)	(1.53)	(0.43)	(0.75)
R^2	0.37	0.24	0.39	0.23	0.21
F-test	11.19***	5.09***	2.90**	2.71**	5.44***
RSS	13.9574	12.0716	6.2092	3.8306	1.7561
n	89	59	29	30	30
K	6	6	6	6	6

Notes: Figures in brackets are respective t-values; *** significant at the 1.0 per cent level; ** significant at the 5.0 per cent level; * significant at the 10 per cent level; ns not significant at the 10 per cent level.

.... F-level is insufficient for further computation.

suggested by Chow[17] was used to answer these questions.

$$F_o = \frac{(RSS_{12} - RSS_1 - RSS_2)/K}{(RSS_1 + RSS_2)/(n_1+n_2-2K)} \tag{6.2}$$

where F_o = the observed F ratio, RSS = Sum of squares of the residual (12 represents the pooled sum of squares of samples 1 and 2), K = the number of estimated parameters including the constant term, n_1 and n_2 are the number of observations of functions 1 and 2 respectively. Degrees of freedom of the F_o ratio are $v_1 = K$ and $v_2 = (n_1+n_2-2K)$.

To test whether the sets of coefficients of the head and the body regressions are significantly different, data for the head and body sections were pooled to estimate the pooled production function for these sections. Then the RSS of the pooled head and body functions (Table 6.4, columns 3, 4 and 5 respectively) were substituted in equation (6.2), which could then be written as,

$$F_o = \frac{(RSS_{HB}-RSS_H-RSS_B)/K}{(RSS_H+RSS_B)/(n_H+n_B-2K)} = \frac{(12.07-6.21-3.83)/6}{(6.21+3.83)/(59-12)}$$

$$= \frac{(0.32)}{(0.21)} = 1.51$$

with degress of freedom (d.f) $v_1 = 6$ and $v_2 = 47$.

$$F_{0.05} = 2.30 \text{ (for } v_1 = 6 \text{ and } v_2 = 47)$$

$$\text{Since } F_o < F_{0.05} \quad (1.51 < 2.30)$$

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17 Chow, G.C. (1960), 'Test of equality between sets of coefficients in two linear regressions', Econometrica, Vol.28, July July 1960, pp.591-605. Equation (6.2) is adapted from Koutsoyiannis (1977, p.166), and see also Etherington (1973, pp.38-55) and Johnston (1963, pp.136-139).

the hypothesis that the sets of coefficients (not including the constant terms) between the head and the body regressions were significantly different was rejected.

To test whether the sets of coefficients between the pooled production function of the head and the body regression and that of the tail regression (Table 6.4, columns 3 and 6) were significantly different, all data of the three sections were pooled to estimate the production function for the whole study area. The RSS of the whole area (RSS_W), of the pooled function of the head and the body section (RSS_{HB}), and of the tail section (RSS_T) were substituted in equation (6.2) which gave,

$$F_c = \frac{(RSS_W - RSS_{HB} - RSS_T)/K}{(RSS_{HB}+RSS_T)/(n_{HB}+n_T-2K)} = \frac{(13.96-12.07-1.76)/6}{(12.07+1.76)/77}$$

$$= \frac{0.02}{0.18} = 0.12$$

with degrees of freedom $v_1 = 6$ and $v_2 = 77$.

Since $F_{0.05} = 2.19$ (for $v_1 = 6$ and $v_2 = 77$), which again showed that $F_c < F_{0.05}$ (0.12 < 2.19), the hypothesis that the sets of coefficients between the tail regression and the pooled regression of the head and the body sections were significantly different was rejected. The above calculations thus show that all three section production functions have the same sets of coefficients.

Using the same techniques as above, it was also found that there were no significant differences amongst the sets of coefficients of the production functions for farm tenure groups, i.e. between owner operators, fixed tenants, and share-croppers, amongst varietal groups (IRV, NIV and LIV growers), or between water source groups, in either season. These calculations also imply that if there was any difference between two production functions of two groups of farmers in the study area it would only have been due to differences in intercepts, and not in the slopes of the functions. Thus the assumption that the shift between the curves was of a Hicks-neutral type was also tested and accepted in this study.

Average Production Function for the Study Area

The Cobb-Douglas production function model of equation (6.1) was fitted to the data from all sample farms in two ways. The first application included the crop damage variable as an independent variable, and actual yields were used as the dependent variable. On the second application the crop damage variable was excluded from the function, and adjusted yields were used as the dependent variable. The results of the estimated production functions for both models are reported in Table 6.5.

The F-test values for production functions of both models in both seasons were significant at the 1.0 per cent level. This means that the hypothesis that all coefficients (except for the intercepts) of the production functions are equal to zero is rejected. The adjusted coefficients of multiple determination ($\bar{R}^2$) are in a sense disappointingly low. However, it is important to note that only cross-sectional data are involved in the functions, and it is therefore probably not reasonable to expect a high R^2 (Taylor et al. 1979 as quoted by Priyono 1980).

The results also show that the coefficients for irrigation water conditions (I) in both models (equations I and II) were significant only in the dry season. This is consistent with the results obtained in Chapter 5. They imply that a one per cent increase in the ratio of the average water depth to the number of stress days increases yield by 0.06 per cent (for the equation I model I) or 0.05 per cent (for the equation model II),[18] with

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[18] This can be done by reducing or minimizing the number of stress days or by increasing the average depth of water or by both ways.

Table 6.5 Estimated average Cobb-Douglas production function parameters using OLS techniques for all sample rice farms, 1978 dry and 1978/79 wet seasons.

Variable	Parameter			
	Equation I		Equation II	
	Dry	Wet	Dry	Wet
Constant	4.1527	4.3056	4.2569	4.2471
ln I	0.0636*** (3.70)	-0.0082^{ns} (-0.21)	0.0463** (1.76)	0.0115^{ns} (0.39)
ln N	0.1151** (2.30)	0.2117*** (4.40)	0.1299*** (5.26)	0.1147*** (4.08)
ln L	0.3647*** (5.55)	0.1833* (1.68)	0.2904*** (3.91)	0.2223** (2.52)
ln D	-0.0938** (-2.50)	-0.2006*** (-6.36)	-	-
ln C	0.1521^{ns} (1.18)	0.1106^{ns} (0.97)	0.1759** (1.69)	0.1171* (1.39)
n	89	87	89	87
R	0.63	0.66	0.61	0.48
$\bar{R}^2$	0.37	0.40	0.34	0.20
F-test	11.19***	12.60***	12.17***	5.97***

Notes: In Equation I, the dependent variable is actual yields and crop damage is included as an independent variable. In Equation II, the dependent variable is the adjusted yields, and crop damage is not included as an independent variable, because yields were adjusted to crop damage levels.

*** significant at the 1.0 per cent level.
** significant at the 5.0 per cent level.
* significant at the 10 per cent level.
ns not significant at the 10 per cent level.

other factors remain unchanged. Thus, variations either in the average water depth or in the number of stress days in the dry season significantly affected the yield of the rice farms.

The coefficients for nitrogen were significant with both models in both seasons. The signs of these coefficients were positive, and they indicated, for example, that by increasing the application level of nitrogen by one per cent the adjusted yield (equation II model) increases by about 0.13 per cent in the dry season or by about 0.11 per cent in the wet season. Thus, the yield of rice farms in the study area could be increased substantially with higher levels of nitrogen application.

Labour input coefficients were also positive and significant statistically, for both models in both seasons. These indicate that a one per cent increase in labour man days increases yield by 0.29 per cent and 0.22 per cent in the dry and wet seasons respectively for the equation II model.[19] It is important to note that an increase in labour inputs alone may be ineffective in increasing yields because the use of labour is typically associated with the use of other physical inputs such as land, irrigation, fertilizer, pesticides, etc. (see Booth and Sundrum 1980).

The coefficients of the other variable costs (C) were positive and significant statistically, except for the dry season in the equation I model. In equation II, these coefficients indicate that increasing expenditure in other variable costs by 1.0%, increases yield by 0.18 per cent in the dry season and by 0.14 per cent in the wet season.[20]

The equation I model, showed the coefficients for the crop

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[19] In this instance, it is however difficult to differentiate which of the labour inputs - hired or family or bullock - is to be increased.

[20] This can be done particularly by increasing expenditure on pest and disease control.

damage variable that were negative and significant at the 5.0 and 1.0 per cent levels for the dry and wet seasons respectively. These imply that with one per cent greater crop damage yield decreases by 0.09 and 0.20 per cent in the dry and wet seasons respectively. The higher coefficient for crop damage in the wet season is consistent with the fact that the damage caused by rats was higher and more widely distributed in that season than in the dry season. In the latter season, rat attacks were found only in the head and tail sections, but in the wet season they were also recorded in the body section. Thus, crop damage caused by rats was more serious in the wet than in the dry season, even though the percentage of crop damage in the two seasons was not reported as being significantly different by the farmers themselves (Table 6.1). This also implies that crop damage caused by rats had a greater impact on yield than that caused by other pests, such as stem borers in that area.

The question arises as to whether the crop damage variable is a controllable factor or not. Theoretically, it should be, because the incidence of rats, stem borers and other pests can be controlled with the application of rodenticides and insecticides. In this area, however, there is a taboo against killing rats. How far this taboo affected farmers' behaviour in the study area is not known, but survey data indicated that not one of the sample farmers applied rodenticides in either dry or wet seasons. As discussed in Chapter 3, the farmers took preventive measures only by draining their rice farms earlier than is recommended.

In this analysis, the crop damage caused by pest and diseases was incorporated as a controllable factor in one model (I) and as an uncontrollable factor in the other model (II). A comparison of these two models shows that for the dry season, the results were not much different (Table 6.5). In the wet season, the fit of the equation I model (with crop damage variable) was better than that of the equation II model (without crop damage variable), with higher values for the adjusted coefficients of multiple determination ($\bar{R}^2$) and for the

F-test.[21] This could be related to the fact that the contribution of the crop damage factor to yield variations was much higher in the wet than in the dry season as shown by the coefficients of ln D (i.e. -0.094 and -0.2006 for the dry and wet seasons respectively). This would suggest that, for average CD production functions, the equation I model was much better than the equation II model.

The sums of the coefficients of the independent variables in the equation I and II models for the dry and wet seasons were less than unity, indicating that a one per cent increase in all inputs increases yields by less than one per cent in both seasons. They also indicate that the returns to scale for rice production in terms of the relationship between yield and inputs per hectare (except for the irrigation variable) was decreasing.

In conclusion, the estimated average CD production function for the study area suggests that the rice yield in the Badenah irrigation command area could be substantially increased by increasing the application levels of fertilizer, pesticides and labour inputs, by improving farm water management and by minimizing crop damage levels.

Technical Efficiency Analysis

In order to measure the technical efficiency rating (TER) of individual sample rice farmers, a frontier production function was estimated, using the linear programming (LP) method obtained by Timmer (1970, 1971) as discussed in Chapter 3 above. The estimated CD frontier production functions with various probability levels are reported in Tables 6.1.1 and 6.1.2 of Appendix 6.1 for the dry and wet seasons respectively. Two models were used, models I and II, which include and exclude the crop damage variable respectively.

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21 It is important to note that all $\bar{R}^2$ in Table 6.5 were significantly different from zero and were satisfactory for cross section data (see Yotopoulos 1967, pp.180-183).

Estimation was carried out first by fitting deterministic CD frontier production functions to the data and variables in the equations of Table 6.5 in its entirety,[22] and the results were labelled as LP-100. These results were unexpected, e.g., the coefficients of ln N (nitrogen) in LP-100 of model II of the dry season (Table 6.1.1 of Appendix 6.1) was completely insignificant and was dropped from the LP-100 function. One possibility is that the extreme observations in the data are so subject to error that results are meaningless. To test this the two per cent most efficient farmers[23] (two observations) were removed from the data deck, which gave LP-98 equations. Removal of another one per cent of most efficient farmers (one more observation) produced LP-97 equations.

The results clearly show that the exclusion of only two per cent most efficient farmers produces a remarkable transformation. Overall, the frontier functions (LP-98) look like the average functions, OLS-98 (Tables 6.6 and 6.7). The contrasts between LP-98 and LP-97 were not much (Appendix 6.1).

Comparisons of Average and Frontier Functions

Comparisons of LP-98 and OLS-98 for each model and for each season indicate that the constant terms of the frontier functions (LP-98) were higher than those of the average functions, OLS-98 (Tables 6.6 and 6.7). This is, according to Timmer (1971), as it should be.

In the dry season (Table 6.6), for model I, the coefficients of the LP-98 were very similar to those of the analogous OLS-98, with an exception that the coefficient of crop damage variable for the LP-98 was completely insignificant and was dropped from that function. This implies that for the model I of the dry season, the frontier production function seems to have shifted almost neutrally outward

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[22] Dummy variables were not included. They are not suitable for LP functions because their substitution elasticities are zero. This was pointed out to me by D.P. Chaudri.

[23] It is important to note that the number of efficient farmers is the same as the number of factors of production on the LP functions (Timmer 1971).

Table 6.6 Estimated average and frontier Cobb-Douglas production function parameters for sample rice farms in the Badenah irrigation system, 1978 dry season.

Variable	Parameter			
	Model I		Model II	
	LP-98	OLS-98	LP-98	OLS-98
Constant	4.6144	4.2845	4.8713	4.2211
ln I	0.0201	0.0474* (1.47)	0.1205	0.0477** (1.89)
ln N	0.1853	0.1229*** (3.07)	0.0637	0.1544*** (5.77)
ln L	0.3571	0.3845*** (5.81)	0.4040	0.3003*** (4.12)
ln D	-	-0.1058*** (-3.62)	-	-
ln C	0.1190	0.1274ns (1.01)	0.1336	0.1635* (1.61)
n	87	87	87	87
R^2		0.42		0.41
F-test		11.56***		14.01***

Notes: In model I, the dependent variable is actual yields, and crop damage is included as an independent variable.
In model II, the dependent variable is adjusted yields, and crop damage is not included because the adjusted yields are adjusted to crop damage levels.

*** significant at the 1.0 per cent level,
** significant at the 5.0 per cent level,
* significant at the 10.0 per cent level, and
ns not significant at the 10 per cent level.

Table 6.7 Estimated average and frontier Cobb-Douglas production function parameters for sample rice farms in the Badenah irrigation system, 1978/79 wet season.

Variable	Parameter			
	Model I		Model II	
	LP-98	OLS-98	LP-98	OLS-98
Constant	5.4229	5.1837	7.0711	5.5205
ln I	0.0638	-0.0370^{ns} (-0.94)	0.0147	-0.0105^{ns} (-0.35)
ln N	0.2231	0.2033*** (4.28)	0.1021	0.1079*** (3.61)
ln L	0.2831	0.1934** (1.78)	0.2145	0.2137** (2.48)
ln D	-0.2314	-0.2057*** (-6.56)	-	-
ln C	0.1237	0.1228^{ns} (1.03)	-	0.0911^{ns} (1.07)
n	85	85	85	85
R^2		0.46		0.20
F-test		16.75***		6.80***

Notes: In model I, the dependent variable is the actual yields, and the variable of crop damage is included in this model. In model II, the dependent variable is the adjusted yields, and the variable of crop damage is excluded because the yields are adjusted to the crop damage levels.
LP-98 is a frontier function estimated by linear programming, and OLS-98 is an average function estimated by OLS method (details are given in the text).
Figures in brackets are respective t-values of the parameters.

*** significant at the 1.0 per cent level
** significant at the 5.0 per cent level
* significant at the 10 per cent level
ns not significant at the 10 per cent level
n number of observations.

from the average function, with an exception that the coefficient of crop damage was zero for the frontier function. For model II of the dry season, the yield elasticities of irrigation and nitrogen of the frontier function seemed to be different from those of the analogous average function. However, these differences cannot be tested statistically.

In the wet season, for both models, the coefficients of the frontier functions were very similar to those of the respective average production functions (Table 6.7). These indicate that in the wet season, the frontier production functions of both models seem to have shifted almost neutrally outward from the respective average production functions.

On the basis of the above evidence, it seems reasonable to assume that there was a Hick's neutral shift between the average and the frontier production functions.

Technical Efficiency of Sample Farmers

The technical efficiency rating (TER) of each sample farmer was computed using equation (3.30), in which

$$TER_i = Y_i/\hat{Y}_i \qquad (6.3)$$

where TER_i is the technical efficiency rating of farmer i, Y_i and $\hat{Y}_i$ are the actual (or adjusted) and estimated yields of farm i. The estimated yields of farm i were calculated from the frontier functions in Tables 6.6 and 6.7. The actual yields of farm i were taken from the survey data, and the adjusted yields of farm i were calculated as shown previously (Table 6.2).[24]

The distribution of the TER among sample farmers for the model II (without crop damage variable) in the dry and wet seasons (Figure 6.1) shows that only 17 and 10 per cent of the farms recorded efficiency within 10 per cent of the frontier (i.e. ratings above 90 per cent) in the dry and wet season respectively. The majority of

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[24] See Appendices 6.2 and 6.3 for the actual yields, the adjusted yields, and the technical efficiency ratings of individual sample farmers in the dry and wet seasons respectively.

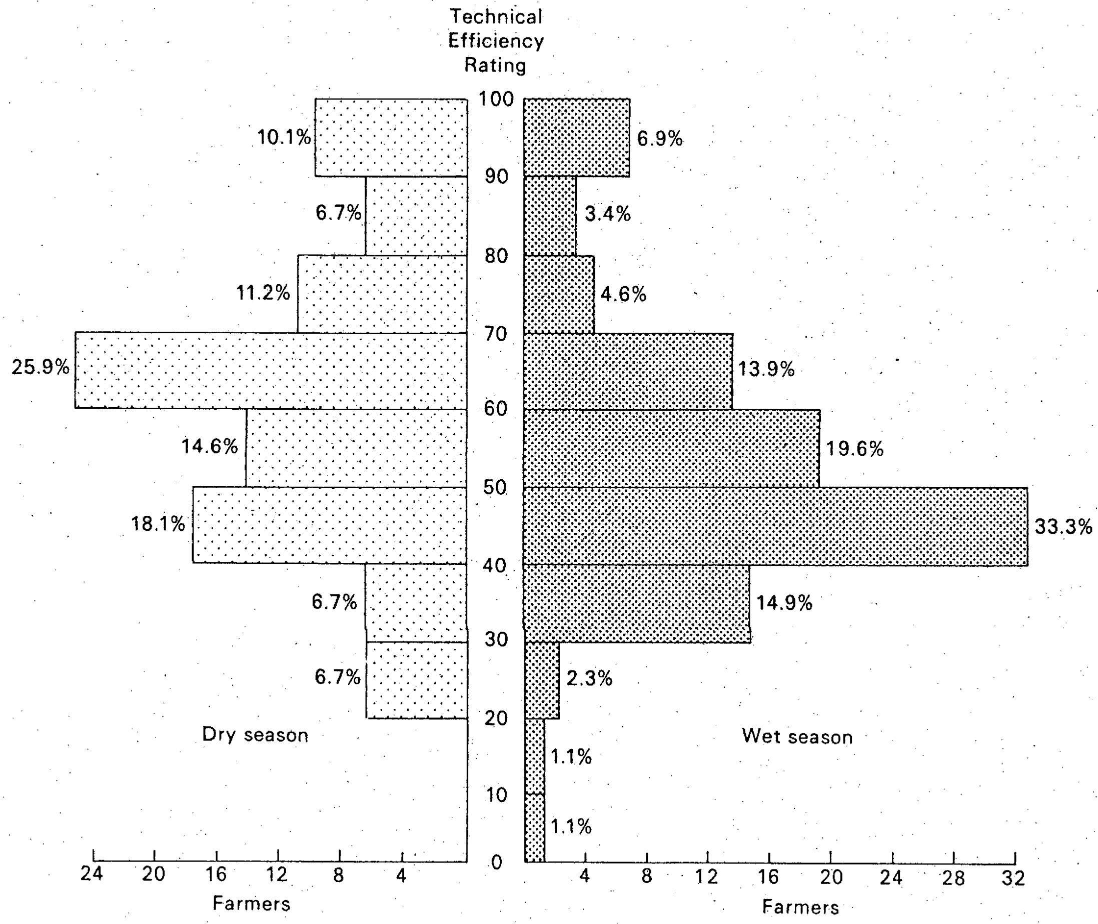

Figure 6.1. Technical efficiency ratings of sample rice farmers in Badenah irrigation system, 1978 dry and 1978/79 wet seasons.

the farms measured efficiencies only between 30 and 60 per cent of the frontier (i.e. TER between 70 and 40 per cent) for the dry and wet season respectively, thus suggesting there was considerable inefficiency among farmers in the study area.

It is important to keep in mind that the high degree of technical inefficiency among the farmers related to a four factor production function, involving farm water conditions, nitrogenous fertilizer, labour, and other variable costs that contain many inputs. Farmers who use these inputs in large quantities and produce high yields can be said to be good farmers. But, as stressed by Timmer (1971), 'the production function itself makes this distinction.'

Factors Affecting Technical Efficiency

To identify factors affecting technical efficiency ratings among the sample farmers, a multiple regression analysis was undertaken in which the individual TER of the sample farmer was set as the dependent variable and a number of relevant factors was chosen as explanatory variables.

The results show R^2s that are low but are significant statistically and are satisfactory for cross section data (Table 6.8). The F-test values are significant at the 1.0 and 5.0 per cent levels for the dry and wet seasons respectively, and indicate that the null hypothesis that all coefficients of the explanatory variables are zero should be rejected.

The most significant factor that affected TER differentials was tenure status. The positive and significant coefficients of the tenure dummy variable for the fixed-rent operator in both seasons imply that this type of operator was more technically efficient than the owner and the share-cropper. The negative coefficients of the tenure dummy variable for the owner operator in both seasons indicate that the share-cropper was more technically efficient than the owner operator. The superiority of the fixed-rent status in TER can be understood in terms of the extra effort that these farmers must exert

Table 6.8 Regression coefficients of factors affecting Technical Efficiency ratings of sample rice farms in the Badenah irrigation system, 1978 dry and 1978/79 wet seasons.

Variables	Coefficients	
	Dry season	Wet season
Constant	0.6039	0.3638
T_1 (tenure dummy, owner)	-0.1451*** (-3.25)	-0.0401^{ns} (-0.92)
T_2 (tenure dummy, fixed rent)	0.1149* (1.49)	0.1085*** (3.08)
REA (education/age of farmer)	0.3654** (2.11)	0.3009** (2.34)
M (migration dummy)	0.0993** (2.30)	0.0136^{ns} (0.32)
RPO (pesticides/other costs)	-0.1788^{ns} (-1.24)	0.2400** (2.00)
TD (time of draining farms)	0.0052^{ns} (1.02)	0.0010^{ns} (0.95)
RHL (hired/total labour)	-0.0522^{ns} (-0.80)	0.0729* (1.39)
D_1 (location dummy, body)	-0.0588^{ns} (-1.06)	0.0473^{ns} (0.83)
D_2 (location dummy, tail)	-0.2256** (-2.69)	-0.2237^{ns} (-0.44)
RPD (output/crop damage)	-0.0001* (-1.57)	0.0002^{ns} (0.50)
LP (land preparation dummy)	0.0480^{ns} (1.08)	-
B (Bimas participation frequency)	0.0031^{ns} (0.24)	....
n (number of sample farms)	89	87
R^2	0.34	0.24
F-test	3.25***	2.34**

Notes: Figures in brackets are the respective t-values of the coefficients.

*** significant at the 1.0 per cent level
** significant at the 5.0 per cent level
* significant at the 10 per cent level
ns not significant at the 10 per cent level
.... F-level is insufficient for further computation.

Individual TER of model II was used as the dependent variable.

relative to the share-cropper and the owner operator to meet the greater risks involved, since the fixed-rent operator pays a fixed annual rent to the landlord. The higher TER of the share-cropper system compared with that of the owner operator can be explained by the fact that if the yield of the farmer is low,his tenancy agreement to operate the farm for the next season will be terminated.

In the present study sample, 57 per cent of farms were under contractual share-cropping arrangements, 34 per cent were owner operators and only 9 per cent had contractual fixed-rent arrangements (Appendix 2.1). The high percentage of share-cropping in the study area follows from the traditions of the Minangkabau society. Most land, including sawah in the study area, is under communal ownership. A large part of sawah land is operated rotationally among the members of a kaum or a group of families of the same suku or sub suku or clan. The rotation is dependent upon the number of members making a livelihood in agriculture, and on the economic conditions of the members. A member of the community who operates the sawah land is expected to give one third of total production to the leader of the group who holds the adat or customary title to the land, and who is usually the oldest in the kaum. The costs of production and all decisions with regard to rice cultivation activities are the responsibility of the operator. Thus the difference between the owner operator and share-cropper is only in the output sharing and the status of the sawah. The superiority of the share-cropper TER over that of the owner operator could be due to the flexible rotation period amongst members. The period depends on the view of the leader of the kaum, and one of his options is to extend the turn of any member who manages his rice farm well to the next crop season. There is thus an incentive for members to make an extra effort in operating and managing the rice farm.

Another important factor which affected TER differentials was the ratio of the education to the age of the farmer (REA).[25] The

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[25] When we applied education or age independently, only the coefficients of age were significant, but not for those of education. There was a negative and significant correlation between age and education in the study area.

positive and significant coefficients of the REA in both seasons indicate that the most technically efficient farmers were those who were young and relatively well educated with other factors constant.

The coefficients of merantau or migration experience dummy variable were positive in both seasons but were significant only in the dry season. The coefficient suggests that merantau[26] experience positively influenced the quality of the management of the farms. Survey data indicated that those with migration experience were less traditional or more progressive than those without it.

The signs of the coefficients of other explanatory variables were not stable between the two seasons (RPO, RHL, D_1 and RDP), they were not significant (TD, LP and B) or their simple correlation signs were misleading (D_2 and B). General conclusions about these factors could not be made.

Farm Group Efficiency

By applying equation (3.31) to the individual TERs (Appendix 6.2), the technical efficiency rating for each of the farmer groups was calculated (Tables 6.9 and 6.10). Interestingly, the TERs of some groups varied significantly between the two measurement models. In model I (including the crop damage variable) the TERs between groups within location and tenure categories (for both seasons) and between those within the rice variety category (for the wet season only) were significantly different. In model II the TERs between groups differed significantly only within the tenure category. This indicates that TER differentials between groups in model I were merely due to variations in crop damage level (except for TER differentials within the tenure category) since, with the exclusion of this variable from the production functions, the TER differentials between groups became non significant in model II, except within the tenure category.

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[26] A farmer is defined as having merantau experience if he or she has been outside the province of West Sumatra.

Table 6.9 Technical Efficiency ratings of sample farmers by groups, in the Badenah irrigation system, 1978 dry season.

Categories	Technical Efficiency Ratings		
	n	Model I	Model II
All sample farms	89	0.61 (0.22)	0.61 (0.20)
Location			
Head section	29	0.55[a] (0.23)	0.64 (0.19)
Body section	30	0.69[b] (0.22)	0.57 (0.24)
Tail section	30	0.58[a] (0.16)	0.62 (0.16)
Tenure			
Owner operator	30	0.51[a] (0.20)	0.53[a] (0.17)
Fixed-rent	8	0.80[b] (0.19)	0.70[b] (0.25)
Share-cropper	51	0.63[c] (0.20)	0.65[c] (0.19)
Rice variety			
IRV (international)	52	0.59 (0.21)	0.61 (0.20)
NIV (national)	17	0.62 (0.23)	0.58 (0.21)
LIV (local)	20	0.63 (0.22)	0.65 (0.20)
Water source			
From channels	70	0.61 (0.22)	0.60 (0.20)
Plot-to-plot system	19	0.59 (0.19)	0.67 (0.20)

Notes: Technical efficiency ratings of Model I were calculated from the frontier function (LP-98) of Model I of Table 6.6. Those of Model II were calculated from LP-98 of Model II of Table 6.6. Figures in brackets are respective standard deviation values. If figures between groups within a category have different letters, the two groups' figures are significantly different at the 5.0 per cent level.

Table 6.10 Technical Efficiency ratings of sample farmers by groups, in the Badenah irrigation system, 1978/79 wet season.

Categories	Technical Efficiency Ratings		
	n	Model I	Model II
All sample farms	87	0.59 (0.22)	0.54 (0.18)
Location			
Head section	27	0.64[a] (0.25)	0.54 (0.18)
Body section	30	0.52[b] (0.21)	0.57 (0.20)
Tail section	30	0.62[a] (0.19)	0.51 (0.16)
Tenure			
Owner operator	28	0.52[a] (0.22)	0.52[a] (0.18)
Fixed-rent	7	0.69[b] (0.26)	0.71[b] (0.27)
Share-cropper	52	0.62[b] (0.21)	0.53[a] (0.16)
Rice variety			
IRV (international)	57	0.60[a] (0.21)	0.53 (0.19)
NIV (national)	9	0.39[b] (0.11)	0.48 (0.12)
LIV (local)	21	0.67[a] (0.24)	0.59 (0.18)
Water source			
From channels	67	0.58 (0.22)	0.53 (0.19)
Plot-to-plot system	20	0.65 (0.23)	0.58 (0.17)

Notes: Technical efficiency ratings of Model I and II are calculated from frontier functions of Model I and Model II in Table 6.7 respectively.
Figures in brackets are respective standard deviation values of the efficiencies.
If figures between groups within a category have different letters, it means that the two groups are statistically different at the 5.0 per cent level.

This finding that the highest TER was found in the fixed-rent group and the lowest was in the owner operator group in both seasons, is consistent with the foregoing regression analysis of factors affecting technical efficiency ratings of the sample farms. This finding is at variance with Cheung's conclusion that 'different contractual arrangements do not imply different efficiencies of resource use as long as these arrangements are themselves aspects of private property right' (Cheung 1969, p.4). The present finding is consistent with the theory of share tenancy by Newbery (1977) which stressed that 'we can show that with only fixed-rent and wage contracts production will be efficient, so that we have an absolute standard or reference against which to compare share tenancy.' However, both writers did not specify whether they were referring to technical efficiency, price efficiency or economic efficiency. If the concern was with technical efficiency, as defined in this study, the present finding is consistent with the Newbery's theory.

Yield Variation Factors

As mentioned above, two possible factors were responsible for rice yield variations, namely: (i) differences in the level of input application, and/or (ii) differentials in technical efficiency of the farmers. To show the contribution of each factor to yield variations, equation (3.32) can be rewritten as,

$$
\begin{aligned}
Y_a(x_a) - Y_b(x_b) = & \quad \text{Yield differential} = \\
\tfrac{1}{2}\left[Y_a(x_a) - Y_b(x_a) + Y_a(x_b) - Y_b(x_b) \right] & \quad \text{due to differences in technical efficiency} + \\
+\tfrac{1}{2}\left[Y_a(x_a) - Y_a(x_b) + Y_b(x_a) - Y_b(x_b) \right] & \quad \text{due to differences in inputs applied levels}
\end{aligned}
\tag{6.4}
$$

where $Y_a(x_a)$ and $Y_b(x_b)$ are the actual (or adjusted) yields of farm a (or farm Group A) and farm b (or farm group B) respectively, $Y_a(x_b)$ is the yield of farm a (or farm group A) using input application level of farm b (or farm group B), and $Y_b(x_a)$ is the yield of farm b (or farm group A) using input application level of farm a (or farm group A).

The values of $Y_a(x_a)$ and $Y_b(x_b)$ are given in Table 6.2 for groups of farmers, and in Appendices 6.2 and 6.3 for individual farmers. The values of $Y_a(x_b)$ and $Y_b(x_a)$ are calculated by using equation (3.33) above, namely

$$Y_a(x_b) = Y_b(x_b) \frac{TER_a}{TER_b}$$
$$Y_b(x_a) = Y_a(x_a) \frac{TER_b}{TER_a} \qquad (6.5)$$

where TER_a and TER_b are the technical efficiency ratings of farmer a (or farmer group A) and farmer b (or farmer group B) respectively. The TERs are given in Tables 6.9 and 6.10 for the groups of farmers and in Appendices 6.2 and 6.3 for individual farmers.

With this technique, yield variations between groups of sample farmers due to the two factors were identified (Tables 6.11 and 6.12). In these calculations only adjusted yields and TERs with Model II (without crop damage variable) were used.

Yield differences between locational groups were due particularly to differentials in input application levels rather than to variations in technical efficiency ratings, in both seasons. This finding is consistent with earlier results which showed that the TER differentials between groups within the location category were not significant statistically. The negative signs of yield differentials due to TE for Body - Head and Body - Tail in the dry season (Table 6.11) indicate that, although TERs of the head and tail sections were higher than the TER of the body section (see Table 6.9 column Model II) the higher levels of inputs applied in the body section raised the average yield of the body section significantly higher than those of the head and tail sections.

In the tenure category, yield differentials between the groups were more strongly determined by variations in TERs (except for Fixed-rent - Share-cropping in the dry season) than by those in input levels.

Table 6.11 Yield variations due to technical efficiency and input level differentials by groups of sample farms in the Badenah irrigation system, 1978 dry season.

Farm group categories	Yield differential (mt paddy)		
	Between two groups a)	Due to	
		TE	IL
Location			
Body - Head	0.30	-0.325 (-108)	0.625 (208)
Body - Tail	1.12	-0.20 (-18)	1.32 (118)
Head - Tail	0.82	0.07 (9.0)	0.75 (91)
Tenure			
Fixed rent - Owner operator	1.34	0.78 (58)	0.56 (42)
Fixed rent - Share-cropper	1.12	0.22 (20)	0.90 (80)
Share-cropper - Owner operator	0.22	0.47 (213)	-0.25 (-113)
Rice Variety			
NIV - IRV	0.50	-0.125 (-25)	0.625 (125)
LIV - NIV	0.03	0.32 (1066)	-0.285 (-966)
LIV - IRV	0.53	0.16 (30)	0.37 (70)
Water Source			
From channels - plot-to-plot	0.06	-0.27 (-450)	0.33 (550)

Notes:

TE = Technical efficiency, IL = Input levels.
Figures in brackets are in percentages.

a) Calculated from adjusted yields of Table 6.2.

Table 6.12 Yield variations due to technical efficiency and input level differentials by groups of sample farms in the Badenah irrigation system, 1978/79 wet season.

Farm group categories	Yield differential (mt paddy)		
	Between two groups a)	Due to	
		TE	IL
Location			
Body - Head	0.35	0.14 (40)	0.21 (60)
Body - Tail	0.73	0.265 (36)	0.465 (64)
Head - Tail	0.38	0.125 (33)	0.255 (67)
Tenure			
Fixed rent - Owner operator	1.04	0.87 (84)	0.17 (16)
Fixed rent - Share-cropper	1.03	0.82 (80)	0.21 (20)
Share-cropper Owner operator	0.01	0.04 (400)	-0.03 (-300)
Rice variety			
IRV - NIV	0.07	0.23 (329)	-0.16 (-229)
LIV - NIV	0.27	0.50 (185)	-0.23 (-85)
LIV - IRV	0.20	0.265 (133)	-0.065 (-33)
Water source			
From channels - Plot-to-plot	-0.12	-0.215 (179)	0.095 (-79)

Notes:

TE = Technical efficiency, IL = input levels.
Figures in brackets are in percentages.

a) Calculated from adjusted yields of Table 6.2.

This is again consistent with our earlier finding which showed that TERs between groups within the tenurial category varied significantly. The negative signs of yield differences between share-cropper and owner operator, due to ILs, in both seasons indicate that, although the owner operator applied higher input levels than the share-cropper, since the latter was more technically efficient, the average yields of the share-cropper were higher.

In the rice variety category, the results were not stable between the two seasons. In the dry season (Table 6.11) the yield differentials were due more to differences in ILs (except for the difference between LIV and NIV) than to variations in TER. In the wet season (Table 6.12), this was reversed and yield differences were influenced primarily by variations in TER. These results are not surprising, for in the dry season, only 50 per cent of the fixed rent operators used IRVs, whilst in the wet season, all of these operators used them (Appendix 2.1). The percentage of share-croppers using IRVs also increased from 63 per cent in the dry season to 65 per cent in the wet season. As we have seen above both fixed rent operators and the share-croppers were more technically efficient than owner operators in both seasons.

Within the water source category, yield differentials between the two groups in the dry season were determined especially by differences in IL rather than in TE. This was reversed in the wet season. These results are consistent with our findings that the plot-to-plot system group was more technically efficient than the group which took water directly from irrigation channels in both seasons (Tables 6.9 and 6.10 column Model II), but that the average adjusted yields were higher in the group which received water directly from irrigation channels in the dry season, and vice versa in the wet season.

The Gap Between Potential and Actual Farm Yields

The potential farm yield of the Badenah irrigation command area is defined in this study as the highest adjusted yield recorded for the sample rice farms, i.e., 5.55 and 5.44 mt paddy/ha in the dry and wet seasons respectively.[27] Both yields were recorded for sample farm No.43 (see Appendices 6.2 and 6.3). The actual farm yield of the study area is defined as the average adjusted yield of the study area, namely, 2.43 and 2.40 mt paddy/ha in the dry and wet seasons respectively (Table 6.2). Thus the gap between potential and actual farm yields in the study area was 3.12 and 3.04 mt paddy/ha for these two seasons.

With the use of equations (6.4) and (6.5) above we found that the yield gaps were due to the two factors, TE and IL variations. In the dry season, about 59 and 41 per cent of the gaps were caused by TE and IL differentials respectively, while for the wet season, the figures were 73 and 27 per cent respectively. Thus TER differentials were more responsible for the yield gap than the IL variations, which is consistent with the fact that the average TERs of average farmers were much lower than those of the frontier farmers in both seasons. Some factors that influenced the TER of sample farmers were identified in the above analysis, but they only explained about 34 and 24 per cent of TER variations in the dry and wet seasons. Further detailed study of factors affecting TER differentials among rice farmers in the Badenah area is therefore clearly needed to ascertain how to raise the technical efficiency of rice farmers. Factors influencing farmers' decisions as to the level of inputs are discussed in detail in Chapter 7 below.

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[27] See Table 6.13 for a comparison of the highest and the lowest yield farms in terms of the level of input application and other factors.

Table 6.13 Performance comparison between sample farmers with the highest and the lowest actual yields in the Badenah irrigation system, 1978 dry and 1978/79 wet seasons.

Characteristics	Unit	Sample farm: Highest yield		Lowest yield	
		Dry	Wet	Dry	Wet
1. Farm					
Yield	mt paddy/ha	5.00	4.25	0.21	0.12
Farm size	ha	0.24	0.24	0.29	0.29
Rice variety		IR-26	IR-26	IR-5	IR-5
Water depth	mm/day	19.5	16.7	11.5	8.8
No. of stress days	day	13.0	28.0	38.0	36.0
Time of draining farm		23.0	41.0	38.0	65.0
Labour	mandays/ha	150	149	74	65
Nitrogen	kg N/ha	114	96	47	25
Phosphorous	kg P/ha	77	48	32	25
Pest control	000Rp/ha	13.5	12.5	3.4	2.75
Crop damage	% crop area	10.0	22.0	70	80
Land preparation techniques	by hoeing (h) by ploughing (p)	p	p	h	h
Fertilizing	frequency	3	3	2	2
Weeding	frequency	2	2	2	2
Seed source		BM	BM	LSP	LSP
Nursery types	wet or dry	wet	wet	dry	dry
2. Farmers					
Sex	male/female	F	F	M	M
Age	years	37	38	60	61
Education	years	12	12	4	4
Tenure status		Fixed-rent		Owner	
Merantau experience	yes/no	yes		no	
Bimas participant	yes/no	yes		no	
Member of farmer groups	yes/no	yes		no	
No. in family	head	9	9	4	4
TER		0.9992	1.000	0.24	0.15

Notes: BM = Bimas Committee; LSP = Last season production.

CHAPTER 7

ECONOMIC PERFORMANCE

In the preceding chapter it was clear that few farmers had combined their given resources in a technically efficient way, and some performed poorly in this regard. This, however, is only part of an analysis of performance. It is necessary to consider the quantity as well as the combination of resources, and for this, price considerations are important. Thus in this chapter price efficiency is measured and this, in combination with technical efficiency, as economic efficiency, will also be assessed. This chapter also includes a discussion of factors affecting input levels.

There are two ways of analysing price or allocative efficiency, the first by testing the economic rationality of sample farmers, as Wise and Yotopoulos (1969) did, and the second by calculating an allocative efficiency index, as foreshadowed in Chapter 3. The first approach tests the ability of farmers to apply successfully the profit maximization rule. The second approach allows calculation of optimum input levels and of the additional yields possible with maximization of price efficiency.

Economic Rationality

The economic rationality of sample farmers was tested by using the index of economic rationality (P), discussed in Chapter 3 above. This index provides a measure of the extent to which farmers are successful in the allocation of inputs to maximize profit. Within the constraint that some inputs must be considered as fixed, an index of one indicates that farmers maximize profit perfectly.

Economic rationality coefficients and related statistics of sample farms were estimated for the dry and wet seasons (Tables 7.1 and 7.2). The diagonal regression coefficients were calculated by estimating equations (3.52) to (3.54) with transformation of the profit maximizing variables into observable ones in the context of equations (3.59a) to (3.59c) in Chapter 3 above.

In this application, output (V) is given as revenue per farm (i.e. adjusted output times the price of output) in rupiah. Labour (L) is expressed in terms of preharvest mandays used per farm. The other cost variable (K) includes expenditures on fertilizer, pesticides, seed and other money costs, but excludes wages paid to labour, rent of land, and interest imputed on own capital. In this model, land, water and fixed capital are subsumed in the intercept term and become part of the technical efficiency component. The index of economic rationality (P) was estimated by product moment coefficient of correlation between log K and log L (Yotopoulos and Nugent, 1976, p.93).[1]

Results for the dry season (Table 7.1) show that the lowest value of P, 0.51, was recorded in the tail section, and that P varied significantly between locations (head, body and tail sections), between types of tenure (owner, fixed-rent, and share-cropping), and between rice varieties (IRV, NIV, and LIV). This minimum value of 0.51 implies that, in the tail section, 51 per cent or more of the variances in the logs of labour and capital was due to the variation in the systematic profit maximizing component of these inputs. The balance of 49 per cent was the maximum that can be attributed to economic irrationality. Irrationality in the present context means that there were constraints that prevented them from pursuing profit maximization more effectively, e.g. credit shortage. The value of P for all sample farmers was 0.69, which indicates that, on average,

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[1] The method of calculating the product moment coefficient of correlation between two variables is explained in detail in Mills (1955, pp.272-281).

Table 7.1 Economic Rationality Coefficients and related statistics for sample farms in Badenah irrigation system, 1978 dry season.

Relation Estimated	Quantity Estimated	Diagonal Regression Coefficients[a]						
		All farms (n=89)	Head (n=29)	Body (n=30)	Tail (n-30)	Owner (n=30)	Fixed-rent (n=8)	S.Cropper (n=51)
ln V on ln K	$[1 + (1/\eta)]$	1.0455 (0.0709)	1.0833 (0.1376)	1.2437 (0.2026)	0.7796 (0.1422)	1.0377 (0.1563)	1.1384 (0.4003)	0.9254 (0.0960)
ln V on ln L	$[1 + (1/\varepsilon)]$	1.1094 (0.0993)	1.0444 (0.1287	1.1649 (0.2272)	1.2674 (0.2759)	1.0358 (0.1484)	1.3025 (0.6102)	1.0633 (0.1451)
ln K on ln L	$\frac{[1 + (1/\varepsilon)]}{[1 + (1/\eta)]}$	1.0611 (0.1203)	0.9641 (0.1229)	0.9366 (0.2136)	1.6257 (0.5140)	0.9980 (0.1679)	1.1441 (0.7299)	1.1490 (0.1844)
P (economic rationality index)		0.69	0.83	0.64	0.51	0.75	0.58	0.66
η (price supply elasticity of K)		21.9	12.0	4.1	-45.4	26.5	7.2	-13.4
ε (price supply elasticity of L)		9.1	22.5	6.1	3.7	27.9	3.3	15.8

a) These were estimated using the property $b_{12} = r_{12}(S_1/S_2)$ where 1 and 2 are the dependent and the independent variables respectively in the least square regression; b = slope coefficient, r = simple correlation, and S = standard deviation. Since the diagonal regression coefficient is (S_1/S_2) sign r_{12}, it can be estimated by (b_{12}/r_{12}). The standard errors (in parenthesis) are obtained by assuming that var (b_{12}/r_{12}) = (var $b_{12})/r_{12}$ (Yotopoulos and Nugent, 1976, p.94).

Table 7.1 (Cont'd)

Relation Estimated	Quantity Estimated	Diagonal Regression Coefficients				
		IRV (n=52)	NIV (n=17)	LIV (n=20)	Direct (n=70)	Indirect (n=19)
ln V on ln K	$[1 + (1/\eta)]$	0.9138 (0.1126)	1.4874 (0.0907)	1.2031 (0.0380)	1.0531 (0.1058)	1.0190 (0.1823)
ln V on ln L	$[1 + (1/\varepsilon)]$	1.1123 (0.1483)	1.0037 (0.0620)	1.1958 (0.0328)	1.1075 (0.1097)	1.1572 (0.2221)
ln K on ln L	$\frac{[1 + (1/\varepsilon)]}{[1 + (1/\eta)]}$	1.2172 (0.1818)	0.6748 (0.0445)	0.9939 (0;0377)	1.0557 (0.1299)	1.1356 (0.2753)
P (economic rationality index)		0.69	0.64	0.77	0.70	0.71
η (price supply elasticity of K)		-11.6	2.06	4.9	18.8	52.6
ε (price supply elasticity of L)		8.9	270.3	5.1	9.3	6.4

rice farmers in the study area were not price efficient (i.e. the value of P was substantially less than unity). Farmers in the head section showed the highest P among all farmer groups (0.83), i.e. these farmers were more efficient than those in the body (0.64) and tail (0.51) sections. Owner operators (0.75) were more price efficient than fixed-rent operators (0.58) and share croppers (0.66). LIV growers (0.77) were more price efficient than IRV (0.69) and NIV growers (0.64). However, these differences cannot be tested statistically.

Another interesting result was obtained from the test of economic rationality. It was assumed that rice farms may operate within different sets of prices. This assumption can be tested by referring to the estimated price elasticity of supply of the other costs (η) and labour (ε), which stem from the estimated diagonal regression coefficients of log V on log K and log V on log L. A diagonal regression coefficient of one means that there is perfect competition in the market for the input. The estimated regression coefficients of log V on log K and log V on log L for the dry season differed from unity (Table 7.1). However, the differences were small enough for the assumption of the perfect competition markets not to be rejected. It can be concluded, therefore, that inter-farm differences in prices could not be great, so that inter-farm variances in inputs applied and output produced were little influenced by inter-farm price differences. This suggests that technical efficiency, the component that has been subsumed in the constant term, in the present analysis, including irrigation water could assume a major role in explaining the differences in observed behaviour among rice farmers.

Results for the wet season (Table 7.2) give similar conclusions, except that, in this season the fixed-rent operator was more price efficient than the owner and share-cropping operators, and the LIV growers were the least price efficient of the rice variety groups.

Table 7.2 Economic Rationality Coefficients and related statistics for sample farms in the Badenah irrigation system, 1978/79 wet season.

Relation Estimated	Quantity Estimated	Diagonal Regression Coefficients						
		All farms (n=87)	Head (n=27)	Body (n=30)	Tail (n=30)	Owner (n=28)	Fixed-rent (n=7)	S. Cropper (n=52)
ln V on ln K	$[1 + (1/\eta)]$	0.8657 (0.1019)	1.0276 (0.1470)	0.9955 (0.1459)	0.6688 (0.2528)	1.0105 (0.2010)	1.1904 (0.2491)	0.7096 (0.1105)
ln V on ln L	$[1 + (1/\varepsilon)]$	1.2499 (0.1347)	1.3564 (0.2444)	1.3334 (0.2024)	1.0301 (0.3076)	1.4710 (0.2413)	1.0699 (0.2797)	1.0890 (0.2358)
ln K on ln L	$\frac{[1 + (1/\varepsilon)]}{[1 + (1/\eta)]}$	1.4438 (0.1906)	1.3199 (0.1695)	1.3394 (0.2360)	1.5402 (0.5289)	1.4557 (0.3209)	0.8988 (0.3096)	1.5347 (0.3425)
P (economic rationality index)		0.63	0.84	0.73	0.48	0.66	0.79	0.54
η (price supply elasticity of K)		-7.4	36.2	-222.2	-3.0	95.2	5.3	-3.4
ε (price supply elasticity of L)		4.0	2.8	2.99	33.2	2.12	14.3	11.2

Table 7.2 (Cont'd)

Relation Estimated	Quantity Estimated	Diagonal Regression Coefficients				
		IRV (n=53)	NIV (n=15)	LIV (n=19)	Direct (n=67)	Indirect (n=20)
ln V on ln K	$[1 + (1/\eta)]$	0.8277 (0.1054)	1.4899 (0.1255)	1.1544 (0.0503)	0.8422 (0.1111)	0.9871 (0.2718)
ln V on ln L	$[1 + (1/\varepsilon)]$	1.2504 (0.2125)	0.6822 (0.0569)	0.9112 (0.1088)	1.3079 (0.2178)	0.9026 (0.2210)
ln K on ln L	$\frac{[1 + (1/\varepsilon)]}{[1 + (1/\eta)]}$	1.5106 (0.2471)	0.4579 (0.0279)	0.7893 (0.1158)	1.5530 (0.3033)	0.9143 (0.3297)
P (economic rationality index)		0.64	0.61	0.49	0.54	0.55
η (price supply elasticity of K)		-5.8	2.04	6.5	-6.33	3.2
ε (price supply elasticity of L)		3.9	-3.1	-11.3	3.2	-10.3

Allocative Efficiency

The condition for profit maximization (see Chapter 3 above) is that the marginal value product of an input is equal to the unit price of that input. From this definition, the allocative efficiency of each group of sample farmers was calculated by using equation (3.37), namely,[2]

$$AEI_{jg} = b_{jg}(\bar{Y}_g/\bar{X}_{jg})\ (\bar{P}_{yg}/\bar{P}_{jg}) \qquad (7.1)$$

where:

AEI_{jg} = allocative efficiency index of the farmer group G for input j;

b_{jg} = yield elasticity of input j for group g;

$\bar{Y}_g$ = average yield of the farmer group g (in geometric means);

$\bar{X}_{jg}$ = average level of the application of input j by the farmer group g (in geometric means);

$\bar{P}_{yg}$ = average price of paddy received by the farmer group g (in arithmetic means); and

$\bar{P}_{jg}$ = average price of input j paid by the farmer group g (in arithmetic means).

A group of farmers is said to be price efficient if its allocative efficiency index for a particular input does not differ significantly from unity. If it is significantly larger than unity, the input level is too low for profit maximization, and conversely a level smaller than unity indicates an excessive use of the input.

In order to test the allocative efficiency index of input j, (AEI_j), and to compare the AEI_j of farm groups, the standard

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2 This formula was drawn from the Cobb-Douglas production function.

deviation of AEI_j is needed. This was computed with the formula,[3]

$$S_{AEI_j} = (AEI_j/b_j)S_{b_j} \tag{7.2}$$

where S_{AEI_j} and S_{b_j} are the standard deviations of AEI_j and b_j respectively. S_{b_j} can be calculated from standard error of b_j.

The t-statistic for testing whether the AEI_j is significantly different from unity at the 1.0 per cent level was computed from the following equation,[4]

$$t = \frac{AEI_j - 1}{S_{AEI_j}/\sqrt{n-1}} \tag{7.3}$$

with degrees of freedom (d.f.) equal to (n-1), where n is the number of observations or sample size.

The t-statistic for testing whether the AEI_j of groups of farmers differ significantly was computed from the following formula,[5]

$$t_{\bar{d}} = \frac{(AEI_{j1} - AEI_{j2})}{S_{\bar{d}}} \tag{7.4}$$

where 1 and 2 stand for farmer groups, and the d.f. are $(n_1 + n_2 - 2)$.

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3 See Yotopoulos (1967, p.194).

4 Mills (1955, pp.227-228).

5 $S_{\bar{d}}^2 = (S^2/n_1 + S^2/n_2)$ where: $S^2 = \dfrac{(n_1-1)S_1^2 + (n_2-1)S_2^2}{(n_1-1) + (n_2-1)}$

in which S_1^2 and S_2^2 are variances of AEI_{j1} and AEI_{j2} respectively, and n_1 and n_2 are the number of observations in groups 1 and 2 respectively. It was assumed that the population of the groups have equal variances (for details, see Nie et al. 1975, p.269).

Estimated Allocative Efficiency

Estimates of allocative efficiency indexes of sample farm groups for the dry season (Table 7.3) indicated that sample farmers as a whole were not price efficient in input use. The AEIs of labour II,[6] (1.9), irrigation (55.8), nitrogen (3.3), and of other cost variable (3.1) were significantly different from unity at the 1.0 per cent level. Since the indexes were all greater than unity, the levels of all inputs applied were too low for profit maximization. Factors affecting farmers' decisions concerning input levels are discussed below.

In the dry seasons the AEIs of the irrigation variable[7] differed significantly between groups within all categories, i.e. between locations, tenure types, and between rice varieties. The groups most efficient in using irrigation water were the body, the fixed-rent and the NIV farmers respectively. As expected, the farmer group which received water directly from irrigation channels was more efficient in utilizing irrigation water than the one which received it indirectly through other farms (plot-to-plot system). These results are consistent with the analysis in Chapter 6 above (Table 6.1).

The AEIs of labour II also differed significantly between groups within all categories. By location, whilst all were greater than unity, the lowest occurred in the body section, indicating that farmers there were relatively most efficient in use of labour. The fixed-rent operator was the least price efficient, and the share-cropper the most price efficient in labour use amongst tenure

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6 Labour I is based on average real wages paid by sample farmers, while labour II is based on the average real wages times the ratio of hired labour (HL) to total labour (TL) used, i.e.: WL_1 = average wages/man day (in Rp); $WL_2 = WL_1$ (HL/TL); where WL_1 and WL_2 are wage levels for labour I and II respectively. the AEIs of labour II were used in this analysis because the unemployment level in the study area was high (Chapter 2), so it is assumed that the opportunity cost of family labour there was zero.

7 Since the irrigation water was free of charge in the study area, its AEI is its marginal physical product.

Table 7.3 Allocative Efficiency Index of sample rice farm groups, 1978 dry season.

Farm groups	Allocative Efficiency Index x/				
	Labour I	Labour II	Irrig.	N	C
All farms (n = 89)	0.7 (0.1)	1.9 (0.4)	55.8 (31.7)	3.3 (0.6)	3.1 (1.8)
Location					
Head section (n = 29)	0.8 (0.2)	2.0[a] (0.4)	64.9[a] (36.9)	2.8 (0.5)	3.1 (1.8)
Body section (n = 30)	0.7 (0.1)	1.7[b] (0.3)	15.6[b] (8.9)	2.7 (0.5)	3.4 (2.0)
Tail section (n = 30)	0.7 (0.1)	2.0[a] (0.4)	171.3[c] (97.3)	4.8[b] (0.9)	2.9 (1.7)
Tenure					
Owner operator (n = 30)	0.7 (0.1)	2.0[a] (0.4)	41.2[a] (23.4)	2.5[a] (0.5)	2.5[a] (1.5)
Fixed-rent (n = 8)	0.9[a] (0.2)	2.3[b] (0.4)	26.6[b] (15.1)	3.6 (0.7)	3.8 (2.3)
Share-cropper (n = 51)	0.7 (0.1)	1.7[c] (0.3)	75.1[c] (42.7)	3.9 (0.7)	3.5 (2.1)
Rice variety					
IRV (international) (n = 52)	0.7 (0.1)	1.8 (0.3)	79.2[a] (44.9)	3.4 (0.7)	3.0 (1.8)
NIV (national) (n = 17)	0.7 (0.1)	1.7 (0.3)	27.8[b] (15.8)	3.1 (0.6)	3.6 (2.1)
LIV (local) (n = 20)	0.91[a] (0.18)	3.4[a] (0.6)	40.9[c] (22.9)	3.4 (0.7)	3.4 (2.0)
Water source					
From channels (n = 70)	0.7 (0.1)	1.7[a] (0.3)	49.6[a] (28.2)	3.4[a] (0.7)	3.1 (1.9)
From other farms (n = 19)	0.8 (0.2)	2.4[b] (0.5)	87.0[b] (49.4)	2.8[b] (0.5)	3.2 (1.9)

x/ The difference between Labour I and Labour II is explained in the text.

Notes: The calculations of AEIs are based on data in Table 7.4; n = number of observations; N = nitrogen; C = other variable costs; and figures in brackets are the respective standard deviations of the AEIs.
If figures between groups within a category have the same letters within a column, the difference between the two figures is not significant, and *vice versa*.

Table 7.4 Yield elasticities of inputs, mean values of inputs and yield, and average prices of inputs and output for each group of sample farms, 1978 dry season.

Farm groups	Items and values				
	Yield elasticity				
	Labour	Irrigation	Nitrogen	Others	
All farms	0.2904*** (5.26)	0.0564** (1.76)	0.1299*** (5.26)	0.1759** (1.69)	
	Geometric means				
	Yield	Labour	Irrig.	Nitrogen	Others
All farms	2243 (0.41)	97.5 (0.40)	1.9 (1.6)	38.8 (0.69)	10300 (0.41)
Location					
Head	2425 (0.41)	100.4 (0.37)	1.7 (1.4)	47.9 (0.47)	11000 (0.33)
Body	2683 (0.41)	112.2 (0.42)	7.9 (1.2)	56.8 (0.44)	11200 (0.48)
Tail	1739 (0.25)	82.3 (0.34)	0.5 (0.6)	21.5 (0.69)	8800 (0.38)
Tenure					
Owner operator	2031 (0.41)	97.2 (0.50)	2.3 (1.7)	46.7 (0.55)	11800 (0.43)
Fixed-rent	3300 (0.40)	113.3 (0.29)	5.8 (1.2)	57.6 (0.54)	12800 (0.48)
Share-cropper	2238 (0.38)	95.3 (0.39)	1.4 (1.5)	32.7 (0.74)	9200 (0.36)
Variety					
IRV	2052 (0.39)	92.7 (0.36)	1.2 (1.6)	35.2 (0.74)	10000 (0.42)
NIV	2518 (0.40)	114.4 (0.49)	4.2 (1.4)	44.7 (0.51)	9900 (0.46)
LIV	2562 (0.39)	96.9 (0.39)	2.9 (1.5)	43.8 (0.66)	11300 (0.35)
Water source					
From channels	2240 (0.42)	100.8 (0.40)	2.1 (1.6)	36.8 (0.74)	10200 (0.45)
From other farms	2250 (0.35)	86.0 (0.37)	1.2 (1.4)	47.2 (0.43)	10500 (0.23)

Cont'd.

Table 7.4 (Cont'd)

Farm groups	Items and values			
	Average prices			
	Paddy	Labour I	Labour II	Nitrogen
All farms	81.6 (6.7)	744 (139)	294	186 (11.9)
Location				
Head	79.9 (1.1)	673 (95.8)	278	189 (8.3)
Body	80.6 (5.6)	790 (164)	328	186 (14.2)
Tail	84.2 (9.6)	768 (123)	265	183 (12.1)
Tenure				
Owner operator	81.9 (5.0)	719 (121)	246	188 (9.18)
Fixed-rent	84.5 (4.4)	805 (69.9)	307	175 (7.0)
Share-cropper	80.9 (7.7)	750 (155)	324	185 (13.3)
Variety				
IRV	83.0 (7.5)	765 (128)	303	184 (5.2)
NIV	80.2 (7.6)	741 (194)	301	188 (17.8)
LIV	82.6 (7.5)	694 (103)	195	191 (16.8)
Water source				
From channels	81.0 (6.9)	739 (124)	302	187 (13.1)
From other farms	83.7 (5.3)	764 (189)	263	185 (6.7)

Notes: Yield elasticity figures were taken from Table 6.5 (equation II) above.
Figures in parentheses are respective t-values for yield elasticities and respective standard deviations for geometric means (in logarithms) and average prices (in arithmetic means).
The yield is in kg paddy, labour in man days, nitrogen in kg N and the other cost variable is in Rp (all are on per hectare basis), and the irrigation variable is measured by ratio of the water depth to the number of stress days.

groups. The price efficiency of labour for two varietal groups (IRV and NIV) did not vary significantly, while the LIV group was the least price efficient. The price efficiency of labour use of the group receiving water from channels was higher than that of the plot-by-plot group. Farmers' choice of the level of labour use depended not only upon the wage level and the prices of the output and other inputs, but was also influenced by other factors such as farm size, the techniques of land preparation, the use of other inputs and so on.[8]

The price efficiency of nitrogen use between groups within categories in the dry season differed little. Farmers in the tail section were the least price efficient in nitrogen use of the three locational groups. The owner operator was the most price efficient of the three tenure groups. Plot-to-plot irrigation farmers were more efficient than those with irrigation from channels, and there were no significant differences amongst varietal groups. It is important to note that the level of nitrogenous fertilizer use in the study area was influenced not only by the relative prices of paddy and this input, but also, and importantly, by the farm water conditions (e.g. the number of stress days), farm size, credit facilities, education of the farmers, etc.[9]

The allocative efficiency of the other cost variable in the dry season only differed significantly between groups within land tenure types. The owner operator was relatively the most price efficient in other cost expenditures of the three tenure groups. Our observations revealed that the majority of rice farmers in the study area used pesticides only as a curative action and not as preventives. Thus, they would apply pesticides only if pest attacks occurred.

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[8] This is discussed in detail below.

[9] For details, see discussion of demand for fertilizer below.

In the wet season (Table 7.5), the AEIs for labour II were very close to unity (except only for the NIV and LIV groups) and were not significantly different from unity at the 1.0 per cent level, indicating that there was appropriate use of labour by sample farmers. For nitrogen and the other cost variable, price efficiency levels were significantly greater than unity, showing inadequate use of these inputs again. The between-group AEIs within these four categories were the same as in the dry season, except that the price efficiency of nitrogen use between groups within the water source category did not differ significantly. The marginal product of the irrigation variable was not included for the wet season, as the yield elasticity of this variable did not differ significantly from zero, even at the 10 per cent level. This means that variations in the irrigation variable in the wet season did not affect rice yields, as already discussed in Chapter 5.

Overall, farmers in the study area were not price efficient in their application levels of inputs in either season, except for labour II in the wet season. This conclusion is consistent with the results of the above test of economic rationality. However, as discussed below, this conclusion does not mean that sample farmers were irrational in their allocative decisions, since the decisions were not only based on the relative prices between inputs and output.

Optimum Input Levels

With input use price efficient, when its marginal value product equals its input price or when the AEI of the input is equal to unity (equation 7.1), the optimum level of each input for maximum profit can be written as

$$\bar{X}_j = b_j \frac{\bar{Y}\,\bar{P}_y}{(AEI_j)\,\bar{P}_j} \tag{7.5}$$

Table 7.5 Allocative Efficiency Indexes for sample rice farm groups, 1978/79 wet season.

Farm groups	Allocative Efficiency Index x/				
	Labour I	Labour II	Irrig.	N	C
All farms (n = 87)	0.68 (0.26)	1.11[ns] (0.44)	....	3.5 (0.9)	2.3 (1.7)
Location					
Head section (n = 27)	0.71 (0.28)	1.15[ns] (0.46)	....	3.1[a] (0.8)	1.9[a] (1.4)
Body section (n = 30)	0.68 (0.27)	1.15[ns] (0.46)	....	2.4[b] (0.6)	2.5 (1.7)
Tail section (n = 30)	0.64 (0.25)	1.05[ns] (0.42)	....	5.7[c] (1.4)	2.6 (1.8)
Tenure					
Owner operator (n = 28)	0.66 (0.26)	1.12[ns] (0.44)	....	3.0[a] (0.7)	1.9[a] (1.4)
Fixed-rent (n = 7)	0.81 (0.32)	1.16[ns] (0.46)	....	3.5 (0.9)	2.7 (1.9)
Share-cropper (n = 52)	0.67 (0.27)	1.11[ns] (0.44)	....	3.8 (0.9)	2.6 (1.8)
Variety					
IRV (n = 57)	0.66 (0.26)	1.07[ns] (0.43)	....	3.5 (0.9)	2.4 (1.7)
NIV (n = 9)	0.67 (0.27)	3.40 (1.34)	....	3.3 (0.8)	2.1 (1.5)
LIV (n = 21)	0.67 (0.30)	2.07 (0.83)	....	4.1[a] (1.0)	2.4 (1.7)
Water source					
From channels (n = 67)	0.64 (0.26)	1.10[ns] (0.44)	....	3.4 (0.8)	2.2 (1.6)
From other farms (n = 20)	0.78 (0.31)	1.16[ns] (0.46)	....	3.7 (0.9)	2.6 (1.8)

x/ The difference between Labour I and Labour II is given in the text.

Notes: All notes in Table 7.3 apply to this table, except that the AEIs in this table are based on data in Table 7.6.

The marginal product of the irrigation variable was not computed because the yield elasticity of this variable was not significantly different from zero at the 10 per cent level.

Table 7.6 Yield elasticities of inputs, mean values of inputs and yield, and the average prices of inputs and output for each group of sample farms, 1978/79 wet season.

Farm groups	Items and values				
	Yield elasticity				
	Labour	Irrigation	Nitrogen	Other costs	
All farms	0.2223** [2.52]	0.0115[ns] [0.39]	0.1147*** [4.08]	0.1171* [1.39]	
	Geometric mean				
	Yield	Labour	Irrig.	Nitrogen	Others
All farms	2242 (0.37)	90.3 (0.37)	0.6 (1.8)	33.0 (0.75)	9504 (0.51)
Location					
Head	2250 (0.40)	90.2 (0.37)	0.4 (1.4)	39.8 (0.51)	12310 (0.39)
Body	2609 (0.34)	101.7 (0.39)	1.2 (1.1)	54.0 (0.53)	9942 (0.44)
Tail	1921 (0.33)	80.4 (0.33)	0.4 (0.9)	17.1 (0.63)	7198 (0.53)
Tenure					
Owner operator	2153 (0.39)	90.2 (0.43)	0.7 (1.4)	36.6 (0.76)	11149 (0.46)
Fixed-rent	3054 (0.47)	93.8 (0.31)	1.3 (1.6)	43.1 (0.50)	10804 (0.49)
Share-cropper	2198 (0.33)	89.9 (0.36)	0.5 (1.1)	30.1 (0.76)	8572 (0.51)
Variety					
IRV	2184 (0.40)	89.1 (0.33)	0.6 (1.2)	32.5 (0.70)	9146 (0.52)
NIV	2204 (0.29)	92.8 (0.64)	1.0 (1.0)	34.0 (0.77)	10223 (0.38)
LIV	2427 (0.32)	88.6 (0.34)	0.5 (1.5)	30.4 (0.85)	9775 (0.51)
Water source					
From channels	2199 (0.39)	92.4 (0.39)	0.7 (1.3)	33.0 (0.78)	9841 (0.51)
From other farms	2394 (0.28)	83.6 (0.32)	0.4 (0.8)	33.2 (0.65)	9457 (0.42)

Cont'd.

Table 7.6 (Cont'd)

Farm groups	Items and values			
	Average prices			
	Paddy	Labour I	Labour II	Nitrogen
All farms	84 (8.5)	686 (105)	417	186 (8.8)
Location				
Head	90 (3.9)	696 (93.5)	434	188 (7.3)
Body	81 (7.7)	679 (120)	401	188 (8.4)
Tail	82 (9.8)	684 (102)	416	184 (9.9)
Tenure				
Owner operator	83 (8.3)	669 (104)	393	186 (7.7)
Fixed-rent	81 (2.3)	723 (153)	506	185 (5.1)
Share-cropper	85 (8.9)	690 (99)	418	187 (9.8)
Variety				
IRV	84 (8.7)	694 (111)	426	184 (6.4)
NIV	84 (8.9)	664 (113)	131	187 (9.4)
LIV	84 (8.9)	673 (108)	246	191 (9.5)
Water Source				
From channels	83 (8.4)	681 (109)	399	184 (5.8)
From other farms	86 (8.6)	701 (93)	472	194 (12.3)

Notes: All notes for Table 7.4 apply to this table.

and $\bar{X}_j$ is optimum when AEI_j is equal to unity.[10]

By substitution,[11] we find for average sample farms[12] that, in the dry season, the AEIs of labour I, labour II, nitrogen, and the other costs become equal to unity at input levels of 71 and 181 mandays for labour I and II respectively, at 128 kg N for nitrogenous fertilizer, and at 32,000 rupiahs per hectare for other costs. In the wet season, the AEIs of these inputs become equal to unity at input levels of 61 and 100 mandays for labour I and II respectively, at 116 kg N for nitrogenous fertilizer, and at 22,000 rupiahs per hectare for other costs.

Diagramatically, the average CD production functions for dry and wet seasons (Table 6.5, equations II) appear as the curves AB (Figures 7.1 and 7.2) which show the relationships between yield and nitrogen levels with other inputs held constant at their geometric mean values (Tables 7.4 and 7.6). The A'B' curves are transformations of the AB curves in which the levels of labour and the other cost input are optimized, and the irrigation variable level is kept at 7.9 units (in both seasons) which is the average level of the body section. Similarly the CD and C'D' curves are the appropriate curves for the CD frontier production functions.[13]

The possible contributions to rice yields of achieving technical and/or price efficiency are as follows:

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10 See Yotopoulos (1967, p.199).

11 The value of b_j and geometric means of Y and average values of P_y and P_j are taken from Tables 7.4 and 7.6 for the dry and wet seasons respectively.

12 Calculated from the average CD production functions for the dry and wet seasons (Table 6.5 equation II).

13 By assuming that the CD frontier functions shift neutrally outward from the average functions, the yields of the frontier functions are calculated from the yields of the average functions, i.e., $Y_f = Y_a/TE_a$, where Y_f and Y_a are the yields of the frontier and average farmers respectively, and TE_a is the technical efficiency rating of the average farmers (taken from Tables 6.9 and 6.10 for the dry and wet seasons respectively).

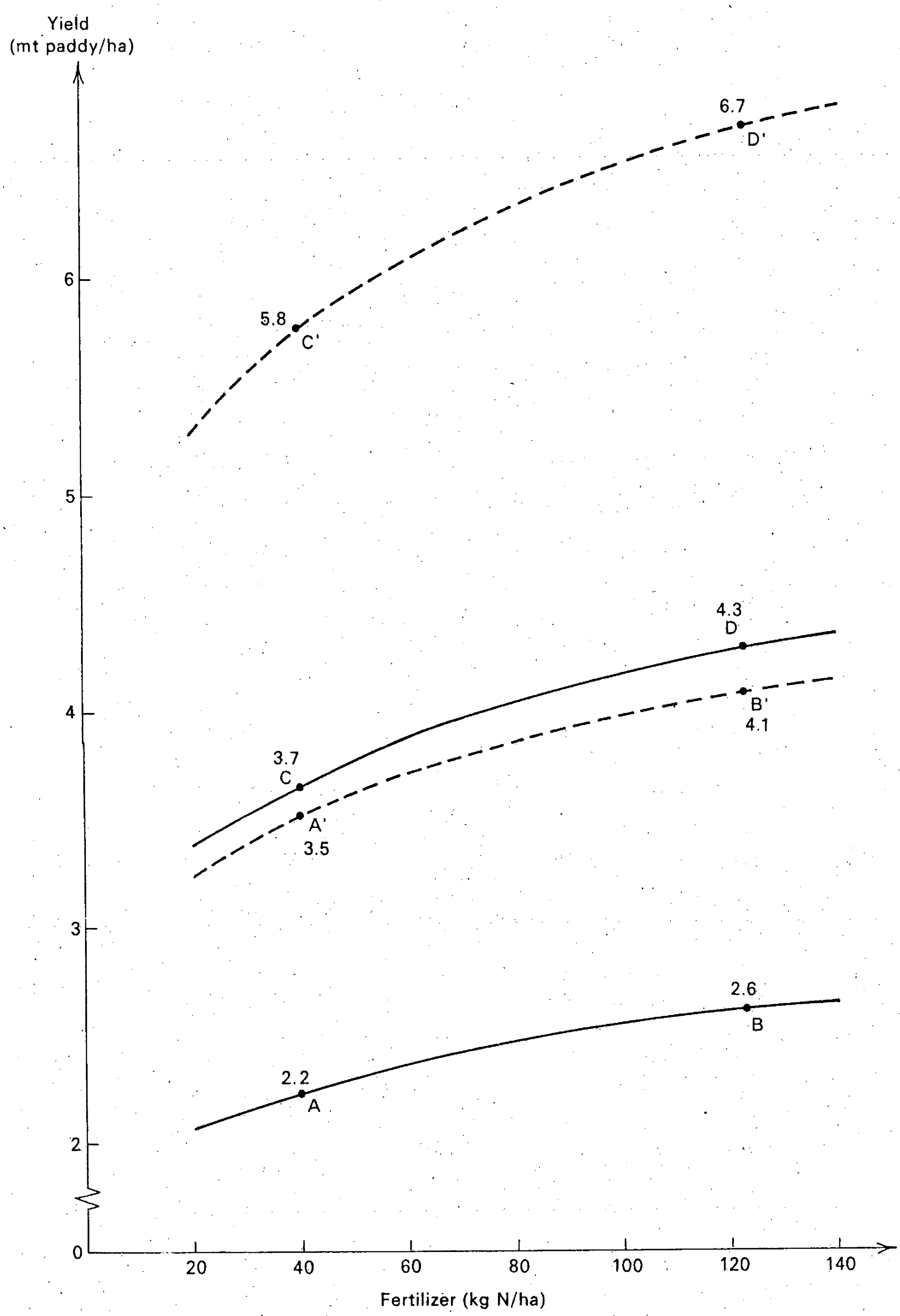

Figure 7.1. Yield response curves for fertilizer in average and frontier functions, 1978 dry season

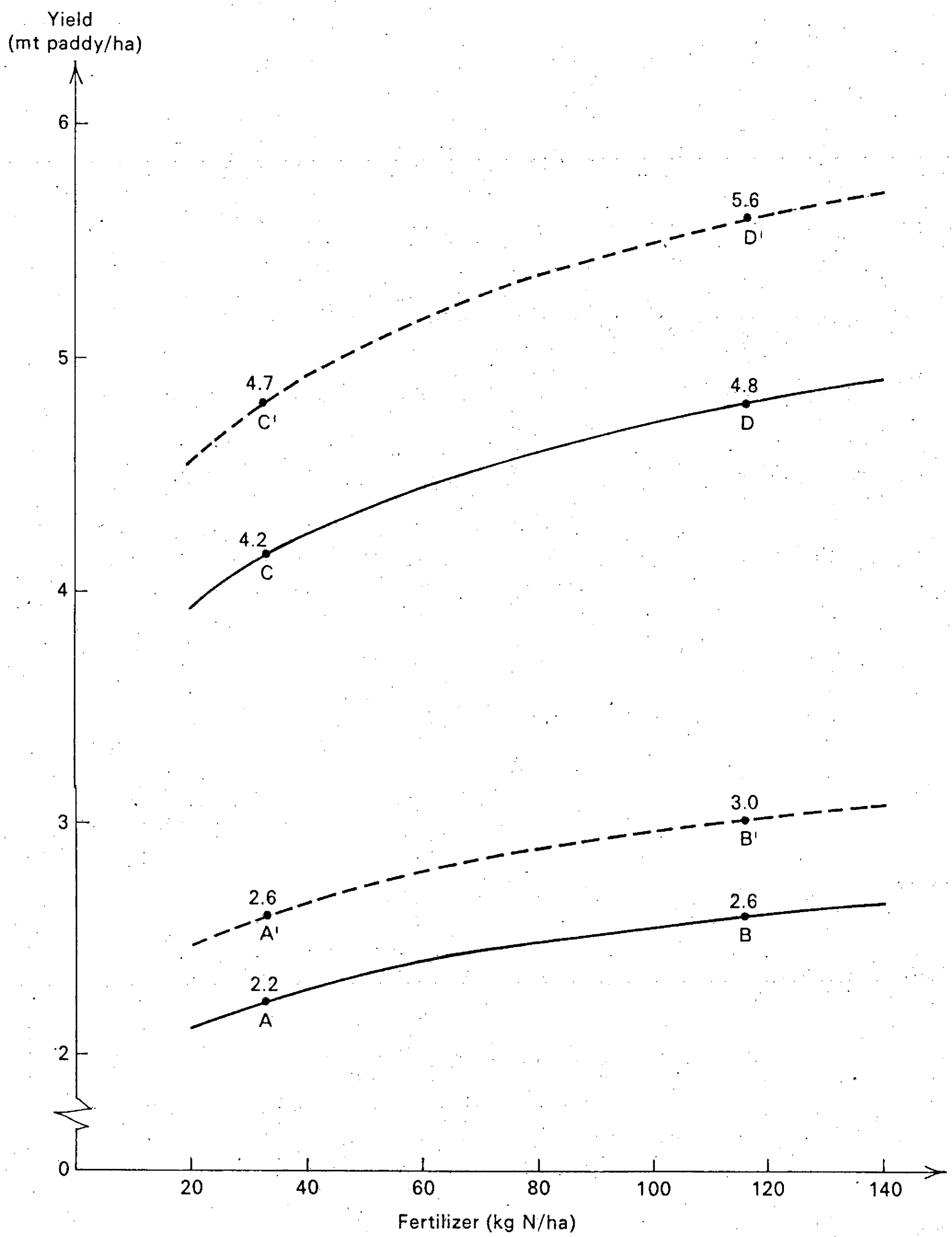

Figure 7.2. Yield response curves for fertilizer in average and frontier functions, 1978/79 wet season.

A. <u>Gains from achieving technical efficiency</u>

1. <u>Without</u> optimisation of input levels to achieve price efficiency, this implies a shift from the average to the frontier function, i.e. from point A to point C in Figures 7.1 and 7.2 and yield gains of:
   2.2 to 3.7 = 1.5 mt paddy/ha in the dry season, and
   2.2 to 4.2 = 2.0 mt paddy/ha in the wet season.

2. <u>With</u> inputs adjusted to price efficiency, including N fertilizer, this implies a shift from the average to the frontier, from point A' to point C' in the two figures and yield gains of:
   3.5 to 5.8 = 2.3 mt paddy/ha in the dry season, and
   2.6 to 4.7 = 2.1 mt paddy/ha in the wet season.

B. <u>Gains from achieving price efficiency</u>

1. <u>Without</u> technical efficiency, there is a shift from average to average curves, and optimising all inputs <u>except</u> N fertilizer input, i.e. from point A to point A' and yield gains of:
   2.2 to 3.5 = 1.3 mt paddy/ha in the dry season, and
   2.2 to 2.6 = 0.4 mt paddy/ha in the wet season.

2. <u>With</u> technical efficiency, there is a shift from frontier to frontier optimising all <u>except</u> N fertilizer, i.e. a shift from point C to point C' in the two figures and yield gains of:
   3.7 to 5.8 = 2.1 mt paddy/ha in the dry season, and
   4.2 to 4.7 = 0.5 mt paddy/ha in the wet season.

3. <u>Without</u> technical efficiency, there is a shift from average to average curves optimising all inputs <u>including</u> N fertilizer, i.e. a shift from point A to point B' in the two figures and yield gains of:
   2.2 to 4.1 = 1.9 mt paddy/ha in the dry season, and
   2.2 to 3.0 = 0.8 mt paddy/ha in the wet season.

4. With technical efficiency, there is a shift from frontier to frontier curves optimising all inputs including N fertilizer, i.e. a shift from point C to point D' in the two figures and yield gains of:
   3.7 to 6.7 = 3.0 mt paddy/ha in the dry season, and
   4.2 to 5.6 = 1.4 mt paddy/ha in the wet season.

C. Gains from achieving both technical and price efficiencies

There is a shift from average curves, without optimisation of input levels, to frontier curves with optimisation of all inputs including N fertilizer, i.e. a shift from point A to point D' in the two figures and yield gains of:
2.2 to 6.7 = 4.5 mt paddy/ha in the dry season, and
2.2 to 5.6 = 3.4 mt paddy/ha in the wet season.
Thus if both are achieved, yields at maximum efficiency will be 205 and 155 per cent higher than the average yields reached in the dry and wet seasons respectively.

It should be noted that with the average production functions in the dry season, if fertilizer use is made price efficient with concurrently efficient use of all other inputs (there is a shift from point A to point A' and to point B'), there is a yield gain from the upward adjustment of fertilizer use of 0.60 mt/ha. If this upward adjustment is made without price efficiency in all other inputs (i.e. a shift from point A to point B) the yield gain from price efficiency in fertilizer use is only 0.40 mt/ha. It thus appears that the former yield response is considerably enhanced, suggesting complementarity between fertilizer and other input use, particularly, one would suspect, from optimisation of water use.[14]

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[14] Similar results were found when the wet season data are used. Thus, in this case, the wet and the dry seasons led to the same conclusion.

The above analysis suggests that rice yields[15] in the study area can be increased substantially by raising both input levels and by achieving technical efficiency, i.e. from 2.2 to 6.7 and from 2.2 to 5.6 mt paddy/ha in the dry and wet seasons respectively (in a move from point A to point D' in Figures 7.1 and 7.2). Actual survey yields indicate that this improvement is feasible, for the highest recorded yields in the two seasons were 5.50 and 5.45 mt/ha respectively, achieved by sample farmer No.43 who, in the dry season, applied inputs per hectare of about 150 mandays labour, 114 kg N, and 23,500 rupiahs of the other costs, and averaged 19.5 mm/day of water depth and only 13 stress days. In the wet season input levels were 149 mandays labour, 96 kg N, 24,500 rupiahs of other costs, and an average of 16.7 mm/day of water depth and 28 stress days (Table 6.13). This farmer was technically efficient in both seasons. She was not price efficient in the dry season, but was almost so in the wet season (Appendixes 6.2 and 6.3). As might be expected therefore, the dry season yield of this farmer (5.55 mt/ha) was lower than the maximum feasibility yield (6.7 mt/ha), while her wet season yield (5.45 mt/ha) was very close to the maximum feasibility yield (5.6 mt/ha).

In review, farmers at point A (Figures 7.1 and 7.2) were inefficient in both technical and price terms. Farmers at point D were technically efficient but not price efficient. Conversely, farmers at point B' were price efficient but not technically efficient. Only farmers at point D' were both price and technically efficient.

The above calculations indicate that farmers in the study area, on average, were not efficient in either technical or price terms, in either season. There were, however, a few individual farmers who achieved high ratings on both efficiency counts in both seasons, such as farm No.43. This raises the major question as to how the efficiencies of other farmers might be increased, e.g.

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15 Unless otherwise specified, the yield is meant as the adjusted yield as defined below.

to the level of No.43.

The situation in the wet season (Figure 7.2) was broadly similar to that in the dry season. The smaller gaps between AB and A'B' curves and between CD and C'D' curves in the wet season are consistent with the fact that yield elasticities of the four factors (I, N, L and C) were also smaller in the wet than in the dry season.

Factors Affecting Input Levels

The next important step is to determine which factors influence farmers' decisions as to the level of inputs. Four factors of production were included in the rice production function for the study area, namely, irrigation water, nitrogenous fertilizer, labour, and the other variable costs. The last named factor comprised many inputs, but principally phosphorous fertilizer and costs of pest control and paddy seed.

Factors affecting the efficiency of irrigation water utilization were discussed in detail in Chapter 5 above. The following analysis is therefore confined to factors influencing the application levels of fertilizer, pesticides, modern rice variety seeds, and of labour.

Demand for Fertilizer

One of the main differences between modern and traditional rice varieties that is emphasized by rice scientists is the greater yield response of the modern varieties to fertilizer (David and Barker 1978). However as discussed in Chapter 5 above, the response will be greater only if the water supply at field level is sufficient. In the present study area, about 58 per cent of sample farmers used IRVs. IRV yield performances, however, were not significantly different from those of other varieites (NIV and LIV). This was due particularly to the early time of draining the farms prior to harvest, and to the low dosage level of fertilizer used on the IRVs (Table 6.1).

Demand factors for nitrogenous fertilizer were analysed using regression analysis with a model as follows,[16]

$$\ln N = \ln a + b_1 \ln(TD) + b_2 \ln F + b_3 \ln(PR) + b_4 \ln D + b_5 \ln B + b_6 \ln(RFE) + c_1(CR) + c_2(RPC) + c_3 E + c_4 T_1 + c_5 T_2 + c_6 M + c_7(WS) + c_8 V + u \quad (7.6)$$

where:

N = amount of nitrogen applied per hectare (kgN/ha);

TD = time of draining farms prior to harvest (in DBH);

F = farm size (in ha);

PR = urea:paddy price ratio;

D = crop damage (in percentage of crop area);

B = frequency of Bimas participation;

RFE = rice farm experience of the farmer (years);

CR = a dummy variable for credit ($CR = 1$ for farmers who obtain credit from any source for any purpose, otherwise $CR = 0$);

E = a dummy variable for education ($E = 1$ for farmers who had more than 6 years of formal education, otherwise $E = 0$);

RPC = a dummy variable for farm family rice production ($RPC = 1$ if rice production per capita per season was greater than or equal to 150 kg paddy, otherwise $RPC = 0$);

T_1 = a dummy variable for land tenure ($T_1 = 1$ for owner operators, otherwise $T_1 = 0$);

T_2 = a dummy variable for the fixed-rent operator ($T_2 = 1$ for the fixed-rent operator, otherwise $T_2 = 0$);

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16 This model was adapted from David and Barker (1978) and David et al. (1979).

M = a dummy variable for merantau experience (M = 1 for farmers who had the experience, otherwise M = 0);

WS = a dummy variable for water sources (WS = 1 for farms that took water directly from irrigation channels, otherwise WS = 0);

V = a dummy variable for rice variety (V = 1 for IRV, otherwise V = 0);

u = a stochastic disturbance term;

ln = natural logarithm; and

a, b, and c are parameters to be estimated.

Estimation of the coefficients of the regression model for fertilizer demand (Table 7.7) indicated that the coefficients for the time of draining farms (TD) were negative and significant at the 5.0 per cent level in both seasons. This implies that a one per cent increase in the days of the time of draining farms decreased the amount of nitrogen applied per hectare by 0.06 and 0.32 per cent in the dry and wet season respectively. With use of W (average depth of water) and S (number of stress days) instead of TD, gave coefficients, in the dry season, of 0.2448 and -0.0546 respectively, which were also significant at the 5.0 per cent level.[17] In the wet season the coefficients of W and S were 0.0668 and -0.0055 respectively, which were not significant even at the 10 per cent level. This could be explained by farmers' confidence that in the wet season, water was not a constraint, which would obviate the need for them to consider water availability in determining the level of nitrogen. The wet season yield might therefore be expected to be higher than that for the dry season. In fact, because of the higher level of crop damage in the wet season, and because of the higher level of solar radiation in the dry season, average actual yields were higher in the dry season (Table 6.1). When, however, yields were adjusted appropriately for crop damage levels, differences in average yields were insignificant between seasons.

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17 See Appendix 7.1 .

Table 7.7 Regression coefficients of factors affecting nitrogen application per hectare (in log), 1978 dry and 1978/79 wet seasons.

Variables	Coefficients	
	Dry season	Wet season
Constant (ln a)	3.7758	4.5511
Time of draining farms (ln TD)	-0.0689** (-1.84)	-0.3185** (-2.37)
Farm size (ln F)	-0.2323** (-1.85)	-0.5165*** (-3.70)
Crop damage (ln D)	-0.0311 ns (-0.60)	-0.1032** (-1.91)
Urea:paddy price ratio (ln PR)	0.3031 ns (0.46)	0.1250 ns (0.19)
Bimas participation frequency (ln B)	....	0.0355** (1.61)
Rice farm experience (ln RFE)	-0.0429 ns (-0.47)	-0.0954 ns (-1.19)
Credit dummy (CR)	0.1343 ns (0.87)	0.3775** (2.48)
Rice production/capita/season dummy (RPC)	0.2943** (1.81)	....
Owner operator dummy (T_1)	0.2528* (1.59)	....
Fixed-rent dummy (T_2)	0.3402 ns (1.27)	0.2339 ns (0.83)
Education dummy (E)	0.3194* (1.54)	0.3890** (1.85)
Migration dummy (M)	0.1365 ns (0.94)	....
Water source dummy (WS)	-0.3936** (-2.23)	-0.1284 ns (-0.71)
Variety dummy (V)	-0.0593 ns (-0.38)	0.1287 ns (0.78)
No. of observations	89	87
R^2	0.33	0.32
Adjusted R^2	0.21	0.22
F-test	2.80***	3.16***

Notes:
*** significant at the 1.0 per cent level
** significant at the 5.0 per cent level
* signficant at the 10 per cent level
ns not significant at the 10 per cent level
.... F-level is insufficient for further computation

The coefficients for crop damage variable were negative in both seasons, which were only significant in the wet season, indicating that the levels of crop damage also affected the levels of nitrogen application.

Interestingly, the coefficients for the urea:paddy price ratio were not significant in either seasons, and their signs were positive in both seasons. This finding is no surprise, for as was seen in the analysis above, inter-farm price differences were not great and therefore did not significantly affect the level of nitrogen applied per hectare.[18]

Another significant factor was farm size, with a negative coefficient, significant at the 5.0 per cent in the dry season and at the 1.0 per cent in the wet season. However, as correctly emphasized by Castillo,[19] farm size alone has little meaning. It will have significance only when viewed within the context of other related factors. In our case, simple correlations between farm size and share cropper operators and between farm size and the tail section were positive and significant at the 5.0 per cent level. It is important to note that 73 per cent of sample farmers in the tail section were share-croppers. Thus, the negative coefficient for farm size could be related to share-cropping system. The low level of fertilizer applied by share croppers relative to owner operators could be due to the fact that landlords were not required to contribute to meeting the costs of fertilizer or of other costs as discussed earlier, and most of the share-croppers reported during the survey interviews that they did not have enough money themselves to buy much fertilizer, and that

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18 The prices of fertilizer and rice are controlled by the government. The retail price of fertilizer (urea and TSP) in rice production intensification programs was almost uniform throughout Indonesia. Rice price is controlled within limits of floor and ceiling prices of paddy.

19 Castillo, G.T. (1975), 'Diversity in Unity: the social component of change in rice farming in Asian villages', in IRRI, Changes in rice farming in selected areas of Asia, pp.346-360, Los Banos, Philippines.

credit facilities were inadequate.[20]

There was a positive coefficient for the credit dummy variable, that was significant at the 5.0 per cent level in the wet season. This implies that farmers with credit applied fertilizer at higher levels than those without it. The insignificant coefficient for CR in the dry season indicating that demand for fertilizer in the dry season was not significantly influenced by credit.

The coefficient of the rice production/capita dummy variable (RPC) was positive and significant in the dry season. This indicates that although the production level reached or exceeded the consumption need level,[21] farmers in the study area still increased the level of fertilizer use in order to raise output. Thus the hypothesis that the goal of rice farmers was only to satisfy household consumption, should be rejected.

The significantly positive coefficient for the education dummy variable indicates the importance of education in the demand for fertilizer. As we have seen in Chapter 3 above (Table 3.1) education positively affected yields but was not significant. It therefore can be suggested that education affectied yields indirectly through influencing the price and technical efficiencies of farmers.[22] The coefficient of merantau experience was also

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[20] David et al. (1979) found that, in the Philippines, the coefficient for farm size was positive and significant. The reasons for this were that the larger farms there had either greater internal savings or more access to lower cost credit. Thus, it shows again that the level of fertilizer demand is heavily determined by the availability of credit facilities and the ability of farmers to borrow.

[21] Ahrens (n.d.), reported that in 1971/72, rice consumption per capita/year in West Sumatra was 125.5 kg milled rice, on average, for urban, and 162.5 kg for rural areas.

[22] It was also shown in the preceding chapter (Table 6.8) that education positively influenced the TER of sample farmers.

positive but not significant in either season. Thus, merantau experience did not directly affect the level of fertilizer application.

The coefficient for Bimas participation frequency was positive and significant in the wet season, but not in the dry season. Therefore, a general conclusion about the impact of the Bimas participation frequency on the demand for fertilizer in the study area could not be made.

Other factors such as rice farm experience and rice variety differences did not significantly influence the level of fertilizer applied. The coefficient for water source dummy was negative and significant in the dry season. This means that farms which received irrigation water directly from irrigation channels applied lower level of fertilizer than those which received water through other farms. The reasons for this were not known.

The above analysis suggests that the significant factors affecting the demand for fertilizer in the study area were the time of draining farms, farm size, and education in both seasons. Other significant factors were RPC dummy, types of land tenure and water source dummy in the dry season; crop damage, Bimas participation and credit in the wet season.

It is important to note that, overall, the supply of fertilizer in West Sumatra was not a problem, and survey observations indicated a number of other relevant factors which also persuaded rice farmers to limit nitrogenous fertilizer use. These factors included:

(a) Uncertainty among some farmers that using more nitrogen than the accustomed level would increase yields;

(b) the relatively low profitability of rice cultivation;[23]

(c) unavailability of their preferred fertilizer type. For example some farmers who were accustomed to using SS (Single Superphosphate) could only obtain Urea and TSP during the survey period; and

(d) the expectation of high crop losses from rats given the taboo against killing rats.

Pesticides

Although pest control is an important component of the improved rice technology, not all sample farmers in the study area applied pesticides, and not one of them used rodenticides, owing to the taboo against killing rats. In the dry season, 83 per cent of sample farmers applied pesticides, while in the wet season only 68 per cent did so. As discussed in Chapter 6, pest damage was more serious in the wet than in the dry season, and reduced yields by 0.47 and 0.65 mt paddy/ha respectively.

The supply of pesticides was not a problem in the study area. The main problem was the prevailing social attitude towards rat control, the most important pest problem there. This attitude also influenced farm water management, to the point where the preferred method of crop protection against the rodents, that of field draining, actually lowered yields, both directly, through water stress, and indirectly, by reducing the level of fertilizer application and crop response to fertilizers. Another problem was the lack of practical knowledge of many farmers in the application of pesticides, particularly in the choice of pesticide

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23 Average net profit/ha for the 1978 dry season was only about Rp69,000 (the wage of family labour is assumed to be zero) with average yields of 1.96 mt paddy/ha. This was very low compared with Rp154,000/ha in Gemini village in East Java, in the 1978 dry season with average yields of 4.95 mt paddy/ha (Collier 1979, Table A17). Thus, the level of net profits is in line with the level of yields. The highest net profit/ha in Badenah irrigation sample area in that dry season was Rp274,000/ha with yield of 5.0 mt paddy/ha.

type to be used and in the timing of its application to pest types attacking their farms. For example, stem borer was an important pest there, but many farmers did not know which types of pesticides should be used and when they should be applied to control the pest effectively.

Paddy Seeds

International varieties (IRV) were used by 58 and 66 per cent of total sample farmers in the dry and wet seasons respectively.[24] The seeding rate used (57 kg/ha) was more than double that recommended (25 kg/ha). Farmers gave the reason that they used more seedlings per hill (8-12) than recommended (3-5) in order to counterbalance damage caused by ducks or uncontrolled water flow in rice fields after transplanting.

The average yield of the IRVs was lower than those of NIV and LIV (Chapter 6). This is consistent with the lower level of fertilizer used, the lower average depth of water, and the earlier draining of farms using IRV. It might also be because the IRV used by sample farmers had degenerated for lack of renewal over a long period, and/or that these varieties were not suited to the local environment. Our field observations showed that, at the time, rice farmers had difficulties in obtaining new seeds owing to limited supplies. The kiosks of the BUUD sometimes sold new seeds (but not of new varieties) supplied by the government agencies, but because the price was high (Rp175/kg) compared with the market price of paddy (Rp80/kg), and the seeds were sold without a certificate of guarantee, farmers preferred not to buy them.

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24 IRVs used in the study area were IR-5, IR-8, IR-20, IR-26 and C4. About 20 and 10 per cent of sample farmers used NIVs (i.e. Pelita I, Pelita II and Adil) in the dry and wet seasons respectively. LIVs used there were Dalin and Kemuning varieties.

Demand for Labour

The analysis of allocative efficiency above showed that the level of labour used in the study area was close to the optimum. This indicates that labour was not a constraint there. This could be related to the fact that the average size of sample farms was small at 0.46 ha, ranging from 0.05 to 1.44 ha/farm, and the average size of farm families was large, at about 7.0 persons, ranging from 2 to 14 persons. Farms in this size range can typically be operated with available family labour, and hired labour is used only when family labour is not sufficient. Our survey data indicated that hired labour was only about 28 per cent of total preharvest labour employed on rice farms.[25]

Demand factors for preharvest labour were analysed using regression analysis with the following model,

$$\begin{aligned} \ln L = \ln a &+ b_1 \ln(WL) + b_2 \ln(FPC) + b_3 \ln F + \\ &b_4 \ln E + b_5 \ln(FL) + b_6 \ln R + b_7 \ln(IC) + \\ &c_1 T + c_2 V + c_3 (WS) + c_4 (LP) + u \qquad (7.7) \end{aligned}$$

where WL is hired labour wages per man day (Rp/day), FPC is fertilizer and pesticide cost per hectare ('000Rp/ha), FL is preharvest family labour used (man days/ha), IC is income/capita/6 months of the farm family ('000Rp), R is revenue/ha (yield x paddy price), PL is a dummy variable for land ploughing system (PL = 1 for hoeing and otherwise PL = 0), and other notations are the same as in equation (7.6). The dependent variable is ln L, i.e. preharvest labour used per hectare (man days) or ln (HL), the amount of preharvest hired labour used (man days/ha).

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25 This figure is lower than those recorded for (in %) Java (78), Central Luzon Philippines (66), Sri Lanka (65), Central Taiwan (38) and Central Korea (30), but is higher than in Malaysia (14). For details, see Barker and Cordova (1978).

The results of the estimation of the model (Table 7.8), as expected, show that the coefficients of wages in both seasons were negative, but they were not significant, indicating that demand for labour was not significantly influenced by the level of wages. This finding is in line with evidence from many parts of Asia that the demand for labour in the agricultural production cycle is quite wage inelastic (Booth and Sundrum 1980).

The results further show that the demand for preharvest hired labour was significantly influenced by the application levels of new inputs (fertilizer and pesticides), farm size,[26] the level of preharvest family labour used, types of land tenure, the source of irrigation water and land ploughing techniques. These factors also affected the total amount (hired and family labour) of preharvest labour used, though the influence of land tenure types was not significant.

The coefficients of the education variable were negative but not significant, except in the total labour equation in the wet season. This indicates that more educated farmers used less preharvest labour per hectare than less educated farmers, and could be related to management capacity. The former may be more efficient and more effective than the latter in the use of preharvest labour. The lack of significance of this factor could be because the variance of sample farmers' education was small.

Economic Efficiency

This section examines the performances of sample farmers with regard to economic efficiency, both relative, with farmers grouped by location, types of tenure, rice variety, and source of

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[26] The negative relationship between farm size and preharvest labour employed in rice cultivation was also found in Griffin (1972, p.39) and Collier (1979). A number of reasons for that negative relationship can be seen in Booth and Sundrum (1980). On the other hand, Barker and Cordova (1978) found positive coefficient for this variable but provided no explanations for that.

Table 7.8 Regression coefficients of factors affecting preharvest hired and total labour input per hectare (in logs), 1978 dry and 1978/79 wet seasons.

Variables	Coefficients			
	Dry season		Wet season	
	Hired	Total	Hired	Total
Constant (ln a)	1.6419	1.6931	3.6167	2.7765
Wages (ln W)	-0.1426 (-0.07)	-0.1250* (-1.64)	-0.3351 (-1.12)	-0.1609 (-1.17)
Fertilizer and pesticides costs (ln FPC)	0.3479* (1.59)	0.1519** (2.06)	0.0660* (1.30)	0.0397* (1.66)
Farm size (ln F)	-0.3146** (-1.78)	-0.2127*** (-2.95)	-0.5065*** (-2.94)	-0.2373*** (-2.93)
Education (ln E)	....	-0.0611 (-1.09)	-0.1680 (-1.12)	-0.1408** (-2.15)
Preharvest family labour used/ha (ln FL)	-0.6689*** (-4.98)	-	-0.7107*** (-7.88)	-
Value of output/ha (ln R)	0.2374*** (4.27)	0.2028*** (5.57)	0.1974 (1.18)	0.1448** (1.86)
Income/capita/6 month (ln I)	0.0526 (0.77)	0.0329 (1.24)	-0.0272 (-0.47)	0.0059 (0.22)
Tenure dummy (T)	0.3674** (1.68)	0.1064 (1.19)	0.3270** (1.74)	0.1081 (1.22)
Variety dummy (V)	-0.0866 (-0.46)	-0.0205 (-0.25)	-0.1551 (-0.90)	-0.0548 (-0.80)
Watersource dummy (WS)	0.4639* (1.48)	0.1738** (1.81)	0.3270** (1.74)	0.2517*** (2.71)
Land ploughing dummy (LP)	-0.4111** (-2.29)	-0.2127*** (-2.95)	-	-
No. of observations	76	76	67	67
R^2	0.48	0.46	0.61	0.31
Adjusted R^2	0.37	0.40	0.54	0.20
F-statistic	5.92***	5.44***	8.89***	2.79***

Notes: Figures in brackets are respective standard deviations of parameters.

*** significant at the 1.0 per cent level
** significant at the 5.0 per cent level
* significant at the 10.0 per cent level

irrigation water, and individual. The influence of technical and price efficiencies have already been analysed separately, and it is their combined effect, measured as economic efficiency, that is considered here.

Relative Efficiency

Relative economic efficiency, in the context of the Cobb-Douglas production function and the UOP (unit output price) profit function (Chapter 3) is judged by testing whether the UOP profits of the various farmer groups differ significantly. For this, respective dummy variables were included in the UOP profit function for all sample farms.

The UOP profit function model to be estimated in this section, drawn from equation 3.89 above, is:

$$\begin{aligned} \text{Ln } P = & \ln a + b_1 \ln(WL) + b_2 \ln(NP) + b_3 \ln(OP) + \\ & c \ln F + d_1 D_1 + d_2 D_2 + d_3 T_1 + d_4 T_2 + \\ & d_5 V_1 + d_6 V_2 + d_7 (WS) + u \end{aligned} \qquad (7.8)$$

where P = UOP profit; WL = hired labour wages; NP = price of nitrogen; OP = price of other variable costs; V_1 and V_2 are dummy variables for IRV and NIV respectively; D_1 and D_2 represent the body and tail sections respectively; other variables (F, T_1, T_2 and WS) and other notations are as defined in equations (7.6) and (7.7).

For the dry season, the F-statistic was significant at the 1.0 per cent level (Table 7.9), indicating that the hypothesis, that all coefficients (except ln a) were equal to zero, should be rejected. The adjusted R^2 showed that about 43 per cent of variations in the UOP profit was explained by the explanatory variables. As expected, the coefficients of WL, NP and OP were negative, indicating negative relationships with UOP profit. The significant WL coefficient of -0.6316 in the dry season, implies

Table 7.9 Cobb-Douglas profit function coefficients and related statistics of sample farms in the Badenah irrigation system, 1978 dry and 1978/79 wet seasons.

Variable	Parameter	
	Dry season	Wet season
Constant (ln a)	8.7026	7.5118
Labour wages (ln WL)	-0.6316*** (-3.29)	-0.0483[ns] (-0.72)
Price of N (ln NP)	-0.3482[ns] (-0.64)	-0.3738[ns] (-0.44)
Other cost price (ln OP)	-0.3102[ns] (-0.80)	-0.1426[ns] (-0.35)
Farm size (ln F)	0.8545*** (6.15)	0.8358*** (4.32)
Location dummy (body)	-0.2498[ns] (-0.52)	0.0712[ns] (0.25)
Location dummy (tail)	-0.3049** (-1.84)	-0.3566* (-1.39)
Tenure dummy (owner)	-0.0427[ns] (-1.22)	0.1950[ns] (0.83)
Tenure dummy (fixed-rent)	0.8499*** (3.04)	0.5140* (1.39)
Variety dummy (IRV)	-0.1662[ns] (-0.75)	-0.2049[ns] (-0.80)
Variety dummy (NIV)	-0.3333*** (-2.74)	-0.3495[ns] (-0.86)
Water source dummy (WS)[a/]	0.0003[ns] (0.23)	-0.1099[ns] (-0.47)
R^2	0.5053	0.3103
Adjusted R^2	0.4276***	0.1899***
F-test	6.4998***	2.5700**
No. of observations	82	75

a/ WS = 1 for farms receive irrigation water directly from irrigation channels, otherwise WS = 0.

Notes: Figures in brackets are respective t-values of parameters.

*** significant at the 1.0 per cent level
** significant at the 5.0 per cent level
* significant at the 10 per cent level
ns not significant at the 10 per cent level

that a one per cent increase in wages reduces the UOP profit by 0.63 per cent. The non-significance of the coefficients of NP and OP could be related to the above analysis which indicated that interfarm price variations were not big. The significant coefficient for F in the dry season, indicates that a one per cent increase in farm size increases the UOP profit by a sizeable 0.85 per cent.

The dry season analysis also gave a negative and significant coefficient for the tail dummy variable, while that for the body variable was not significant. These results imply that farmers in the tail section were least efficient economically, relative to those in the body and head sections, while there was no significant difference in economic efficiency between those in the other two sections.

The coefficient for the tenure dummy variables indicates that the fixed-rent operator was the most economically efficient of the tenure groups, and that owner operators and the share croppers did not differ significantly in this respect. Amongst varietal groups, NIV growers were the least efficient economically, but there was no significant difference in economic efficiency between the water source groups.

The wet season results were mostly very similar to those of the dry season. The most important differences were that the coefficient of WL was not significant in the wet season, and that the relative economic efficiencies of rice variety groups showed no significant differences. The adjusted R^2 for the wet season was much lower than that for the dry season, indicating that less of the total variation of the UOP was explained by the variables included.

Individual Efficiency

The economic efficiency rating (EER) of individual sample farmers is given by the ratio of the actual profit to the maximum profit of the farm, namely,

$$EER_i = (ANP)_i/(MANP)_i \tag{7.9}$$

Where EER_i is the EER of farmer i (i = 1, 2, ..., n; n = the number of observations); $(ANP)_i$ is the actual adjusted net profit (total revenue less total variable costs) per hectare of farm i; and $(MANP)_i$ is the maximum adjusted net profit/ha of farm i. The actual and the maximum profits of farm i were calculated by the following formula,

$$(ANP)_i = Y_i P_{yi} - \sum_{j=1}^{m} X_{ji} P_{ji} \tag{7.10}$$

$$(MANP)_i = Y_i^* P_{yi} - \sum_{j=1}^{m} X_{ji}^* P_{ji} \tag{7.11}$$

where Y_i is the adjusted yield of farm i; P_{yi} is the price of paddy received by farmer i (Rp/kg); X_{ji} is the actual level of input j (j=1, 2, ..., m; m = the number of explanatory variables) applied by farmer i; P_{ji} is the unit price of input j paid by farmer i; Y_i^* is the estimated yield for farm i computed from CD frontier production functions (LP-98 of Model II in Tables 6.6 and 6.7 for the dry and wet seasons respectively) using the optimum levels of the inputs (X_{ji}^*). The optimum levels of the inputs for maximum profits were calculated using the following equation,

$$X_{ji}^* = \hat{b}_j (Y_i^* P_{yi})/P_{ji} \tag{7.12}$$

where X_{ji}^* is the optimum level of input j for the maximum profit of farm i; $\hat{b}_j$ is the estimated yield elasticity of input j of the CD frontier production function; and other notations are as above.[27] With this measure, the values of EERs range between zero and one, with 100 per cent economic efficiency indicated by an EER of one.

Since economic efficiency is the product of technical efficiency (TER) and price efficiency (PEI), namely,

$$EER_i = TER_i \times PEI_i \tag{7.13}$$

a price efficiency index (PEI) of a farm is the ratio of economic efficiency to technical efficiency,[28]

$$PEI_i = EER_i/TER_i \tag{7.14}$$

Individual TERs of sample farmers were calculated and discussed in Chapter 6 above, and by computing individual EERs of sample farmers using techniques discussed above, individual PEIs of sample farmers can be obtained. Individual EERs and PEIs were calculated and the results along with individual TERs and ANPs (actual net profits/ha) of sample farmers are reported in Appendixes 7.2 and 7.3 for the dry and wet seasons respectively.

The results show that individual efficiencies (TER, PEI and EER) of sample farmers were, as expected, between zero and one in both seasons. This is consistent with the theoretical analysis discussed in Chapter 3 above, where both technical and price efficiency ratings of farmers are between zero and one.

The results also show that two farmers with equal levels of

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27 See Yotopoulos (1967, p.199) for the calculation technique of the optimum level of an input. In equation (7.12) we apply estimated yields as used by Sahota (1968), rather than actual yields.

28 See Farrell (1957), Hall and Le Veen (1978) for these definitions and assumptions.

both technical and price efficiencies had the same levels of economic efficiency too (e.g. farmers with serial nos. 37 and 38 in Appendix 7.2). Conversely, two farmers with different levels of TER and/or PEI should have different levels of economic efficiency too. But, since economic efficiency is the product of technical and price efficiencies (EER = TER x PEI), it is not impossible that two farmers with different levels of TER and/or PEI could have the same levels of economic efficiency, as shown, for example, by farmers with serial nos. 6 and 25 in Appendix 7.2. The results further indicate that these two farmers with the same levels of economic efficiency had different levels of profit/ha. Moreover, farmers with higher economic efficiency levels could obtain lower levels of profits/ha, and vice versa (e.g. farmers with serial nos. 1 and 5 in Appendix 7.3). This is not surprising because profits/ha are not only determined by technical and price efficiency levels, but also by input and output price levels. Thus, two farmers with equal levels of economic efficiency will only have the same levels of profits/ha if these two farmers also operate at the same input and output price levels. This implies that the levels of profits/ha of farmers are not always consistent with the levels of the economic efficiency of the farmers.

Farm Group Efficiency

From individual PEI and EER of sample farmers, the average values of PEIs and EERs were calculated for each group of farmers. These results were compared with the results of the economic rationality and profit function analyses, as shown in Tables 7.10 and 7.11.

A comparison of the price efficiency and economic rationality analyses showed some contrasts. First, the absolute values of PEIs were very different from those of respective ERIs in the dry season (Table 7.10), but were similar in the wet season (Table 7.11). This could be due to the fact that the values of individual PEIs of sample farmers were estimated with the assumption that the shift between curves of the average and frontier functions was Hicks-

Table 7.10 Technical Efficiency Rating (TER), Price Efficiency Index (PEI), Economic Rationality Index (ERI), and Economic Efficiency Rating (EER) by groups of farmers in Badenah irrigation system, 1978 dry season.

Farm groups	n	TER	PEI	ERI	EER
All sample farms	89	0.61 (0.19)	0.27 (0.10)	0.69	0.17 (0.09)
Location					
Head	29	0.64	0.27^{a}	0.83	0.18^{a}
Body	30	0.58 (0.23)	0.31^{a} (0.13)	0.64	0.19^{a} (0.13)
Tail	30	0.62 (0.15)	0.21^{b} (0.06)	0.51	0.14^{b} (0.07)
Tenure					
Owner operator	30	0.53^{a} (0.17)	0.25^{a} (0.10)	0.75	0.13^{a} (0.07)
Fixed-rent	8	0.70^{b} (0.25)	0.34^{b} (0.12)	0.58	0.25^{b} (0.16)
Share-cropper	51	0.65^{c} (0.18)	0.26^{a} (0.10)	0.66	0.18^{c} (0.10)
Rice variety					
IRV	52	0.61 (0.19)	0.24^{a} (0.10)	0.69	0.16^{a} (0.10)
NIV	17	0.58 (0.20)	0.31^{b} (0.09)	0.64	0.19^{b} (0.11)
LIV	20	0.65 (0.20)	0.29^{b} (0.10)	0.77	0.18^{b} (0.08)
Water source					
From channels	70	0.60 (0.19)	0.27 (0.11)	0.70	0.17 (0.10)
Plot-to-plot	19	0.67 (0.19)	0.27 (0.09)	0.71	0.18 (0.09)

Notes: Figures in brackets are respective standard deviations. If figures between groups within a category have the same letters within a column, the difference between the two figures is not significant at the 5.0 per cent level, and vice versa.

n = number of observations.

Table 7.11 Technical Efficiency Rating (TER), Price Efficiency Index (PEI), Economic Rationality INdex (ERI), and Economic Efficiency Rating (EER) by groups of farmers in Badenah irrigation system, 1978/79 wet season.

Farm groups	n	TER	PEI	ERI	EER
All sample farms	87	0.54 (0.18)	0.60 (0.11)	0.63	0.33 (0.15)
Location					
Head	27	0.54 (0.18)	0.60[a] (0.09)	0.84	0.33[a] (0.13)
Body	30	0.57 (0.20)	0.66[b] (0.11)	0.73	0.39[b] (0.18)
Tail	30	0.51 (0.16)	0.55[c] (0.09)	0.48	0.28[a] (0.13)
Tenure					
Owner operator	28	0.52[a] (0.18)	0.60[a] (0.09)	0.66	0.31[a] (0.14)
Fixed-rent	7	0.71[b] (0.27)	0.68[b] (0.12)	0.79	0.50[b] (0.26)
Share-cropper	52	0.53[a] (0.29)	0.59[a] (0.12)	0.54	0.32[a] (0.13)
Rice variety					
IRV	57	0.53 (0.19)	0.60 (0.11)	0.64	0.33 (0.17)
NIV	9	0.48 (0.12)	0.61 (0.13)	0.61	0.29 (0.07)
LIV	21	0.58 (0.18)	0.61 (0.08)	0.49	0.36 (0.13)
Water source					
From channels	67	0.53 (0.19)	0.60 (0.11)	0.54	0.33 (0.16)
Plot-to-plot	20	0.58 (0.17)	0.60 (0.08)	0.55	0.35 (0.12)

Notes: As for Table 7.11.

neutral. In fact, as shown in Chapter 6 above, the coefficients of the frontier function in the dry season were not so similar to those of the analogous average function. Thus, the Hicks-neutral shift is not likely to be valid for the dry season functions. If this was the case, the absolute estimated values of individual PEIs could be biased by the difference between the average and frontier functions.

Second, the relative values of PEIs between the farmer groups were not always consistent with those of ERIs in both seasons. For example, the highest values of average PEIs among locational groups was in the body section in both seasons, while that of ERIs among those was in the head section. The lowest value of ERIs among tenurial and varietal groups in the dry season was in the fixed-rent and NIV groups respectively; but in terms of the relative value of PEIs, the fixed-rent and NIV groups recorded the highest PEIs among the respective groups.

Third, the absolute values of PEIs of the farmer groups were very different between the two seasons, while the absolute values of ERIs did not differ much between the dry and wet seasons. This implies that according to PEI analysis the price efficiency level of sample farmers did vary between the seasons, while the ERI analysis in contrast suggests that the price efficiency levels of sample farmers were similar in both seasons. It is important to note that the previous analysis of price efficiency of sample farmers, using the allocative efficiency index (AEI), concluded that the ERI and AEI analyses of the price efficiency levels of the farmer groups came to the same conclusions; and the AEIs of the farmer groups did not differ much between the seasons.

The analyses above suggest that in the dry season, ERI analysis was better and more accurate than PEI analysis in comparing the absolute and relative price efficiency levels amongst the farmer groups. They also suggest that both analyses (ERI and PEI analyses) will only come to similar results if the shift between curves of average and frontier functions is a Hicks-neutral shift, as shown in the wet season analyses. Thus the levels of price efficiency among the farmer groups were consistent with the ERI of the farmer groups discussed in conjunction with Tables 7.1 and 7.2. However, it is important to note that ERI differentials between two groups of farmers cannot be tested statistically, since there is no standard deviation or standard error values of the ERIs.

Comparison of profit function analysis and the EER of the farmer groups showed similar conclusions, except for rice variety groups in the dry season and for locational groups in the wet season. Profit function analysis (Table 7.9) suggested that, locationally, the least economically efficient group was the tail section, and this was also the group with the lowest EERs in both seasons (Tables 7.10 and 7.11). The profit function analysis also indicated that the economic efficiency levels between groups in the head and body sections were not significantly different in both seasons, but the EER analysis indicated that in the wet season, farmers in the body were more economically efficient than those in the head section. The estimated profit functions indicated the most economically efficient of the tenure groups was the fixed-rent group in both seasons, and similarly the EER analysis suggested that the highest EER was obtained by this group. They also indicated that significant EER differentials among the locational groups were due particularly to variations in price efficiency (PEI) rather than to those in technical efficiency (TER). On the other hand, EER variations among the tenurial groups were caused by differentials in both technical and price efficiency levels (TER and PEI). Moreover, variations in economic efficiency levels among rice varietal groups in the dry season were due particularly to differences in price efficiency levels rather than to those in technical efficiency ratings. The estimated profit function for the dry season suggested that the least economically efficient among varietal groups was NIV growers, but the EER analysis indicated IRV growers as the least efficient.

It is important to note that it is not impossible for two groups of farmers to be equally efficient economically without being equally efficient technically or equally price efficient (Yotopoulos and Lau 1973). In the present study, for example, in the wet season, the TER and ERI of the head group differed significantly from those of the tail group, but their EERs did not.

It is important to note too that the absolute values of EER of each group of farmers were much smaller in the dry than in the wet season. This could be related again to the problem of unequal coefficients between the average and frontier production functions as discussed above.

Distribution of Profits

Another important concern in development is that of the distribution of its benefits. The following section analyses the distribution of profits from padi growing among sample farmers.

Rice farming in the study area was profitable, but the average levels of actual net profits/ha (AP) were very low (69,000 and 64,000 rupiahs in the dry and wet seasons respectively),[29] compared, for example, to the average of Rp154,000/ha for an East Java village in 1978 (Collier 1979). The highest APs in the Badenah irrigation sample area were Rp274,000 in the dry and Rp210,000 in the wet season.

The average levels of adjusted net profits/ha (ANP) were higher (at Rp103,000 and Rp107,000 for the respective seasons) than those of APs, while the highest ANPs were substantially higher, at Rp370,000 and Rp384,000 per hectare for the respective seasons, indicating that crop damage from pests and diseases had substantially reduced yields and profits of rice farmers there.

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29 A survey conducted by UNAND (Universitas Andalas) in 1978 for the whole irrigation command areas of Batang Arau and Batang Kuranji (Kuranji and Arau rivers), reported that average net profits/ha from rice farming there was Rp77,000, which is very close to our findings. For details, see UNAND (1978, p.83).

The distribution pattern of APs (Table 7.12) shows that 79.7 per cent of sample farmers in the dry season received less than Rp100,000/ha, with an average of Rp49,125. As has already been shown, the average farm size of sample farms was only 0.5 ha/farm; thus on average, farmers only received about Rp24,500/farm/season as compensation for family labour used on that rice farm. By contrast, the distribution of ANPs showed that 72 per cent of sample farmers in the dry season received more than Rp100,000/ha with an average of Rp167,000/ha. Thus if pests could be controlled and crop damage avoided, and assuming other factors remain the same, the profitability of rice farms would increase substantially. Further, if farmers apply optimum levels of all inputs in the absence of crop damage by pests and diseases, the profits per hectare will average Rp438,000 at existing prices. Thus potential profits, like potential yields, were high.

The distribution of AP of sample farmers was examined by grouping farmers in decile distributions from lowest to highest APs in both seasons. The share of total AP was then calculated for each decile group (Table 7.13).

The inequality in AP distributions was clearly considerable. The thirty per cent in the three groups with smallest profits (Deciles I to III) received only 7.5 and 4.6 per cent of total APs in the dry and wet seasons respectively, whilst the thirty per cent in the three groups with highest profits (Deciles VIII to X) received more than 50 per cent of total APs in both seasons. These inequalities were due mainly to the inequality distribution of crop damage among sample farmers, for when yields were adjusted to take account of crop damage, the inequality was reduced substantially. Gini concentration ratios,[30] for example, were reduced

[30] Gini concentration ratios (G) were obtained from the following formula,

$$G = 1 - \Sigma(ab)(bd+ac)$$

where ab is obtained from non-cumulatively tabulated percentages of sample farmers, while bd and ac represent the cumulative share of AP, ANP, FS, PI, TER, PEI and EER in this study (see for details, Yotopoulos and Nugent 1976, p.242).

Table 7.12 Distribution of actual and adjusted net profits per hectare of sample rice farms in Badenah irrigation system area, 1978 dry and 1978/79 wet seasons.

Net profits/ha ('000Rp)	Dry season				Wet season			
	Average actual profits[a)]	Number of farmers[b)]	Average adjusted profits[a)]	Number of farmers[b)]	Average actual profits[a)]	Number of farmers[b)]	Average adjusted profits[a)]	Number of farmers[b)]
<50	20.713 (15.178)	31 (34.8)	21.375 (21.988)	4 (4.5)	21.095 (17.746)	39 (44.8)	31.375 (11.245)	4 (4.6)
50 - 100	71.145 (14.706)	40 (44.9)	78.738 (14.006)	21 (23.6)	70.912 (14.549)	25 (28.7)	84.267 (14.763)	15 (17.2)
100 - 150	123.530 (9.405)	10 (11.2)	121.352 (14.352)	31 (34.8)	118.700 (13.655)	19 (21.8)	119.356 (23.376)	34 (39.2)
150 - 200	163.072 (5.618)	7 (7.9)	170.133 (12.629)	21 (23.6)	167.633) (14.814)	3 (3.5)	179.418 (14.465)	17 (19.5)
>200	274.200 (0.0)	1 (1.2)	280.892 (53.176)	12 (13.5)	209.600 (0.0)	1 (1.2)	262.500 (53.725)	17 (19.5)
<50 - >200	68.976	89 (100.0)	139.825	89 (100.0)	63.946	87 (100.0)	148.968	87 (100.0)

a) In '000Rp, and figures in parentheses are respective standard deviations.

b) Figures in parentheses are in percentages.

Table 7.13 Distribution of actual net profits of sample farmers by farmer decile group, 1978 dry and 1978/79 wet seasons.

Farmer Decile Group	Percentage of actual profits		Cumulative percentage of actual profits	
	Dry	Wet	Dry	Wet
I	0.41	0.14	0.41	0.14
II	2.54	0.76	2.95	0.90
III	4.54	3.66	7.49	4.56
IV	7.39	6.16	14.88	10.72
V	8.89	7.89	23.77	18.61
VI	9.81	8.95	33.58	27.56
VII	12.08	12.63	45.66	40.19
VIII	14.92	15.82	60.58	56.01
IX	20.34	18.98	80.92	74.99
X	19.08	25.01	100.00	100.00
Gini Ratio			0.3595	0.4611
Coefficient of variation			1.2045	1.5575

from 0.3595 (Table 7.13) to 0.2539 (Table 7.14) in the dry season and from 0.4611 (Table 7.13) to 0.2472 (Table 7.15) in the wet season. Inequalities, however, still remained in the distributions of ANPs, suggesting the next question as to what factors determined residual inequalities of distribution.

To examine this, farm size (FS), per capita incomes (PI),[31] technical efficiency ratings (TER), price efficiency indexes (PEI), and economic efficiency levels (EER) of sample farmers were ranked from the lowest to highest values, and the decile distributions for each variable were calculated for both seasons with the same technique as was used for calculating the decile distribution of APs.

In the dry season (Table 7.14), the pattern of distributions of ANP, FS, and PI seem to be very similar, as shown by Gini ratios for these variables. Lorenz curves for these variables are very close to each other (Figure 7.3). In contrast, the pattern of distribution of PEI, TER, and EER look to be very different from each other, in the dry season as shown by the differences of their Gini ratios and Lorenz curves (Table 7.14 and Figure 7.4).

Statistical tests are not available to test differences in Gini ratios. However, the variances of the logarithms of the variables can be considered as a measure of inequality.[32] An F-test was applied to test the significance of differences between the variances of the logarithms of the variables, on the assumption that the logarithms of AP, ANP, FS, PI, TER, PEI and EER were normally distributed.

In the dry season, seven of the F-ratios calculated (Table

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[31] Per capita incomes of sample farmers were calculated from total expenditure less net credit of the family divided by the number in the family.

[32] Theil, H. (1967), Economic and information theory, North-Holland Publishing Company, Amsterdam, pp.121-125.

Table 7.14 Distribution of adjusted net profits/ha (ANP), farm size (FS), per capita incomes (PI), technical efficiency ratings (TER), price efficiency indexes (PEI), and economic efficiency ratings (EER) of sample farmers in Badenah irrigation system, 1978 dry season.

Farmer Decile Group	Percentage of						Cumulative percentage of					
	ANP	FS	PI	TER	PEI	EER	ANP	FS	PI	TER	PEI	EER
I	3.0	2.7	3.3	4.9	4.7	3.1	3.0	2.7	3.3	4.9	4.7	3.1
II	5.7	4.9	5.6	6.9	6.7	5.3	8.7	7.6	8.9	11.8	11.4	8.4
III	6.9	6.4	6.6	7.9	7.4	6.2	15.6	14.0	15.5	19.7	18.8	14.5
IV	7.7	7.6	7.3	8.5	7.9	7.2	23.3	21.6	22.8	28.2	26.6	21.7
V	8.8	8.8	8.1	9.7	8.8	8.1	32.1	30.4	30.9	37.9	35.4	29.8
VI	9.7	10.3	9.8	10.6	10.1	9.0	41.8	40.7	40.7	48.5	45.5	38.8
VII	11.2	11.2	11.0	11.0	11.8	10.6	53.0	51.9	51.7	59.5	57.2	49.4
VIII	12.5	13.4	12.2	12.0	12.7	13.4	65.5	65.3	63.9	71.5	69.9	62.9
IX	14.6	15.9	15.5	13.9	14.4	15.5	80.1	81.2	79.8	85.4	84.3	78.4
X	19.9	19.8	20.2	14.6	15.5	21.6	100.0	100.0	100.0	100.0	100.0	100.0
Gini Ratio							0.2539	0.2674	0.2676	0.1666	0.1925	0.286
Coefficient of variation							0.25977	0.3466	0.3307	0.1124	0.2953	0.544

Table 7.15 Distributions of adjusted net profit/ha (ANP), farm size (FS), per capita incomes (PI), technical efficiency ratings (TER), price efficiency indexes (PEI), and economic efficiency ratings (EER) of sample farmers in Badenah irrigation system, 1978/79 wet season.

Farmer Decile Group	Percentage of						Cumulative percentage of					
	ANP	FS	PI	TER	PEI	EER	ANP	FS	PI	TER	PEI	EER
I	2.9	2.7	3.2	4.8	6.4	3.7	2.9	2.7	3.2	4.8	6.4	3.7
II	6.2	5.4	5.8	7.2	8.5	6.3	9.1	8.1	9.0	12.0	14.9	10.0
III	7.1	5.7	6.8	8.0	8.9	7.6	16.2	13.8	15.8	20.0	23.8	17.6
IV	7.9	7.7	7.9	8.9	9.4	8.1	24.1	21.5	23.7	28.9	33.2	25.8
V	7.7	8.6	8.9	9.4	9.0	7.8	31.8	30.1	32.6	38.3	42.2	33.6
VI	9.5	10.3	9.5	10.0	10.7	9.7	41.3	40.4	42.1	48.3	52.9	43.3
VII	11.3	10.1	10.8	10.0	11.3	10.9	52.6	50.5	52.9	58.3	64.2	54.1
VIII	13.2	13.4	12.7	11.8	11.7	12.0	65.8	63.9	65.6	70.1	75.8	66.1
IX	15.3	15.7	15.1	13.9	12.0	14.7	81.1	79.6	80.7	84.0	87.8	80.8
X	28.9	20.4	19.3	26.0	12.1	19.2	100.0	100.0	100.0	100.0	100.0	100.0
Gini Ratio							0.2472	0.2785	0.2497	0.1931	0.098	0.230
Coefficient of variation							0.2785	0.2942	0.2884	0.1073	0.036	0.199

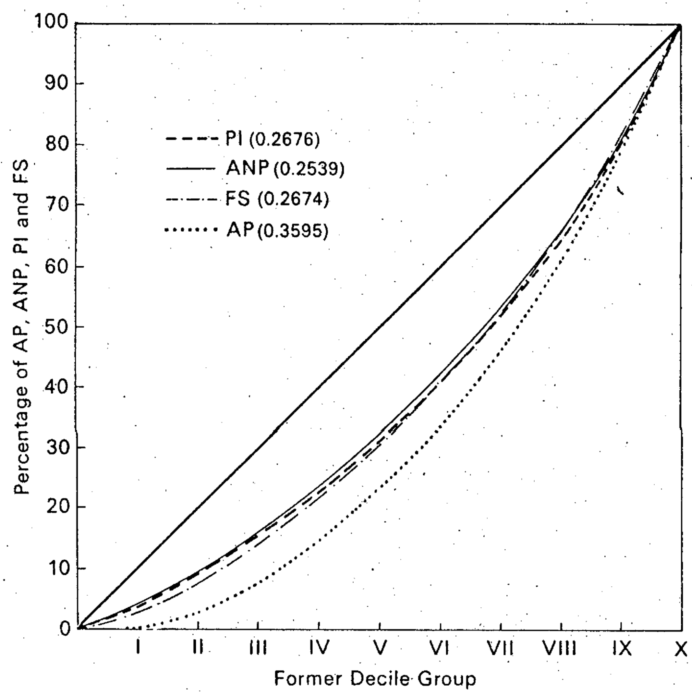

Figure 7.3. Lorenz curves showing distributions of actual profits (AP), adjusted profits (ANP), per capita income (PI), and farm size (FS) of sample farmers, 1978 dry season.

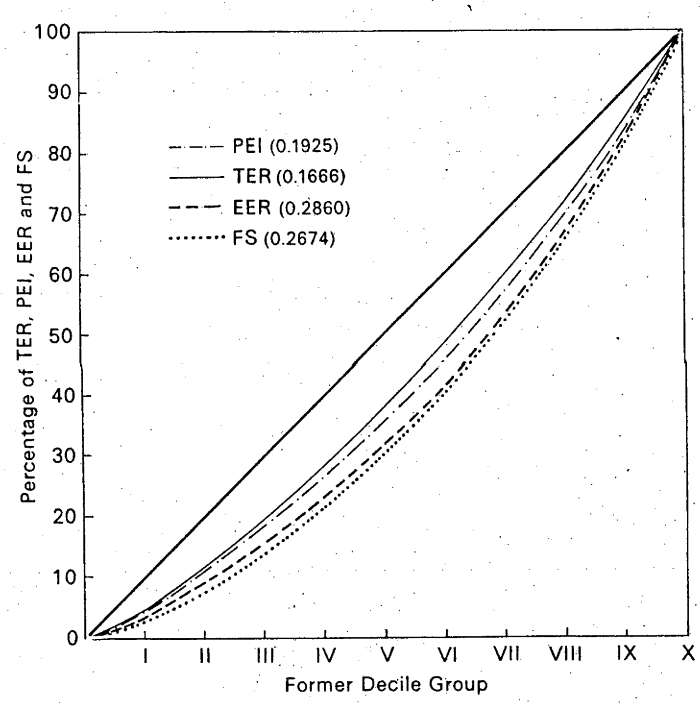

Figure 7.4. Lorenz curves showing distribution of technical efficiency rating (TER), price efficiency index (PEI), economic efficiency rating (EER) and farm size (FS) of sample farmers, 1978 dry season.

7.16) were less than the tabulated F-ratio, namely, those between ANP and FS, between ANP and EER, between FS and PI, between FS and PEI, between FS and EER, between PEI and PI, and between EER and PI. Thus, the above visual interpretation that the Gini ratios of ANP, FS and PI, were almost the same in the dry season is quite correct. The F-tests show that Gini ratios between ANP and FS, between FS and PI, between ANP and EER, between PEI and PI, and between EER and PI were not significantly different statistically. They do show that the inequality in the distribution of both adjusted net profits (ANP) and per capita income (PI) arose mainly from inequality in the distribution of farm size (FS).

In the wet season (Table 7.15), the distributions of ANP, FS, and PI again appeared to be very similar. Their Lorenz curves (Figure 7.5) were also very close; their Gini ratios differed little and their coefficients of variation were also very similar (Table 7.15). The distributions of TER, PEI and EER in the wet season also appeared to be different to each other (Table 7.15). Their Lorenz curves were not very close (Figure 7.6); their Gini ratios and coefficients of variation were not very similar either. The F-ratio values for this season showed clearly (Table 7.16) that the Gini ratios of ANP, FS, PI, TER and EER did not significantly differ from each other. Thus in the wet season too, the inequality in distribution of adjusted net profits (ANP) and of per capita incomes (PI) among sample farmers also arose mainly from inequality in distribution of farm size.

The F-ratio values between ANP and FS, between ANP and EER, between FS and PI, between FS and EER, and between EER and PI were not significantly different in both seasons, indicating that the inequality distribution of farm size not only affected the distributions of adjusted net profits and per capita incomes of the farmers, but also influenced the distribution of economic efficiency rating of sample farmers. Moreover, since the values of F-ratios between ANP and PI, between FS and PEI, between TER and PI, between TER and EER, and between PEI and PI were not consistent between the two seasons, general conclusions about their

Table 7.16 Computed F-ratio values for pairs of variables, 1978 dry and 1978/79 wet seasons.

Pairs of variable	F-ratio value	
	Dry season	Wet season
AP and ANP	2.02	5.59
AP and FS	3.48	5.29
AP and PI	3.63	5.40
AP and TER	10.72	14.52
AP and PEI	4.07	43.26
AP and EER	2.21	7.83
ANP and FS	1.72^{ns}	1.05^{ns}
ANP and PI	1.80	1.04^{ns}
ANP and TER	5.32	2.60
ANP and PEI	2.02	7.74
ANP and EER	1.10^{ns}	1.40^{ns}
FS and PI	1.04^{ns}	1.02^{ns}
FS and TER	3.08	2.74
FS and PEI	1.17^{ns}	8.17
FS and EER	1.57^{ns}	1.48^{ns}
TER and PI	2.94	2.69
TER and PEI	2.63	2.98
TER and EER	4.84	1.85
PEI and PI	1.12^{ns}	8.01
PEI and EER	1.84	5.52
EER and PI	1.64^{ns}	1.45^{ns}

Notes:

AP = actual profits, ANP = adjusted profits, FS = farm size, PI = per capita income, TER = technical efficiency rating, PEI = price efficiency index, and EER = economic efficiency rating.

The tabulated values of F-ratio are 1.76 for the dry and wet seasons, i.e. for (89,89) and (87,87) degrees of freedom at the 1.0 per cent level.

n.s. = not significant at the 1.0 per cent level.

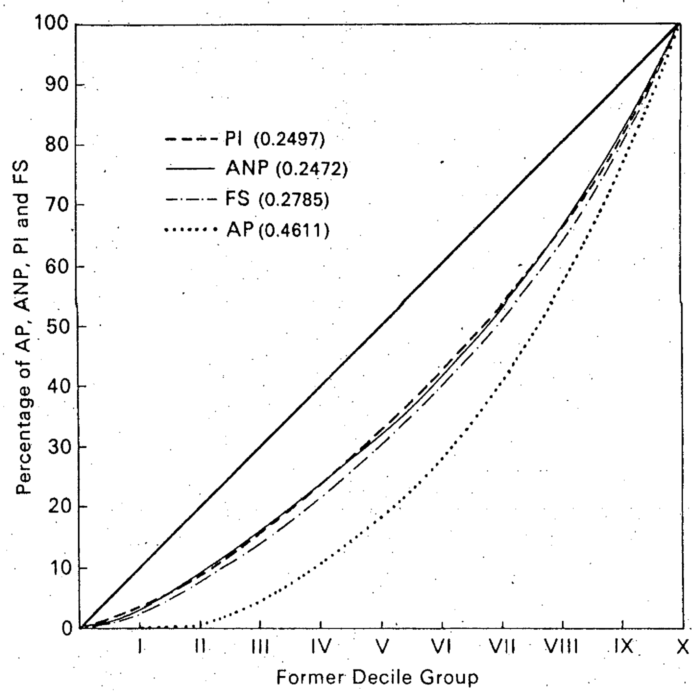

Figure 7.5. Lorenz curves showing distribution of AP, ANP, PI and FS of sample farmers, 1978/79 wet season.

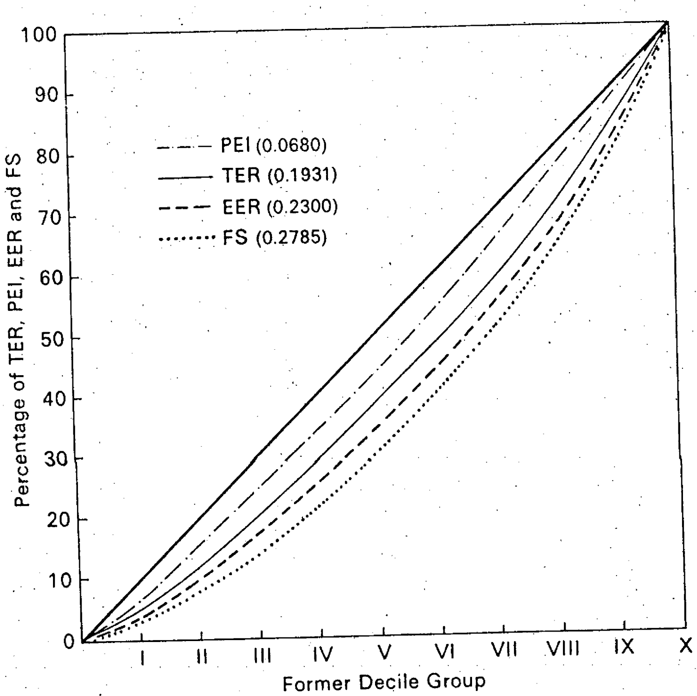

Figure 7.6. Lorenz curves showing distribution of TER, PEI, EER and FS of sample farmers, 1978/79 wet season.

relationships could not be drawn. Coefficients of variation of ANP, PEI and EER were significantly different between the two seasons, indicating that Gini ratios of these variables were also significantly different between the two seasons. This could be related partly to the problem of unequal coefficients between average and frontier functions in the dry season as discussed previously.

It is important to note that although there were inequalities in the distributions of per capita income and profit which (due, as explained above, mainly to the inequality in distribution of farm size), these inequalities were not a serious problem, since the Gini ratio for farm size was low (0.27) compared to that in a West Java village (0.58) as reported in Kikuchi et al. (1980). In the West Java village, Gini ratio for income was also much higher (0.52) than in this study area (0.26). Thus, income distributions in Badenah irrigation area were much better than those in the West Java village.

Conclusions

The foregoing analysis of the economic performance of sample farmers in Badenah irrigation system indicates levels of economic rationality, allocative or price efficiency, and of economic efficiency that were fairly low. The average net profits/ha were also low as a direct consequence. Levels of fertilizer application in the survey area were heavily determined, not by relative prices of output and inputs, but by non price factors such as water conditions at field level, credit facilities and education levels of farmers.

The distributions of profits and per capita incomes among the farmers showed concentrations favouring large farmers. It was shown that these inequalities in distributions arose mainly from inequalities in the distribution of farm size amongst the farmers. Notably, these inequalities were not due mainly to variations in technical and price efficiencies among sample farmers. Finally, since farm size inequalities were not large, the problem of inequality in income distribution in the study area was not a major problem.

CHAPTER 8

SUMMARY AND CONCLUSIONS

In the initial years after the release of the first high yielding varieties by IRRI in 1960s, predictions of imminent self-sufficiency in rice production for many developing countries were common. But after a brief period in 1970, various problems in the adoption of the improved rice technology were recognized. One of the most important constraints is the availability of irrigation water and its control at farm level, not only as a key input itself, but also as a vital element in encouraging the effective use of other scarce and costly inputs necessary for higher rice yields, e.g. modern rice varieties, chemical fertilizers and pesticides. With ample water and with good water control at farm level, rice farms in the humid tropics can be cultivated twice or three times a year. 'Much of the current controversy about the success or failure of the so-called "green revolution" .... may be explained partly by the paucity of detailed analyses of concrete farm studies, including water management at the farm level.' (APO, 1977, p.1). It was therefore considered appropriate and timely to investigate the relationship between different degrees of farm water management and the performance of rice farmers within an irrigation command area.

This study examined the availability and the efficiency of irrigation utilization of irrigation water at the farm level and the relation of the irrigation variable to the performance of the improved rice technology in the Badenah technical irrigation scheme in West Sumatra, Indonesia.

The variable finally chosen to represent irrigation, for the analysis of the efficiency of irrigation water utilization, was the ratio of average depth of water/day to the number of stress days from one day after transplanting to 15 days prior to harvest. The timing of draining farms before harvest was used as the proxy variable for farm water management. The performances of rice farmers in the study area were analysed with a sample of rice farmers selected from the head, body and tail sections of a single lateral system of the Badenah irrigation system, in two rice growing seasons of the crop year 1978-79. Farm level analysis focussed on:

(a) Technological performance, with measurements of productive capacity and actual yields of sample farms, and the technical efficiency ratings of sample farmers;

(b) economic performance, with measurements of the economic opportunities provided by the irrigation facilities on the one hand, and the response of rice farmers to these on the other, as identified in terms of the degree of allocative or price efficiency and economic efficiency of the farmers; and

(c) distributional performances which showed the patterns in the distribution of benefits among sample rice farmers.

These measurements were made both for individual rice farmers and for various farmer groupings, i.e. by location, land tenure type, rice variety used and sources of irrigation water.

Technological Performance

Overall, the average yields from rice farming in the study area were found to be low in both seasons. Our analysis showed that this was due largely to low levels of technical efficiency (TER) among farmers and to low input levels (IL). There was a high percentage of crop damage caused by pests especially rats and stem borers, but no one applied rodenticides, apparently because of the social taboo against killing rats. Another factor was the inefficient use of irrigation water. Farms were drained too early prior to harvest, a practice that was also related to the pest problem.

These factors were found to be interrelated. Using the neo-classical production function and linear regression analyses, it was found that, in the dry season, the incidence of water stress not only lowered yields directly, but also inhibited the response of the crop to fertilizer and influenced the application levels of fertilizer. It was also found that the high incidence of water stress was not due to a lack of irrigation water supplies, but to the practice of draining farms earlier than recommended before harvest. Variations in times of draining farms reflected the existence of farmers' beliefs in the taboo, their expectation of rat attacks, the swampy conditions of their farms in part of the survey area, their knowledge of the farm water requirements of rice at various cultivation stages. Results in the wet season also showed that levels of fertilizer use were significantly influenced by crop damage levels.

There were substantial differences in average yields between groups of farmers in different locations. Water availability to farms in the study area did, as expected, vary inversely with distance from the headworks, but contrary to experience elsewhere, this was not the principal way in which the irrigation variable influenced technological performance within the command area. In order of technical achievement, head and tail followed body, rather than the expected order of head, body and tail. This was largely because field water management was best in the body section. In this area, the technological performance of rice farms depended not only on the supply and distribution of irrigation water to the farms, but also, and more importantly, on the way farmers utilised irrigation facilities. The average yields were highest in the body section partly because farmers there drained their farms later than elsewhere in the command area, and consequently the incidence of water stress was lowest. The higher yields were also due to the higher levels of fertilizer used in the body section. These input levels were related to the better water management and also to a lower percentage of crop damage, a higher education level of the farmers, better leadership capacity of their leaders compared to those in the head section, and the impact of various Kelompok Tani (farmers' groups) which have been absent in the head section. Since average technical efficiency ratings of farmers in these three locations were not found to differ, the main cause of yield variations between locations was the difference in average input levels used by the farmers.

Use of IRRI varieties (IRVs) was widespread, but there was no significant yield superiority over national improved varieties (NIVs) or local improved varieties (LIVs) under field conditions. This was due largely to the low levels of fertilizer applied and to the fact that IRV growers drained their farms earlier than NIV and LIV growers, which caused a higher level of water stress. It is possible that IRV growers do not understand the requirements of high yielding varieties, and suppose that, because IRVs are high yielding, they do not need high levels of fertilizer and better farm water control.[1] Other factors which inhibited the performance of the improved rice technology included a shortage of credit, the high price of IRV seed relative to paddy, a shortage of preferred fertilizer types, and the uncertainty amongst some farmers whether the use of a level of nitrogen higher than the customary would increase yields. It is possible, too, that the available IRVs were not suited to local conditions and/or that their yield performance suffered for lack of pure replacement seed.

There were significant differences in yields among sample farmers grouped by land tenure types. The highest technological

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[1] This is consistent with the fact that the percentage of IRV growers was highest in the tail section where water conditions were worst. In a study in Java, Pitt (1980) found that the demand for IRVs was also negatively related to irrigation quality. Reasons for this were not elicited, but might include the above.

performance was found in the fixed-rent group in both wet and dry seasons, which recorded the highest level of technical efficiency (TER), and the highest level of input use including farm water management in both seasons. It is interesting to note that this group drained their farms significantly later than the other two groups, but recorded the highest percentage of crop damage in the wet season. Thus the time of draining farms did not always determine crop damage levels.[2] The superior performance of the fixed-rent group is understandable because these farmers must make extra efforts in managing their farms to meet the greater risks involved, since they must pay a fixed annual rent for the land.

Differences in farm water sources (i.e. direct from irrigation channels or plot-to-plot system) did not significantly affect yields nor the level of input applications in either season. This again showed that the irrigation problem at farm level was not one of distribution, i.e. field channel density, but rather one of farmers' own water management.

Among factors found to influence the level of technical efficiency of sample farmers significantly were education, age, merantau experience, and type of land tenure. These factors seem to be a proxy for management, and therefore it is not unlikely that management could be one of the most important factors in influencing technical efficiency differentials and this factor needs further study. Our analysis also indicated that Bimas participation frequency did not significantly influence technical efficiency differences, implying that the Bimas program, as an extension institution, has not been effective, at least in this study area. This could be explained by the limited number of field extension workers (PPL). At the time of the survey, there was only one PPL per 1,000 ha sawah or 2,000 rice farmers in the study area.

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2 When we regressed TD on crop damage, the coefficients of crop damage were not significant in both seasons.

The study showed that yields would be increased substantially with the existing technology, if the technical efficiency of the farmers could be improved. This was demonstrated by applying the concept of the yield frontier, i.e. the maximum possible yield which can be obtained from given quantities of a set of inputs, estimated in this study with the Linear Programming technique for both seasons. The maximum possible yield (MPY) was actually achieved by some sample farmers who did follow the guidance of the Bimas program very closely, but these farmers were few.

The analysis showed that differences between the MPY and average yields of sample farmers were substantial in both seasons, and that these might not be due to accidental factors, but rather to the fact that these farmers did not fully understand or were misled about the new rice technology. It appears that, because PPLs had not visited their farms to advise them, these farmers did not use the best practices of the new technology, and so a majority of sample farmers failed to realise the MPY. In addition to the problem of extension staff adequacy relative to farmers' needs, there was also a lack of proper focus in the extension advice given to farmers on important cultural practices of the improved rice technology, including farm water management and pest control practices.

Economic Performance

The economic performance of sample farmers was seen as a response of the rice farmers to the combination of new opportunities offered by the development of the irrigation project and by the new rice technology. With the completion of the irrigation project, the cropping intensity of the command area has been raised substantially. In 1977, about 90 per cent of sawah in the command area has been double cropped with rice, resulting in a substantial increase in rice production levels in the study area. However, the opportunity to maximize profits thereby, by increasing modern input levels such as fertilizer and pesticides has not been fully utilized by most farmers. This was not because of constraints on supplies of inputs or high input prices, but rather, and particularly, to non price factors. For example, our analaysis of economic rationality indicated that inter-farm differences in input (labour and capital) levels were little influenced by inter-farm variations in price of inputs and output. The analysis suggests that technical efficiency components, including the efficiency of irrigation water use, that have been subsumed in the constant term in that analysis, could be a major factor in explaining differences in input levels. The allocative efficiency analysis showed clearly that the average dosage of nitrogen (47 kg N/ha) was far below the optimum level (128 kg N/ha) for maximizing profits. The demand function analysis for fertilizer also showed that inter-farm differences in fertilizer dosages were not significantly influenced by urea:paddy price ratio, but were significantly affected by non price factors such as the time of draining farms, farm size, credit facilities, land tenure and education of farmers. Similarly, the profit function analysis indicated that relative prices of inputs and output did not significantly influence the UOP profits of the farmers, except for normalized wages of hired labour in the dry season.

The profit function analysis also showed that the hypothesis of equal economic efficiency between locations and between land tenure types had to be rejected. Sample farmers in the tail section as a whole, were found to be the least efficient economically in both seasons of the three locations, whilst the other two showed no significant differences in economic efficiency in the dry season, farmers in the body were more efficient economically than those in the head section. Among land tenure types, the fixed-rent group was the most economically efficient in both seasons, while the owner operator and share cropper groups did not differ significantly in this sense. Given that the economic efficiency of farmers is a combination of their technical and price efficiencies, it is possible for two farmers or two groups of farmers with different TER and/or PEI to have equal levels of economic efficiency. This was in fact demonstrated in this study, where the PEI of the head group in the wet season varied significantly from that of the tail group, whilst their economic efficiency levels showed no such variation. In the case of farmers grouped by water sources, by way of contrast, there was no significant differences in TERs and PEIs and this was also true for their relative economic efficiency.

Distributional Performance

Absolute and relative profit levels, and the distributional pattern of profits among sample farmers were also considered. Both absolute and relative actual profits per hectare (AP) of sample farmers were significantly influenced by crop damage caused by pests and diseases in both seasons. The pattern of AP distribution varied significantly from that of the size of farms, indicating that the inequality in the distribution of AP was largely due to the impact of crop damage and was not mainly because of the inequality in farm size distribution. With adjustment of yields for crop damage, the absolute and relative levels and the distributional pattern of adjusted net profits (ANP) were substantially different. Statistical comparison of these inequalities showed that the pattern of the ANP distribution did not significantly differ from that of farm size in either season, and indicated that the inequality in distributions of ANP stemmed mainly from the distribution pattern of farm size, and was skewed in favour of large (greater than 0.5 ha) farmers.

It was also found that the distribution pattern of per capita income of sample farmers closely followed those of ANP and farm size distributions. The inequality in the distribution in per capita incomes was thus also determined primarily by the inequality in the distribution of farm size. In West Sumatra, the size of sawah holding is widely used as an indicator of the socio-economic status of farmers (Nurdin 1975), so this finding gives credence to its use. It is also important to note that the extent of inequality in the distribution of per capita incomes was not serious in the study area, as shown by the Gini concentration ratio of 0.2676.

The distribution pattern of technical efficiency ratings varied significantly from those of income, profits and farm size. This means that the inequality of TER distribution did not arise mainly from these latter three distributions. Rather, it should be noted that variations in profits and economic efficiency ratings were significantly influenced by TER differentials, because TERs affected yields. The distribution of farm size was very similar to that of PEIs in the dry season, but was significantly different in the wet season. We cannot, therefore, reach a general conclusion about their distributional relationship. Similarly, the distribution of PEIs differed significantly from that of farm size in the wet season, but did not in the dry season.

It is also important to note that inequalities in the distribution of rice farming benefits in the study area were due mainly to unequal distribution of sawah operational holdings, and not to the improved rice technology.

Finally, this study analysis showed clearly that of the five hypotheses set out in Chapter 1 three were accepted. The hypotheses of a universal relation between yields, profits and distance from the main irrigation system outlet, and that higher yields are obtained by farms with direct access to irrigation channels, were rejected.

Policy Implications

The implications of this study's findings for policy are serious. It is a matter of concern that yields and profits within a leading irrigation area of West Sumatra are, on average, so low, and are apparently well below the provincial average. This study suggests that a high priority should be given to policies aimed at increasing yields and profitability of rice farming. This will encourage fuller utilization of improved rice technology . The large gap between MPY and actual yield was shown to be due mainly to inadequate and incorrect knowledge of the technology among farmers, which requires that attention should be focussed on extension policy. In terms of practical measures, the number and quality of PPLs should be increased and improved, and their duties should be modified to enable them to spend more time on field visits and demonstration plots. Extension activities and advice should include farm water management, and extension plots should demonstrate the efficient use of irrigation water and should highlight important details as to the appropriate timing and levels of application of inputs (including water) and other practices. Close attention should be given to evolving pest control practices for rats, that are acceptable to farmers and would eliminate the need for them to drain their fields prematurely. This alone could make a substantial contribution towards raising yields and net returns in the command area. There is also a need for an effective seed replacement industry to ensure a supply of pure seed of IRVs and an improved supply of credit to farmers.

Further technical research is needed to determine the relative field performance of the international, national improved and local improved rice varieties, as it is not clear from this study where superiority in performance lies, if any, under the conditions within the study area. The MPY should be seen as a shifting frontier, the location of which is determined primarily by the success of agricultural research efforts. Further research should also be directed towards more closely determining those factors that influence the technical efficiency of farmers and those which are currently constraining the upward shift in yields. Finally the superior performance of the fixed-rent operator in the command area deserves further study in relation to appropriate forms of land holding arrangement.

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APPENDIX 2.1

Table 2.1.1 Distribution of sample farms by group inter-relationships, 1978 dry season.

	Head	Body	Tail	Owner operator	Fixed-rent	Share cropping	IRV	NIV	LIV	From channels	Plot-to-plot
Head	29	-	-	13	-	16	12	5	12	22	7
Body		30	-	10	7	13	13	12	5	23	7
Tail			30	7	1	22	27	-	3	25	5
Owner operator				30	-	-	18	5	7	26	4
Fixed-rent					8	-	4	2	2	7	1
Share-cropping						51	30	10	11	37	14
IRV							52	-	-	45	7
NIV								17	-	12	5
LIV									20	13	7
From channels										70	-
Plot-to-plot											19

APPENDIX 2.1 (cont'd)

Table 2.1.2 Distribution of sample farmers by group inter-relationships, 1978/79 wet season.

	Head	Body	Tail	Owner operator	Fixed-rent	Share cropping	IRV	NIV	LIV	From channels	Plot-to-plot
Head	27	-	-	11	-	16	13	2	12	19	8
Body		30	-	11	6	13	20	7	3	23	7
Tail			30	6	1	23	24	-	6	25	5
Owner operator				28	-	-	17	5	6	24	4
Fixed-rent					7	-	7	-	-	6	1
Share-cropping						52	33	4	15	37	15
IRV							57	-	-	49	8
NIV								9	-	8	1
LIV									21	10	11
From channels										67	-
Plot-to-plot											20

APPENDIX 2.2

QUESTIONNAIRE

SURVEY OF THE IMPACT OF IRRIGATION EFFICIENCY ON PERFORMANCE OF THE IMPROVED RICE TECHNOLOGY IN WEST SUMATRA OF INDONESIA

1978 - 1979

I. IDENTIFICATION

1.1 Card No.: [ ][ ]

1.2 Sample No.: [ ][ ][ ]

Farmer's name: ______________________

Jorong (Sub-village): ______________________

Nagari (Village): ______________________

Kecamatan (Sub-district): ______________________

Kabupaten (District): ______________________

1.3 Rice planting season: [ ]

1. The 1978 dry season (MK 1978)
2. The 1978/79 wet season (MH 1978/79)

1.4 Farm location from the irrigation headworks: [ ]

1. At the head
2. At the body
3. At the tail

Note: The location will be measured in the distance (in km) from the headworks.

1.5 Source of water: [ ]

1. Direct from irrigation channel
2. Through other rice farms.

1.6 Bimas participant or not in this season: [ ]

1. Yes
2. INMAS participant only
3. No

Note: The INMAS is the BIMAS without credit.

1.7 Rice variety used by the farmer: [ ]

1. International varieties (IRV)
2. National varieties (NIV)
3. Local varieties (LIV)

Please give the names of the varieties:

____

Note: If the sample farmer uses more than one variety, he/she should be seen as having more than one rice farm, so that she/he should fill out one questionnaire for each rice variety.

II. FARMER'S CHARACTERISTICS

2.1 Family size: [ ][ ]

No.	Relationship[1]	Sex[2]	Age (yrs)	Education (yrs)	Occupation Major	Occupation Minor
1.	The farmer	___	___	___	___	___
2.	Spouse	___	___	___	___	___
3.	___	___	___	___	___	___

[1] This is relationship to the farmer.

[2] L = Laki2 (Male) and P = perempuan (female).

2.2 Your marital status: [ ]

1. Married
2. Unmarried
3. Widow or widower.

2.3 Your position in the community: [ ]

1. Ninik Mamak (adat leader)
2. Alim Ulama (religious leader)
3. Cerdik Pandai (intellectual)

   ______________________________ (specify)

4. Orang awam (common people)

5. Others

_______________________________ (specify).

2.4 Have you been to other provinces or overseas? [ ]

1. Yes

2. No

2.5 How many years have you had experience in rice farming? [|]

2.6 How many years have you been involved in rice Bimas programs? [|]

2.7 Why do you like to participate in Bimas programs? [ ]

1. To find loan

2. To increase yield

3. Obligation

4. Other reasons

_______________________________ (specify).

2.8 If you have never participated in Bimas, please give reasons:

____

____

____

2.9 Do you regard the Bimas program as: [ ]

1. Very useful

2. Useful

3. Not useful

4. Others

_______________________________ (specify).

Please explain your answer by giving reasons:

____

____

____

2.10 Please offer any critique or suggestion that you may have about the Bimas program:

____

____

____

2.11 From whom or where do you usually get information about the new rice technology? [ ]

1. Extension worker
2. Other rice farmers
3. Rural Broadcasting program
4. Newspapers
5. Magazines

   ______________________________ (specify)

6. Books

   ______________________________ (specify)

7. Through Bimas program
8. Others

   ______________________________ (specify)

9. Mixed sources

   ______________________________ (specify)

Please explain your answers:

____

____

____

III. RICE FARMING PRACTICES

A. Land and Tenurial Systems

3.1 What is the size of your paddy field that is included in this survey for this season?

Local unit: ______________________

or in hectare (Ha): [ ]

3.2 What is the tenurial system of the rice field? [ ]

1. Owned land
2. Leased land
3. Share cropped land
4. Pawned land
5. Mixed

3.3 If it is mixed, please specify the size of each tenurial system.

1. Owned land: ______________

   (Local unit), or in Ha: ______

2. Leased land: ______________

   (Local unit), or in Ha: ______

3. Share cropped land: ______

   (Local unit), or in Ha: ______

4. Pawned land: ______________

   (Local unit), or in Ha: ______

3.4 If it is a leased land, how much is the rent of the rice field per season at the moment?

In local unit: ______________

in Rp: ______________

or in Rp/Ha/season: | | | | | | |

Since the introduction of HYVs in this area, has the leased system changed?

If so, what were the changes?

3.5 If it is a share cropping system:

1. What is the share of production costs between the tenant and the land owner?

   a. When using IRVs

   b. When using non-IRVs.

2. What is the share of output between the tenant and the land owner?

   a. When using IRVs

   b. When using non-IRVs.

3. Who makes the decision in choosing seed variety to be used? [ ]

   1. The tenant

   2. The land owner

   3. Both the tenant and the land owner.

   If both, how do you do that?

4. Who makes decision in determining the types and the levels of the following inputs?

   a. Chemical fertilizer ☐

   b. Pesticides ☐

   c. Hired labour ☐

   1. The tenant

   2. The land owner

   3. Both the tenant and the land owner.

   If both how do you do that?

   <u>Chemical fertilizers</u>:

   <u>Pesticides</u>:

   <u>Hired labour</u>:

3.6 Since the introduction of HYVs in this area, has the share cropped land system changed?

If so, how and what were the changes?

3.7 If it is a pawned land, how long have you taken the land in pawn and how much was the pawned value?

a. It has been taken in pawn for: ☐☐ years

b. The pawned value :

Local unit: ____________________

or in Rp: ____________________

or in Rp/Ha: ☐☐☐☐☐☐

3.8 What are conditions and procedure of the pawned land?

B. <u>Nursery</u>

3.9 What seed variety did you use for your surveyed ricefield in this season? ☐

1. IRV

   ____________________ (variety name)

2. NIV

   ____________________ (variety name)

3. Local variety

   ____________________ (variety name)

3.10 How much was the price of the seed variety that you are using in this season and what seeding rate did you use for this variety?

1. The buying price of the seed variety: Rp/kg: ☐☐☐

2. The seeding rate : Local unit/Ha:

______________________/Ha;

or kg/Ha: ☐☐

Please explain your answer to Q.3.10.2 by giving reasons:

____

____

____

3.11 How many years have you applied that seed variety? ☐☐

3.12 When and from whom did you know that variety for the first time?

a. About ☐☐ years ago

b. From: ☐

1. Other farmers
2. Extension worker
3. Radio/TV
4. Newspapers
5. Cooperatives (BUUD/KUD)
6. Other sources:

______________________ (specify)

3.13 Where did you get the seed for this season? ☐

1. Owned
2. From other farmers
3. From Bimas committee
4. Other sources

______________________ (specify)

3.14 What kind of nursery did you use for seeding in this season? ☐

1. Wet nursery
2. Dry nursery

Please explain your answer by giving reasons:

3.15 How many labourers did you use for nursery works?

Family labour: Hours: Men ______; Women ______;

Children ______

Hired labour: Hours: Men ______; Women ______;

Children ______

Wage rate of hired labour: Rp/day:

Men __________; Women __________; Children __________

3.16 Did you have other expenses for the nursery works?

If so, how much, and for what is it?

Other expenses : Rp __________ for:

3.17 When did you do the nursery works for this season?

____________________ (date)

What factors influencing the decision to start the nursery works?

C. Field Preparation

3.18 When did you start working on the field preparation for this season?

____________________ (date)

What factors influencing the decision to start the field preparation works?

3.19 Did you have enough water for the field preparation works in this season? [ ]

1. Yes

2. No

If not, why?

3.20 How many labourers did you use for the field preparation works in this season?

a. Family Labour (in days)

1. First plowing/hoeing:

Man with draught animal: __________

Men: __________; Women: __________; Children __________

2. Second plowing/hoeing:
   Man with draught animal: ________;
   Men: ________; Women: ________; Children: ________

3. Third plowing/hoeing:
   Man with draught animal: ________;
   Men: ________; Women: ________; Children: ________

4. First harrowing:
   Man with draught animal: ________;
   Men: ________; Women: ________; Children: ________

5. Second harrowing:
   Man with draught animal: ________;
   Men: ________; Women: ________; Children: ________

b. Hired Labour

1. First plowing/hoeing:
   Man with draught animal: ________;
   Men: ________; Women: ________; Children: ________

2. Second plowing/hoeing:
   Man with draught animal: ________;
   Men: ________; Women: ________; Children: ________

3. Third plowing/hoeing:
   Man with draught animal: ________;
   Men: ________; Women: ________; Children: ________

4. First harrowing:
   Man with draught animal: ________;
   Men: ________; Women: ________; Children: ________

5. Second harrowing:
   Man with draught animal: ________;
   Men: ________; Women: ________; Children: ________

c. Wage rate of hired labour (Rp/day):
   Man with draught animal: ________;
   Men: ________; Women: ________; Children: ________

3.21 Did you have other expenses for the field preparation works?

If so, how much and what for?

Other expenses : Rp ______________; for:

D. Transplanting

3.22 When did you start transplanting in the field for this season?

__________________ (date)

What factors influence the decision to start the transplanting?

3.23 Do you use the straight line planting system in the field? ☐

1. Yes
2. No

If not, why?

3.24 Was the seedling from the nursery enough for planting the paddy field that is included in this survey? ☐

1. Just enough
2. More than enough
3. Not enough

If it is lack or excessive, how much was it?

____

3.25 How many labourers did you use for the transplanting?

Family labour (in days):

Men: ________; Women: ________; Children: ________

Hired labour (in days):

Men: ________; Women: ________; Children: ________

How much are the wage rates for (Rp/day):

Men: ________; Women: ________; Children: ________

3.26 Did you have other expenses for the transplanting works?

If so, how much, and what for?

Rp __________________ for:

E. Fertilizing

3.27 What are the names of chemical fertilizers you used for your rice farm in this season?

a. N Fertilizer:

1. For basal: ______________________

2. For top dressing: ______________________

b. P fertilizer:

1. For basal: ______________________

2. For top dressing: ______________________

c. NP fertilizer: ______________________

1. For basal: ______________________

2. For top dressing: ______________________

3.28 How much did you use each of the above fertilizers for the rice field in this season?

a. N fertilizer:

1. Basal: ____________ kg

2. Top dressing: ________ kg

3. Sub-total: [| |] kg

b. P fertilizer:

1. Basal: ____________ kg

2. Top dressing: ________ kg

3. Sub-total: [|] kg

c. NP fertilizer:

1. Basal: ____________ kg

2. Top dressing: ________ kg

3. Sub-total: [| |] kg

3.29 How much were the buying prices of the fertilizers? (Rp/kg).

a. N fertilizer: [| |]

b. P fertilizer: [| |]

c. NP fertilizer: [| |]

3.30 When did you do fertilizing in this season?

a. Basal: ______________ (date)

b. Top dressing: __________ (date)

What are factors influencing the moment of the fertilizing?

3.31 If you never use or you have used chemical fertilizers before but not in this season, please explain why.

3.32 How many labourers did you use for the fertilizing works in this season? (days)

a. Basal:

Family labour: Men: _____; Women: _____; Children: _____

Hired labour: Men: _____; Women: _____; Children: _____

b. Top dressing:

Family labour: Men: _____; Women: _____; Children: _____

Hired labour: Men: _____; Women: _____; Children: _____

c. Wage rate of hired labour, Rp/day:

Men: __________; Women: __________; Children: __________

3.33 Did you have other expenses for fertilizing works?

If so, how much and what for?

Rp ________________, for:

F. Weeding

3.34 Did you do weeding on your ricefield this season? [ ]

1. Yes

2. No

3.35 If yes, how many times did you do it? ____________ (times)

If not, please explain why not.

3.36 How many labourers did you use for the weeding this season? (days)

a. First weeding: ____________________ (date)

Family labour: Men: _____; Women: _____; Children: _____

Hired labour: Men: _____; Women: _____; Children: _____

b. Second weeding: ____________________ (date)

Family labour: Men: _____; Women: _____; Children: _____

Hired labour: Men: _____; Women: _____; Children: _____

c. Wage rate of hired labour (Rp/day):

Men: __________; Women: __________; Children: __________

3.37 Did you have other expenses for the weeding?

If so, how much and what for?

Rp ________________, for:

G. Pest and Disease Control

3.38 Did you have any pest and disease problems this season?

If so, did you give them:

a. Preventive treatment?

If so, how do you decide to or not?

b. Curative treatment?

1. Yes
2. No

If not, why not?

3.39 What kind of pesticides did you use for preventive and curative treatments this season, how much did you use them, and how much were the buying prices of the pesticides?

Pesticide Used	Amount Used (kg/l)	Unit Price Rp/kg/l	Value Rp
1. ___________	___________	___________	_____
2.			
3.			
Total			

3.40 What sorts of pest and disease attacked your ricefarm during this season, when did they attack and what are their effects?

Pest and Disease	Age of plant when attacked (days)*	Area of damage	
		Hectare (Ha)	Percentage (%)
1. ___________	___________	_______	_________
2.			

* i.e. number of days after transplanting.

3.41 Did you have any disaster problems this season?

If so, what are they and what are its effects?

3.42 How many labourers did you use for pest and disease control this season?

a. Family labour: Men: _____; Women: _____; Children: _____

b. Hired labour: Men: _____; Women: _____; Children: _____

c. Wage rate of the hired labour: (Rp/day):

Men: __________; Women: __________; Children: __________

3.43 Did you have other costs for pest and disease control?

If so, how much and what for?

Rp ____________________ for:

H. Harvesting, Processing and Marketing

3.44 When did you harvest your ricefield this season?

____________________ (date)

3.45 How much was the production of the ricefield in this season?

Local unit: ____________________

in kg paddy: | | | | | |

Is the production the same with your expectation or not?

If not, why?

3.46 How many labourers did you use for the harvesting and transporting from field to your house?

1. Cutting (days):

a. Family labour: Men: _____; Women: _____; Children: _____

b. Hired labour: Men: _____; Women: _____; Children: _____

c. Wage rate of hired labour (Rp/day):

Men: __________; Women: __________; Children: __________

2. Threshing (days):

a. Family labour: Men: _____; Women: _____; Children: _____

b. Hired labour: Men: _____; Women: _____; Children: _____

c. Wage rate of hired labour (Rp/day):

Men: __________; Women: __________; Children: __________

3. Tranporting (days):

a. Family labour: Men: _____; Women: _____; Children: _____

b. Hired labour: Men: _____; Women: _____; Children: _____

c. Wage rate of hired labour (Rp/day):

Men: __________; Women: __________; Children: __________

3 3}.47 Did you have other costs for harvesting and transporting?

If so, how much and what for?

Rp ____________________ for:

3 3}.48 Did you process any (your) paddy during this season?

If so, how many, when, how much is its cost, and how?

Processing Date	Quantity[1] Unit	Cost Unit[1] Rp/unit	Way of processing*
1. ____________	________	_________	___________________
2.			
3.			
Total			

[1]i.e. local unit. Enumerator should get information how many kg per local unit (1 L.U = kg).

* e.g. hand pounding, water milling, huller, rice milling, etc.

3.3}.49 Did you sell any paddy or rice during this season?

If so, when, how much, where or to whom, and how much is its selling price?

Sales Date	Quantity[1] Loc.Unit	Price Unit[1] Rp/L. unit	To Whom[2]	Value (Rp)
1. _______	________	__________	_______	_____
2.				
3.				
Total				

[1] i.e. local unit (1 loc. unit = kg)

[2] e.g. to consumer, rice traders, rice processors, etc.

I. Credit for Rice Farming

3.50 Did you get any loans for managing your ricefield this season?

If so, when, how much, what for, from whom, and how much is its interest?

Date of Loans	Amount Rp'00	Terms month	Uses[1]	Sources[2]	Interest rate %/month
1.					
2.					
3.					
Total					

[1] e.g.: Paddy farm inputs (fertilizer, pesticides, seed, etc); farm equipments (sprayers, hoes, etc); cost of living (consumption goods, etc); and so forth and so on.

[2] e.g.: Banks, cooperatives, traders, neighbours, friends, etc.

3.51 Could you get all borrowing you needed for your rice farm this season?

If not, why not?

If yes, did you borrow all?

If not, why not?

3.52 Have your past borrowings affected your capacity to borrow for this season?

If so, how?

3.53 Since adopting IRVs, have you had to borrow more?

If so, for what?

Did you obtain all the extra credit you needed?

If not, why not?

3.54 Were the terms satisfactory for you?

If not, why not?

3.55 Were the interest rates satisfactory for you?

If not, why not?

3.56 What is your preferred source of credit?

J. Rice Farm Equipments and Assets

3.57 What equipment or assets do you have this season for your rice farm?

Could you tell us the names, unit number, date of purchase, average life, purchase price, and present estimated value of the equipment and assets?

LIST OF EQUIPMENT OR ASSETS OF THE RICE FARM THIS SEASON

Items	Unit Number	Date of purchase	Average life (year)	Purchased price (Rp)	Present est. value (Rp)
Plough					
Harrow					
Hoe					
Sickle					
Sprayer					
Sack					
Mat					
Rice barn					
Thresher					
Others:[a]					

[a] Only equipment or assets that are used for rice production.

IV. IRRIGATION WATER

4.1 What kind is your rice field irrigation method? [ ]

1. Field to field irrigation
2. Through irrigation channel directly
3. Both systems 1 and 2.

4.2 Are you able to control the supply of water to your field? [ ]

1. Yes
2. No

If so, can you control it to your satisfaction? [ ]

1. Yes
2. No

If not, why not?

4.3 How often did you check the water level in your rice field during this season?

A. During the first month after transplanting [ ]

1. Every day
2. Three times a week
3. Twice a week
4. Once a week
5. Once in two weeks
6. Once only
7. Never

Why like that?

Did you have stressing days during that month?

If so, how many days? [|]

B. During the second month after transplanting: [ ]

1. Every day
2. Three times a week
3. Twice a week
4. Once a week
5. Once in two weeks
6. Once a month
7. Never

Why like that?

Did you have stresing days during the month?

If so, how many days? [|]

C. During the third month after transplanting: [ ]

1. Every day
2. Three times a week
3. Twice a week
4. Once a week
5. Once in two weeks
6. Only once
7. Never

Why like that?

Did you have stressing days during the month?

If so, how many days? [|]

D. During the fourth month after transplanting: [ ]

1. Every day
2. Three times a week
3. Twice a week
4. Once a week
5. Once in two weeks
6. Once only
7. Never

Why like that?

Did you have stressing days during the month?

If so, how many days: [|]

4.4 When did you drain your rice field in this season?

[|] days after transplanting or

[|] days before harvesting.

Why at that time?

4.5 Is the availability of water from your ricefield this season the same as your expectation?

If not, why not?

Type of Works	Owner of Facilities[1]	Frequency of Works[2]	Material Costs (Rp)	Labour Used (Men days)	
				Family	Hired
1. New irrigation construction	______	______	______	______	______
2. Improvement, replacement or repairing irrigation construction	______	______	______	______	______
3. Digging new irrigation channel (______ m)	______	______	______	______	______
4. Improvement or repairing irrigation channel (______ m)	______	______	______	______	______
5. ______	______	______	______	______	______
6. ______	______	______	______	______	______
Total					

[1] Farmer's own facilities = 1; Public facilities = 2.

[2] e.g., every season, once a year etc.

4.6 According to your opinion, how many days do you need water for your field after transplanting until harvesting?

Until [| |] days after transplanting or

until [|] days before harvesting.

Please explain why.

Which period is the most important supply of water for your rice field?

Until [|] days since transplanting.

Why? Give reasons.

4.7 Did you have any irrigation works during this season?

If so, please specify type of works, when it was done, how much it cost, how many labourers used, etc.:

4.8 Did you get any information on water supplies at various times during this season? [ ]

1. Yes

2. No

If so, when and from whom did you receive it?

Time	Source of information	Information types
1. ________	________________	________________
2.		
3.		

Does this information influence your decisions about paddy practices?

If so, how?

4.9 Did you or any member of your family have "gotong royong" works on irrigation this season?

If so, when and how many of your family members participated?

Time/date	Type of works	No. of family members participating	Working hours (hours/day)
1. ______	____________	____________	__________
2.			
3.			

If you do not participate in the "gotong royong" works should you pay penalty?

If so, how much?

Rp/day: ____________________

Did you pay any penalty this season?

If so, how much?

Rp ____________________

4.10 Did you have any irrigation fee this season?

If so, how much?

Rp ____________________/season/year

Did you pay it?

If not, why not?

When do you want to pay it?

4.11 If your irrigation system is field to field irrigation how about the following items?

A. Water distribution procedure:

B. Irrigation costs responsibility procedure:

C. Others:

4.12 If your irrigation system is directly from irrigation channels, how about the following items?:

A. Water distribution procedure:

B. Irrigation costs responsibility procedure:

C. Others:

TABLE OF THE DEPTH OF WATER IN THE RICE FARMER'S RICE FIELD THIS SEASON

Month	The Depth of Water/day (mm)									

Note: Water depth measurement is started on the first day after transplanting.

INTERVIEWER'S REMARK

Record below any other information regarding the preceding questions and others which in your opinion are of some importance:

Interviewer's Name: ______________________

Address: ______________________

____

Date of First Interview: ____________

Date of Second Interview: ____________

Date of Third Interview: ____________

Date of Fourth Interview: ____________

Date of Fifth Interview: ____________

Interviewer's signature

____

APPENDIX 6.1

Table 6.1.1 Estimated Cobb-Douglas frontier production function coefficients, using LP technique with various probability levels, for both models, for all sample rice farms, 1978 dry season.

Variable	Model I			Model II		
	LP-100	LP-98	LP-97	LP-100	LP-98	LP-97
Constant (ln a)	4.8537	4.6144	3.7973	4.8308	4.8713	4.7325
Ln I (irrigation)	0.0359	0.0201	0.0243	0.1048	0.1205	0.1120
ln N (nitrogen)	0.2047	0.1853	0.2330	...	0.0637	0.0507
ln D (crop damage)	...	...	-0.0334	-	-	-
ln C (other costs)	0.1598	0.1190	0.2612	0.2160	0.1336	0.1155

Notes:

Model I includes crop damage as an independent variable and actual yield is the dependent variable.

Model II does not include crop damage as an independent variable and adjusted yield was used as the dependent variable.

... It is a non basic activity, and therefore it means zero in an LP program.

APPENDIX 6.I (cont'd)

Table 6.1.2 Estimated Cobb-Douglas frontier production function coefficients, using LP technique with various probability levels, for both models, for all sample farms, 1978/79 wet season.

Variable	Model I			Model II		
	LP-100	LP-98	LP-97	LP-100	LP-98	LP-97
Constant (ln a)	5.1196	4.4229	5.4229	7.0075	7.0711	7.0763
ln I (irrigation)	0.0352	0.0638	0.0638	0.0114	0.0147	...
ln N (nitrogen)	0.0828	0.2231	0.2231	0.0794	0.1021	0.0359
ln L (labour)	...	0.2831	0.2831	0.1822	0.2145	0.1906
ln C (other costs)	0.3548	0.1237	0.1237	0.0323	...	0.0340
ln D (crop damage)	-0.2296	-0.2314	-0.2314	-	-	-

Notes:

All notes of Table 6.1.1 apply to this Table.

APPENDIX 6.2

Individual Technical Efficiency ratings of sample rice farms in the Badenah irrigation system, 1978 dry season.

Farm No.	Actual yields	Adjusted yields	Actual TER	Adjusted TER	Rank
61	2.01	2.88	0.9503	1.0000	1
58	2.79	3.71	0.9996	1.0000	2
48	3.77	5.02	1.0000	0.9994	3
12	3.38	4.82	0.9995	0.9993	4
29	3.10	4.43	0.9535	0.9993	5
43	5.00	5.55	1.0000	0.9992	6
89	2.69	2.77	0.9997	0.9992	7
51	3.22	4.96	0.9236	0.9516	8
14	1.61	3.34	0.4676	0.9006	9
42	3.13	4.47	0.8646	0.8894	10
10	1.18	2.37	0.4228	0.8654	11
59	2.90	4.11	0.8551	0.8530	12
70	1.65	2.45	0.5269	0.8377	13
7	2.50	2.50	0.9674	0.8105	14
62	1.53	2.04	0.6211	0.8028	15
84	1.21	1.80	0.5487	0.7926	16
2	3.01	3.41	0.9210	0.7916	17
30	2.07	3.18	0.4937	0.7633	18
26	2.50	3.73	0.5718	0.7604	19
9	1.82	2.14	0.7937	0.7264	20
85	0.86	1.32	0.5005	0.7248	21
1	2.18	2.42	0.7228	0.7144	22
49	4.27	4.59	0.9995	0.7089	23
25	1.58	2.16	0.4884	0.7064	24
16	1.74	2.39	0.6010	0.7049	25
38	2.88	2.94	0.9129	0.6979	26
63	1.75	1.94	0.7222	0.6882	27
13	1.11	2.47	0.4651	0.6878	28

APPENDIX 6.2 (cont'd)

Farm No.	Actual yields	Adjusted yields	Actual TER	Adjusted TER	Rank
23	2.36	3.36	0.5522	0.6655	29
64	1.82	2.60	0.6068	0.6587	30
22	1.91	2.39	0.7233	0.6577	31
37	2.36	2.95	0.6528	0.6554	32
75	0.73	1.82	0.3412	0.6502	34
56	3.16	3.19	0.7725	0.6528	33
15	1.89	2.37	0.5962	0.6444	35
73	1.75	1.79	0.7875	0.6443	36
81	1.89	1.95	0.6519	0.6442	37
57	1.58	2.43	0.4444	0.6439	38
5	2.40	3.58	0.5126	0.6403	39
80	1.53	1.70	0.6599	0.6389	40
8	1.37	2.74	0.3768	0.6356	41
41	1.82	1.92	0.8234	0.6308	42
79	1.74	1.78	0.6584	0.6297	43
24	0.68	1.94	0.2244	0.6214	44
27	1.89	2.37	0.4909	0.6198	45
90	1.53	1.71	0.5813	0.6103	46
86	1.89	2.23	0.6278	0.6077	47
88	2.21	2.25	0.8563	0.6047	48
71	1.74	2.04	0.5659	0.5800	49
65	1.02	1.45	0.4509	0.5795	50
31	3.60	3.64	0.8853	0.5583	51
82	1.29	1.51	0.5149	0.5451	52
74	1.00	1.67	0.4209	0.5405	53
76	1.23	1.53	0.4207	0.5290	54
60	2.53	2.66	0.7782	0.5209	55
18	1.68	1.74	0.6687	0.5193	56
52	2.42	2.48	0.8129	0.5120	57
28	2.75	2.86	0.6712	0.5088	58
66	1.94	2.04	0.6456	0.5063	59

APPENDIX 6.2 (cont'd)

Farm No.	Actual yields	Adjusted yields	Actual TER	Adjusted TER	Rank
68	1.36	1.37	0.5489	0.5058	60
54	3.96	4.17	0.7493	0.5014	61
6	0.71	1.79	0.2117	0.4997	62
4	3.53	4.20	0.6740	0.4995	63
40	2.19	2.21	0.7380	0.4923	64
55	2.30	2.39	0.6174	0.4851	65
33	1.71	1.74	0.5725	0.4806	66
87	1.07	1.34	0.4807	0.4776	67
69	1.26	1.49	0.5140	0.4723	68
78	0.58	1.16	0.2984	0.4659	69
77	1.13	1.15	0.5928	0.4645	70
36	2.14	2.16	0.5655	0.4545	71
45	2.23	2.29	0.5481	0.4495	72
35	2.67	2.74	0.5137	0.4471	73
67	1.46	1.51	0.4680	0.4409	74
32	3.16	3.19	0.6279	0.4295	75
72	1.06	1.12	0.5248	0.4278	76
20	0.79	1.58	0.3071	0.4044	77
21	1.14	1.34	0.3916	0.3995	78
83	1.35	1.41	0.3698	0.3867	79
3	1.53	2.05	0.4360	0.3795	80
34	2.07	2.11	0.4904	0.3784	81
47	1.26	1.40	0.4987	0.3359	82
46	2.31	2.33	0.4584	0.3081	83
50	0.55	1.11	0.2198	0.2960	84
53	1.96	2.02	0.4779	0.2956	85
39	1.89	1.92	0.4205	0.2956	86
19	0.83	1.38	0.2305	0.2699	87
11	0.21	0.69	0.0714	0.2373	88
44	1.18	1.24	0.3613	0.2193	89

Note: Yields are in mt paddy/ha.

APPENDIX 6.3

Individual Technical Efficiency ratings of sample rice farms in the Badenah irrigation system, 1978/79 wet season.

Farm No.	Actual yields	Adjusted yields	Actual TER	Adjusted TER	Rank
12	2.50	4.17	1.0000	1.0000	1
48	3.54	4.72	0.9958	1.0000	2
43	4.25	5.45	0.9953	1.0000	3
47	0.98	4.78	0.3414	0.9999	4
88	4.11	4.11	0.9957	0.9999	5
42	1.51	4.32	0.6927	0.9598	6
29	2.69	4.14	0.9198	0.8556	7
64	2.58	3.64	0.9957	0.8493	8
49	2.77	3.96	0.8873	0.8042	9
78	3.63	3.63	0.6328	0.7778	10
31	0.30	3.00	0.1878	0.7623	11
30	2.48	3.81	0.7622	0.7483	12
23	2.35	3.36	0.8227	0.7269	13
61	1.34	2.69	0.9957	0.6966	14
26	2.00	3.33	0.7064	0.6823	15
14	1.07	2.69	0.6177	0.6668	16
89	1.03	2.58	0.6110	0.6432	17
17	1.89	2.37	0.9965	0.6309	18
46	3.34	3.34	0.3950	0.6268	19
90	2.05	2.73	0.8058	0.6263	20
53	2.36	2.95	0.7514	0.6231	21
32	2.84	3.16	0.6796	0.6179	22
10	2.05	2.57	0.8402	0.6178	23
70	1.26	2.29	0.8579	0.6152	24
13	1.66	2.37	0.8679	0.6122	25
25	2.21	2.46	0.7847	0.5879	26
28	2.13	2.83	0.6654	0.5876	27
54	2.14	2.85	0.6307	0.5834	28
2	2.37	2.72	0.5979	0.5719	29

APPENDIX 6.3 (cont'd)

Farm No.	Actual yields	Adjusted yields	Actual TER	Adjusted TER	Rank
58	2.05	2.74	0.6631	0.5695	30
85	1.57	1.57	0.7321	0.5586	31
50	2.53	2.53	0.4074	0.5469	32
27	2.21	2.76	0.6328	0.5446	33
59	2.08	2.60	0.7412	0.5438	34
81	1.89	1.95	0.6647	0.5380	35
71	1.79	2.16	0.6918	0.5347	36
52	2.64	2.64	0.4373	0.5333	37
60	2.42	2.69	0.5455	0.5231	38
36	1.07	2.14	0.6087	0.5219	39
73	2.13	2.13	0.5189	0.5191	40
38	1.34	2.21	0.5018	0.5166	41
34	1.89	2.90	0.4816	0.5151	42
3	1.40	1.95	0.6188	0.4997	43
8	1.16	2.32	0.4830	0.4970	44
1	2.09	2.32	0.6429	0.4968	45
9	1.73	2.03	0.6660	0.4934	46
44	2.10	2.10	0.4354	0.4933	47
57	2.13	2.13	0.3637	0.4907	48
84	0.94	1.70	0.5655	0.4898	49
66	1.45	1.94	0.6465	0.4871	50
35	1.89	3.00	0.3275	0.4840	51
16	1.53	2.19	0.5377	0.4724	52
75	0.73	1.82	0.5196	0.4721	53
80	1.67	1.86	0.4262	0.4696	54
65	1.36	1.94	0.6913	0.4687	55
62	1.07	1.78	0.6417	0.4685	56
68	1.87	1.87	0.3898	0.4684	57
40	1.97	2.19	0.5831	0.4677	58
22	1.80	2.25	0.6525	0.4624	59

APPENDIX 6.3 (cont'd)

Farm No.	Actual yields	Adjusted yields	Actual TER	Adjusted TER	Rank
63	0.75	1.88	0.3862	0.4537	60
86	1.58	2.11	0.5638	0.4332	61
7	1.65	2.19	0.7390	0.4319	62
45	2.19	2.26	0.3541	0.4266	63
79	0.81	1.61	0.5674	0.4260	64
24	1.06	2.11	0.3837	0.4216	65
69	1.46	1.72	0.6385	0.4173	66
15	1.58	1.97	0.5016	0.4162	67
51	1.00	1.82	0.4644	0.4141	68
41	1.34	1.78	0.5734	0.4133	69
20	0.68	1.51	0.4177	0.4123	70
76	1.00	1.82	0.5054	0.4095	71
87	1.34	1.34	0.8881	0.3937	72
74	0.63	1.56	0.3882	0.3820	73
56	1.91	1.91	0.2705	0.3778	74
33	0.51	1.70	0.2405	0.3774	75
83	1.58	1.58	0.4893	0.3696	76
55	1.75	1.75	0.2403	0.3587	77
82	1.14	1.43	0.5624	0.3558	78
39	1.58	1.75	0.3895	0.3550	79
67	1.07	1.34	0.4731	0.3267	80
37	1.34	1.48	0.5164	0.3252	81
72	0.69	1.06	0.5884	0.3183	82
21	1.24	1.38	0.3761	0.3110	83
18	0.63	1.26	0.3264	0.3069	84
19	0.83	1.38	0.2996	0.2927	85
77	0.51	1.02	0.2070	0.2203	86
11	0.12	0.62	0.0758	0.1574	87

Note: Yields are in mt paddy/ha.

APPENDIX 7.1

Regression coefficients of factors affecting nitrogen application per hectare (in logs), 1978 dry and 1978/79 wet season.

Variable	Coefficient			
	Dry Season		Wet Season	
	I	II	I	II
ln a	2.7732	3.5484	3.1715	3.3906
ln W	0.2448** (2.53)	-	0.0668^{ns} (0.16)	-
ln S	-	-0.0546** (-2.79)	-	-0.0054^{ns} (-0.27)
ln F	-0.2684** (-2.06)	-0.2758** (-2.73)	-0.4725*** (-2.99)	-0.4652*** (-2.85)
ln D	-0.0109^{ns} (-0.18)	-0.0257^{ns} (-0.49)	-0.0985** (-1.66)	-0.1027** (-1.76)
ln PR	0.1806^{ns} (0.13)	0.2392^{ns} (0.41)	0.2486^{ns} (0.33)	0.3288^{ns} (0.22)
ln B	0.0064^{ns} (0.29)	0.0023^{ns} (0.11)	0.0319^{ns} (1.00)	0.0322^{ns} (0.94)
RPC	0.3075** (1.88)	0.2917*** (3.06)	0.4475^{ns} (0.17)	0.4458^{ns} (0.06)
ln RFE	-0.0642^{ns} (-1.00)	-0.0315^{ns} (-0.34)	-0.0895^{ns} (-0.49)	-0.0934^{ns} (-0.49)
CR	0.2074* (1.35)	0.1717* (1.36)	0.4475** (2.76)	0.4458** (2.76)
T_1	0.2753* (2.12)	0.2591* (1.37)	0.0061^{ns} (0.63)	0.0091^{ns} (0.67)
T_2	0.2414* (1.54)	0.3139^{ns} (1.21)	0.3106^{ns} (1.29)	0.3109* (1.42)
E	0.2922** (1.89)	0.3169** (1.94)	0.4020** (1.86)	0.4063** (1.91)
M	0.1174* (1.59)	0.1318^{ns} (0.87)	-0.0241^{ns} (-0.15)	-0.0189^{ns} (-0.29)
WS	-0.3364** (-1.98)	-0.4356** (-2.38)	-0.068^{ns} (-0.56)	-0.0663^{ns} (-0.53)
V	-0.0867^{ns} (-1.08)	....	0.0723^{ns} (0.30)	0.0835^{ns} (0.39)
n	89	89	87	87
R^2	0.3101	0.3507	0.2673	0.2665
F-stat	2.375	3.1159	1.8764	1.8681

Notes: All notes for Table 7.7 apply to this table.

APPENDIX 7.2

Individual Technical Efficiency Rating (TER), Price Efficiency Index (PEI), Economic Efficiency Rating (EER), and Adjusted Net Profit/ha (ANP) of sample rice farmers in Badenah irrigation system, 1978 dry season.

Serial No.	TER	PEI	EER	ANP ('000Rp)	Farm No.
1	1.000	0.460	0.460	227.1	58
2	1.000	0.390	0.390	190.7	61
3	1.000	0.620	0.620	315.2	48
4	0.999	0.400	0.400	285.4	29
5	0.999	0.196	0.196	325.8	12
6	0.999	0.239	0.239	147.8	89
7	0.999	0.282	0.282	370.2	43
8	0.952	0.388	0.370	316.8	51
9	0.906	0.372	0.337	181.5	14
10	0.889	0.250	0.223	323.9	42
11	0.865	0.201	0.174	155.4	10
12	0.853	0.331	0.282	234.1	59
13	0.838	0.311	0.260	133.1	70
14	0.810	0.193	0.156	170.4	7
15	0.803	0.304	0.244	127.8	62
16	0.793	0.194	0.154	96.5	84
17	0.792	0.442	0.350	168.3	2
18	0.763	0.215	0.164	186.2	30
19	0.760	0.329	0.250	218.3	26
20	0.726	0.172	0.125	137.7	9
21	0.725	0.177	0.128	105.6	85
22	0.714	0.345	0.247	98.5	1
23	0.709	0.303	0.215	305.7	49
24	0.706	0.149	0.105	134.7	25
25	0.705	0.339	0.239	126.6	16
26	0.698	0.375	0.262	86.1	38
27	0.688	0.324	0.223	179.2	13
28	0.688	0.212	0.146	124.8	63
29	0.676	0.195	0.132	166.0	22

APPENDIX 7.2 (Cont'd.)

Serial No.	TER	PEI	EER	ANP ('000Rp)	Farm No.
30	0.665	0.353	0.235	149.7	23
31	0.659	0.171	0.113	205.5	64
32	0.655	0.210	0.138	189.0	37
33	0.653	0.410	0.268	153.0	56
34	0.650	0.191	0.125	116.8	75
35	0.644	0.329	0.212	132.8	57
36	0.644	0.165	0.106	135.6	81
37	0.644	0.154	0.099	128.2	73
38	0.644	0.154	0.099	156.0	15
39	0.640	0.372	0.238	242.6	5
40	0.639	0.200	0.128	102.9	80
41	0.636	0.174	0.110	180.5	8
42	0.631	0.213	0.134	100.2	41
43	0.630	0.257	0.162	109.6	79
44	0.621	0.253	0.157	78.4	24
45	0.620	0.234	0.145	73.6	27
46	0.610	0.170	0.104	127.9	90
47	0.608	0.213	0.130	80.1	86
48	0.605	0.206	0.124	120.4	88
49	0.580	0.292	0.169	76.6	71
50	0.580	0.252	0.146	57.9	65
51	0.558	0.544	0.304	171.7	31
52	0.557	0.254	0.141	160.8	52
53	0.545	0.184	0.100	61.7	82
54	0.540	0.217	0.118	82.2	74
55	0.529	0.264	0.140	102.4	76
56	0.521	0.321	0.167	167.9	60
57	0.519	0.267	0.138	114.5	18
58	0.509	0.445	0.226	133.4	28
59	0.506	0.219	0.111	154.2	66
60	0.506	0.183	0.092	97.4	68
61	0.501	0.420	0.210	183.3	54
62	0.500	0.382	0.191	150.4	4

APPENDIX 7.2 (Cont'd.)

Serial No.	TER	PEI	EER	ANP ('000Rp)	Farm No.
63	0.500	0.210	0.105	106.5	6
64	0.492	0.391	0.192	108.5	40
65	0.485	0.278	0.135	101.1	55
66	0.481	0.334	0.160	105.8	33
67	0.478	0.185	0.089	82.2	87
68	0.472	0.182	0.086	115.2	69
69	0.466	0.194	0.090	83.6	78
70	0.464	0.157	0.073	52.2	77
71	0.454	0.326	0.149	149.1	36
72	0.450	0.384	0.172	168.7	45
73	0.447	0.195	0.087	159.6	35
74	0.441	0.160	0.071	108.8	67
75	0.430	0.315	0.135	179.2	32
76	0.428	0.254	0.109	91.6	72
77	0.404	0.334	0.135	88.9	20
78	0.399	0.189	0.076	81.8	21
79	0.387	0.144	0.056	70.7	83
80	0.380	0.169	0.064	126.1	3
81	0.378	0.026	0.010	4.6	34
82	0.336	0.305	0.102	110.2	47
83	0.322	0.275	0.088	59.1	50
84	0.321	0.258	0.083	60.3	53
85	0.310	0.307	0.095	117.9	39
86	0.308	0.209	0.064	45.6	46
87	0.270	0.343	0.093	94.2	19
88	0.236	0.198	0.047	34.3	11
89	0.219	0.009	0.002	1.0	44

APPENDIX 7.3

Individual Technical Efficiency Rating (TER), Price Efficiency Index (PEI), Economic Efficiency Rating (EER), and Adjusted Net Profit/ha (ANP) of sample rice farmers in Badenah irrigation system, 1978/79 wet season.

Serial No.	TER	PEI	EER	ANP ('000Rp)	Farm No.
1	1.000	0.844	0.843	309.2	43
2	1.000	0.822	0.822	273.3	48
3	1.000	0.693	0.693	235.7	88
4	1.000	0.779	0.779	383.8	47
5	1.000	0.524	0.524	368.7	12
6	0.960	0.611	0.587	338.8	42
7	0.856	0.764	0.653	282.4	29
8	0.849	0.674	0.573	236.7	64
9	0.804	0.769	0.619	231.7	49
10	0.778	0.704	0.548	321.0	78
11	0.762	0.443	0.338	213.8	31
12	0.748	0.556	0.416	285.9	30
13	0.727	0.680	0.494	178.0	23
14	0.697	0.500	0.348	247.7	61
15	0.682	0.668	0.456	288.7	26
16	0.667	0.686	0.457	186.1	14
17	0.643	0.549	0.353	220.6	89
18	0.631	0.628	0.396	156.5	17
19	0.627	0.640	0.401	123.4	46
20	0.626	0.569	0.357	200.3	90
21	0.623	0.705	0.440	266.5	53
22	0.618	0.635	0.392	231.4	32
23	0.618	0.481	0.297	225.8	10
24	0.615	0.519	0.319	203.6	70
25	0.612	0.600	0.367	194.3	13
26	0.588	0.687	0.403	151.4	28
27	0.588	0.505	0.297	207.7	25
28	0.583	0.761	0.444	140.4	54
29	0.572	0.608	0.348	127.6	2
30	0.570	0.728	0.415	213.9	58

APPENDIX 7.3 (Cont'd.)

Serial No.	TER	PEI	EER	ANP ('000Rp)	Farm No.
31	0.559	0.496	0.277	98.5	85
32	0.547	0.630	0.345	116.0	50
33	0.545	0.660	0.359	193.9	27
34	0.544	0.672	0.365	213.8	59
35	0.538	0.551	0.297	104.2	81
36	0.535	0.521	0.278	151.9	71
37	0.533	0.530	0.282	185.7	52
38	0.523	0.698	0.365	150.2	60
39	0.522	0.682	0.356	132.1	36
40	0.519	0.613	0.318	160.1	73
41	0.517	0.674	0.348	102.3	38
42	0.515	0.658	0.339	98.9	34
43	0.500	0.628	0.314	129.7	3
44	0.497	0.625	0.311	126.6	1
45	0.497	0.513	0.255	185.8	8
46	0.493	0.511	0.252	172.5	44
47	0.493	0.476	0.235	165.2	9
48	0.491	0.529	0.259	151.7	57
49	0.490	0.495	0.242	143.5	84
50	0.487	0.492	0.240	128.6	66
51	0.484	0.906	0.438	210.3	35
52	0.472	0.594	0.281	118.9	16
53	0.472	0.526	0.248	137.7	75
54	0.470	0.631	0.296	134.6	80
55	0.469	0.514	0.241	69.7	65
56	0.468	0.573	0.268	146.8	68
57	0.468	0.549	0.257	159.1	40
58	0.462	0.737	0.341	190.4	22
59	0.459	0.612	0.281	99.9	62
60	0.454	0.564	0.256	98.6	63
61	0.433	0.580	0.251	132.7	86
62	0.432	0.676	0.292	185.1	7
63	0.427	0.542	0.231	148.9	45

APPENDIX 7.3 (Cont'd.)

Serial No.	TER	PEI	EER	ANP	Farm No.
64	0.425	0.560	0.238	108.2	79
65	0.422	0.476	0.201	152.4	24
66	0.417	0.677	0.282	126.2	69
67	0.416	0.655	0.273	147.5	15
68	0.414	0.681	0.282	132.1	51
69	0.413	0.697	0.288	112.6	41
70	0.412	0.609	0.251	106.8	20
71	0.409	0.274	0.112	37.4	76
72	0.394	0.454	0.179	119.3	87
73	0.382	0.653	0.249	116.9	74
74	0.378	0.637	0.241	125.1	56
75	0.377	0.672	0.253	122.2	33
76	0.370	0.457	0.169	113.4	83
77	0.360	0.522	0.188	135.9	55
78	0.356	0.476	0.169	53.1	82
79	0.355	0.687	0.244	106.1	39
80	0.327	0.486	0.159	115.6	67
81	0.325	0.525	0.171	79.6	37
82	0.318	0.559	0.178	81.0	72
83	0.311	0.617	0.192	100.5	21
84	0.307	0.398	0.122	87.8	18
85	0.293	0.647	0.189	102.1	19
86	0.220	0.392	0.086	32.7	77
87	0.157	0.460	0.072	41.5	11