MICRO LEVEL PLANNING, ECONOMIC PERFORMANCE AND HUMAN CAPITAL: A STUDY OF THE SETTLER FARMERS IN MAHAWELI PROJECT IN SRI LANKA

By

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Declaration

Except where otherwise indicated
this thesis is my own work.

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To Panchi

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I have incurred many debts, both of an intellectual nature and otherwise, to many individuals and institutions at various stages of this study. The settler farmers in Mahaweli System-H, whose performance I have been monitoring since 1979, were responsible for generating the initial interest in an in-depth study of farmer adjustment to technological and other changes.

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Abstract

New technologies, irrigation and changes in the broader socio-economic environment are often major causes of disequilibria in the decision making environment of farmers in developing countries. The pace and pattern of their adjustment to these situations have important efficiency and equity implications both in private and social contexts. Most of the literature on adjustment of farmers to new situations has concentrated on the adoption process of new technologies as a whole or in terms of particular component practices. However, situations where farmers are required to adopt and adjust to a single component practice while other elements of their environment remain static are rare. Technologies often appear in the form of packages and accompany broader socio-economic changes.

In this thesis, a conceptual framework which draws heavily on human capital theory is developed to address broad issues of farmer adjustment to simultaneous changes in many aspects of their environment. This framework is applied to farm survey data gathered from a sample within the Pilot Phase of the Mahaweli Project, the single most important irrigation cum land settlement project in Sri Lanka. The empirical analysis utilizes stochastic frontier production functions to obtain measures of technical and allocative efficiencies of individual farmers which reflect their technical and allocative abilities. The analysis was conducted at two levels, using market and economic prices.

The findings show first that different types of human capital have significantly different impacts on the ability of farmers to adjust to specific changes in technological and environmental factors. Second, the major source of losses to the economy is shown to be farm level inefficiencies rather than price distortions. Third, the differential performance of farmers resulting from varying ability to adjust to disequilibria and the heterogeneity in farm micro environments are shown to result in an unequal distribution of income unanticipated by planners, but significant in terms of future consequences.

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CHAPTER 1

Introduction

The development of agriculture is widely accepted to be of vital importance for the overall economic development of much of today's third world. The large number of small, traditional or near traditional, farmers in the developing countries are now accepted to be economically rational and capable of making substantial contributions to these economies given new technologies and improved access to resources. Accordingly, the basic strategies employed for agricultural development by national and international authorities involve investments in research, extension and the provision of land, water and other inputs. These are resource intensive strategies. Given the scarcity of resources in these economies, the provision of technology and resources are often limited to selected locations and communities, and this inevitably results in inequalities between the beneficiaries of such programmes and others. Most of the extensive literature on the "Green Revolution" addresses issues related to differential rates of technology adoption between farmer types, possible scale economies of the technology, and implications for rural income distribution.

Our research, however, is focussed on the causes and effects of variable performance among farmers who have adopted a basic technology. It is hoped that this will yield valuable insights for future planning of alternative development strategies and possibly for improving the performance of existing agricultural development projects.

1.1 Role of Agriculture in Economic Development

Although there are many variants of models employed to analyse economic development, mainstream development economics theory is derived from observing the historical experience of already developed nations. The role of agriculture in economic development is seen as that of generating a surplus for investment in the modern industrial sector, creating a market for its products, and releasing labour for industry aided by a food surplus which leads to a structural transformation in the economy. This classic path of economic development is characterized by a falling share of agriculture in the gross national product and of employment of the labour force. Capital intensity and the resulting high labour productivity in the industrial sector results in increased per capita incomes. Migration of labour out of agriculture and mechanisation increases labour productivity in agriculture too. This overall increase in labour productivity and the resulting increase in real incomes leads to the broadening of domestic markets and continued capital accumulation. A demographic transition occurs from high to low birth rates and eventually a greater equality in income distribution emerges (Jorgensen 1969, Kuznets 1969, Lewis 1958, Rostow 1963).

While the relevance of this particular historical path of development for present day developing nations is often questioned (see Dillon 1979) , it is clear that many of the past and present development policies and strategies of governments in developing countries are shaped by this broad view of the development sequence.

A widespread and popular strategy for the development of agriculture, to transform it into an "engine of growth", is to provide new technology and improved inputs to traditional or subsistence farmers. The basis for this interest in the provision of new technology to traditional farmers is provided by Schultz's "efficient but poor hypothesis". Schultz's traditional farmer is small, poor, tradition bound, but efficient. Given the resources currently at his disposal, the institutional environment and his objectives, it is impossible to achieve a more efficient reallocation of resources. However, with new technologies and better resources this poor but economically motivated farmer can produce a surplus. Such thinking has resulted in major investments in land and water resources development, in international and national agricultural research networks, and in the expansion of agricultural extension services with national and international funds. The "Green Revolution" has been the major manifestation of these investments.

1.2 Green Revolution

There was much optimism that the new agricultural technology based on high yielding varieties of cereal grains would usher in a "green revolution" which would solve the chronic problems of widespread shortages of food, unemployment and poverty in the developing world. This euphoria was short lived as is evident from the post green revolution literature. The inability of the majority of farmers adopting this technology to achieve productivity levels sufficiently close to the potential observed under experimental conditions, the performance variations among farmers using the same technology package, and the differences between adopters and non adopters have raised concern among the social scientists monitoring the new technology.

The earliest writings suggested that this technology had increasing returns to scale thereby favouring larger and richer farmers at the expense of small poor farmers (Frankel 1971, Griffin 1974). Others argued that the technology *per se* is scale neutral and that biased rural institutions and imperfect factor markets are to be blamed for the apparent big and rich farmer bias of the technology (Hayami 1981, Ruttan 1977, Ryan 1984). Feder et al. (1985) in a comprehensive survey of literature on the adoption of agricultural innovations state that

> The conventional wisdom is that constraints to the rapid adoption of innovations involve factors such as the lack of credit, limited access to information, aversion to risk, inadequate farm size, inadequate incentives associated with farm tenure arrangements, insufficient human capital, absence of equipment to relieve labor shortages (thus preventing timeliness of operations), chaotic supply of complementary inputs (such as seed, chemicals, and water), and inappropriate transportation infrastructure. (p 255).

The conclusions of this survey raised several important points:

1. Most adoption research views the adoption decision in dichotomous terms (adoption or nonadoption), although for many types of innovations, the interesting question may be related to the intensity of the use of that innovation or of its components (e.g., seed and fertiliser).

2. Often, several innovations which have varying degrees of complementarity are introduced simultaneously. Thus adoption decisions for various innovations are interrelated. When such interrelated innovations are introduced over time in a partially overlapping manner, a lasting disequilibrium is created.
3. Many adoption models assume perfectly competitive markets with homogeneous inputs. However, price effects in input and output markets resulting from technology adoption may influence the progress and the direction of the diffusion process by affecting the relative profitability of alternative technologies and by changing the income distribution. Further, the "non existence" of government policies which influence adoption is bothersome.
4. The conflicting conclusions about the causes and effects of adoption sometimes indicated by studies from different regions or countries may in many cases be the result of differing, social, cultural and institutional environments quite apart from "pure economic" factors.
5. Even if differential adoption rates of green revolution technology may disappear once the diffusion process is sufficiently advanced (e.g., Ruttan 1977) the early adopters (usually larger and wealthier farms) can accumulate more wealth and acquire more land from the laggards. This acquisition of new wealth enables further adoption and thus affects the dynamic pattern of aggregate adoption. Thus, special attention to changes in landholding patterns and wealth accumulation (as well as tenency arrangements) is warranted.

We explore the performance of farmers in relatively favourable environments where it is planned that they attain high productivity together with equity. We will argue that even in such favourable environments, i.e., well irrigated areas, where all farmers adopt, they may still differ in terms of the degree of adoption, especially when the technology is introduced as a package; that farmers will be required to adjust continuously to disequilibria resulting from technological and other changes; that the rate and the success of adjustment may vary between individuals; and that the differences between farmers in the degree and the success of adoption may have significant efficiency and equity implications.

1.2.1 Irrigation and the Green Revolution

Much of the Green revolution technology, particularly for rice, has been designed for well irrigated environments. The importance of irrigation for reaping full benefits of this technology has resulted in a redefinition of wealth of farmers in terms of both land holding size and the extent of irrigation instead of purely in terms of the former (Grabowsky 1981). Even prior to the advent of "Green Revolution" irrigation helped to increase cropping intensity enabling double or even triple cropping of land per year. This substantially increased the productivity of cultivable land which is a highly scarce resource in densely populated countries. Naturally, irrigation development has been closely associated with the history of permanently settled agriculture in the tropics and sub-tropics since the early days of human civilization. The oldest known dam was built some 5000 years ago in Egypt (Smith 1971). The new technology, however, has widened the productivity difference between irrigated and non-irrigated lands.

Modern irrigation schemes are typically the result of detailed and in-depth studies and planning by both national and international agencies and represent major investments in agriculture. Goering (1978) gives an account of high and rising costs of irrigation and land settlement projects in general. An example of the high costs of an individual project is given by Wallace (1981) who studied the Kano River Project in Nigeria. Such high investment costs of irrigation projects can only be justified by the higher benefits expected from agriculture.

The higher productivity of irrigated agriculture is illustrated by the fact that in 1982, 40 per cent of the the world's total harvest of crops came from irrigated lands which covered only 20 per cent of the total harvested area (IBRD 1982). This explains the continuing trend of investment in irrigation which was growing at a rate of 2 per cent annually in 1980. Accordingly, irrigated agriculture is expected to provide most of the increase in world food supply in the near future. Oram et. al., 1979 suggest that nearly 60 per cent of the increase in food production in Asia, North Africa and the Middle East, West and East Africa and Latin America up to 1990 will come from irrigated agriculture. It will account for nearly three fourths of the increase in food production in Asia, North Africa and the Middle East up to 1990. Out of 98.7 billion dollars (at 1975 prices) estimated to be the required capital investment for this increase, 52 billion dollars will be for water resource development followed by 9.9 billion for land settlement, the two most important items in IFRI projections. The importance of irrigation for increased land productivity is further emphasised by FAO (1984) which predicts that the proportion of irrigated area in arable land of developing countries will increase from 13 per cent in 1975 to 20 per cent in 1995.

Irrigation accounted for nearly 20 per cent of international capital aid to food and agriculture in 1976-80 period (Carruthers, 1983). Total multilateral aid for irrigation in 1980 was U.S. $ 2.2 billion, but the total value of investment in irrigation development would have been far in excess of this since many of the internationally funded projects have had around 50 per cent local funding, and many such projects in developing countries are entirely domestically financed.

Apart from this high productivity of irrigated agriculture, large scale government investment in irrigation and land development in developed and developing countries is induced by the following factors (Ruttan 1986).

1. The view that irrigation and land development projects have social benefits which substantially exceed the potential private benefits in the form of user charges, making them unattractive to private investors,
2. the presumption that infrastructural investments such as transportation, communication, power, irrigation, and related activities are a necessary precondition for the inducement of the private investment required for a sustained growth in the economy,
3. the political appeal of "monumental" investments such as big dams and super highways, and
4. the amenability of physical infrastructure investment to the algebra of conventional cost benefit calculations including the ability to plan and develop them in "project units" which attracts external financing in comparison to research and education which are relatively difficult for cost-benefit or cost-effectiveness calculations.

1.3 New Land Settlement

Many large irrigation development projects (e.g., Kariba dam in Zambia, Volta reservoir in Ghana, Aswan High Dam in Egypt, Bhakra Nangal project in India etc.,.), involve the settlement of farmers in newly developed lands. The term "new land settlement" is synonymous with other common terms such as "colonization" popularly used in Latin America and pre-independance South Asia, and "transmigration" in Indonesia. By and large these terms refer to state sponsored settlement of migrants in previously uninhabited or sparsely populated lands. Sponsored land settlement is undertaken with a number of common objectives, with different emphasis given to each depending on the circumstances. The immediate objectives of land settlement are:

1. population re-distribution,
2. regional development,
3. increasing agricultural production and employment, and
4. achieving greater equality in income distribution.

In the long run, the achievement of these objectives is expected to make a significant contribution to overall national development. Spontaneous settlement in new lands, on the other hand, occurs owing to the natural increase in population and the resulting land hunger as well as to various other economic incentives. Spontaneous settlements and settlers have been observed to be relatively more successful than sponsored settlements and settlers in terms of their greater net productivity and the lesser reliance on state aid (Nelson 1973, James 1984). However, the latter, have been known to create a negative impact on the natural environment and ecology owing to the indiscriminate exploitation of nature for private profits with no regard to social costs (Majid 1978). They often exclude the poorest sections of the society, for only relatively well off people can afford to take the risk of settling in new lands in the absence of state support.

Sponsored new land settlements may either be irrigated or rainfed. Although sponsored land settlement has a long history, its importance in productivity terms has increased only relatively recently, with the advent of "green revolution". The main reasons for the undertaking of pre-green revolution land settlement schemes were related to objectives other than increasing production mentioned above. In this study, the focus is on irrigated sponsored new lands settlements. We study the performance of new technology among farmers who adopt it simultaneously, and with equitable access to resources which rules out the influence of initial differences in access to resources to a great extent. But even in irrigated land settlements, there may still be some differences among farmers in their factor endowments, e.g., in human capital.

The realisation of the long term goal of irrigated new land settlement projects, i.e., making a significant positive contribution to national development effort, is dependent on the performance of these schemes in terms of productivity and equity. Hence the analysis of short run performance of these projects can illustrate likely trends in terms of the achievement of long term goals. Successful performance of such projects is complicated by the presence of a large number (often running into thousands) of individual farmers who are to a great extent independent decision makers and managers with varying ability and resource endowments[1].

The ability to make a significant impact on population density in highly populated areas by resettlement of sufficiently large numbers of people in new lands within a background of rapid population increase has been questioned. Further, this strategy had no support in terms of actual accomplishments so far, despite the long history of such attempts in many parts of the world (Arndt and Sundrum 1977, Goering 1978, and Scudder 1981). At best, such a strategy may have only a marginal impact in relieving population pressures.

Planners of new irrigated land settlements are often given "a clean slate" to design the physical and social infrastructure, and appropriate institutions. They are often allowed to design settler selection criteria as well. Thus deliberate planning is often undertaken to provide settlers with equal access to the major resources. This in fact, provides a veritable laboratory for the close monitoring of developments in these planned societies for the study of many important social phenomena, e.g., differences in the ability to derive the maximum benefit from the new HYV technology. Such understanding may prove to be useful both in other non planned rural settlements and in future planned settlements elsewhere. In the following section, we discuss the performance of a large irrigated land settlement project, in which careful planning was applied to achieve the objectives of high productivity together with equity using new rice technology. This project is the subject matter of this thesis.

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[1] There are land settlement projects which are centrally managed, e.g., tree crop schemes in Malaysia, where individual decision making is markedly less important.

1.4 Mahaweli Development Project in Sri Lanka

The Mahaweli project in Sri Lanka is a good example of a large irrigated land settlement scheme with a declared goal of equity among the beneficiaries of the project apart from the usual production goals, and with detailed planning and significant costs incurred for the achievement of equity. The objectives of the project stated in various project related documents and government policy statements can be summarised as follows:

1. increasing agricultural production,
2. increasing the output of hydro-electricity,
3. increasing employment, and
4. improving rural income distribution.

Table 1-1: State sponsored land settlement for agriculture in selected Asian countries

Country	Total Population In 1982 (Millions)	No.of families settled	Land area ha.
India (1971) 1/	705	160,000	600,000
Pakistan (1982) 1/	87	44,000	83,682
Sri Lanka (1981) 2/	15	110,000	307,567
Thailand (1979) 3/	48	110,000	n.a
Indonesia (1984) 4/	154	1,000,000	n.a
Malaysia (1976) 5/	14	350,000	n.a
Philippines (1976) 3/	50	100,000	n.a

1/Johnson (1983)
2/Wimaladharma (1982)
3/Klempin (1979)
4/Hardjono (1977) and (1986)
5/Macandrews (1979)
6/Crystal (1982)
Note: The years within parentheses refer to the year up to which the cumulative settlement data are given for each country. The numbers given are approximations only.

This project diverts water from the largest river in Sri Lanka, the Mahaweli Ganga, to the Dry Zone of Sri Lanka for irrigation and the generation of hydro-power. It continues the 50 year old tradition of modern land settlement under irrigation in the Dry Zone of Sri Lanka (see Farmer 1957). Sri Lanka's experience in land settlement under irrigation is perhaps greater than that of any other country in the region. More than 90 per cent of land settlement reported (Table 1-1) falls within major irrigation schemes. The Dry Zone, i.e., that part of Sri Lanka which receives less than 75 inches of rainfall annually, has the largest extent of uninhabited land. This is partly due to historical reasons and partly to natural reasons. The Dry Zone has pronounced dry and wet seasons. The wet season has an often high but somewhat unpredictable rainfall and the dry season receives much less rainfall, and thus requires irrigation for successful cultivation of crops. Historically, much of the Dry Zone was inhabited and developed under irrigation, but was abandoned eventually owing to the difficulties in resisting persistent foreign invasions from powerful kingdoms in South India. An increase in the incidence of malaria has also been thought to have contributed to the abandonment of the Dry Zone settlements.

The modern development of the Dry Zone had its beginnings in the British colonial regime. The colonial administrators of the island saw a potential for increased food production under rehabilitated ancient irrigation works. However, the process of irrigation development and land settlement, then known as "colonisation", accelerated in the period immediately prior to independence when Sri Lankans were given greater powers in domestic administration. The motivation for resettlement in this period came from a desire to recapture the ancient *glory* of the Dry Zone civilization as well as from the desire to assist the peasantry. The plantation economy, which developed around the cultivation of tea, rubber, and coconuts in the highly populated Wet Zone under the sponsorship of the colonial government had adversely affected the peasantry. More recently the development of the Dry Zone for agriculture has been viewed as a major avenue for increased employment and food production together with equitable distribution of newly generated wealth.

This is the background to the undertaking of the massive multi-purpose project of diverting the water of Mahaweli Ganga. The programme of new land settlement under Mahaweli Project envisages the settlement of approximately 140,000 families and a doubling of the land area irrigated for agriculture in Sri Lanka. The series of dams and reservoirs built across Mahaweli and some of its tributories were designed to double the availability of hydro power. From the beginning of the settlement programme in 1976 to the end of 1985, the number actually settled under the project amounted to around 47,000 families, and of these, the 26,000 families among them settled in System H contributed 5 per cent of paddy produced in the country in 1985 (Central Bank 1985).

The long experience in irrigated land settlement in the Dry Zone had significant benefits for the design of Mahaweli Project. Apart from a series of engineering and technical studies dating from 1958, agronomic and pilot farm studies for the Mahaweli Project were undertaken on a highly organised basis from 1964. An entire section of the major research station of the Department of Agriculture for the Dry Zone was devoted to Mahaweli research. Two pilot projects were carried out in nearby locations to determine the optimum size of farm and related issues (Department of Agriculture, 1981).

Detailed socio economic surveys were carried out in all areas identified for development under the project. Separate professional bodies were established for engineering investigations, physical planning of social infrastructure such as spatial aspects in the location of settlements, transport, for settlement studies related to the selection of settlers, and for the determination of various forms of assistance. Foreign consultants with widespread experience in similar exercises internationally (UNDP/FAO 1965, Sogreah 1972, and Nedeco 1979) were hired to provide detailed plans for irrigation infrastructure, social infrastructure and physical layout planning. For example, the detailed feasibility study for the pilot phase of the new settlement component comprised volumes covering agriculture, land classification, land classification maps and tables, engineering, engineering drawings, settlement planning and development and finally agricultural marketing (Sogreah 1972).

The main strategies adopted to achieve high and equitable benefits from the Mahaweli Project in its Pilot Phase (System H) which commenced in 1974 as a result of these studies were as follows:

1. Provision of equal sized farm allotments to all settlers. This is a principle followed from the earliest days of state sponsored land settlement in Sri Lanka. Cropping patterns for different soil classes in the project area were developed after research station and pilot farm trials in such a way that the annual net farm income would be more or less similar irrespective of the class of soil in any particular farm (Sogreah, Vol II, 1972).

2. Previous irrigation schemes had long tertiary channels often extending beyond a kilometre in length, resulting in tail end problems. Tertiary channels are farmer managed and when they are designed to serve a large number of farms equitable division of water became virtually impossible. Therefore, these channels in Mahaweli Project were designed to serve a small number of farms, i.e., twelve on the average, and were by and large uniform in length and had equal capacity to carry water (one cubic foot per second). This small number of farms per field channel (turn-out area) was considered to be advantageous for forming water user associations which were expected to take the responsibility of sharing water within the field channel. The overall operation of the irrigation system from primary to tertiary channels was designed on a rotation basis. A greater number of control structures were built along the channels to ensure equity and efficiency in the management of the irrigation system.

3. Previous settlement schemes in Sri Lanka allocated homesteads for settlers along main irrigation channels, thus creating ribbon type settlements which were difficult to be effectively and equitably served by various social and extension services. Those who were settled away from service centres in these settlements suffered from difficult access to various essential services. Accordingly, Mahaweli homesteads were arranged in small hamlets which were sited radially around village centres which provided basic services. These in turn were radially located around town centres which in turn provided a higher level of services than could be made available at village centre level. At the top end of this hierarchy there were area or regional centres which had the administrative centres, banks, etc.,.

4. Homesteads and farm allotments were located in such a way that no settler would have to travel more than a kilometre from home to the farm.

5. Special consideration was exercised in allocating homesteads in hamlets to ensure social cohesion. Traditional dry zone farmers were settled as close as possible to places where their pre-project villages were located and care was taken to settle relatives and people of the same background such as the place of origin and cast in order to preserve and benefit from the extended families and community relations in traditional villages. On the other hand settlers who were brought from outside were settled together according to the particular electorate and village from which they originated.

6. The settlers were given fully developed land which could be cultivated immediately after the date of settlement. The World Food Programme of the United Nations provided food rations to settler families for up to one year or up to the harvest of their second season, whichever was the earlier.

7. The agricultural extension services provided were of the highest intensity ever provided in Sri Lanka. For example the ratio of extension workers to the number of farmers was more than thrice the number outside the project. Health services, schools etc., were comparable to those services in highly developed areas in the country at least in terms of quantity (the numbers) if not in the quality of the services provided. Importantly, most of these services were functional by the time the settlers arrived.

8. Selection criteria were developed which were expected to ensure selection of deserving and potentially good farmers for settlement. A strict scoring system was developed to give priority to landless, educated, young and married people with previous experience in agriculture. However, these criteria were not adhered to in the case of people who traditionally lived in the area developed for settlement (traditional farmers or *purana settlers*) as well as the inhabitants of lands inundated by project reservoirs outside the new lands developed for settlement. Such people were paid compensation for their loss of property and were given the option of having a farm within the project or a homestead close to their original residence. In addition, squatters on state lands who had been continuously residing on the lands developed for the project for a minimum period of five years prior to its commencement were also allocated farms in the project in recognition of their pioneering nature and enterprise.

Naturally, the cost of all these provisions was very high. A rough calculation of cost per settler family (at the financial cost of the project minus the headworks costs worked out to Rs. 125,000 per settler family (US $ 5000) at 1985 prices. The Mahaweli Authority of Sri Lanka, the organisation responsible for the implementation of the project, maintains that the head works costs which amount to a further Rs.169,000 (US $ 6700) per settler family can be entirely recoverd from hydro power benefits of the project (see ACRES 1984). The economic costs may have been far higher. For example, the Sri Lanka rupee is thought to be overvalued and therefore the true value of imports for the project may be understated when expressed in financial terms.

The entire Mahaweli Project may take another 3-4 years to attain completion. However, the pilot phase of the project which commenced in 1974, with the first settlers being introduced in 1976, has functioned long enough to reveal the future trends for the whole project. The basic settlement strategy and the physical plan followed in the pilot phase, System H, is to be replicated in other areas of the project. Project planners expected the farmers to reach full potential output or target levels in 8 years from the date of original settlement. For rice, the major crop, the average target yield in both wet and dry seasons was 100 bushels per acre (5.15 tonnes per hectare) at full development, after about 8 years from the initial date of settlement (Sogreah, 1972). The cropping intensity of rice was to be around 140 per cent with another 60 per cent of non-rice crops.

Actual experience in the performance of the pilot project has not been quite up to expectations. Output in the wet season, according to official estimates has been near 100 bushels per acre in good seasons. However, the average dry season yield has been only about half of the target level (Table 1-2). Further, the cropping intensity has been around 150 per cent with very little cultivation of non-rice crops (Table 1-3).

Table 1-2: Average rice yields in System H in bushels per acre (tons /ha.)

Year	Dry season	Wet season
1977/78	59.34 (3.04)	74.79 (3.86)
1978/79	51.32 (2.64)	74.22 (3.82)
1979/80	52.74 (2.71)	87.68 (4.52)
1980/81	54.02 (2.78)	95.68 (4.93)
1981/82	52.17 (2.69)	71.74 (3.69)
1982/83	52.16 (2.69)	104.23 (5.37)
1983/84	80.93 (4.17)	81.21 (4.18)
1984/85	n.a	92.43 (4.76)
Target	100.00 (5.15)	100.00 (5.15)

Source: Mahaweli Authority of Sri Lanka.

Table 1-3: Cropping intensity in System H expressed as a percentage of the land area available for cultivation

Year	Paddy	Other crops	Total
1981/82	1.03	.22	1.25
1982/83	1.36	.23	1.59
1983/84	1.41	.25	1.66
1984/85	1.19	.28	1.47
Target cropping Intensity	1.40	.60	2.00

Source: Mahaweli Authority of Sri Lanka.

The variability in crop yields among Mahaweli farmers has been similar to that observed in other planned and unplanned settlements as shown in Tables 1-4 to 1-6.

Table 1-4: Interfarm variation in rice yields in Block 313 in System H

Units		Percentage of farmers		
bushels/ac.	(tons/ha.)	Wet season 83/84	Dry season 84	Wet season 84/85
30 <	(1.5 <)	33	35	8
30 -39	(1.50-2.01)	13	13	10
40 -49	(2.02-2.52)	17	11	13
50 -59	(2.53-3.04)	16	13	18
60 -69	(3.05-3.55)	2	10	9
70 -79	(3.56-4.07)	12	9	13
80 -99	(4.08-5.10)	2	5	19
100 >	(5.11 >)	5	4	10
Average yield *		47.56 (2.45)	46.15 (2.38)	62.77 (3.23)
Maximum yield *		160.00 (8.24)	140.00 (7.21)	133.00 (6.85)

Source: Farm survey of Block 313 in 1984/85 crop year by author.

* figures in parentheses are yields in tonnes per hectare.

The available indicators of possible sources of income inequality, i.e., operational land holding size and crop yield per unit area, are alarmingly wide. There is increasing evidence of differentiation between settlers with high yields and incomes and those with low yields and low incomes. Krimmel (1986) showed that in the 1981/82 wet season, only 52 per cent of the farmers in one village cultivated 2.5 acres, the size of original allotment. In this village, 9 per cent of the farmers cultivated more than 2.5 acres. In the 1985/86 wet season, another study in a different location within System H (Thilakasiri 1986), reported that only 56 per cent of the farmers were cultivating 2.5 acres of land. Overall, the performance record of System H creates doubt about the likelihood of achieving project targets in terms of both productivity and equity.

Table 1-5: Percentage Distribution of farms by yield classes in selected irrigated land settlement schemes in the Dry Zone of Sri Lanka in Maha 1972/73

Range Bu/ac.	Settlement Scheme Nachchaduwa	Usgala Siyam-balangamuwa	Kandalama	Giritale	Kaudulla	Kantalai
30 <	14	5	15	7	6	8
30-39	18	18	22	8	10	12
40-49	27	19	21	13	14	20
50-59	18	31	23	26	19	21
60-69	12	16	9	24	20	24
70-79	6	1	4	10	13	7
80-99	4	6	3	12	11	5
100 &>	1	5	4	4	6	3
average yield (Maha) Bu/Ac.	45.9	53.0	46.7	57.0	55.6	55.7
The year of settlement	1935-55	1960-62	1954-57	1956-59	1958-65	1950-59
Irrigable holding size (Ac.)	5	3	3	3	3	3

Source: Jogaratnam (1974)

The data on interfarm variation in rice yields show that between 5-10 percent of the farmers in one location (Block 313 of System H) obtained target yields in the three crop seasons from 1983-85. The maximum yields obtained were 30 to 60 percent above the targets. This wide interfarm yield gap may perhaps indicate a potential for increasing average output in Mahaweli System H if the lower yields were the result of inefficient use of resources. Therefore, research into the causes of such interfarm variation in yields may be useful.

Table 1-6: Percentage distribution of paddy yields in a non-settlement area in the Dry Zone of Sri Lanka (Hambantota District) in 1973/74 crop year (in Bu./ac.)

Bu/Ac.	Yala 1973	Maha 1973/74
40<	44	34
40-70	36	46
70-80	12.4	11
80>	7.6	9
Average Yield (Bu./Ac.)	52.6 [2.71]	56.3 [2.90]
Highest Yield	89.4 [4.60]	122.5 [6.31]
Lowest Yield	12.0 [0.61]	40.0 [2.06]

Source: Dias (1977)
Note: Yield in tonnes/Ha. given within square brackets.

Table 1-7: Paddy yield distribution in a non-land settlement area in Tamil Nadu in 1973/74 (in Tonnes/Ha.) with HYV's

Season	Sornavari	Samba	Navarai
Average Yield	4.08	3.34	3.72
Maximum Yield	5.65	5.45	5.85

Source: Chinnappa (1977)

1.4.1 Performance of irrigated new land settlements

Given the extent of planning and implementing irrigated new lands settlement schemes and the enormous costs involved, nations embark on such projects with great expectations. However, such expectations are not always realized. In fact, irrigated land settlement schemes "appear more prone to failure than settlement projects in rainfed areas" (Goering, 1978), and typically show economic rates of return at least 50 percent below those in project appraisal documents three to five years after the implementation (van Raay and Hilhorst quoted by Scudder 1981). The study of the causes of such poor performance in irrigated new land settlements may therefore have important lessons for future settlement schemes as well as other non planned settlements which have been exposed to the new technology.

These low rates of return are the result of low average output and profits at project level by comparison with initial targets. Such low average output may be the outcome of any one or more of the following three reasons.

- First, there may be unanticipated/exogenous changes in the economic environment, e.g., the oil price shock of 1973 and the resulting increase in fertilizer prices which affect all farmers in agricultural projects,
- Second, there may be farm specific variations in soil fertility and access to water and other resources depending on their location within the irrigation network and the topography of the area resulting in interfarm variations in output which lower average output.
- Finally, interfarm variations in output may occur due to variation among farmers in their ability to understand and practice the available technology.

By definition, the first situation does not imply any inefficiency at project or farmer level. An example of such exogenous changes in relative prices with adverse implications for farmer incomes and overall net returns from a project is given in Table 1-8. This shows the changes in real prices of crops and inputs in System H of Mahaweli Project in Sri Lanka from the time of project appraisal (1972) to 1984/85. While the real price of rice remained virtually constant, real prices of urea (the major fertilizer) and labour wages increased substantially. The real price of chillies increased more than the real wage rate but still less than the price of urea. This suggests a decline in real profits for rice assuming that the technology remained unchanged. The impact on real profits of chillies is not clear, since this depends on the intensity of fertilizer and labour use. However, the overall effect of relative price changes on profits were less for chillies than rice. If this is the case, then chillies were more profitable in 1984/85 relative to rice than at the time of project appraisal. This inference is subject to constant technology and factor use intensities. Technological change may alter factor use intensities and counteract the adverse influence of price changes. Normally, standard project appraisal procedures allow for price changes by testing the sensitivity in the economic rate of return to price changes in key variables. Such sensitivity tests, however, do not allow for more than 10 - 20 per cent fluctuations in prices. Large unanticipated changes in prices, may, therefore, substantially depress net returns if diversification of resource use is not technically feasible. For example, in much of the land developed under Mahaweli Project rice is the only crop which can be grown in the Wet Season, and in about half the area in the Dry season. Diversification, therefore, is not technically feasible in much of Mahaweli Project lands.

Table 1-8: Real changes in market prices at farm gate in System H since 1972

Year	Rice price Rs./Bushel	Dried chillies Rs./Kg.	Urea Rs./Kg.	Hired Labour Rs./Man day
1972 a/	14.00	5.59	0.40 b/	6.00
1984/85	62.00	30.00	2.92	29.00
1984/85 prices in constant 1972 prices c/	14.31	6.92	0.67	6.69
% change in real prices	+ 02	+ 23	+ 67	+ 11

a/ the prices used in the appraisal of System H (Sogreah 1972).

b/ 50% of the economic farm gate price used by Sogreah (1972). The fertiliser subsidy during this period was 50%.

c/ adjusted on the basis of the implicit GNP deflator of the Central Bank of Ceylon. See Table 7-4.

The second category of causes leading to low net returns represents inefficiencies at project level in the optimal provision of water and other resources. These are related to differences in natural environment, to deficiencies in project infrastructure, and to the operation and management of project services to the settlers. Such issues have been widely studied in Sri Lanka and elsewhere. In the recent times, several studies have been undertaken to examine the impact of differential access to irrigation water on farmer performance (Bromley et al. 1980, Skold et al. 1984, Moore et al. 1983). Some have incorporated the impact of soil type differences in their analysis of crop yield differences (Samarasinghe and Samarasinghe 1984). Others have surveyed settler views on causes of water shortages which depress rice yields and have found that they were mainly related to deficiencies in irrigation infrastructure (Thilakasiri 1986). This observation has considerable support from the findings of engineering studies in Mahaweli System H (Nedeco 1984) and in Rajangane Scheme (Water Management Synthesis Project 1983).

The third is the least studied cause of interfarm variation in performance in relation to land settlement schemes, although passing reference has been made to the possible influence of differences in farmer ability (Dias 1977, Harriss 1984). The second and third causes are the determinants of interfarm variation in performance described earlier. The available evidence on interfarm variations in crop yields within planned settlements suggests that the the mere provision of equal access to resources and institutions, as intended (if not actually achieved) has not been successful in ensuring high and equal performance of farmers under the new technology. In fact, many of the investigations into the failures of such schemes have been aimed at determining the weaknesses and inadequacies of the physical and social infrastructure investments at project level and making proposals for further investments for their improvement (e.g., Nedeco 1984).

1.4.2 Settlement Studies

Geographers and anthropologists were the pioneers among social scientists in the study of the performance, development, and the evolution of irrigated new land settlements (Chambers 1969, Farmer 1957 and 1974). In general, they were mainly concerned with spatial aspects of such settlements such as communications, access to information and water, etc., as well as the relationships between man and the natural environment. Anthropologists have been interested in the implications of resettlement of traditional communities in new land settlements; the influence of physical and psychological stress of settlement on their innovative behaviour and motivation; and the implications of attempts to improve human capital through formal education etc., (Scudder 1973 and 1978). Sociologists have concentrated on social behaviour of such settlers, such as conflicts among settlers in the sharing of water and the formation of organisations (Harriss 1977 and 1984).

Economic research to date on new land settlement has been mainly concerned with *ex-ante* and *ex-post* appraisal of such projects using standard benefit-cost criteria. Benefit cost analysis is normally conducted as an evaluation of costs and benefits of resource allocation of a representative farm/farmer at economic prices based on technically feasible input/output ratios, and other simplifying assumptions on the rate of adjustment (World Bank funded projects expect full development in 8 years from the date of initial settlement). This preoccupation with an "average farmer" and the lack of appreciation of processes of adjustment in economic appraisal of irrigated land settlement projects, has been attributed to the inadequacy of available methodological approaches and has been criticised as a "black box" paradigm which ignores what happens within the box, i.e., from settlement to full development, when the reality is in fact a "pandora's box" (Barnett 1981).

Harriss (1984) describes the process of social and economic differentiation arising from differential rates of adoption and performance under the new rice technology characteristic of Sri Lankan Land Settlement schemes as follows:

> What seems to happen is this: the settler households start off with more or less the same resources, but differences in family size and in the stage in the developmental cycle of the household (which determines the ratio between the numbers of consumers and the number of workers on the family farm); differences in access to resources from outside and to cheap credit; and differences resulting from what may initially be random factors like variations in soil fertility or differences in access to water; as well as, *perhaps differences in individual ability*, soon begin to create disparities of wealth between households which tend to become accentuated over time, and particularly as the second generation takes over [italics are mine]. (p 327).

Typically, studies of causes of performance variation ignore the contribution of farmer ability to this process (for example, see Samarasinghe and Samarasinghe 1984, Thilakasiri 1980, Siriwardhana 1984, James 1984). This arises from an implicit assumption that the new technology is simple enough to be effectively adopted and implemented by any farmer irrespective of his stock of human capital. In reality, the new technology is highly complex and involves the adoption of technological packages in whole or in part, often requires the adaptation of the recommended practices to specific environments, and continuous adjustment during the crop growth cycle with frequent calls for changes in strategies according to vagaries in the weather and exogenous shocks in the form of pest and disease outbreaks[2]. This lack of attention to the role of human capital is widespread in development studies. Schultz (1981) observed that much of the current decline in the understanding of the economics of productivity is related to an overrating of the importance of land (and other physical factors of production) and an under rating of the importance of human capital since the time of Ricardo and Malthus.

Some researchers have recognised that the rate and the degree of adoption may vary according to the individual's ability, but assume that efficiency differentials will disappear in the long run with the demonstration effect of successful farmers and a process of learning from experience (Dias 1977, Ruttan 1977). Others, however, have noted the long term implications of short run differential adoption and performance between farms (e.g., Feder et al. (1985) quoted earlier). Ryan (1984) states that:

> It is clear that early adopters of technologies earn innovators' rents. Indeed in situations where commodity demand is inelastic these can be the only producer benefits. Operators of large farms will often (but not always) be the early adopters due to potential size economies. Innovators rents are thus a pay-off to superior information searching and processing capacity, and also a necessary compensation for the risk of failure of new techniques born by early adopters with cheaper and more reliable information. (pp 118-120).

Clearly, short run variability in productivity between individuals in irrigation and land settlement schemes and elsewhere can have substantial equity implications. On the other hand, where this variability is due to variations in individual abilities, related to

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[2] See, Godell et al. (1982) on the complex nature of modern pest control methods and Godell (1984) on organisational requirements in coordinating water issues with timing of crop establishment etc., for successful practice of the new technology.

information searching and processing capacities, and perhaps to market imperfections which favour some farmers at the expense of others, they may result in significant efficiency losses. Such efficiency losses may be detrimental to the success of large capital intensive agricultural development programmes where overall performance depends on the individual decisions of a multitude of small farmers. For example, the low average productivity resulting from interfarm variation in productivity may lead to negative net benefits from investments in agriculture in terms of social opportunity cost. The net present values of such projects can be substantially reduced with a significant drop in the net benefits in the early years, even if eventually all farmers reach the target output level and raise the overall project output to the expected level. The impact on the economic rate of return of a project affected by poor average performance in the early period will depend on the social rate of discount in the economy. The higher this rate, the greater will be the reduction in project benefits owing to a delay in reaching the target.

In addition, the rural differentiation noted by Feder (1985), Harriss (1984) and Ryan (1984) may have substantial social costs due to increasing inequality in income although such costs do not usually enter the calculus of benefit-cost analysis.

1.5 Research Objectives

While the introduction of new technologies and better inputs to small farmers is an accepted means of developing agriculture, a major concern is that differences in productivity, incomes and inequality among farmers appear to increase with such a strategy. Often researchers attribute such differences in performance and their consequences solely to initial differences in factor endowments among farmers. Irrigated new land settlements offer an interesting experiment where equal initial endowments of resources are provided with the objective of achieving equity together with high productivity. Yet these projects, too, often end up with differences in interfarm performance, low average productivity and income inequality.

This thesis focusses on the issues related to differential performance among farmers who adopt modern high yielding seed varieties, but apply different levels of other inputs, e.g., fertilizer, labour etc., and who vary in their ability to realize the full potential of the technology. Technological change creates a disequilibrum in the farmer environment which requires adjustment by each individual. The ability to adjust and the success achieved may vary between individuals depending on their human capital endowments. A continuing stream of technological changes creates a persisting disequilibrium with individuals at different stages of adjustment. In such circumstances, differences in relative efficiency may be observed among individuals as well as between groups of individuals. Inefficiencies may also be caused by market imperfections some of which may arise from government intervention in markets. Such imperfections may create inefficiencies in resource allocation even when farmers have fully adjusted to technological change. Finally, the differential performance may imply inefficiencies or losses to the society as well as to the individuals concerned. In the case of development projects, differences in farmer performance may lower average output and thus reduce net economic returns. Further, even if all farmers fully adjust over time, the differences in their individual rates of adoption may set off trends in inequality.

This approach, in analysing the causes and effects of varying farmer performance under conditions of technological change, is applied to a selected sample of farmers of the Pilot Phase of the Mahaweli Project in Sri Lanka surveyed in the 1984/85 crop year.

1.6 Thesis Outline

Literature relevant to the analysis of differential performance among apparently similar firms in a given industry is reviewed in Chapter 2, in which the conceptual framework of the thesis is also developed.

The formal methodology to be used in the measurement of interfarm productivity/efficiency differentials is presented in Chapter 3. This methodology is based on recent developments in the estimation of stochastic frontier production functions, which provide a basis for measurement of firm specific technical and allocative efficiencies, and costs of market price distortions. A definition of allocative efficiency appropriate to this situation is presented, and measures of social efficiency are also derived.

The study area, the sample, methods of data collection etc. are described in Chapter 4. Empirical estimation of the parameters of frontier functions are reported in Chapter 5. Technical, allocative and economic efficiencies are estimated and reported for each farm and their determinants are explored. In Chapter 6, the implications of interfarm variation in performance for the economy in general are discussed and the potential for improvements in current resource allocation are examined. An analysis of the distribution of farm incomes from various sources in the context of the efficiency differentials discussed in Chapter 5 is given in Chapter 7. A summary of the research and conclusions is presented in Chapter 8.

CHAPTER 2

Literature Review

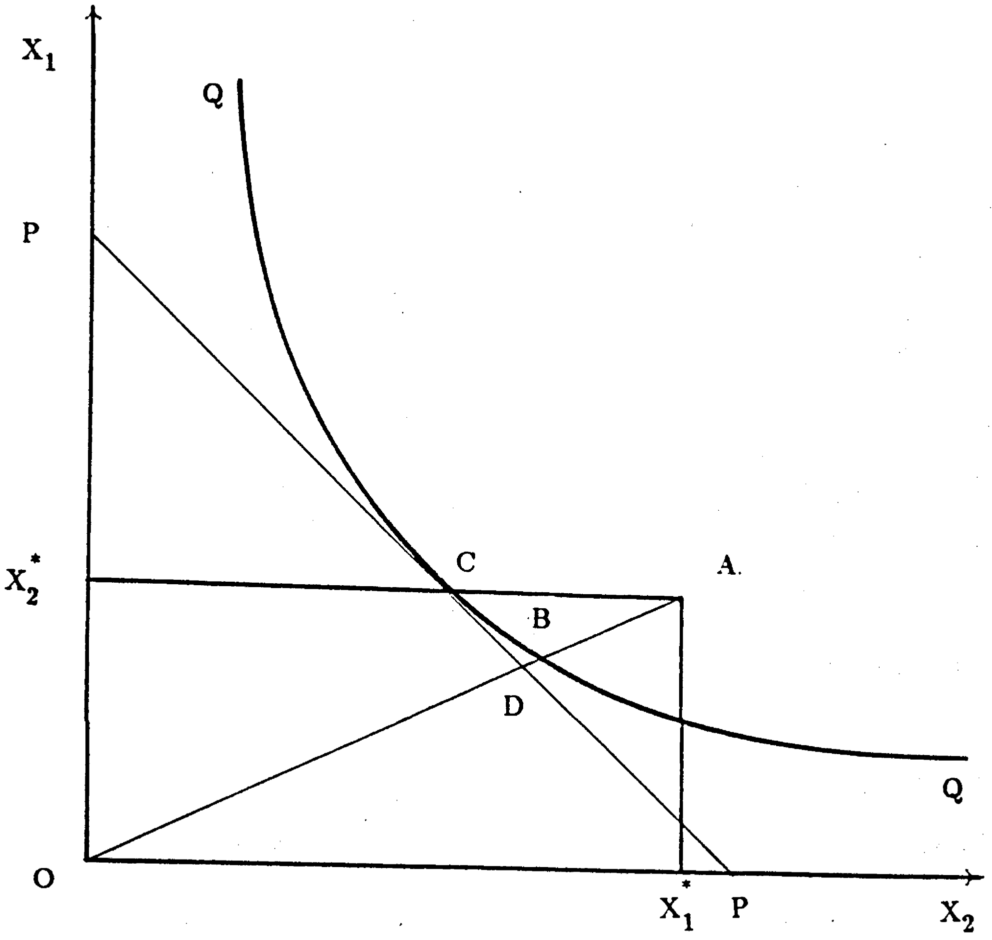
The extant literature bearing on issues related to efficiency variation among similar firms, and the literature which distinguishes divergences between private and social efficiency are reviewed in this chapter. This is followed by an exploration of the available alternative approaches for empirically analysing firm level efficiency variation. The formal modelling based on the concepts developed here is undertaken in the following chapter. Although we present our review in separate sections as mentioned above, it is impossible to divide the literature into mutually exclusive compartments or to order it into a neat sequential pattern consistent with our approach in this thesis. Thus there is a certain amount of unavoidable overlapping between sections and therefore some degree of repetition in the presentation.

2.1 The Measurement of Productivity Differences

The existence of productivity differences between farms/firms with similar land/capital endowments has been the subject of interest and the study of some economists for a considerable time (see Koopmans 1951 and 1957, Debreu 1951). It was Farrell (1957) who introduced the now standard approach to define and measure firm efficiency in production. He measured firm efficiency in relation to the neoclassical production function ("frontier") which gives the maximum feasible output for a given level of inputs. Those firms which operate below this frontier by obtaining less than the maximum output for a given level of inputs are technically inefficient. Those who do not use the profit maximizing combination of inputs (given the production frontier and prices of inputs and output) are allocatively inefficient. This model is illustrated in Figure 1.

For simplicity, and to allow graphic illustration, let us assume a two input

Figure 2-1: Farrell's decomposition of the economic efficiency of the firm



technology for the production of one commodity, i.e., $Y = f(X_1,X_2)$. Assuming constant returns to scale, the frontier may be characterized by the efficient unit isoquant (alternative representations of the frontier technology are discussed in the following chapter). This is QQ in Figure 1. Suppose the firm uses inputs X_1^* and X_2^* to produce Y^* level of output operating at point A. The technical inefficiency of the firm, 1-OB/OA, measures the proportion by which inputs (and costs) can be reduced without reducing output. Now given input price ratio PP, the cost minimising combination C is obtained. Since the cost at D is the same as at C, allocative efficiency is defined by the ratio OD/OB and allocative inefficiency by 1-OD/OB. Finally, the overall economic efficiency of the firm A given the technology QQ is given by the ratio OD/OA. Total efficiency can be decomposed as the product of technical and allocative efficiency.

Although Farrell provided a means of measuring efficiency, his analysis did not provide an explanation as to why firms would vary in their individual technical and allocative efficiencies. Needless to say, without theoretical reasoning as to the causes of firm level inefficiency, a purely empirical search for them cannot be very rewarding. Therefore, in the following section, we undertake a literature survey of alternative theoretical explanations of variations in efficiency among similar firms.

2.2 Theories Explaining Variations in Firm/Farm Performance

Farrell's approach to measure firm level efficiency is based on the neo-classical definition of the optimum input/output combination under a competitive market environment with profit maximizing individuals. Therefore, we will briefly look at the way the neo-classical model analyses variable performance between firms. This is followed by other approaches which relax some or most of the assumptions of the former, e.g., where firms cannot adjust instantaneously to disequilibria, where firms are not always motivated to maximize profits, where markets are often imperfect, where firms operating in risky environments have alternative objectives, etc.

2.2.1 The Neo-Classical Theory

Neo-classical economic theory shows that if all factor markets were competitive and firms were profit maximizing , production would be carried out with identical techniques by all firms. It follows that when there are differences in the quality of fixed factors of firms, their optimum techniques will differ, e.g., where land quality differs between farms. In such a setting productive efficiency cannot be improved with a reallocation of resources. Income distribution among individuals will be determined purely by their factor endowments and this would not affect optimum resource allocation in production, i.e., production will be efficiently carried out regardless of the nature of the distribution of factor ownership. In other words, the economy would be in a "Pareto optimum". Therefore, given sufficient faith in the equilibrating tendency of markets and maximizing behaviour of farmers, inefficiencies in production have to be necessarily treated as short term phenomena. In the long run, inefficient firms will be forced to increase their efficiency or suffer losses and eventually be crowded out from production. In fact, the theory of general equilibrium addresses different states of equilibrium and ignores the dynamics of adjustment. The conditions required for an equilibrium after particular disequilibria, e.g., technological change, are provided by costs of information and transaction costs. When interpreted in this manner, observed variations in performance between individuals do not represent losses in private or social efficiency or welfare.

The major disadvantage of this approach in the analysis of firm level efficiency variations is the absence of a useful economic role for entrepreneurship. The reward for entrepreneurship in an economy in equilibrium is zero. The total revenues of enterprises are fully exhausted when the other factors, e.g., land, labour, and capital, are rewarded at their market prices. Most of the alternative approaches to explain variable performance of firms are attempts to provide a useful role to entrepreneurship and stem from a conventional wisdom that entrepreneurship is an important factor explaining differences in performance between firms and is an important force in economic development.

2.2.2 Ability to Adjust to Disequilibria

Given our interest in explaining observed productivity differences between farmers who initially had apparently similar factor endowments under conditions of technological and environmental change, an interesting approach is provided by Schultz (1975) with his concept of the differential ability of individuals to adjust to disequilibria.

2.2.2.1 Farmer Efficiency in Static Environments

The view that farmers in static environments are efficient has gained general acceptance among development economists as against the earlier view that traditional farmers were inefficient and were incapable of a "rational" response to economic stimuli. The best known proponent of the view that farmers in static environments are rational economic beings is Schultz (1964) who formulated the hypothesis of *efficient but poor farmers* in traditional agriculture. The general acceptance of this hypothesis among development stategists has had a great influence on agricultural development policies which concentrate on improving the resource base of farmers (through land and irrigation development, subsidised credit etc) as well as in developing new technologies.

Schultz (1975) summarised this concept as follows:

> ...farm people under traditional conditions are closer to an economic optimum, given the resources that are available to them than are 'modern farm people' in view of the new and better possibilities that are constantly crowding on the latter... The reasoning underlying this inference can be stated simply. Farm people who have lived for generations with essentially the same resources tend to approximate the economic equilibrium of the stationary state. A stationary state implies zero growth, and it also implies that the economic value of allocative abilities would be zero. If the supply of resources and the demand for their services were to remain constant long enough, the economy would arrive at a stationary state with no economic disequilibria. When the productive arts remain virtually constant over many years, farm people know from long experience what their own effort can get out of the land and equipment. (p 831).

Although Schultz (1964) explicitly referred only to allocative efficiency of farmers it is clear that he implicitly assumed technical efficiency too as shown by the following statement:

> the number of times and depth of cultivation, the time of planting, watering, and harvesting, the combination of hand tools, ditches to carry water to the fields, draft animals and simple equipment-are all made with a fine regard for marginal costs. (p 39).

The reference to the time and the manner of cultivation implies technical efficiency i.e., the ability to get the maximum output from a given level of inputs, while the reference to marginal cost is made in relation to allocative efficiency (see Shapiro (1983) on this point).

Although many empirical studies have been cited as providing support for the *efficient but poor traditional farmers* hypothesis (Hopper 1965, Tax 1953, Chennareddy 1967, Sahota 1968) it has been criticized on several grounds. In particular, on the inference that farmers are allocatively efficient in a neo-classical sense, i.e., that they equate marginal value products with their marginal costs has been contested. Lipton (1968), for example, argued that the risks and uncertainties, as well as various imperfections in rural markets and associated constraints make farmers non-maximizers from a neo-classical sense. Rather, they are optimizers with a *survival algorithm*, but he accepted that

> ...the farmer is no fool. A non-fool, in a static environment learns to live efficiently: to optimize, given his values and constraints, and teach his children to do the same. (p 327).

Similarly, Myrdal (1968) described traditional farmers in South Asia in the following manner:

> the absence of anything like perfect markets; many transactions are not of the market type at all...price incentives are weak. few people calculate in terms of costs and returns, and if they do, their economic behaviour is not primarily determined by such calculations. The masses of people are survival minded. (Vol 2, pp 912-13).

A recent re-examinantion of the empirical studies which were earlier thought of as supporting the view that traditional farmers were allocatively efficient indicated that in fact, the results show substantial deviations from an allocative optimum (Shapiro 1983). However, it should be noted that Schultz (1964) cautioned that static environments are difficult to observe in the modern world. The traditional settings which have been studied may in fact be static only in a relative sense and observed deviations from economic efficiency in such situations - in a static sense - cannot be used to reject the Schultz thesis. In any case, the argument that technological change will disrupt existing equilibria even in relatively static environments is an appealing concept and merits further attention. Indeed the source of the relatively rapid changes in farmer environment in recent times is at least partly related to technological changes which have taken place in a context of dynamic change in the wider economic environment itself.

2.2.2.2 Economic Disequilibria

Schultz (1975) argues that a disequilibrium created in a stationary state (such as with new technology in traditional agriculture) results in people responding to the economic incentives created by the new opportunities to the best of their ability. He notes that received economic theory has not progressed far in explaining what people in a disequilibrium situation would do to regain equilibrium. This is in fact, concealed in the implicit assumption that people would regain an equilibrium instantaneously. However, it is unlikely that they will be able to do so, and even if they could, it may not be economic for them to make all the required reallocations of their resources instantaneously. The regaining of an equilibrium takes time; the manner in which people proceed over time depends on their efficiency in responding to a given disequilibrium and on the costs and returns of the sequence of adjustments available to them.

Further, Schultz postulated that there are economic incentives to reallocate resources under conditions of disequilibria; people respond to these incentives to the best of their abilities and observed differences in their performance in a particular activity is an indicator of the differences in their ability to adjust. In broad terms, the ability to optimize in a state of disequilibrium may be called entrepreneurship. Hence, differences among individuals in economic performance may be attributed to their entrepreneurial abilities.

2.2.2.3 Adoption of New Innovations

With the advent of the green revolution, a substantial literature has developed around the issues related as to how farmers and firms adopt new innovations. In general, they are consistent with the hypothesis that individuals *do not* adjust instantaneously to disequilibria. The early work in this area was carried out by sociologists who discovered that typically there is a time lag between the moment when an individual learns of the existence of an innovation and when he actually adopts it. For example, Beal et al. (1957) described the thought process of farmers leading to the eventual adoption of a technology from the time it becomes available in five different stages. In brief, they are: the stage of awareness when an individual is exposed to the fact that a new technology exists; the stage of information when individuals search for information on the technology and relate it to their own experiences and environment; the application stage when a decision to practice the innovation is taken after weighing the pros and cons; the trial stage when the decisions related to how, when and where it is going to be practiced is decided; and finally the adoption stage where the trial is evaluated and a decision is taken to continually practice the innovation. Economists often attribute such time lags to risk aversion. However, risk aversion cannot explain the existence of a time lag when the individuals are either risk neutral or are risk taking (Lindner 1979).

Griliches (1957a) in a seminal paper on the economics of technological change, argued that the process of innovation the process of adapting and distributing a particular invention to different markets, and the rate at which it is accepted by entrepreneurs are amenable to economic analysis. He related the observed lag in the development of hybrid corn to different areas and the lag in the entry of seed producers into these areas on the basis of varying profitability of entry. Mansfield (1961) related the rate of imitation of new innovations in an environment of technological change in twelve US industries to the proportion of firms already using an innovation, the profitability of doing so and the size of investment required. Later, he (1971) found that the level of education among corporate executives in the US was important in determining the differences between firms in their research work and innovations. Lindner et al. (1982) conceptualized the time lags in innovation adoption as the discovery stage lag, the evaluation stage lag and the trial stage lag. In a study of trace element fertilizer adoption between farmers in South Australia, they found that differences in information availability (as indicated by various measures of distance between the farm and the location of innovation) and the level of education of farmers were important in explaining interfarm differences.

Apart from the above mentioned decision theoretic approaches to explain the adoption of innovations, a somewhat different approach was developed by Welch (1978) to measure the ability to adjust to disequilibria. This approach was based on Schultz's proposition that the observed differences between individuals in their efficiency of performing certain tasks provide information on their ability related to the performance of that particular task. Thus Welch (1978) identified two measures of ability to adjust to disequilibria related to technological change which he called worker ability and allocative ability. He attributed the difference in allocative ability between individuals in the adoption of fertilizer to differences in their education. Given that modern technological changes in agriculture appear in the form of packages of several innovations, this approach has the advantage that the overall ability to adjust can be measured and explained by various factors. The concentration of adoption research on individual innovations rather than on technological packages has been shown to be a major limitation of the existing literature on the adoption of innovations (Feder et al. 1985). Byerlee and de Polanco (1986) documented the pattern of technology adoption by farmers during a period of rapid technological change. They found that farmers adopt the components of packages in a stepwise manner with those components giving the highest returns being adopted first.

Accordingly, measures of firm specific efficiency of Farrell (1957) may be used as indicators of technical and allocative ability of individual farmers. Thus rather than concentrate on specific innovation, the overall performance within a given enterprise (e.g., rice production) is taken as evidence of an individual's ability to adjust to disequilibria. The observed efficiency variations between individuals in an environment of disequilibrium can then be related to their differences in the ability to adjust.

2.2.2.4 Ability to Adjust to Disequilibria and Human Capital

The above approach to explain variable farmer performance can be based on the theory of human capital. Therefore, we look into human capital literature in an effort to identify possible determinants of differences in this ability to adjust. Human abilities are either acquired or innate. Human capital is defined as those acquired abilities which are valuable and can be augmented (Schultz 1981). Empirical research in this area is motivated by the fact that if the specific abilities related to adjustment for different types of disequilibria are identified and the way in which they can be imparted are known then it may be possible to increase or improve the abilities of selected target groups. Although the works of Schultz (1964, 1975) and Becker (1964) were most influential in popularizing human capital theory, it was Mincer (1958, 1970) who first put forward this theory. He attempted to develop a model in which the characteristic features of the personal distribution of income are explained entirely by differences between individuals in the amount of labour training they received.

It is important to recognize that the type of disequilibria encountered by a group of farmers may vary by time and by place. Therefore the particular type of disequilibria faced by a group of farmers should be clearly understood to discern the relevant forms of human capital which may determine the ability to adjust. Disequilibria may arise from new technologies, new markets, changes in economic incentives, broad changes in the mode of production and society, and environmental changes due to irrigation and land settlement etc. Often a change in one of these parameters may be accompanied by simultaneous changes in others, and one change may lead to a series of changes in the broad socio economic setting.

The introduction of the new rice technology has often been accompanied by irrigation and other infrastructural changes. The mode of production changes from subsistence or semi-subsistence to market oriented capitalist systems as the need for purchased inputs creates a need for sales of the produce. These create further changes in social relations, rural institutions etc. Settlement in new lands, for example, requires settlers to adjust to an environment which can be different from their previous environments in many ways. Adaptation becomes difficult when technological and physical environmental changes accompany or result in changes in the mode of production, which require skills and knowledge in responding to market signals. Such commercialization results in greater individualization (in comparison to subsistence economies) with an impact on many aspects of community life. For example, they can result in the loss of security provided by such institutions as the extended sytem and similar welfare cushions (Scott 1976). There is a considerable literature, largely in the area of social anthropology, on the success of traditional communities and other communities which have had some exposure to the forces of modernization within new lands settlements. Some of this work is briefly surveyed in section 1.2.6 below.

In our particular case, the adoption of the new cereal grain production technology (green revolution) required farmers to make many new types of decisions at different stages in the crop season in a situation characterized by many of these broader changes. In a static environment, necessary decisions in crop production as well as other economic activites are perfected over generations and are learned by practice. The new decisions include the selection of the most suitable variety from a range of new varieties depending on the season and the availability of water, the optimal method of crop establishment (e.g., whether to broadcast or transplant), the timing of planting, the quantities, types and times of fertilizer application, methods of weed and pest control. These are all closely interrelated decisions. Godell et al. (1982) described the many complexities involved in the correct use of even a single management practice: proper pest management requires the identification of major pests, choosing the appropriate chemicals among the dozens of labels available in the market, calculating the correct dosage etc.. Given the location specificity of the technology and the farm-to-farm differences in soil quality, access to water and drainage, a general package may not perform equally well for all the farmers even in a small contiguous agro-climatic region. Even when the farmer has full information and ability to use the information, he may be constrained by various organizational factors (Godell 1984) as well as resource constraints.

The heterogeneity in farm environments results in variability in performance of a technological package even if it is identically practiced on all farms. As Farmer (1977) points out:

> Macro-scale planning of agricultural development spreads far too coarse a net over the landscape, given the great variations between areas and, within areas, between villages....(p 198).

This requires farmers to adapt and tailor technological packges to suit their particular environments.

While much of empirical research into the economics of human capital have been conducted in the context of labour markets in developed countries, it is being increasingly utilized to explain agricultural productivity in developing countries. Education has been the most intensively studied form of human capital as it has been hypothesized to facilitate the acquisition of information related to technologies and markets and to help in the evaluation of benefit costs of alternative courses of action. Jamison and Lau (1982) have reviewed eighteen studies with thirty seven data sets on the role of education, both formal and informal (such as extension), on farm productivity. Formal education falls into Becker's (1964) general training category while extension is more specific to particular crops and/or enterprises and may be treated as "specific training".

The ability to make good (profitable) decisions may also be affected by the experience of individuals in relation to specific enterprises and tasks as well as the knowledge obtained by experience and skills in relation to particular natural environments. This is called specific experience. Recently, Rosenzweig and Wolpin (1985) used the concept of land specific experience to explain some widely observed phenomena in agriculture in developing countries. They argued that the predominance of inter-generational family transfer of land, "over use" of family labour, and scarcity of land sales in traditional agriculture can be explained on the basis of an optimal implicit contract between generations to maximize the gains from the knowledge obtained by land specific experience without having to assume market imperfections. This knowledge, which raises profitability, is acquired over time by those who cultivate the land in a particular farm. Such specific knowledge is productive because it enables the choice of best practices for the particular micro-environment of the farm and is particularly useful in years with adverse climatic conditions.

On the other hand, it has been argued that the knowledge acquired through experience may be a liability during times of technological change. As Welch (1978) noted

> The more rapid the change, the greater the rate of obsolesence and lower the stock of experience relevant to today (p 264).

Thus experience, may have an ambiguous impact on the ability to adjust to disequilibria depending on the particular circumstances.

In general, the contribution of individual components of human capital to the ability to adjust is dependent on the types of human capital available, i.e., general and specific training and experience; as well as the nature of changes encountered by farmers in a given environment.

2.2.3 The Theory of X-Efficiency

The theory of X-efficiency, developed by Leibenstein (1966), argues that there are important non allocative inefficiencies resulting from non maximizing behaviour of firms and agents due to motivational factors as well as to imperfections in markets which prevent automatic equilibration in markets. Leibenstein (1966) attributes varying output levels obtained by seemingly identical firms at comparable input levels to the fact that "firms and economies do not operate on an outer bound production possibility surface consistent with their resources".

The formal definitions of X-inefficiency and technical inefficiency (Farrell 1957) appear to be similar. Both inefficiencies refer to the inability of firms to operate on the outer bound production possibility frontier. This similarity has resulted in some researchers attempting to explain technical inefficiency as a result of X-inefficiency (e.g., Shapiro and Mueller 1977). However, Leibenstein (1973) argues that technical inefficiency as defined in "standard micro theory" is an "undesirable simplification of the nature of the firm". He (1978) claims that neo-classical "micro theory" is a special case relevant to competitive markets and profit maximizing firms, and a more general theory is required to fit economic realities of imperfect competition and non maximizing behaviour of firms.

Non maximizing behaviour is explained in terms of psychological costs of rationality, motivation, effort, organizational characteristics of firms etc. Entrepreneurs have an important economic role to play in an environment of imperfect markets. Firms have to perceive and identify profitabilities between existing alternative markets and technologies as well in new innovations. The absence of markets for certain goods and services or various imperfections in such markets result in their having to marshal these goods and services which are not readily available to everybody. Therefore, the major roles of the entrepreneur according to Leibenstein (1978) are "input completion" which involves making available inputs which improve the efficiency of existing methods of production or the introduction of new methods; and "gap filling", required by impeded, incomplete or "dark" areas in the imperfect market environment as against an unimpeded and "well lit" competitive market set up.

The growing literature and empirical evidence on the existence and importance of technical inefficiency has been treated as evidence in support of the theory of X-efficiency (Leibenstein 1976, Frantz 1985, Rozen 1985) although Leibenstein emphasizes that the concept of technical inefficiency is within the domain of neo-classical economics and that X-efficiency is a much broader concept.

> The concept of T.E. suggests that the problem is a technical one and has to do with the techniques of an input called management. Under X.E. the basic problem is viewed as one that is *intrinsic* to the nature of human organization, both organization within the firm and organization outside the firm. Thus the production process is viewed as quite differently under T.E. than it is under the X.E. approach. Under T.E. some firms are always assumed to be on the production frontier isoquant, whereas under X.E. we should usually presume that there probably are not any firms on the production frontier... Two underlying neo-classical notions are retained in the notion of T.E.: the notion of maximizing decisions and the view of the firm as a unified and integrated decision-making unit in the same sense in which an individual can be such a decision making unit. My X-efficiency notion departs from both of these implicit assumptions... I agree with Shapiro and Mueller that T.E. is an enigmatic concept if it is viewed within the framework of maximizing decisions. Either the production function is underspecified, or it is a disequilibrium phenomenon. It does not fit easily into the framework of comparative statics if all inputs are included. However, under X.E. theory the static equilibrium of the firm allows for variants in output for the same set of given purchased inputs (Leibenstein 1977, pp 312-13).

Stigler (1976) argued that the inefficiency arising from the failure to attain the production frontier can be usefully assimilated into the traditional theory of allocative inefficiency. He argued that differences in output are the results of differences in quality of inputs including entrepreneurship, and given the differences in inputs each firm will have a unique production function on which it operates. Therefore, all inefficiencies become allocative. Further, he states (Stigler 1976):

> Motivation can be invoked to explain every unperformed task that is physically possible, no matter how unrewarding. (p 214).

While the X-efficiency approach provides further reasons for the existence of firm level differences in performance due to market imperfections and motivational considerations, whether such differences represent actual inefficiencies is not clear. For example, a utility maximizing firm, which attempts to choose an optimum between income and effort may use less effort and recieve lower profits than a profit maximizing firm (Corden 1970, Martin 1978 and 1983). Here, the lower profits and the implied allocative iefficiency of the former cannot be necessarily taken to be an inefficiency from a private point of view. That firm may be privately efficient. Second, the use of neo-classical tools such as technical and allocative efficiency of the firm do not appear to be appropriate within the X-efficiency framework which claims to be a much broader concept of which the neo-classical model is a special case. Recently, it has been argued that neo-classical and X-efficiency approaches should and could be reconciled on the grounds of the desirability and the necessity to incorporate inherent motivational variability factors into an expanded conception of maximizing behaviour. Rozen (1985) states that the recognition that maximizing behaviour can be interpreted as reaching empirically determined performance standards still leaves intact the fundamental equilibrium concept of economics, while this need not lead to the automatic presumption that firms always intend to do their best. Thus he argues that the theory of X-efficiency does not reject the neo-classical ideal but provides explanations for variabilities in performance observed in the real world. This line of argument supports the use of the neo-classical optimum as an ideal standard for making comparisons against the real world which is characterized by X-inefficiency.

2.2.4 Management and Entrepreneurship

Observed efficiency differentials between firms have often been attributed to differences in management ability. However, it is often difficult to distinguish the difference between management and entrepreneurial abilities of individuals as discussed in the previous section[1]. In developed market economies and in the modern sector of dualistic economies, a clearer distinction between entrepreneurship and management may be distinguished. An entrepreneur may hire a manager to organize and coordinate his resources in production. A market for management exists where better managers are paid higher wages. The entrepreneur may decide in broad terms the markets to operate in, technologies to be adopted, the manner of raising capital and particular strategies in production and marketing to be employed. Given such broad policy framework, a manager's task is to run his enterprise in the most efficient manner.

Entrepreneur/managers are not uncommon even in modern enterprises (especially in small business, and in agriculture). In developing countries, small farm agriculture is dominated by such persons who perform both entrepreneurial and management functions simultaneously. In large enterprises within developed market economies the reward for entrepreneurship is profits while the reward for management is the associated wage. Profit of course is a residual after all other factor earnings are paid out of the gross revenue of a firm. In owner-managed farming both entrepreneurship and management functions are rewarded simultaneously by the residual income after payment of all other factor earnings. With certain tenancy arrangements, the management functions may be left in the hands of the tenant while the landlord retains entreprenurial functions. Even then, the reward for the tenant's managerial input is a residual after meeting other costs, including the owner's share which is in whole or in part land rent. In fact tenancy based on crop share results in a sharing of the risks associated with crop production. The risk

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[1] See Casson 1981 for a general review of other theories of entrepeneurship not mentioned in this chapter. See also (Upton 1976) for a description of entrepreneurial functions in agriculture. In our view, the apparent differences between these alternative definitions rest on the particular characteristics of entrepreneurship emphasized by their authors when in reality, all these individual characteristics make up entrepreneurship.

bearing of the tenant makes him an entrepreneur too from the point of view of those who relate entrepreneurship to risk bearing. Such complications, make the separation of entrepreneurial tasks from management difficult in farming in developing economies.

It may, however, be argued that a separation of the two functions for purely analytical reasons could be useful. For example, two farmers may be equally efficient as managers, but may differ in their entrepreneurial skills or vice versa. Early adoption of a superior technology by a farmer may reflect higher entrepreneurial skill in comparison with another who adopts after many others have adopted and when the technology is proven beyond reasonable doubt. The early adopters therefore bear higher risks and face greater uncertainty than the followers. It should be noted, however, that entrepreneurship may consist of many other functions apart from technology adoption. For example, entrepreneurs may decide to operate in entirely new markets. Even if the early and the later adopters are equal in their management skills, the former will make greater profits owing to their use of the technology before the market adjusts to the new supply situation. This extra income is the payment for entrepreneurship, for risk taking etc. On the other hand two farmers with equal entrepreneurial ability may have different profits depending on their management skills. Thus, two farmers who adopt the same basic technology to the same degree may differ if they varied in their manner of input use (technical efficiency) and in the allocation of input quantities in production (allocative efficiency).

Productivity differences between cross sectional observations of farmers using a given (broadly defined) technology with similar land in a dynamic environment may be caused by differences in management as well as entrepreneurship. Entrepreneurs have no role to play in a static environment with no risk and uncertainty. More enterprising farmers (e.g., risk takers and information searchers) may use newer and better innovations within a broad technology and may use inputs more efficiently as well. The demarcation between management and entrepreneurship can be blurred in the case of farming in developing economies and there may be considerable overlap between the two.

The two terms are often used interchangeably. Thus it is more useful to base an analysis of productivity differences between firms on the observable (measurable) components of efficiency, i.e., technical and allocative efficiency, rather than on entrepreneurship and management which cannot be separated.

2.2.5 Risk and Uncertainty

The relatively low levels of investment in fertilizer and other inputs by farmers in developing countries, and in general, the slow rate of adoption of new innovations have often been attributed to risk aversion. A wide range of interpretations have been given to risks and uncertainties in crop production using new technology. It has been argued that the alleged susceptibility of new varieties to pests and diseases and greater dependence on timely and adequate water resulted in increased year to year variability in yield and therefore led to underutilization of inputs by small farmers with low risk taking ability (Frankel 1971, Griffin 1974). Others have argued that the process of commercialization in rural communities and the resulting individualization weakens the traditional welfare cushions and therefore increases the risks of small farmers (Scott, 1976).

Risk increases when the density function of returns is subjected to a mean preserving spread. Uncertainty refers to the state of mind of the decision maker who perceives more than one possible consequence of a particular act. It is represented in decision theory as a probability distribution. Since risk is a parameter of probability distribution (e.g., variance), risk is a property of uncertainty (Roumasset 1976).

Risk and uncertainty may explain farmer to farmer variations in input use in addition to explaining general underuse of inputs. Uncertainty leads to the introduction of subjective elements into decision making; not only consumption decisions but also allocative decisions cannot be made independently of the preferences of the decision maker in an uncertain environment (Hirshliefer 1970). Therefore, decision making under uncertainty involves personal or subjective judgements about the chances associated with (a) the various feasible outcomes from any particular action (risk perceptions), and (b) risk preferences (whether risk taking, risk neutral or risk averse). Hence, the optimum choice for one person may differ between farmers (Dillon 1977).

Although a considerable body of literature has developed on risk there is no consensus as to how risk should be defined to represent adequately farmers' attitudes to outcome uncertainty. Given the inadequacy of knowledge in the field of risk perception, it is obvious that understanding of farmers' response to risk is equally limited (Huijsmans, 1986). Much of the literature assumes risk aversion (with no attempt to actually measure it) on the part of farmers and then simulates or predicts resulting behaviour given other assumptions or observed facts and data. This indirect or revealed preference approach has been criticised for the reason that it may be feasible to formulate a utility function to attribute any observed decision making behaviour to that of utility maximization. Thus Roumasset (1976) recommends that

> When the temptation strikes to reconcile your view of the world with fact through an appeal to risk aversion, resist it, at least for a while. Try revising your view of the world first. (p 234).

Graaf (1984) comments on an attempt by Bliss and Stern (1982) to reconcile the observed deviation in input use of a sample of Indian Farmers from the profit maximizing levels by the aid of a utility maximizing model as follows:

> Why an explanation along these lines is so remarkable is because it resorts to things we cannot observe between field observations and received theory. In that way almost any theory can be saved. Indeed, it is difficult to think of one that would have to be rejected. (p 331).

On the other hand some researchers have gone to considerable lengths to measure risk attitudes of farmers (Binswanger and Sillers 1984, Roummasset 1973, Rosegrant 1978). In his study of decision making in a Philippine village Huijsmans (1986) concludes that it is dangerous to base risk analysis on superficial observations and generalize about the small farmers' risk behaviour. He argues that many practices and strategies of farmers erroneously attributed to risk averse behaviour in fact help to raise expected profits. Such strategies result from cautious optimization over time together with adaptation to the household and external circumstances, search for improvements and experimentation, sequential choice procedures and risk control. Therefore, such strategies allow for an optimum use of environmental resources and are economically sound practices.

Recent papers on the impact of risk aversion using both these approaches appear to move towards a consensus that production risk does not have a substantial effect on input use (fertilizer) in irrigated rice growing environments (Roummasset 1973, Rosegrant and Herdt 1981) and also in favourable shallow rainfed rice growing areas (Smith and Umali, 1985). According to Smith and Umali, although the random temporal variation in yield increased with increasing applications of fertilizer, in a favourable rainfed environment in the Philippines, this rate of increase was insufficient to affect input levels significantly. It has also been argued that differences in risk attitudes (preferences) are not significant in explaining variations in allocative efficiency in the use of inputs among small farmers in similar environments, although risk aversion is an important factor leading to underutilization of inputs by farmers in general (Binswanger and Sillers 1983). This is due to the fact that all farmers are generally moderately risk averse in spite of differences among them in terms of wealth, farm size, age, sex, and tenure status.

Huijsmans (1986) argues that risk perceptions (how the probability attached to a particular outcome is subjectively assessed) are important in explaining the behaviour of individuals; risk perceptions may vary between individuals and, even for the same individual, they may vary for different activities and at different points of time in a crop cycle. He shows the difficulties involved in the incorporation of risk perceptions in formal models due to these variations in risk perceptions in relation to time and activity for the same individual. Thus, even if risk preferences are similar among a group of farmers, their decisions will vary if their risk perceptions differ. Risk perceptions are shown to be related to factors such as resource endowments of households which determine the capacity to absorb the risk, access to information, off farm sources of income etc..

Roumasset (1979) argues that

> it is useful to distinguish between situations where the decision maker has had substantial experience regarding the various outcomes and situations where he has very limited information on which to base his subjective probabilities. Thus just as risk can be regarded as a characteristic of uncertainty, knowledge (i.e., how much the decision maker has learned about the likelihood of various outcomes) is a second variable by which uncertainty can be characterised. (p 49).

further, he states that

> Few economists would disagree with the contention that representing a decision problem under uncertainty with a complete certainty model is likely to be misleading. (If many outcomes are possible, which is relevant to insert into full-certainty model?). It does not follow, however, that risk and risk aversion must be incorporated into decision models to get useful results. Indeed, it is the contention here that for many types of decision making in agriculture, uncertainty is important but risk is not. (p 49).

Significantly, Schultz (1981) defined entrepreurial ability as

> the ability to perceive, interpret and respond to new events in the context of risk. (p 25).

Thus differences in farmer performance in an uncertain or risky environment may be explained by the entrepreneurial ability of farmers which captures the capacity to respond successfully to risky situations.

2.2.6 An Anthropological Perspective

Anthropologists have taken a considerable interest in characteristics of stresses (physical as well as psychological) involved in dislocation and settlement of people, patterns of individual and group reactions and strategies in new settlements, similarities and differences in cases of involuntary migration and similarities and differences between involuntary and voluntary migration in new land settlements (Hansen and Oliver-Smith, 1982).

Some of the major issues raised and analysed by anthropologists which may have important economic implications are as follows.

1. Newly settled people may suffer physically due to inadequate water supplies, housing, and health services etc., in new settlements.

2. The need to adjust to a new physical environment as well as to a new community may create psychological stress due to the uncertainty of the future.

3. Physical and psychological stress may restrict the capacity for major innovations in the transition period in adjusting to the new environment (Scudder, 1973).

4. Such "stress" may be especially serious among groups of people with greater disparity between their own cultural background and the culture of the dominant society (Berry and Annis, 1974).

5. The need for negotiation with government agencies which provide or are responsible for various services may create leadership problems.

6. Old skills (attained prior to settlement) may no longer be useful in the new environments.

7. Inequalities may increase in that some individuals, in clinging to old patterns no longer useful lose out to those who take advantage of sudden new opportunities (Partrige, et al., 1982).

These theories and related empirical observations provide extra insight into areas related to human capital such as experience and may be useful in explaining the observed differences in performance among different farmer types settled in new lands.

2.3 Social Efficiency in Production and Project Appraisal

Agricultural development projects in developing countries are often characterised by the presence of a large number of farmers whose individual decisions and performances determine overall project success. These individual farmer decisions are taken on the basis of market signals received by them. Agricultural markets in developing countries are subject to government intervention and other market imperfections which distort price signals and lead to divergences in private and social profitability of resource allocation. Much of the government intervention in agricultural markets is justified by the need to correct natural imperfections in certain markets; for certain commodities they may be incompleteness or even completely absent. Other reasons advanced for such interventions are based on considerations of public goods, increasing returns to scale and externalities etc. (Stiglitz 1987).

Further, governments also intervene in agricultural markets with a range of often conflicting objectives such as consumer welfare protection, increasing farmer income, generating government revenue, generating foreign exchange, food self sufficiency, price stability, regional development and the provision of adequate nutrition (Timmer 1975). Timmer (1975) listed the means by which governments intervene in national agricultural sectors to influence production or consumption of commodities. They are 1. consumer programmes (including subsidies for food commodities or substitutes); 2. farm production programmes (either intensification or diversification); 3. domestic marketing investments; 4. concessional foreign trade (including exchange rate biases); 5. direct taxation or other forms of fiscal transfers; and 6. price controls by legal fiat and/or market operations, including (a) ceiling prices, (b) buffer stocks as stabilisers usually in conjunction with (a), (b), and 7. physical controls, including rationing and non-price collections and disbursements.

The literature which addresses issues related to efficiency and welfare implications of government interventions in markets are basically of two types. They are:

1. (a) Studies of efficiency implications of distorted trade regimes in given industries or in economies, and
2. (b) Appraisal of projects in an environment of market distortions.

Both approaches are based on the neo-classical welfare economic theory which shows that in the absence of any distortions in the economy, the social opportunity costs of marketed goods and services would equal their market prices thereby ensuring efficient utilization of resources. While the former type of studies concentrate on the macro agricultural markets and the implications of distortions in them on public sector investment decisions, the latter attempt to search for the best investment opportunities in an environment characterised by distorted markets. This latter approach, therefore, is an exploration of "second best" situations. If one accepts the fact that governments need to raise revenue somehow, and that available means are limited making distortionary interventions inevitable, then, even the former type of studies should be conducted within a second best framework (Stiglitz 1987). Importantly, both these types of studies assume that individual firms participating in markets are efficient. Inefficiency can only occur due to imperfect markets.

Project appraisals can be both *ex-ante* and *ex-post*. *Ex-post* analyses follow basically the same approach as that used for *ex-ante* appraisals to check whether a given project has achieved its targets in social benefit-cost terms. However, such studies typically assume that individual farmers in a project are efficient (Bell et al. 1982). The basis for the benefit cost calculations is usually a "representative" farmer or the entire project taken as one farm. Once all individuals are assumed to be efficient, a project with a large number of farmers is similar to one which has a single efficient decision maker for the whole project. Then, any deviations from the socially optimum resource allocation have to be assigned to market distortions. Further, any shortfalls in meeting project targets in irrigation and land settlement schemes need to be treated as due to either exogenous shocks to the markets or incorrect planning assumptions or both. Given that market distortions are created to attain a variety of objectives and cannot be easily removed, the *ex-post* appraisal of a project in this manner becomes a mere academic exercise with no practical use.

Page (1980) concludes his study of technical efficiency and economic performance of logging firms in Ghana with the following suggestion:

> Heretofore project analyses have explored the sensitivity of social profitability calculations to assumed factor and product prices and to the level of capacity utilization, assuming constant levels of technical efficiency. Given the sensitivity of economic performance to variations in technical efficiency, efforts should be directed as well toward determining the level and variability of technical efficiency in a project and to assesing sensitivity of project returns to changes in these parameters. (p 338).

While in *ex-ante* project appraisal this may simply mean that the sensitivity of the economic rate of return to variations in project output at given levels of inputs should be examined, this approach can have far more interesting applications in *ex-post* appraisal. The former needs only the acceptance of the likelihood of technical inefficiency and sensitivity tests carried out at arbitrarily selected levels of efficiency, say at 75%, 50% and so on. In the latter case, the determinants of efficiency variations can also be explored with a view to finding means of increasing efficiency.

2.4 Empirical Research on the Variability in Farmer Performance

There is an extensive literature consisting of attempts to measure and explain observed differences in farmer performance in relation to various economic issues. Fare et.al. (1985) review some of the many areas of research in which the efficiency of the firm is explored. They are:

1. *Average and best practice technologies* - Examples are Farrell (1957) and Salter (1966). These are attempts to measure the extent to which an industry keeps up with the performance of its best practice firms.
2. *Competitive pressure* - The quiet life hypothesis of Hicks (1935) suggests that the pursuit of efficiency is an option for monopolistic firms rather than being a necessity as for competitive firms. Studies of allocative inefficiency due to monopolies (Harberger 1954) and research related to Leibenstein's X-efficiency theory are examples.
3. *Type of ownership* - These are studies which examine the hypothesis that public ownership of industries or firms is inherently less efficient than those under private ownership (Alchian 1965).
4. *Efficiency and firm size* - These are studies which examine a hypothesized relationship between the firm size and some measure of efficiency which is unrelated to the type of ownership or market power. Examples are Lau and Yotopoulos (1971), Bharadwaj (1974) and Sidhu (1974) who studied the relationship between farm size and productivity in Indian agriculture.
5. *Regulatory effects* - A good example is a study by Averch and Johnson (1962) which showed that the regulation of the effective rate of return of electricity industry had the side effect of the regulated industry becoming allocatively inefficent by selecting inefficiently large capital-labour and capital-fuel ratios.
6. *The economics of discrimination* - Becker (1957) argued that, if an individual has a taste for discrimination against minorities, he must act as if he is willing to pay for the opportunity to avoid associating with that minority, which may raise his costs and result in allocative inefficiency.
7. *Land tenure in agriculture* - The argument of Adam Smith that crop sharing is an allocatively inefficient form of tenure under certain conditions resulted in a large and a rich literature on the related issues.
8. *Surplus labour and choice of technology in developing countries* - These are works which investigate the appropriateness of technology adopted within an environment of market distortions due to government interventions or a lack of competitive pressure. Examples are Sen (1966,1975) and Leibenstein (1978).
9. *Uncertainty* - Uncertainty may lead to the use of relatively low risk inputs (and techniques) and low input quantities. This is the subject of a relatively new but growing and already substantial body of literature. An example is given by Roumasset (1976).
10. *Total factor productivity growth* - These are studies which attempt to decompose the effect of technological change and input growth in the increase in productivity. An example is Nishimizu and Page (1982).

Until the popularisation of Farrell's work by Timmer (1970), much of the analysis of efficiency of firms/farms was limited to comparisons of average efficiency between groups of farmers. The basis of such comparisons was the average production function estimated from cross section data by using the method of ordinary least squares (OLS). Average profit and cost functions have also been used in average efficiency comparisons by drawing on duality theory which shows that any "well behaved' cost or profit function corresponds to a neo-classical production function.

A major drawback of this average production (or cost or profit) function approach is that the estimated production function coefficients do not correspond to the neo-classical definition of a production function. Neo-classical theory of the firm defines a production function as a technological relationship which shows the maximum output obtainable at given input levels. The production functions (and profit and cost functions) however, are based on the average output obtained at given input levels.

Given an OLS estimate of a production function for a group of farmers, the only feasible test of an economic hypothesis is to check whether their input use on average corresponds to the level at which the marginal value product of inputs are equated to their marginal costs, i.e., whether the firms are on the average allocatively efficient. While the concept of averaging recognises the fact that different firms may obtain varying outputs for given input levels, apart from their application of different input levels, these implied technical efficiency differences cannot be measured with this method. Hence, in practice technical efficiency differences within a group of farmers are ignored. However, a comparison of average technical efficiencies of different farmer groups could be made. Similarly, the practice of testing for allocative efficiency of a group of farmers at the geometric mean of inputs applied could mean that individuals in the group may have varying levels of allocative efficiency (Massel and Johnson 1968, Jones 1978, Rudra 1982). In other words, efficiency at the mean is a necessary but not a sufficient condition to ensure efficiency of each individual in a group. Further the comparison of the marginal value product to mean price and not the farmer specific price has been argued to be inconsistent with the assumption of perfectly competitive markets. If markets are perfect there is only one price. Hence the issue of a mean price does not arise (Junankar 1980a, 1980b, 1982). Finally if farmers are maximizing profits, and markets for *all* inputs and outputs are competitive, then it is not feasible to estimate a production function with cross section data. All farmers will use the identical input levels and achieve the same output.

The recognition of the important role of mangement in production led to the development of alternative methods for incorporting the influence of management in production. Apart from the need to estimate the best practice output, another concern was the so-called "management bias" which exists in production function coefficients estimated by OLS without allowance for the influence of management on output elasticities of inputs. Griliches (1957b) showed that the bias which results from the omission of management from a production function depends on the relationship between the management variable and other included variables. Thus the estimated coefficients will be biased upwards if a positive relationship exists, and downward if a negative relationship exists. Timmer (1970) suggested that a positive relationsip will prevail for expected profit maximizing firms with a Cobb-Douglas production function.

The obvious solution to this problem was to specify the production function to include the influence of management as a variable which may neutrally or otherwise shift the production function. However, in practice this was not always feasible due to the lack of a suitable measure of management.

A major issue related to the specification and estimation of production functions with a management variable (even if it can be measured or adequately represented by some proxy) is the unrealistic assumption that other inputs are independent of management in determining output. Otherwise the OLS estimates of the production function will be inconsistent due to multicollinearity.[2] . A good illustration of this problem is given by the results obtained by Shapiro and Muller (1977). Their estimates of OLS production functions with management related variables suffered from a high level of multicollinearity.

Another important objection to the inclusion of management in a production function is given by Johnson (1964). He argued against the treatment of management as a conventional factor of production.

> ..a decision to use more fertilizer does change output indirectly, it is the fertilizer, not the decision, which is a factor of production. (p 120).

. Further, according to him:

> ...technological advance, improvements in managerial capacity, and improvements in the human agent involve the use of conventional kinds of inputs in conventional kinds of production processes and [that] the production economic analyst's task is to estimate the productivity of various amounts and combinations of such inputs as are involved. At the same time, it is contended that regarding technological advance, improvements in managerial capacity, and improvements in the human agent in this way would free investigators to examine the processes of developing new technologies, improvements in managerial capacity, and improvements in the human agent without the restrictions imposed by the rather mechanistic production function concept. (p 124).

Samuelson (1947) also suggests that

> only "inputs" be explicitly included in the production function, and that this term be confined to denote measurable quantitative economic goods or services. (p 84).

An alternative means of allowing for management is to use time series data (data for two years or two seasons) of a sample of farms and obtain farm specific dummies through covariance analysis (Hoch 1962, Mundlak 1961). The farms are then ranked in

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[2] Of course, multicollinearity is a common "problem" when estimating Cobb-Douglas type production functions. As Doll (1974) has shown, an exact collinearity problem exists between the variable inputs of a Cobb-Douglas production function, first, if their use is proportional but not equal between all firms, and second, that a collinearity problem may exist between any variable input and any fixed input. Indeed, he shows that the presence of multicollinearity serves to verify that the true model for the data is Cobb-Douglas.

terms of management ability or technical efficiency according to the values of the coefficients of farm specific dummy variables. This approach has a serious limitation in that it assumes that technical efficiency remains constant over the time period under consideration. This may not be realistic for a dynamic situation characterised by technological change. Further, results thus obtained suffer from what Timmer (1970) calls "covariance analysis bias". The returns to scale of production functions estimated are often substantially lower than the estimates obtained through OLS while the technical efficiency variation as shown by the difference in magnitude between firm specific dummy variables appears to be exaggerated. The inclusion of an ommitted variable in the production function is expected to increase returns to scale while reducing the output elasticities of individual inputs. Dawson and Lingard (1982) argued that such a decrease in returns to scale may be explained by the fact that in the OLS model the management input is not held constant, while in the Hoch-Mundlak model it is held constant. Holding one input constant while others are varied can result in reductions in returns to scale. However, Dawson and Lingard (1982), too, recognised that the farm specific dummy may pick up the influence of other ommitted variables and therefore exaggerate the true magnitude of management. Finally obtaining data for more than a single time period for a sample of farmers can be difficult.

The third approach is to estimate a frontier function of the type discussed by Farrell (1957). This is the approach adopted in this study and is discussed in detail in the next chapter. A formal definition of a production frontier, and the alternative means of estimating frontiers etc., are discussed in detail in the next chapter prior to the development of our approach to analyse the problem of interfarm variation in performance.

CHAPTER 3

Farmer Efficiency in Production

3.1 Conceptual Model

In the introduction to this thesis it was argued that differential performance of farmers under new technologies may have important efficiency and equity implications. The review of literature undertaken in Chapter 2 yielded several alternative explanations for variable performance among similar firms in a given industry. They were:

1. differences among firms in their fixed factor endowments, e.g., land quality differences and differences in human capital;
2. differences among firms in their ability to adjust to disequilibria;
3. differences in motivation or non maximizing behaviour;
4. market imperfections which cause differences among firms in their access to resources, e.g., credit;
5. various risks and uncertainties related to the natural environment, technologies, and markets.

Undoubtedly, as discussed in the previous chapter, all these factors are important in the explanation of differential firm performance to varying degrees under different circumstances. Thus farmers with different endowments such as land and managerial ability will have different optimum techniques and input/output combinations. Therefore, even if farmers are profit maximizers operating in competitive markets who adjust instantaneously to various disequilibria, they may have different optimum techniques and input/output combinations. On the other hand. considerations such as in the varying ability of individuals to adjust to disequilibria and the fixity of some factors in the short run, suggests that not all farmers can or will adjust instantaneously to disequilibria.

The introduction of a new and complex technology together with irrigation and other economic and social infrastructure under Mahaweli Project set off complex forces of modernization in the project area resulting in a series of interrelated disequilibria in a hitherto relatively static environment. The changes were in the technology, as well as in the natural and socio-economic environment resulting in the need for different degrees of adjustment by individual settlers depending on their background. Prior to the project, this area was mostly covered in jungle with a few scattered and isolated villages dependent on semi-subsistence farming. The inhabitants of these traditional villages were subject to a major change in their mode of production with the requirements and the opportunities created by irrigation, new rice technology, access to markets and the pattern of land ownership[1] brought by the project. For those settlers who had previous exposure to the process of modernization and new technology (such as those selected from the Wet Zone of Sri Lanka) the change in the natural environment required major adjustments.

Individual settlers in the project were endowed with varying types and levels of human capital, though the project attempted to create a degree of homogeneity with strict settler selection criteria and the provision of apparently equal access to resources within the project. Naturally, the rate of adjustment and the degree of success actually achieved varied between individuals and created concern about the success of the project in terms of its productivity and equity goals.

Given this background, the concept of the "ability to adjust to disequilibria" (Schultz 1975) has much relevance to the economic performance of farmers in Mahaweli Project. Testable hypotheses can be formulated on the basis that the observed performance of individuals in particular activities are related to specific abilities. Thus

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[1] Prior to the project, the traditional villagers owned both lowlands and wetlands which permitted them to be near self sufficient in their food requirements. By allocating only irrigable land for farming (the homestead is only .5 Ac. in extent and thus too small for a significant level of cultivation.) the project imposed mono cropping of rice in the wet season and rice/chillie cultivation in the dry season.

technical efficiency is a measure of a farmer's technical ability, while allocative efficiency is a measure of his allocative ability. The measurement of these well defined abilities also averts the problems in defining and measuring entrepreneurship and management discussed earlier.

We adopt a conceptual model which permits the identification of the role of farmer ability to adopt and efficiently practice the new technology at farm level. It would be expected that differences in farmer ability to adjust to technological and environmental changes will be a major determinant of differential performance at farm level in new land settlement schemes since access to major resources is relatively equal in these and the basic technology is adopted simultaneously by the farmers. The ability of an individual to perform a given task is best measured by his performance (Schultz 1975). There are no direct measures of such abilities. The theory of the firm provides suitable measure of performance in the form of "economic efficiency" of profit maximizing firms in competitive market environments. Following Farrell (1957) economic efficiency of a firm can be decomposed to obtain measures of technical and allocative efficiencies. Once the inherent fertility differences between farms and the purely random variations in output are accounted for, variations in farm output are explained by the levels of measurable inputs applied (allocation of inputs) and the manner of applying those inputs (technical efficiency). The ultimate profit of a farmer depends on both the manner of input application as well as the level of inputs used given the prices for inputs and output.

In the following sections we define various measures of private efficiency of the firm and some measures of social efficiency followed by an elaboration of our empirical approach. The analysis of a dynamic process of adjustment using a static equilibrium model, i.e., efficiency measures based on the neo-classical theory of the firm, is open to criticism, although similar exercises have been conducted by other researchers (Shapiro and Muller 1977). Given time series data, a dynamic model can be derived with the cross section efficiency measures outlined in this chapter based on an "adjustment coefficient" following Huffman (1974, 1977). Such an extension is presented in the final section of this chapter.

3.1.1 Technology and Farmer Performance

A technology in agriculture is usually defined to include a particular package of inputs, e.g., the technology of growing high yielding varieties of rice (HYV's) with fertilizer etc.,. These inputs, such as HYV seed and fertiziser, are responsive to the manner in which they are applied, i.e. yields vary according to the practices associated with input applications. For various reasons discussed earlier, farmers do not always adopt the entire package of inputs and the associated "best practices" immediately after they become available and the rate of adoption varies between individuals. These practices relate to the optimal timing and the method of application of the inputs. If farmers do adopt the entire package of inputs and "best practices", and apply equal quantities of inputs, then any differences in performance between them have to be attributed to environmental differences between farms. In reality, farmers who cultivate the new high yielding varieties of crops vary substantially in their timing of nursery establishment, date and depth of transplanting, timing and dosages of fertiziser application etc., even when they apply similar quantities of measurable physical inputs. Varying output responses from given input levels, even in identical natural environments, makes "technical efficiency" an important component of farmer performance.

A technology defined broadly to include such alternative practices may not yield a unique functional relationship of inputs and output. Rather, a range of such relationships may be observed, depending on the specific techniques or practices used in the application of inputs (i.e., the timing and the manner of application). However, a unique best practice input-output correspondence, or in other words a production frontier, may be defined and identified as an envelope of the entire range of relationships for various techniques within a technology. All such relationships, other than the best practice relationship, will then be inefficient relative to the frontier production function representing the best practice input-output relationship.

It may be argued that such differences in the timing and manner of application of inputs imply differences in quality of inputs and therefore, these varying outputs are in fact, obtained from different inputs. In practice, it is hard to identify and measure such differences in the quality of inputs arising from the differences in the timing and the manner of application. Our definition of a technology with best and inferior practices, where the best practice frontier is an envelope for inferior functions, results in technical efficiency being a residual, i.e., the unexplained portion of the variability in output. Hence, the measurement problem of *non measurable inputs* does not arise. Such a definition of the production function is supported by Johnson (1964) who advices the use of only "conventional inputs" and by Samuelson's (1947) suggestion to use only "measurable quantitative economic goods or services" as inputs in a production function.

We shall assume that the realistic potential of a new technology at any given time and place is indicated by the "best performance" achieved in a farming community[2] . In other words, "best farmers" achieve the highest possible output at any given level of inputs (technical efficiency) and highest profits by applying optimum input levels (allocative efficiency). Since the process of learning new technologies takes time, the best practice frontier of a group of farmers will typically shift upwards over time. In this sense, the frontier observed within a community at a particular time may itself be inferior to the highest achievable best-practice frontier. However, the latter cannot be observed empirically. If available technology changes continually with new innovations appearing successively, farmers will be in a continuous process of adjustment. Hence, no farmer may ever achieve 100 percent economic efficiency. However, individual farmers will differ in their level of efficiency at any given time.

3.1.2 The Structure of Technology

Although Farrell (1957) defined his technology as an output correspondance (a unit isoquant as illustrated in the previous chapter), it is possible to define a technology either as an input correspondence or as an input-output correspondence. Farrell modelled his technology subject to restrictions of linear homogeneity and constant returns to scale. It

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[2] This contrasts with the approach followed by Herdt and Mandac (1981) in which potential was set at the level achievable by researchers on farmers' land.

has been observed that the removal of these strong technological assumptions will result in Farrell measures yielding different input and output based efficiency rankings for a given firm (Fare and Lovell 1978). In recent years, a literature has developed which attempts to formalize the structure of underlying technology and to derive generalized measures of technical and allocative efficiency in order to allow for a wide variety of production functions with varying degrees of restrictiveness and to yield identical cost, output and profit interpretations for given firms (see Schmidt 1985/86).

Fare et al. 1985 provide an exhaustive discussion of such formal definitions of efficiency and they attempt the...

> development of a taxonomy of efficiency which allows the decomposition of efficiency into a series of meaningful components (or sources) which are mutually exclusive or exhaustive. (p 188).

They define the components of efficiency as follows:

1. A producer is said to be technically efficient if production occurs on the boundary of the producer's production possibility set, and technically inefficient if production occurs in the interior of the production possibilities set.

2. A technically efficient producer is said to be structurally efficient if production occurs in the uncongested or "economic" region of the boundary of the production possibilities set. Structural inefficiency can occur only if some non zero subvector of inputs and outputs is not freely disposable. If all inputs and outputs are freely disposable, as is often assumed in production theory, structural inefficiency cannot occur.

3. A technically and structurally efficient producer is said to be allocatively efficient if production occurs in a subset of the uncongested boundary of the production possibilities set that satisfies the producer's behavioural objective. The location of this subset is determined by the prices faced by the producer and by the producer's behavioural goal.

4. A producer's input-output decision is said to be scale efficient if it corresponds to the inputs and outputs that would arise from a zero profit long run competitive equilibrium situation. They stress that this inefficiency is social, and not necessarily private.

The components of efficiency measured in most studies fall into 1 and 3 above, which were introduced by Farrell. The other two concepts were introduced in the subsequent literature, and as clarified in the following discussion, their measurement is dependent on the manner in which the technology of production is characterized.

These basic types of firm level efficiency can be defined in terms of radial measures of efficiency; hyperbolic graph measures of efficiency; and non-radial and non-hyperbolic graph measures of efficiency.

Radial measures of efficiency may be input based or output based. Input based measures are those which measure the efficiency of an input vector in the production of a given output vector, using the input correspondence to represent the technology. Since they hold output to be constant, these measures are appropriate to situations in which a firm takes its output as being exogeneous as in a cost minimization context. Measures which take inputs to be exogenous, as in a revenue maximizing context are called radial output efficiency measures. These measures are termed radial since the search for smaller feasible input vectors (or larger feasible output vectors) is constrained to proportionally smaller feasible input vectors (or proportionally larger output vectors) relative to which the efficiency of an observed input (or output) vector can be calculated.

Hyperbolic graph efficiency measures are appropriate to situations in which neither inputs nor outputs are taken to be exogenous by the firm, as in the case of profit maxizisation. They are called hyperbolic because they seek the maximum proportionate change in all variables (decrease for inputs, increase for outputs) consistent with the technology as represented by its graph.

Non-radial and non-hyperbolic graph measures have been developed to handle situations where the technology is not extremely well behaved, in order to avoid calling inefficient input output vectors efficient. Radial and graph efficiency measures have the appropriate isoquant as the reference set for efficiency measures, and although isoquants include efficient subsets, the converse is not necessarily true. This can lead to an overstatement of the true technical efficiency of a vector, in a wide variety of situations characterized by technologies such as Leontief, variable elasticity of substitution, and, apparently, all flexible functional forms.

Following Fare et al. (1985) and their notation, the three alternative representations of technology can be expressed as follows:

A production technology transforming factors of production (inputs) $x = (x_1,x_2,\ldots,x_n) \in R^n_+$ into net outputs $u = (u_1,u_2,\ldots,u_n) \in R^m_+$ is modelled by an input correspondence $u \to L(u) \subseteq R^n_+$ or inversely by an output correspondence $x \to P(x) \subseteq R^m_+$. For any $u \in R^m_+$, L(u) denotes the subset of all input vectors $x \in R^n_+$ which yield at least u. Inversely, for any x in R^n_+, P(x) denotes the subset of output vectors obtainable from x. The inverse relationship between L and P is given by

$$x \in L(u) \Leftrightarrow u \in P(x). \tag{3.1}$$

If the correspondences L and P are to model a production technology, they must satisfy certain properties (axioms). It is assumed here that the input correspondence L satisfies the following subset of axioms suggested by Shephard (1974)[3]

L.1 $0 \notin L(u)$ for $u \geq 0$, and $L(0) = R^n_+$,

L.2 If $||u^l|| \to +\infty$, as $l \to +\infty$, then $\cap L(u^l)$ is empty.

L.3 If $x \in L(u)$, $\lambda x \in L(u)$ for $\lambda \geq 1$.

L.4 L is a closed correspondence.

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[3] Bol (1986) gives two examples of technologies which satisfy the following properties but do not have a technical efficiency measure with properties given by Fare and Lovell (1978).

L.5 $L(\theta u) \subseteq L(u)$ for $\theta \geq 1$.

L.1 states that semi positive output cannot be obtained from a null input vector (i.e., free production is excluded), and that any non negative input yields at least zero output. L.2 states that finite inputs cannot produce infinite outputs. L.3 states that proportional increases in inputs do not decrease outputs. This axiom is referred to as "weak disposability" of inputs. L.4 is a mathematical requirement imposed to enable definition of input isoquants as subsets of the boundaries of the input sets L(u). It is equivalent to assuming that the graph of the input and output correspondences is closed (Shephard 1970). The graph is defined as:

$$GR:=\left\{(x,u):x\in L(u),u\in R^{m}_{+}\right\}=\left\{(x,u):u\in P(x),x\in R^{n}_{+}\right\} \tag{3.2}$$

L.5 states that a proportional increase in outputs cannot be obtained if inputs are reduced. This axiom is referred to as "weak disposability of outputs".

From the inverse relationship between the input and output correspondences it follows that there exists a set of axioms on P that is equivalent to L.1 to L.5. This set is:

P.1 $P(0) = \left\{ 0 \right\}$,

P.2 $P(x)$ is bounded for $x \in R^{n}_{+}$,

P.3 $P(\lambda x) \supseteq P(x)$ for $\lambda \geq 1$,

P.4 P is a closed correspondence,

P.5 $u \in P(x) \Leftrightarrow \theta u \in P(x)$ for $\theta \in |0,1|$

P.1 states that the null input vector yields zero output; P.2 states that finite input cannot produce infinite output; P.3 "weak disposability of inputs"; P.4 allows the definition of output isoquants as subsets of the boundaries of the output sets P(x), and is equivalent to the closure of the graph; and P.5 states "weak disposability of outputs".

Where more restrictive parameterizations of the technology (e.g., Cobb-Douglas form) are adopted, stronger axioms than L.3, L.5 and P.3, P.5 are needed. They are:

L.3.S $y \geq x \in L(u) \Rightarrow y \in L(u)$

L.5.S $v \geq u \Rightarrow L(v) \subseteq L(u)$,

or equivalently,

P.3.S. $y \geq x \Rightarrow P(y) \subseteq P(x)$,

P.5.S. $u \leq v \in P(x) \Rightarrow u \in P(x)$.

Properties L.3.S and P.3.S. strengthen L.3 and P.3 by imposing strong disposability of inputs, while properties L.5.S and P.5.S. strengthen L.5 and P.5 by imposing strong disposability of outputs. Thus by L.3.S and P.3.S an increase in inputs, including but not limited to a proportional increase, cannot lead to a reduction in output. By L.5.S and P.5.S, any reduction in outputs including but not limited to a proportional reduction, remains producible with no change in inputs. Clearly, if inputs are strongly disposable they are also weakly disposable, although the converse is not true.

The strong disposability axiom excludes congestion in the technology and is often justified on socio economic grounds, provided inputs and outputs can be fully adjusted. Thus, if the option is available, producers simply dispose of congesting inputs or outputs. In this case, instead of assuming that the technology only satisfies (L.1-L.5), an additional assumption is made, namely that if an input vector $x \in R^n_+$ is available, then each $y \in R^n_+$, $y \leq x$ may also be used in production.

Frequently, again on socio-economic grounds, it is assumed that outputs are freely (strongly) disposable. However, such an assumption is not always justified, since outputs may be "bads", such as toxic chemical wastes, as well as "goods".

Two convexity assumptions are often made in the parametric frontier approach. They are:

L.6 L(u) is convex for all u $\in R_+^m$,

L.7 The input correspondence is quasi-concave R_+^m,

or equivalently,

P.6 The output correspondence is quasi-concave on R_+^n,

P.7 P(x) is convex for all x $\in R_+^n$.

Finally, an output attainability assumption is also made at times. This is:

L.8 If x $\in$ L(u) for some u$\geq$ 0, then the ray $\{ \lambda x:\lambda \geq 0 \}$ intersects all L(θu) for $\theta \geq 0$,

or equivalently

P.8 If u $\in$ P(x), u $\geq$ 0, then for each $\theta \geq 0$ there is a $\lambda \geq 0$ such that θu $\in$ P(λx).

By L.8 and P.8,if an input vector x can produce an output vector u, then all proportional scalings of u can be produced by some proportional scaling of x.

Based on the above axioms, the input isoquant, Isoq L(u); the weak efficient subset of L(u) WEff L(u); and the efficient subset of L(u), Eff L(u) may be defined. Measures of efficiency are defined as deviations from these efficient subsets.

In equation (3.2), the graph was defined in terms of either the input or equivalently in terms of the output correspondence. The graph must satisfy the following axioms:

GR.1 $0 \in GR$, $(0,u) \in GR \Rightarrow u = 0$,

GR.2 $(GR \cap \left\{ (x,u): x \leq \bar{x} \right\})$ is bounded for each $\bar{x} \in R^n_+$,

GR.3 If $(x,u) \in GR$ then $(\lambda x,u) \in GR$ for $\lambda \geq 1$,

GR.4 GR is a closed set,

GR.5 If $(x,u) \in GR$ then $(x,\theta u) \in GR$ for $1 \geq \theta \geq 0$.

These properties are equivalent to (L.1-L.5). If in addition, inputs and outputs are strongly disposable, then (and only then) we have

GR.6 $(x,u) \in GR \Rightarrow (y,v) \in GR$ for $(y, -v) \geq (x, -u)$.

Given these properties, the graph isoquant is defined by

$$IsoqGR := \left\{(x,u):(x,u) \in GR, (\lambda x, \lambda^{-1} u) \notin GR for 0 < \lambda < 1\right\}. \tag{3.3}$$

the weak efficient subset of GR is

$$WEffGR := \left\{(x,u):(x,u) \in GR (y.-v)^{*} < (x,u) \Rightarrow (y,-v) \notin GR\right\}. \tag{3.4}$$

the efficient subset of GR is

$$EffGR:=\left\{(x,u):(x,u)\in GR.(y,-v)\leq(x,-u)\Rightarrow\in GR\right\}. \tag{3.5}$$

from these definitions it is clear that

$$EffGR\subseteq WEffGR\subseteq IsoqGR \tag{3.6}$$

In the case of a technology parameterised by the Cobb-Douglas form all three subsets are equal since this form is homogeneous and satisfies strong input disposability, with no congestion and scale inefficiency. However, a technology may be parameterized with a less restrictive functional form which in turn may restore these inefficiencies.

This raises the major disadvantage of parametric measures of technical efficiency, where the assumed functional form may wrongly impose a technology different from the underlying technology and thus identify efficiency as inefficiency and vice versa.

The above measures of efficiency are price independent and the definition of price dependent efficiency measures requires their efficient sets to be identified. Therefore, the set of profit maximizing input-output vectors is defined as follows:

$$\pi=sup\left\{ru-px:(x,u)\in GR\right\} \tag{3.7}$$

where u and x are output and input and r and p their prices respectively.

The set of profit maximizing input and output vectors is given by

$$\Pi M(r,p)=\left\{(x,u)\in GR:ru-px=\pi(r,p)\right\} \tag{3.8}$$

3.1.3 Modelling the Technology of Mahaweli Farmers

We model the technology of Mahaweli farmers in the form of a production function, i.e., an input-output correspondence as both inputs and outputs need not be taken as exogenous by Mahaweli farmers[4] , by and large, they are not subject to output or input

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[4] While the extent of land cultivable by each farmer is fixed legally, an active land market exists in System H as discussed in the following chapter.

regulation in the short run. It should be noted that duality theory shows that production parameters can be obtained for a technology either directly from a production function or indirectly through cost or profit funtions. Such indirect approaches are preferred to obtain production parameters in order to avoid the econometric problem of simultaneous equations bias (Lau and Yotopoulos 1971). It has been shown that, when farmers maximize profits, the output attained is dependent on input quantities as well as the first order conditions for profit maximization. This invalidates the assumption required in regression analysis that the independent variables (inputs) are independent of the error term. Thus consistent estimates of a production function cannot be obtained. However, as Zellner et al. (1966) have shown, the assumption that farmers attempt to maximize expected profits and that expected output may vary from the realized output removes this problem. The assumption that farmers do maximize profits is not essential for our approach to explain inter-farm variations in performance. Allocative efficiency is used only as a standard of measurement. Measured deviations from this optimum may be explained by any one or all of the five factors listed in the beginning of this chapter for explaining variable performance of farmers.

The main arguments of cost and profit functions are prices. Therefore, the observed data should contain price variations for the estimation of these functions. This requirement is hard to fulfil with cross section data, from a small and contiguous area such as our sample. On the other hand in a spatially widely distributed sample, transport costs may create price variations for commodities and inputs of the same quality. But when locations are dispersed widely, it is difficult to assume that the environmental conditions affecting crop production are identical. In the absence of significant transport costs, price variations for commodities and inputs of same quality can be observed only with imperfect markets. Profit functions may be estimated within a background of imperfect markets only if farmers can be assumed to be price takers. If the relevant markets are characterized by rationing, interlinking, and non-market relations in production as are often argued to exist in less developed economies (Binswanger and Rosenzweig 1981, Bharadwaj 1974) then farm gate opportunity costs may vary, but, observing all actual farm gate prices will be extremely difficult in practice. The observed market prices may not represent the opportunity costs for the individuals. Most importantly, the use of a competitive maximizing model for the explanation of farmer behaviour within such a background cannot be justified (Junankar 1980a,1980b,1982).

Given these reasons there is a strong case for expecting that the estimates of cost and profit functions obtained from cross section data from a small contiguous area, say one village or a handful of neighbouring villages, will be based on "spurious" variations in prices (Martin 1983, Quiggin and Bui-Lan 1984).

If it can be established that farmers are price takers but experience farm specific variations due to exogenous factors such as discriminatory government subsidies, and that correct price data can be obtained, the use of the competitive profit maximizing model can be justified. Even then, the manner of estimating profit frontiers introduces further problems. Profit functions are estimated in log linear form and therefore the dependent variable, profit has to be greater than zero. Thus farmers obtaining zero or negative profits have to be dropped from the sample. In a dynamic situation where farmers are adjusting to technological and environmental changes, farmers who aim at profit maximization may make both technical and allocative errors which can result in zero profits or losses in a particular time period. Zero profits are obtained when the total revenue ($P_q .Q$) equals total cost ($P_x .X$) and negative profits when total revenue is less than total cost ($P_q .Q < P_x .X$, where Q is output, X inputs and P prices). Thus the practice of dropping farmers who make zero or negative profits from a sample can lead to considerable bias and loss of information. Allowing profit maximizing farmers to vary from the maximum, but limiting this variation to a positive number greater than zero does not seem to have any particular economic justification.

The estimation of a frontier profit function rather than an average profit function with cross section data creates further problems. In order to obtain farm specific measures of technical and allocative efficiencies a suitable approach has to be developed to decompose the observed residuals from the fitted function into those due to technical, allocative and random causes. Such an approach has not been yet developed.

We may define the production funtion for an individual farmer as follows:

$$Q_i=f(X_1,....X_n;X_{n+1},....X_k;X_{k+1}....X_m) \tag{3.9}$$

Where Q is output,

1. X_1 to X_n are measurable inputs such as land, labour, and fertilizer,
2. X_{n+1} to X_k are non measurable inputs such as management, and
3. X_{k+1} to X_m are uncontrollable (exogenous) factors such as weather which influence output.

If the entire group of variables X_1 to X_k can be measured, a production function may be specified for estimation by the ordinary least squares method. Our interest in the study of differential performance of farmers in a dynamic setting with cross section data makes the frontier production function (FPF) approach the best for the task. Theoretically this approach is more appealing as it corresponds to the accepted definition of a production function, i.e., it is a technological relationship between given inputs and the maximum feasible output[5].

Accordingly, we have chosen the following stochastic frontier production function approach for our analysis.

$$Q=f(X)+U+V \tag{3.10}$$

with Q denoting ouput, X various measurable inputs, U relative technical efficiency and V

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[5] Given two observations for each farm it is feasible to obtain measures of technical efficiency following Hoch-Mundlak approach discussed in the previous chapter. Although our field survey yielded two observations for each sample farmer. they were for two different seasons with varying environmental conditions which require markedly different types of technical abilities for high performance in crop cultivation. Further, some farmers cultivated different crops in the two seasons. Accordingly, the assumption of constant technical efficiency is not realistic for the two observations available for each farm.

random exogenous shocks. This specification makes technical efficiency a random residual term which accounts for variations in output unexplained by X, and is realistic in a world where individual firms using a given technology are observed to be achieving varying output levels for a given level of measurable inputs. A substantial literature has appeared in the recent years on this stochastic frontier production function (SFPF) model. A state-of-the-art review of this literature is given by Schmidt (1985/86).

3.2 Private Efficiency of the Firm

Given a production frontier (the frontier production function estimation procedure is discussed in the latter part of this chapter) the private efficiency of farmer may be defined as explained below. We distinguish between private and social efficiency of farmers since government interventions in markets result in divergences between private and social profits.

3.2.1 Technical Efficiency

Technical inefficiency, the inability to operate on the best practice frontier (Q_f in the Figure 3-1) for the single input single output case may be illustrated as follows. At the input level I_1 if a farmer obtains only O_1 as against O_f, he is technically inefficient to the extent of (O_1/O_f)x100. Thus technical efficiency is a measure of the difference between actual output and best practice output at a given level of measurable inputs. Where a farmer is operating on the frontier and $O_1=O_f$ his technical efficiency is 100%. At the other extreme, if a farmer gets a zero output for a positive level of inputs, i.e, $O_1=0$, his technical efficiency is zero.

3.2.2 Allocative Efficiency

Differences in input quantities applied may also cause variations in output observed among farmers. These differences may be measured as departures from the neo-classical optimum, i.e., a profit maximum by individual farmers. Alternative explanations for such departures from allocative efficiency were discussed previously. Allocative efficiency is the ability to the maximize profits given the production technology and markets prices. The frontier production function represents the best practice technology. Farmers are often selective in their adoption of various practices within a new technology and do not adopt the entire package. Then, actual output for a given level of inputs will depend on the particular set of practices adopted which may be distinct from the best practice technology. Therefore, failure or success in maximizing profit is given by the ratio of actual to the maximum profit from the farmers own technology rather than the best practice technology, e.g., at B on Q_1 where the price line PP_2 is tangent to Q_1 in Figure 3-1. Note that line PP_2 is drawn parallel to the line PP, and therefore, both lines express the same input output price ratio. This definition of allocative efficiency was introduced by Herdt and Mandac (1981) and allows a farmer to be allocatively efficient while being technically inefficient. Farrell's (1957) measure of allocative efficiency compares the actual input level of a farmer with the optimum on the frontier unit isoquant (=production function), and identifies technically inefficient farmers as being allocatively inefficient as well[6] . The allocatively efficient input level I for Q_1 the farmer specific production function, is allocatively inefficient for the frontier Q_f.

Any farmer specific production function (Q_1) can be obtained by a neutral transformation of the estimated production frontier by the level of technical efficiency of the farmer (see, Appendix I for details; also Ekanayake 1987). Although it is reasonable to argue that an inefficient farmer will operate on a production function located below that of an efficient farmer, there is no apparent necessity for the former to be a neutral transformation of the latter. Clearly, a non neutral transformation would be more realistic and thus represent an important area for future methodological development. If the farmer is 100 per cent efficient technically, he operates on the best practice frontier and therefore his present practice production function and the best practice frontier are identical. Otherwise, his actual production function will lie below the frontier. The distance between the frontier and the actual present practice production function depends on the degree of technical inefficiency.

In the short run, farmers maximize profits with respect to their variable inputs

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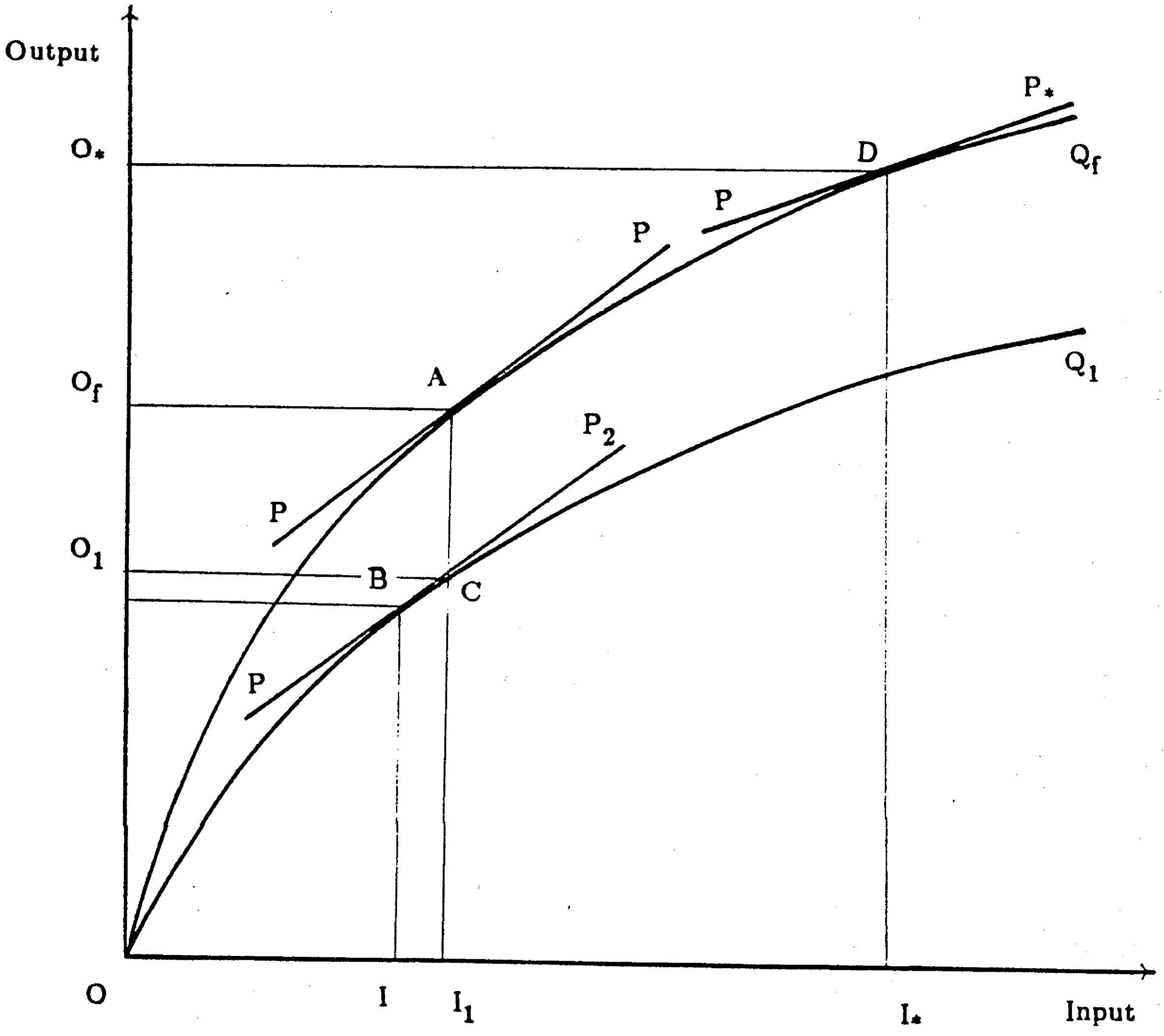
[6] See Schmidt (1985-86 pp 294-5).

Figure 3-1: Technical, allocative and economic efficiencies of the firm/farm relative to a frontier production function



given fixed inputs such as land[7]. Therefore, we obtain a measure of allocative efficiency of individual farmer by introducing an error term K_i to the first order conditions for a profit maximum. For a Cobb-Douglas technology this measure of allocative efficiency with respect to variable inputs is given by:

$$P_i = P_q \frac{b_i Q}{X_i} (K_i) \qquad (3.11)$$

where $i = 1,2,3,....,n$

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[7] This definition of profit yields an allocative efficiency measure for a technology with constant or increasing returns to scale.

Where, P_q denotes price of output, P_i input prices and X_i variable input quantities. The error term K accounts for the failure to maximize profits, or allocative inefficiency. When K=1, a farmer is allocatively efficient. A measure of a failure to maximize profits can be obtained by comparing the maximum profit on the farmer specific production function and input and output prices, against the predicted profit given the farmer specific production function and the level of inputs actually used. The realized output may be affected by purely random influences on output and therefore such output variations should not be attributed to allocative efficiency of a farmer. Profit used for our calculation is the ex-ante expected profit based on the output as predicted by the estimated frontier rather than the ex-post actual profit at realized output. The realized output may be affected by purely random influences and therefore should not be attributed to allocative efficiency of a farmer. Accordingly, our measure of allocative efficiency measures the failure to maximize expected profit by adjusting the input output combination.

Where a farmer applies the profit maximizing level of inputs, his allocative efficiency is defined as 100 per cent. Allocative inefficiency may occur due to over allocation and/or under allocation of inputs in relation to the profit maximizing level. In extreme situations where the value of output achieved by a farmer is less than the value of inputs applied, and results in a negative profit, his allocative efficiency measure will be negative. Thus our measure of firm specific allocative efficiency may range from 100 to a negtive real number.

3.2.3 Overall Productive Efficiency

The actual profit made by a farmer depends on his technical efficiency as well as allocative efficiency. This is measured by the difference between profit at full technical and allocative efficiency and profit at actual levels of technical and allocative efficiency. This is represented in Figure3-1as the difference in profits at the input level I_i on production function Q_1 and resulting output O_1 compared to the output O_f on production frontier Q_f. Economic efficiency and allocative efficiency measures are identical when a farmer is 100% technically efficient. In any lower level of technical efficiency, economic efficiency will be less than allocative efficiency (See Appendix I).

3.3 Social Efficiency of the Firm

Measures of firm specific efficiency discussed above are based on private profitability. Where market prices are distorted and diverge from scarcity values of commodities, private profitability does not coincide with social profitability. In such situations, social profitability may be correctly measured as economic efficiency using shadow prices (P_i^* and P_q^*) rather than distorted market prices (P_i and P_q).

For the Cobb-Douglas case, deviations from a social profit maximum can be measured as follows:

$$P_i^* = P_q^* \frac{b_i Q^*}{X^*_i}(K^*_i) \tag{3.12}$$

where i=1,2,3,....,n; and K^*_i measures individual deviations from the optimum. When $K^*_i = 1$ the profit is maximized.

The simultaneous solution of the first order conditions of social profit maximum together with the estimated production frontier yields the social profit maximizing output and input combination. These and the resulting profit level may be compared with inputs, output, and profits expected by firms at their current (private) level of efficiency. The ratio of potential to expected profits shows the success in maximizing social profits. Figure 3-1 illustrates this concept of social efficiency. The new line PP* shows the shadow price ratio. The socially optimum input output combination occurs at the point of tangency between the line PP* and production frontier Q_f. The resulting output O* and input level I* may now be compared with O_f and I_1 which represents the private optimum at the actual market price ratio PP.

3.4 The Empirical Model

The frontier production function may be obtained using several alternative methods. One is to use data obtained from on-farm trials by researchers to fit an average production function to obtain the maximum potential output for given input levels and to treat this function as the frontier for farmers (Herdt and Mandac 1981). However, such data are usually not available. The more common approach is to use cross section data from a sample of farmers and to estimate a frontier production function using one of the following methods:

1. The non parametric programming approach - This is the approach used by Farrell (1957) where he constructed a piecewise linear technology through mathematical programming. Farrell's technology was subject to linear homogeneity and constant returns to scale. Later, following Shepard (1970, 1974), much progress has been made in the definition of inefficiencies using less restrictive technologies (see, Fare et al. 1985). The adherents of this approach are critical of other approaches which impose various parameterizations (functional forms) on data which may lead to wrong interpretations of efficiency if the underlying technology varies from the imposed technology. This approach is extremely flexible and yields input based, output based and graph based measures of efficiency.

2. The parametric programming approach - This approach also uses a sequence of mathematical programming to define measures of efficiency relative to a particular parameterization of a technology. Thus the resulting frontier is parametric and smooth in contrast to the former piecewise linear technology. Examples are the use of Cobb-Douglas form by Aigner and Chu (1968) and Timmer (1970). The major drawback to both these programming approaches is that they are entirely deterministic and thus do not account for statistical noise, measurement error, and exogenous shocks beyond the control of the farm. Accordingly, deterministic approaches are likely to yield biased estimates of inefficiency. Another parametric deterministic approach is the Corrected Ordinary Least Squares method (COLS) applied by Greene (1980). This approach although not a programming approach, suffers from the lack of accomodation for statistical noise, as do programming models.

3. The parametric statistical approach - This approach was originally introduced by Aigner, Lovell, and Schmidt (1977) and Meeusen and van den Broek (1977) independently. The major advantage of this approach is its accomodation of stochastic variations in output. The weakness is the possibility of imposing an incorrect parameterization on a data set thereby misrepresenting the frontier as well as the distribution of inefficiency.

In general, we have followed the parametric statistical approach of Aigner, Lovell, and Schmidt (1977) and Meeusen and van den Broek (1977). This is primarily due to concern about the likelihood of overestimating inefficiency with the parametric approach. However, a comparison of deterministic (COLS) and statistical approaches was carried out with some of the data to explore the relative performance of the two approaches (Ekanayake and Jayasuriya 1987). The results of this analysis are given in Appendix II. This comparison demonstrates the major shortcoming associated with deterministic procedures when estimating firm specific technical efficiency. They generally tend to overestimate the average level of technical inefficiency and the extent of this bias is unknown. In contrast, the SF model enables the separation of random "noise" from deviations arising from technical inefficiency. As such "noise" becomes smaller, these estimates converge to those obtained from deterministic procedures. TE measures calculated with deterministic procedures will exhibit variability when derived from data obtained through repeated sampling - such as sampling over time - even when there is no variation in true TE.

It has been pointed out that a major disadvantage of the stochastic method is that it is parametric; thus there is a possibility of erroneously assigning inefficiency to an efficient firm or vice versa depending on the disparity between the true underlying technical relationship and the assumed functional form. On this basis it has been claimed that non-parametric-deterministic approaches are superior (Fare et al. 1985). However, the superiority of non-parametric deterministic approach in this respect is in doubt due to its sensitivity to outliers. Accordingly, a technology identified with the non-parametric approach may also diverge from the true technology due to random variations of observations from the true frontier (available non-parametric approaches are deterministic).

Given our interest in the measurement of true technical inefficiencies and relating these to human capital and other determinants, the stochastic frontier approach is superior to any deterministic method. Attempts to explain "apparent technical" and "apparent" allocative inefficiencies obtained with the deterministic approach which contains random influences of unknown magnitude with systematic differences in farmer attributes cannot be expected to be a rewarding exercise.

The statistical model of a production frontier may be written as follows:

$$Y_i = X_i B + E_i, \quad i = 1,2,3,\ldots,N \tag{3.13}$$

where

$E_i=U_i+V_1$, $i=1,2,3,\dots,N$

Y_i, X_i and B are output, inputs and constants respectively.

Let σ_u^2 and σ_v^2 be the variances of a technical inefficiency parameter "U" and statistical "noise" "V"[8] respectively,

$$\sigma^2=\sigma_u^2+\sigma_v^2$$

and

$$\gamma=\sigma_u^2/\sigma^2$$

Let σ_u^2 and σ_v^2 be the respective variances of the technical inefficiency parameter "U" and the statistical "noise" "V".

then

$$\sigma^2=\sigma_u^2+\sigma_v^2$$

and

$$\lambda=\sigma_u^2/\sigma_v^2$$

while

$$\gamma=\sigma_u^2/\sigma^2$$

The parameter γ was adopted by Battese and Corra (1977) for computational convenience as its value ranges from zero to one, whereas λ can be any positive real number. Assuming that "U" and "V" are independent, "U" is normally distributed[9] but truncated at the mean, and "V" is normally distributed, production frontiers can be

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[8] Note that this term is absent in deterministic models.

[9] Alternative specifications of "U" have been used, and have been demonstrated to yield more or less identical results (see Coelli and Battese 1986, Stevenson 1980, and Waldman 1984).

estimated using maximum likelihood methods (Aigner et. al 1977, Battese and Corra 1977, Kalirajan and Flinn 1983). Maximization of the relevant likelihood function by numerical techniques, gives the maximum likelihood estimates of the production function parameters, the intercept, input coefficients, σ^2 and γ or λ. The details of the derivation of the likelihood function and the method of estimation of the frontier production function are given Appendix III.

Jondrow et al. (1982) showed that the conditional mean of U_i, given (U_i+V_i), is

$$E(U_i/U_i+V_i)= \frac{\sigma_v\sigma_u}{\sigma}\left\{\frac{f(.)}{1-F(.)} - \frac{E_i\lambda}{\sigma}\right\} \qquad (3.14)$$

where E_i is the estimated residual for each farmer and f(.) and F(.) are the values of the standard normal density function and standard normal distribution function evaluated at the value of the following expression:

$$\frac{E_i\lambda}{\sigma}$$

The conditional mean of U_i, given $(U_i + V_i)$ using the parameter γ is : $(1983)^{10}$ is as follows:

$$E(U_i/U_i+V_i)= - \frac{\sigma_v\sigma_u}{\sigma}\left\{\frac{f(.)}{1-F(.)} - \frac{E_i}{\sigma}\left(\frac{\gamma}{1-\gamma}\right)^{1/2}\right\} \qquad (3.15)$$

It is easily observed that the two formulas are identical except for the differences in parameterization and sign. The difference in the sign in the two formulas is due to the definition of U_i as being non negative in Jondrow et al (1982) while it was defined to be non positive in Kalirajan and Flinn (1983).

Following this latter approach, firm-specific technical efficiency estimates are derived from the conditional distribution of U given (U+V). The conditional means of U_i given (U_i+V_i), are

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[10] The formula published in Kalirajan and Flinn (1983) is erroneous but has been corrected in later publications (Kalirajan and Shand, 1986; also see Ekanayake and Jayasuriya 1987).

$$E(U_i/U_i+V_i) = -\frac{\sigma_v\sigma_u}{\sigma}\left\{\frac{f(.)}{1-F(.)} - \frac{E_i}{\sigma}\left(\frac{\gamma}{1-\gamma}\right)^{1/2}\right\} \qquad (3.16)$$

Where E_i are the estimated residuals for each farmer and, f(.) and F(.) are the values of the standard normal density function and standard normal distribution function evaluated at the value of the following expression:

$$\frac{E_i}{\sigma}\left(\frac{\gamma}{1-\gamma}\right)^{1/2}$$

3.4.0.1 A Measure of Farmer Specific Technical Efficiency

This formulation of the stochastic frontier can be written as follows and estimated in log linear form, e.g., in the Cobb-Douglas form.

$$Y_i=(X_iB)e^{E_i}, \quad i=1,2,3,...,N \qquad (3.17)$$

where

$$E_i=U_i+V_i, \quad i=1,2,3,...,N$$

Y_i, X_i and B are output, inputs and constants respectively.

Technical efficiency according to this formulation is

$$TE = \frac{(X_iB)e^{U+V}}{(X_iB)e^{V}} = e^U \qquad (3.18)$$

where the denominator represents output at full technical efficiency and the numerator is the actual output (technically inefficient). This yields a ratio of technical efficiency ranging between zero and one.

Schmidt and Lovell (1979) and many others subsequently used an alternative formulation:

$$Y_i=(X_i;B)e^{E_i}, \quad i=1,2,3,\ldots,N \tag{3.19}$$

where

$$E_i=V_i-U_i, \quad i=1,2,3,\ldots,N$$

and Y_i, X_i and B are output, inputs and constants respectively.

The error structure in this formula is similar to the earlier model with "U" and "V" being independent, but "U" ≥ 0 with a half normal distribution and "V" is normally distributed. Technical efficiency measure relevant to this formulation is as follows:

$$TE=\frac{(X_i;B)e^{V-U}}{(X_i;B)e^{V}}=e^{-U} \tag{3.20}$$

3.4.0.2 A Measure of Farmer Specific Allocative Efficiency

A measure of farmer specific allocative efficiency may be obtained by comparing the maximum feasible profit for each farmer, with his expected profit at the level of inputs actually used. Two measures of farmer specific allocative efficiency can be calculated: the maximum feasible profits can be obtained from the best-practice technology or the farmers own (possibly inefficient) technology. To isolate the "pure" allocative inefficiency we use the latter measure, and the failure or success in maximizing profit is measured by the ratio of expected to the potential profit from the farmers own technology.

The farmers own technology (Q_1) is obtained by a neutral transformation of the estimated frontier by his level of technical efficiency. The distance between the frontier and the actual present practice production function depends on the level of technical efficiency of each farmer. Mathematically, this is obtained by replacing U_f the random technical efficiency parameter in the estimated production frontier by the estimated technical efficiency of a farmer while the other coefficients remain at the frontier values (See Appendix I for details.). Assuming a Cobb-Douglas technology, farmer specific present practice production function is given by:

$$Q_1 = A\prod_{i=1}^{m} X_i^{b_i} \prod_{j=m+1}^{n} X_j^{b_j} e^{U_f} \tag{3.21}$$

Where, X_1 to X_m are variable inputs and X_{m+1} to X_n are fixed inputs. The A,b_i, and b_j are estimated coefficients of the frontier, and U_f is farm specific technical efficiency.

In the short run, farmers are likely to maximize profits with respect to their variable inputs (if they do maximize profits) given fixed inputs such as land. Therefore, allocative efficiency can be measured as follows by introducing and error term K_i to the first order conditions for a profit maximum with respect to variable inputs:

$$P_i = P_q \frac{b_i Q}{X_i}(K_i) \tag{3.22}$$

where $i=1,2,3,....,n$

where P_q denotes price of output, P_i input prices and X_i variable input quantities. The error term K accounts for the failure to maximize profits, or allocative inefficiency. When K=1, allocative efficiency is achieved. A measure of this failure to maximize profits can be obtained by comparing the potential maximum profit at the optimum input and output level obtained by simultaneously solving the farmer specific production function and the first order conditions for a profit maximum given input and output prices, against the expected profit given at output predicted by the farmer specific production function at the level of inputs he actually used.

3.4.0.3 A Measure of Farmer Specific Economic Efficiency

The economic efficiency of a farmers is dependent on both his technical and allocative efficiencies. Therefore, this is measured as the ratio of his predicted profit at his own frontier with the levels of inputs actually used, compared against his maximum feasible profit. His maximum feasible profit is obtained by simultaneously solving the frontier function and the first order conditions for a profit maximum at given input and output prices. The measures of economic and allocative efficiencies for a particular farmer will coincide only if he is 100 per cent technically efficient. Otherwise the two will differ.

3.5 Extending the Static Analysis of Firm Level Efficiency to Study the Dynamics of Adjustment

The static productive efficiency model of the firm described in the foregoing sections cannot distinguish between immediate changes in efficiency in response to a disturbance in an existing equilibrium, and the changes in efficiency over time. The literature on the rate of imitation of innovations (Griliches 1957) and adoption (Feder et al. 1987) shows that new techniques are initially adopted by a few farmers, but are soon adopted by the others too. Overall, this pattern takes the form of a sigmoid curve. Productive efficiency of farmers faced with technological change may also follow a similar pattern. Some farmers may be able to achieve high efficiency immediately after a change while the efficiency of others may increase over time, as they gain more and more experience of a technology.

According to Schultz (1975)

> An equilibrium model, however, applied to cross-sectional data of a given date is not sufficient in analysing the equilibrating capacities of farmers in dealing with new input opportunities. We want to know who is first and who is fastest in arriving at the new equilibrium. The ability to be among the first to act appropriately and to proceed most promptly in completing the reallocations has an economic value. To get at this component of adjustment requires an equilibrating model and data of the behaviour, in this case, of farmers in adopting the more profitable new inputs. (p 842).

Huffman (1974, 1977) used a stock adjustment model to study the role of education on changing allocative efficiency of American Corn Belt farmers over time in the use of nitrogenous fertilizer. Although he recognized its importance, he did not study technical efficiency (which he called "worker effect"). Our static equilibrium model, on the other hand, provides measures of technical efficiency and a measure of overall allocative efficiency as well measures of allocative efficiency for each input if necessary. Thus our approach encompasses all the practices as well as inputs made available by the new technology.

Given panel data it is then possible to exploit the adjustment model of Huffman to study the rate of adjustment to the new technology over time by farmers and relate this to various farmer attributes consisting of human as well as other conventional capital.

$$E_t - E_{tn} = B(E_t^* - E_{tn})$$

Where,

$B = f(Z)$, $0 < B < 1$

and,

E_t = efficiency (technical or allocative) today

E_{tn} = efficiency n years ago

E_t^* = 1, which is the optimum today.

Z is a vector of variables determining efficiency (technical/allocative/economic) such as various forms of human capital and conventional capital.

Using B the adjustment coefficient, the path of adjustment in efficiency for each individual can be traced over time. While initial differences among settlers in technical and allocative efficiency may be determined by certain factors, the rate of change in these efficiencies over time may well be influenced by others. The latter may be identified by analysing the relationship between the adjustment coefficient and factors hypothesized to be the determinants of the rate of change in efficiency. This may lead to the identification of factors influencing the rate of change in farmer efficiency, some of which may be manipulable by policy. Past experience, and farmer age may determine the rate of change in efficiency, but they are not factors which can be manipulated by policy. while, formal and non formal education, alternative forms of agricultural extension, information services, and market intervention can be guided by policy.

CHAPTER 4

The Project Area, and the Sample

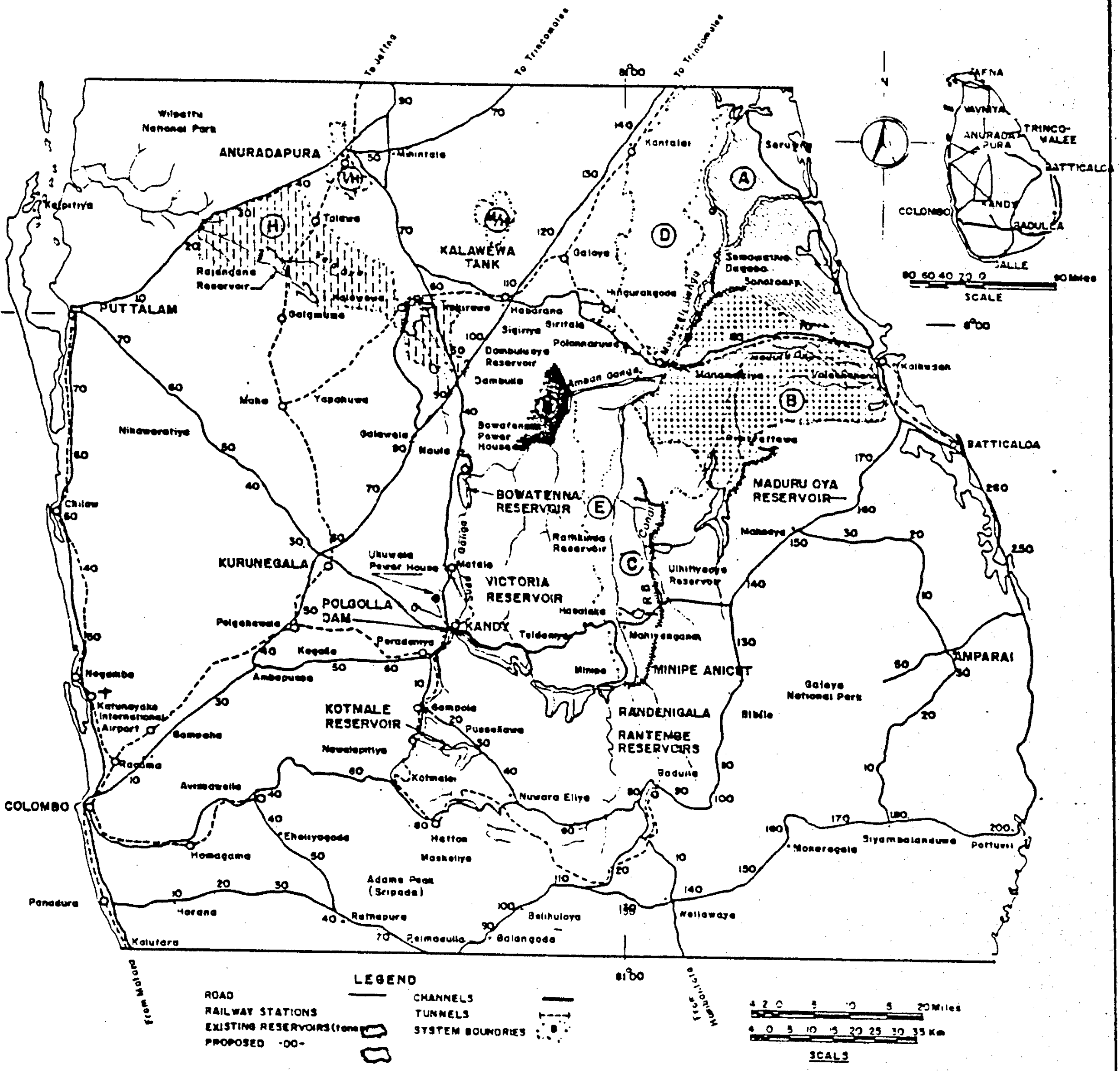
4.1 The Project Area

The construction work of the first stage of the Mahaweli project, the diversion weirs and the tunnels complexes at Polgolla and Bowatenna (see Figure 4-1) commenced in 1970. The construction activities of System H, the pilot phase of new land development under the project, commenced in 1972. This is an area of 35,000 hectares, within the Kala Oya River basin, in the North West of Sri Lanka. The agricultural development model for the new lands based on small irrigated family farms was to be tested out in System H prior to its adoption in the other areas to be developed under the project. Although land settlement is currently underway in Systems B and C, their settlers have not had sufficient time to adjust and establish themselves under the project. In the oldest of the settlements in System H, the farmers have been cultivating continuously for at least 8 - 10 years. In project appraisal and planning documents farmers were expected to take about 8 years to reach their full potential under the project. These areas of System H can, therefore, be expected to reflect the future performance of the project in terms of its agricultural and social goals during the year of the survey (1984/85).

Natural Environment

The major tasks of the project in System H were: (a) to provide irrigation for intensive year round cultivation of hitherto uncultivated or undercultivated lands under small family farms, and (b) to provide the necessary economic and social infrastructure. The importance of irrigation for intensive agriculture is explained by the natural environment of the project area which falls within the Dry Zone of Sri Lanka and suffers from a limited and unreliable rainfall. System H has a bimodal pattern of the monthly rainfall distribution with two distinct dry periods, one short and the other prolonged,

Figure 4-1: Map of the Mahaweli Project



Source: Mahaweli Authority of Sri Lanka

similar to the other parts of the Dry Zone. The annual average rainfall is 1500mm. Nearly seventy percent of the total annual rainfall occurs in the period October - mid January, which is the "Maha" season and often referred to as the "wet" season. The remaining rainfall occurs in the period from mid March to mid May ; this is known as the "Yala" season and crops grown during this season are referred to as the "dry" season crops. The months of June, July, August and September comprise the dry season proper and have little or no rain.

The average annual temperature is 26° C. The minimum temperature varies between 20° C and 25° C over the year, while the maximum temperature varies between 27° C and 34° C. Daily temperature fluctuations exceeding 10° C occur only in the period from mid February to the end of April. This high temperature causes rapid loss of soil moisture from evaporation. Pan evaporation measured from a class A pan varies from 3.5 mm/day to 7.5mm/day. The rate of evaporation is less than 5mm/day in the wet season (Nedeco 1983).

Prolonged periods of rainless days cause severe moisture stress in crops and result in total or partial loss of harvest. Somasiri (1978) computed the probabilities of the occurence of 7 day and 10 day consecutive rainless periods in the area. He found that the probability of 7 consecutive rainless days in the Maha season was about 50 per cent while the probability of 10 consecutive rainless days was about 25 per cent. In other words, rainless periods exceeding 10 consecutive days, which may lead to a major crop failure in the absence of irrigation, can be expected once in every four years during the Maha season. Thus even in Maha, the wet season, reliable irrigation is required for intensive agriculture at least on a supplementary basis. The dry season, of course, is dependent on irrigation as the primary water source with rain water as a supplement. In the Yala season, the probability of a 7 consecutive rainless day period is above 90 percent while the probability of a 10 consecutive rainless day period is above 75 percent. A safe crop can be expected only once in four years. Further, irrigation systems which have catchments within the Dry Zone are inadequate to meet the irrigation requirements of both seasons.

The rains in the Maha season are mainly due to convectional thunderstorms, which are usually of high intensity with a high run off but are unreliable. Sometimes they fail and their time of arrival can vary from the first week of October to the third week although the probability of their commencement in the third week is high (70 per cent).

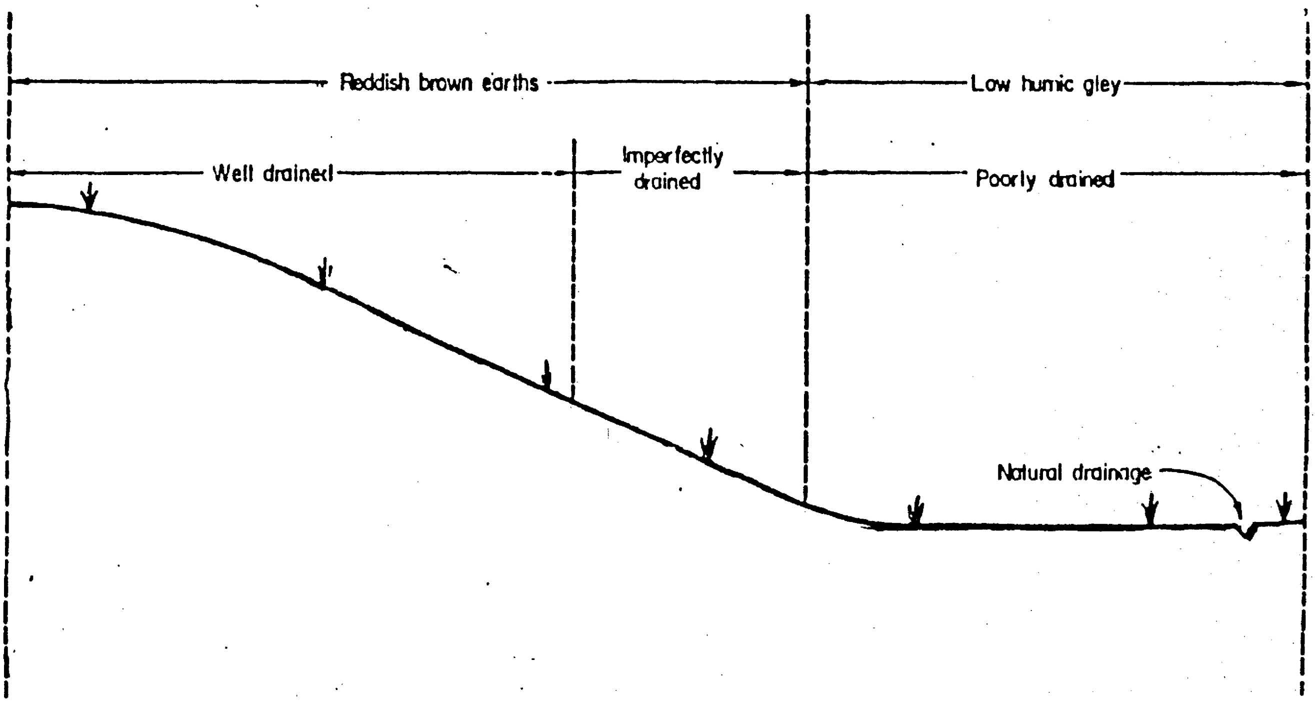
The source of water for the Mahaweli project is the Mahaweli "Ganga" (River) which has its source and major catchment area in the Wet Zone of Sri Lanka which in most years gets plentiful rain. Thus the Project has a perennial source of water in contrast to the small irrigation schemes which depend on rainfall in the locality as their major source of water. Mahaweli Ganga is dammed at Polgolla near Kandy in the hill country of Sri Lanka (see Figure 4-1) and is diverted through a series of weirs and tunnels before the water reaches the main storage reservoirs in System H along a transbasin canal.

The physiography of the region is gently undulating to rolling, with 3 to 4 per cent slopes. The landscape is a composite of minor watersheds or micro catchment basins. The major soil types found in the region occur in a catenary sequence in this undulating landscape (Figure 4-2). The soils which occur in the convex upper slopes and mid slopes are well drained and imperfectly drained reddish brown earths (RBE) respectively. The soils found on the concave valleys and bottom lands are low humic gley (LHG) soils which are poorly drained. About 60 per cent of the area in System H has RBE soils while about 40 per cent has LHG soils (Somasiri 1978).

Panabokke (1978) states that RBE soils have the highest inherent productivity for rice, while Rasiah (1980) found that irrigated rice yields are more or less similar in RBE and LHG soils if RBE soils can be given a sufficient number of irrigations (up to 5 times that for LHGs) to maintain the required level of soil moisture.

Owing to their poorly drained nature, only rice can be cultivated in LHGs. In the Maha season much of the imperfectly drained RBEs are also suitable only for rice.

Figure 4-2: Distribution of Soils in the Dry Zone Landscape



However, well drained RBEs can be cultivated with other crops in the wet season. In the Yala season all RBEs are suitable for crops other than rice.

4.1.0.1 Pre project economy

The Dry Zone was a well developed agricultural area during the early history of Sri Lanka. The great ancient capital cities, Anuradhapura and later Polonnaruwa, were located in the Dry Zone which was the cradle of a highly developed civilization. This civilization, a "hydraulic" society, was based on irrigated agriculture (Wittfogel 1957; Leach 1959). Irrigation water was collected and stored in often interconnected reservoirs of varying sizes. Some of these reservoirs were capable of storing up to 100,000 acre feet of water, while the majority were small village tanks capable of serving small village communities. During subsequent periods, the Dry Zone ceased to be the centre of agriculture in Sri Lanka for reasons which are not clearly understood to date, but are often attributed to foreign invasions from south India and to an increase in the incidence of malaria. The Wet Zone became the major population centre and, with the exception of Jaffna peninsula, much of the Dry Zone reverted to jungle. Malaria was brought under control during the last 40 years of Sri Lanka's modern history. This led to the rehabilitation of many of the ancient tanks and new settlers were brought into these areas. Some traditional settlements, however, continued to exist. These traditional villages were based on small village tanks (reservoirs), had a semi subsistence economy and little contact with the rest of the Sri Lankan economy.

The few settlements which existed in System H prior to the project were of this traditional type. These were based on small tanks built to irrigate a rice crop in the Maha season in valley bottoms with LHG soils. Leach (1980) described the organization and the economy of a tank based village in the Dry Zone of Sri Lanka which provides a picture of traditional villages which used to exist in the project area;

> A village tank is created by damming up a natural stream and building a long earthwork wall to hold the water up behind it. The resulting reservoir when full is usually about seven feet deep immediately behind the earthwork (bund). Very roughly, the full tank covers much the same area of ground as the land below it which it is capable of irrigating. (p 94).
>
> ... the basic scarce commodity [in these communities] is water. Economic and political influence throughout the community is determined by the control of water... (p 95).

The main source of cash income was shifting cultivation of the dry lands. In the Maha season, rice was cultivated in the irrigable land under the reservoir for subsistence needs. According to Leach (1980)

> While the irrigated lands are devoted exclusively to rice, the shifting cultivation areas can be used for a variety of alternative crops. Traditionally the most important of these is a species of millet, known as *kurakkan*. In years when there has been a rice crop failure, this may be a very important standby item of diet. But shifting cultivation can also be used for a number of important cash crops, such as gingelly and mustard. (p 105).

> ...He [the traditional farmer] looks upon this shifting cultivation as his main means of earning a cash income, in contrast to his ordinary activities as a rice farmer, which provides him with a subsistence living. (pp 105-6).

A detailed picture of the socio economic characteristics of these farmers is provided by the Pre-project Socio Economic Survey undertaken by Mahaweli Development Board in 1971. Prior to the project, only 7,000 of the 32,000 hectares of cultivable land in the area was under cultivation. This area was cultivated by 8,000 families consisting of a total population of some 50,000 people. More than 80 per cent of them were entirely dependent on farming for their sustenance. Only 34 per cent of the cultivated area was under paddy cultivation while the major part of the land (55 per cent) was in chena cultivation (shifting/ slash and burn dry land cultivation). Since the early 1970s, the cash crops cultivated in the chenas included chillies in addition to traditional crops such as gingelly and mustard. The cropping intensity of the entire cultivated area was less than 100 per cent; though there were potentially two cropping seasons, in practice the entire land was not fully cultivated even once a year. About one third of the families owned cattle or buffaloes; about 13 per cent had poultry while a few (1.5 per cent) had goats. Livestock and poultry raising were small scale activities and supplemented incomes from crop cultivation. The average land holdings per family were 1.8 acres (.32 ha.) of paddy land (irrigable lowlands) 1.2 acres (.49 ha.) upland, and 1.0 acre (.40 ha.) of Chena land.

Nearly 20 per cent of the heads of households had no formal education. About 45 per cent of them had 1 to 5 years of formal schooling.

These farmers mainly cultivated traditional varieties of rice, which were established entirely by broadcast seeding. Weed control, apart from impounding water in paddy fields, was not practiced. Only 25 per cent of the farmers used any chemical fertilizer on their farms. The average input of fertilizer was less than 5 per cent of the recommended dosage. The average yield was only 30 bushels per acre (1.5 tonnes/Ha.) in Maha season. Rice cultivation was not normally feasible in the Yala season. The average farm family income was Rs. 1210 with an income of Rs.7 per workday per person. This indicated a relatively low standard of living since, the average rural household income in the whole island in the year 1970 was about Rs.3600. These purana villages had semi-subsistence type economies with very limited links with outside markets. According to the pre-project socio economic survey of the area (1971), less than 4 per cent of the total farm produce was sold in the market.

The poverty of the traditional settlers in the project area ("Purana" villagers) and their "primitive" economy left a deep impression among the settlement planners. They were concerned about the ability of these farmers to adjust to the forces of modernization set off by the project. The final report of the pre-project socio-economic survey (MDB 1975) describes the Purana villager as follows:

> While lack of water, education, transport and communications may have been some of the other factors it seems like psychological poverty that has not made them rebel against the environment. Why are the natives of the Raja Rata not like the hardy southerners or the Northern Jaffna Tamils? Why have they been so docile to remain for centuries what they are today? With better food, housing, health and sanitation, education, transport and communications, it is left to be seen whether they will run better in the race against poverty. There is some doubt in our minds as to whether it will automatically happen. The way out as we see it is in planned cultural redirection through catalytic agents of cultural change, whom they could emulate. By this, we mean that culturally advanced families should be selected and planted in between groups that are not advanced. Such agents would exert magnetic fields of influence and help the demagnatised psyches to remagnatise after which the magnatised forces will be more effective. But, planting agents of cultural change alone may not bring about the desired changes unless legal and institutional arrangements are also made to avoid exploitation of other members of the community. (p 2).

4.1.1 The Post Project System H

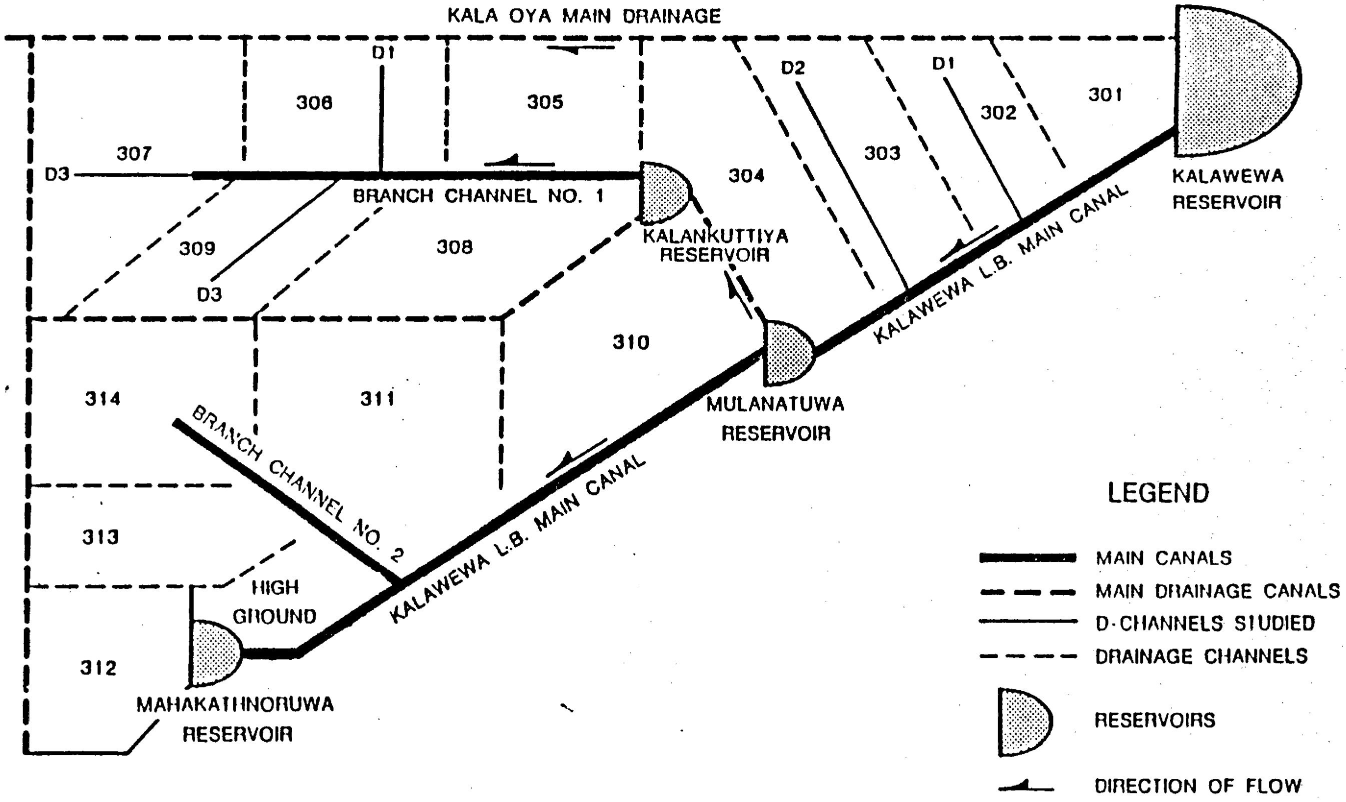
Under the Mahaweli Project, the physical environment and the socio economic environment of System H underwent major changes. The forest which covered much of the 35,000 ha. area was cleared except for the occasional reserve along natural drainage ways. The majority of the traditional village tanks were breached and 70 kilometers of main channels, 56 kilometers of branch channels, and 313 kilometers of distributory channels were newly constructed. Ninety kilometers of new roads were built, together with new townships, storage and marketing facilities, schools, hospitals etc. The old land cultivated by pre-project inhabitants of the area (Purana villagers) was redeveloped, re-demarcated and incorporated into the new irrigation network so that the old villages were indistinguishable from the newly created ones.

4.1.1.1 The Structure of the Irrigation System

System H has five major reservoirs, Kandalama, Dambuluoya, Kalawewa, Rajangane and Angamuwa, which are supplied with water diverted from Mahaweli Ganga at Polgolla and Bowatenna in addition to water collected from their own local catchments. These reservoirs irrigate an area of 43,500 hectares in the Maha season. About 8,000 hectares of this are in the command area of Rajangane and Angamuwa reservoirs which were developed in the mid 1960s as a land settlement scheme. The irrigation distributory system below each reservoir in the new lands has been designed and constructed according to a standard hierarchy of irrigation channels. Main and branch channels are designed to carry water on a continuous basis along the length of the project area. For example, the Left Bank main channel is 27 kilometers in length. The area is divided into a number of irrigation blocks which are between 300 to 500 ha. Each of these blocks are in turn irrigated by 2 - 4 distributory channels taking off from a main or branch channel. Both main and distributory channels are constructed along contours and are designed to irrigate the maximum possible area. While these contour channels run along ridges in the landscape, field channels taking off from the distributories run down the slopes towards valley bottoms. Farms are located on both sides of these field channels, on the average, numbering between 12 and 16 per field channel. Each farm is 2.5 acres in extent (1 ha. approx.). As described earlier, the soils found along the field channels, i.e., down the slope, vary from well drained to poorly drained. The natural drainage in the valley bottoms carry the excess water to the river which is the main drainage of the area, Kala Oya (see Figure 4-3).

The main and branch channels are in continuous use during the two crop seasons. These are large, sophisticated engineering works with many regulatory structures and serve as means for the transportation of water over long distances as well as for storage of water for diversion into the distributories. The distributories vary in length and capacity (60 to 850 litres per second) but typically they are between 1 - 2 kilo meters in length. In large blocks these channels may carry water continuously or in small blocks for up to 4 days a week. System H has 43 blocks with an average irrigable area of 650 acres.

Figure 4-3: Schematic Diagram of the Irrigation System in Kalawewa Left Bank Area in System H



Individual blocks range between 400 to 1100 acres of irrigable area. Each block is irrigated by one or more distributory channels taking off from a main or branch channel. Each distributory channel has a number of field channels each of which irrigate between 10 - 16 farms. Field channels are designed to carry a flow rate of 28 litres per second (one cubic foot per second [c.f.s]) and have one farm supply gate (turnout) of 0.5 c.f.s capacity for each farm served by the channel. According to the project design, each field channel was to be kept open for up to four consecutive days of the week with a discharge of 28 litres per second to feed every four allotments (4 ha.) per day at the rate of 63.5 mm of water for a week.

Although the project plans envisaged adequate water for double cropping land in System H, this has not been realized for the following reasons:

1. First, the actual water used for given crops is about 20 per cent more than expected (Nedeco 1984). This may reflect inefficiency at farm level as well as unanticipated rates of water loss in conveyance.

2. Second, the actual cropping pattern deviated from the planned pattern. It was expected that farms with well drained soils will be cultivated with upland rice (with dry sowing) as against the present practice of wet sowing under puddled conditions. Upland rice has a lower profit margin than lowland rice but consumes much less water. Research trials have shown that upland rice yield is about 80 per cent of lowland rice but the consumption of water by the former is about 20 per cent of the latter (Gamage 1983). However, weed control is difficult with upland rice, and where water is free, the profit margin will be considerably lower than with lowland rice. Upland rice was never cultivated by project farmers for several reasons. In the first place, when water is available free of charge, the net profit to the farmer is greater with lowland rice. If farmers pay for the actual quantity of water used, then the profit from upland rice is greater than from lowland rice in well drained soils. Second, the well drained soils are invariably located in the head reach of field channels and, therefore, these have better access to water. Third, Mahaweli farmers have had no experience in cultivating rice with intermittent irrigation as required for upland rice culture.

3. Third, the duration of water issue per season turned out to be longer than originally expected. Farmers plant their crop in a staggered time sequence due to problems related to resource mobilization by individual farmers at the beginning of the season. This leads to increased water losses in conveyance through seepage and percolation as well as by evaporation.

Efficient on-farm water management and improved system management have been recognized as having significant potential for improved performance of irrigation projects (Barker et al. 1985). The basic idea is that the total area cultivated can be increased either by bringing in new land or by increasing cropping intensity of existing project lands while maintaining current levels of productivity through the reduction of water losses at the system level and on farm. The determination of water use efficiency and the exploration of possible means of improvement require a multi-disciplinary research approach (Water Management Synthesis Project 1982). These issues, although important, are not addressed in this thesis. A substantial amount of research has been undertaken in System H and elsewhere on these issues and we will draw on these experiences and conclusions where necessary.

The entire area of System H is irrigated during the Maha season, but only a portion can be irrigated in the Yala season. During the Maha season, water is supplied on the basis of a rotation schedule so that the first half (or a section) of the distributory channel ("head") gets water for a certain number of days after which the second half(the remaining section - "tail") is supplied for the same number of days. In practice, farmers located in the head have much better access to water throughout the season while those in the tail have access to water only during their turn. Effectively, however, even less water is available to the latter as some water is illegally taken by "head" farmers. There are no physical controls (such as gates) or effective institutional controls (such as ditch riders and water courts) to prevent the "head" farmers taking water out of turn.

During the Yala season, a number of distributory channels are selected for irrigation depending on the estimates of water available. Thus the area cultivated in the Yala season may vary. In 1985 this was 50 per cent in some areas while some other areas were not issued with any water. These selected distributories supply sufficient water to cultivate only half of their command area. The areas irrigated are rotated so that no farmer has to forgo cultivation in two consecutive Yala seasons. Therefore, farmers owning land in the "tail" of such channels share the farms located in the "head" (which receive irrigation water) with their owners. The farmers who move to the head in the Yala season do not get the same allotment in each Yala season since the actual location irrigated is also rotated depending on the water availability in each season. Accordingly, the "tail" farmers move to the "head" in the Yala season. This system of water and land sharing is an adaptation of a traditional practice in village tanks in the Dry Zone of Sri Lanka (Leach, 1980).

4.1.1.2 Settler Types

The post-project population of farm families is about 25,000 with a total farm population of more than 100,000. The non-farm population engaged in various services in the area would be approximately the same number. These settlers are drawn from different locations and thus have significantly different backgrounds. The major types are:

1. Purana settlers (those who have traditionally lived in the area),

2. Settlers selected from the Wet Zone, and
3. Others (those who have previously been squatters on state lands and farmers from other Dry Zone areas).

The Purana villagers and their economy were discussed in the previous section on the pre-project economy in system H. They were allocated newly developed land of equal size irrespective of the land area they owned prior to the project and were settled as closely as possible to the location of their original settlement and were paid compensation for the land they lost. Thus, while these farmers brought their experiences in the pre-project environment, social relationships and traditions to the new settlements, they faced a drastically different physical and economic environment in the project area.

The latter two types of settlers were selected on the basis of pre-determined criteria which give preference to young, educated, married but unemployed and landless people with experience in agriculture. These criteria were not applied in respect of Purana villagers or those who were displaced by the project, i.e., whose lands were inundated by reservoirs, canals, roads etc.

Perhaps the culturally advanced people referred to in the pre-project report quoted earlier (MDB 1975) are those selected mainly from the Wet Zone of Sri Lanka and settled newly in the project area. The relative modernization of this group of farmers in terms of their technology is described by the findings of an agro-socio-economic survey carried out in 1971/72 (ARTI 1975), at the same time as the Mahaweli pre-project surveys. Farmers in Kandy district (from where the majority of Wet Zone settlers of the selected sample area originated) cultivated mainly high yielding varieties of paddy (only 13 per cent cultivated traditional varieties in Maha season and 14 per cent in Yala season), more than 90 per cent transplanted their crop and more than 90 per cent applied chemical fertilizers. The average application of fertilizer was 40 per cent of the quantity recommended. More than 80 per cent of the farmers manually weeded their plots and the average yield in the Maha season was above 50 bushels per acre. In the Yala season, the average yield was above 40 bushels per acre.

These Wet Zone farmers are generally known to be highly skilled in activities such as land levelling and bunding, which facilitate good on-farm water management. These skills reflect the accumulated experience of many generations of rice cultivation on terraced hill slopes with water tapped from small mountain streams. Further, the Wet Zone has long been subject to the forces of modernization. Since the mid-nineteenth century the inhabitants of the Wet Zone were exposed to the market forces emanating originally from the plantations. For more than a century, transport, health services and most importantly, modern education were available in these areas.

The settlers of the third category are mixed but many have been relatively more exposed to modernization than Purana settlers. Many of them had migrated from the Wet Zone on their initiative. Such "spontaneous" settlers are often better endowed with human and other capital than sponsored settlers. There also are some who had been selected from the second generation of settlers from other pre-Mahaweli Dry Zone land settlement schemes.

4.1.1.3 Crop Growing Environments in System H

We may categorize the environment for crop production within System H into three major types. These are determined by a combination of season, location in the irrigation water distribution system and the soil type. This categorization is necessarily very broad. Individual farms within these may substantially vary in terms of their micro-characteristics while different parts of a given farm may also exhibit substantial differences. However, such detailed differences are not easily identified (see Chang 1978). System H is one of the most intensively mapped areas in Sri Lanka. Yet the existing soil maps identify only the major soil differences discussed earlier.

1. *Maha/head* This is a most favourable environment for new rice technology due to the the high degree of water control and the flexibility given by the favourable location in the irrigation system. Further, this season has a high and relatively stable pattern of rainfall. Adequacy of irrigation water can reduce the impact of heterogeneity in soil characteristics between farms on rice cultivation. The major differences between the major soil types in System H are basically due to their drainage characteristics (Panabokke 1978, Alwis 1982). These have been observed to perform equally well for the rice crop under conditions of unlimited irrigation, i.e., if well drained soils can be given up to five times the water applied to poorly drained soils (Rasaiah 1980).

2. *Maha/tail* This is a less favourable environment than the Maha/head. The level of control over irrigation water is low owing to the relatively unfavourable location along distributory channels. This relative scarcity of water in this environment may lead to more between-plot variation, or heterogeneity, in natural environment. Farmers are required to devote more time and energy to adjust their operations to a given water availability regime as well as to obtain water. By contrast, farmers in the former environment may adjust their water use to suit their needs, and so avoid significant water stress. In the latter situation, the variety selected, manner of crop establishment, weed and pest control, the application of fertilizer and chemicals have to be determined to suit the availability of water in terms of timing and volume.

3. *Yala season* The rainfall pattern in this season is highly variable and the availability of irrigation water is restricted. The availability of irrigation water in this season is dependent on the quantity saved from the Maha season. Its supply cannot be varied during the season if the rainfall diverges from the expected pattern at the beginning of the season. Therefore, the crop share arrangement described earlier has been adopted for this season. This adds to uncertainty for "tail" farmers owing to their lack of familiarity with the micro-environmental conditions of plots of land cultivated by them. Even with the relative scarcity of water in this season, the only feasible crop in the poorly drained soils is rice. On the other hand, the restricted water availability does not permit the cultivation of rice in well drained soils. However, these soils are well suited to the cultivation of other cash crops.

4.1.1.4 Post Project Economy in System H

The post-project land use for agriculture has been determined to a large extent by the availability of water and the soil type. In the Maha season, all project lands are cultivated with rice. In the Yala season, well drained soils are cultivated with non rice crops (mainly chillies) while poorly drained soils are cultivated with rice. Unlike in the pre-project setting, farmers have no dry land for agriculture (except a half acre of homestead allotment where a few perennial trees and a small patch of vegetables are typically grown). The new technologies for rice and chillies generate substantial marketable surpluses and are dependent on purchased inputs such as fertilizer, pesticides, weedicides and hired labour (see Table 4-1). Thus post-project economy in System H is market oriented. The total output of paddy and chillies, on the average farm exceeds the household consumption requirements of those two items and as a result more that 90 per cent of farm production is sold in the market. The average per capita consumption of rice in Sri Lanka is about 100 Kgs. per year (Ministry of Finance and Planning 1984).

All project farmers adopted new high yielding varieties of rice from the first season of cultivation after settlement and used chemical fertilizer although the amounts used varied. From the first season, average productivity increased to more than double the pre-project average. Even the Purana farmers immediately adopted the new technology although the level of efficiency in input use may not have been very high. Such rapid transitions from traditional to modern technology with the provision of new inputs have been similar to observations elsewhere (Marooka et al. 1979). This is consistent with the conventional wisdom in agricultural development economics; traditional farmers are rational economic beings, who when given new technology and improved access to factors of production, will increase productivity. The breakdown of previous self sufficiency due to the change in land availability placed the farmers of System H firmly within a market setting. Unlike a traditional setting where the only inputs were family labour and seed, the new technology is highly dependent on purchased inputs in the form of seed, fertilizer, chemicals, and hired labour.

The farms are small in size and large in number so that individual farmers are price takers in the relevant markets. The land market is regulated by law which prohibits transactions such as mortgage, lease or outright sale. However, illegal land transactions take place, and in some areas a trend towards increased operational size of farms has been observed (Krimmel 1986, Siriwardhana 1980). Water, the other major factor of production, is not marketed, but is supplied in fixed quantities to farmers. They are charged on the basis of the area cultivated and not on a volumetric basis. Thus, a market for water does not exist and water availability is determined by the location of farms. As a result, the value of available water is capitalized into land values. Hired labour is an essential requirement for farming in System H. The wages for hired labour do not appear to vary within the project area, and rates paid correspond closely to those paid for similar work elsewhere.

The major sources of draught power are water buffaloes and tractors. There is an active rental market for their services. Farm products are sold in the open market while inputs are also purchased in the open market. Farm gate prices may sometimes vary depending on transport costs, but these costs are minimal since the project physical plan has been developed in a radial pattern around service and marketing centres to ensure that distance is not a great disadvantage to farmers (as observed in previous "ribbon" type setlements).

The government provides subsidized capital to farmers in the form of cultivation loans through commercial banks. This source is available to any farmer as long as he does not default. As at present bank credit is available only to a small percentage of farmers in the System H. In 1984/85 crop year, the total number of farmers receiving bank loans for cultivation purposes was estimated to be less than 10% of the total number (Panditharathne 1984). However, farmers obtain credit from non-institutional sources at varying rates of interest. Bank interest rates for loans to farmers are regulated and repressed. Credit rationing is therefore expected. Varying interest rates for different borrowers in the informal credit market may suggest market imperfections. However, as Stiglitz (1987) points out such variation may be related to the differences in risk of loan default among borrowers and does not necessarily indicate market imperfections. The varying interest rates charged by other sources in System H may, therefore, be related to the varying risk of loan default depending on the repayment capacity of individual borrowers and may not reflect market imperfections (see Stiglitz 1987).

4.1.2 The New Rice Technology

The term "new rice technology" means the technology of rice cultivation using new high yielding varieties, inorganic fertilizers and other chemical inputs. The widespread adoption of this technology was expected to usher in the "green revolution". This technology may be contrasted with the cultivation of traditional varieties of rice with little or no application of chemicals. With the new technology, there is a multiplicity of techniques/practices which can be used by farmers.

Many high yielding varieties of rice are now available for cultivation in a given location. For example, in Sri Lanka, a farmer in a major irrigation scheme in the Dry Zone has the choice of cultivating a long aged variety (four to four and a half months) or a short aged variety (three months). HYVs are non photosensitive and mature after a fixed time period unlike the traditional varieties which mature at approximately the same time irrespective of the date of planting. Accordingly, farmers who wish to plant late in the season due to delayed rainfall or late arrival of irrigation water to the field can plant a short aged high yielding rice variety. Delayed planting of a long aged variety may lead to crop loss due to water stress at the tail end of a season. However, short aged varieties typically have a lower yield potential and losses due to departures from optimal timing of input applications are greater (Yoshida 1981).

New rice technology depends on the application of chemical fertilizer for high yields. Fertilizer promotes the growth of weeds as well as the rice crop. Hence weed control is an essential component of this technology. One way of weed control is to transplant the crop in a flooded field where the impounded water controls weed growth. Row transplanting also facilitates manual or mechanical weed control. However, a transplanted crop is susceptible to water stress in the initial period after transplanting. Hence the decision as to transplant or broadcast seed has to be taken in the light of expected water availability. Herbicides are the only effective means of weed control in a broadcast seeded plot. Land preparation is the other major means of weed control. Land preparation may be undertaken with tractors, manually or with draught animals. There are alternative implements to be attached to tractors or draught animals to suit particular soil conditions. Land preparation work and pre-emergent weedicides are substitutes to a certain extent.

The other major component of the new rice technology is pest control. Staggered planting (or direct seeding) of rice in irrigation systems results in staggered maturing of the crop and provides a continuous source of food for pests. As a result late maturing fields suffer most from pest damage. Even with staggered planting, traditional varieties matured simultaneously. Further, the long fallow periods in the traditional setting (with only one season per year) controlled pests by depriving them of food for long periods. In modern irrigation schemes two rice crops a year are common. Traditional varieties, on the other hand, were resistant to the most common pests in given locations. Therefore, farmers experienced in the cultivation of traditional varieties, but newly introduced to HYVs are often unable to identify the pests which attack them. The available chemical treatments are specific to different pests and have strict requirements in terms of the times of application, the stage of growth of plants and the pests, prevailing weather, the rate of dilution, the dosage, etc. The correct application of available treatments by one farmer alone may not be fruitful when neighbouring affected farmers do not treat their attack in the correct way (Godell 1982, 1984). This is one externality among many others in a small farm environmnet. The complex nature of chemical pest control is certainly responsible for the often observed ineffective use of pesticides (Abilay 1978).

The major types of fertilizer, nitrogen, potassium and phosphorus, are packaged in different ways, and a rice crop requires different combinations of them applied in varying dosages corresponding to its growth stage. Apart from applying fertilizer at the correct time the farmer has to drain the field and ensure that the field does not have standing water for a certain time period. Where irrigation water is available on a strict rotation, correct timing may be difficult since a farmer cannot allow the crop to suffer from water stress. Thus he may wait until the water from one rotation is fully absorbed before applying the fertilizer or a chemical. When the next rotation comes the farmer has to decide between skipping the rotation which may subject the crop to water stress, or else using water at the risk of losing at least a part of the effect of the fertilizer or chemical applied. Unexpected rains often wash off fertilizer and chemicals applied. Then the farmer has to decide whether the crop requires an additional application, and if so, what the correct dosage is. Favourably located farmers can avoid these problems since they can organize water supply to meet their individual needs. Farmers in many locations have been observed to be inefficient in their timing of fertilizer application (Abilay et al. 1984).

The output response from given packages of inputs and practices will vary according to the availability of water (see Wickham and Sen 1978). The best package for a given environment will therefore depend on the availability of water. Where water is not available on demand, but is supplied on a rotation schedule the farmer has to package his technology to suit an expected water availability regime which can be disrupted by the vagaries of rainfall. On the other hand, favourably located farmers may be able to vary the use of water according to the needs of a particular technological package.

4.2 The Sample

Project authorities continuously monitor the performance of settlers by collecting data on certain basic indicators. These are, cropping pattern, average crop yields, issues of cultivation loans from commercial banks, issues of fertilizer from government stores and water issues at critical points within the irrigation system. However, data on farm specific input use are not routinely collected. Therefore the data required for this thesis had to be collected from a farm survey. To avoid the well known problem of recall lapse of small farmers (who rarely keep any records of their operations), a multiple visit rather than a single visit survey was conducted. The financial resources available limited the feasible sample size to about 120 farmers located within a fairly small geographic area.

As the major focus in this thesis is on the success of adjustment of farmers with varying backgrounds to the new technology in different cropping environments within the project an irrigation block was chosen as the sample area. This is the smallest contiguous area which contains these different environments.

The distributory channels irrigating a block may be divided into head and tail reaches according to the demarcation of the area to be served by the first water rotation and the second. Field channels are constructed down the slopes as against distributories which are contour channels, and therefore serve first the farms with well drained soils on convex upper slopes and then the farms with imperfect and poorly drained soils on lower slopes. Accordingly, one irrigation block contains all the major environmental categories for agriculture in the project area.

The different distributory channels within a block do not have significant differences in access to water from the main channel. However, depending on the distance from the nearest regulatory reservoir, water availability between blocks may vary. The optimal distribution of water between blocks is an issue related to the efficiency of the overall system design and operation. Thus one criterion in the selection of the sample area (block) was to select a block which was midway from a regulatory reservoir and therefore unlikely to represent an extreme situation in terms of water availability.

Some of the blocks in System H have only one of three major settler types. Therefore the second criterion was to select a block which had all three settler types in substantial numbers.

Although settlement in System H commenced in 1975, it continued till 1985. The study of very new settlers was not considered to be useful for studying the adjustment process over time. Hence the third criterion was to select a block with at least 6 - 7 years of cultivation since original settlement. The pre-project plans expected the settlers to reach their full potential in about 8 years from the date of original settlement in the project.

On the basis of these criteria, block 313, the second block served by branch channel No. 2 in the command area of Kalawewa Left Bank Main Channel (see Figure 4-4) was chosen. This branch channel serves three blocks with Block 313 in the middle. This block has 436 settlers with significant populations of Wet Zone, Purana and "other" settlers. The settlement in the block took place in the year 1977. The block was stratified into head and tail areas as outlined earlier and a random sample of 63 farmers from the head and 61 farmers from the tail was obtained (Figure 4-5). Wet Zone farmers accounted for 44 per cent of the sample while 34 per cent were Dry zone farmers and the rest were others. The field survey covered the Maha season in 1984/85 and the Yala season of 1985. The sample farmers were visited at least once a fortnight during this period and detailed records of farm activites were obtained. The questionnaire used is given in Appendix IV.

Figure 4-4: Location Map of Block 313 in Kalawewa Left Bank Area of System H

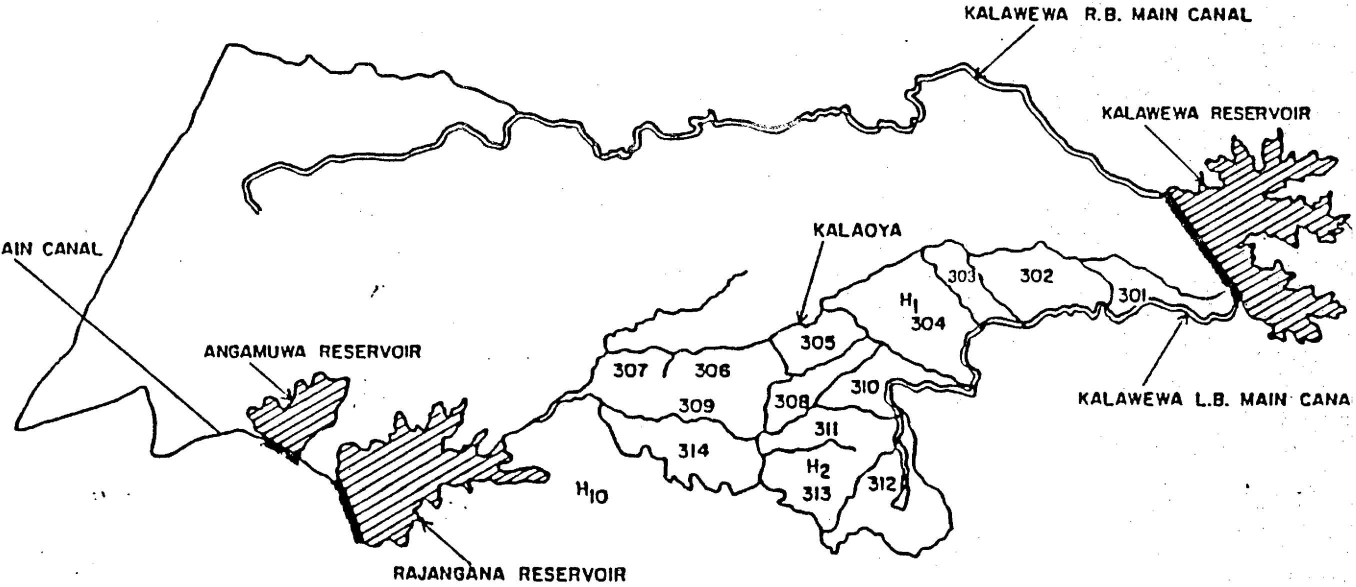
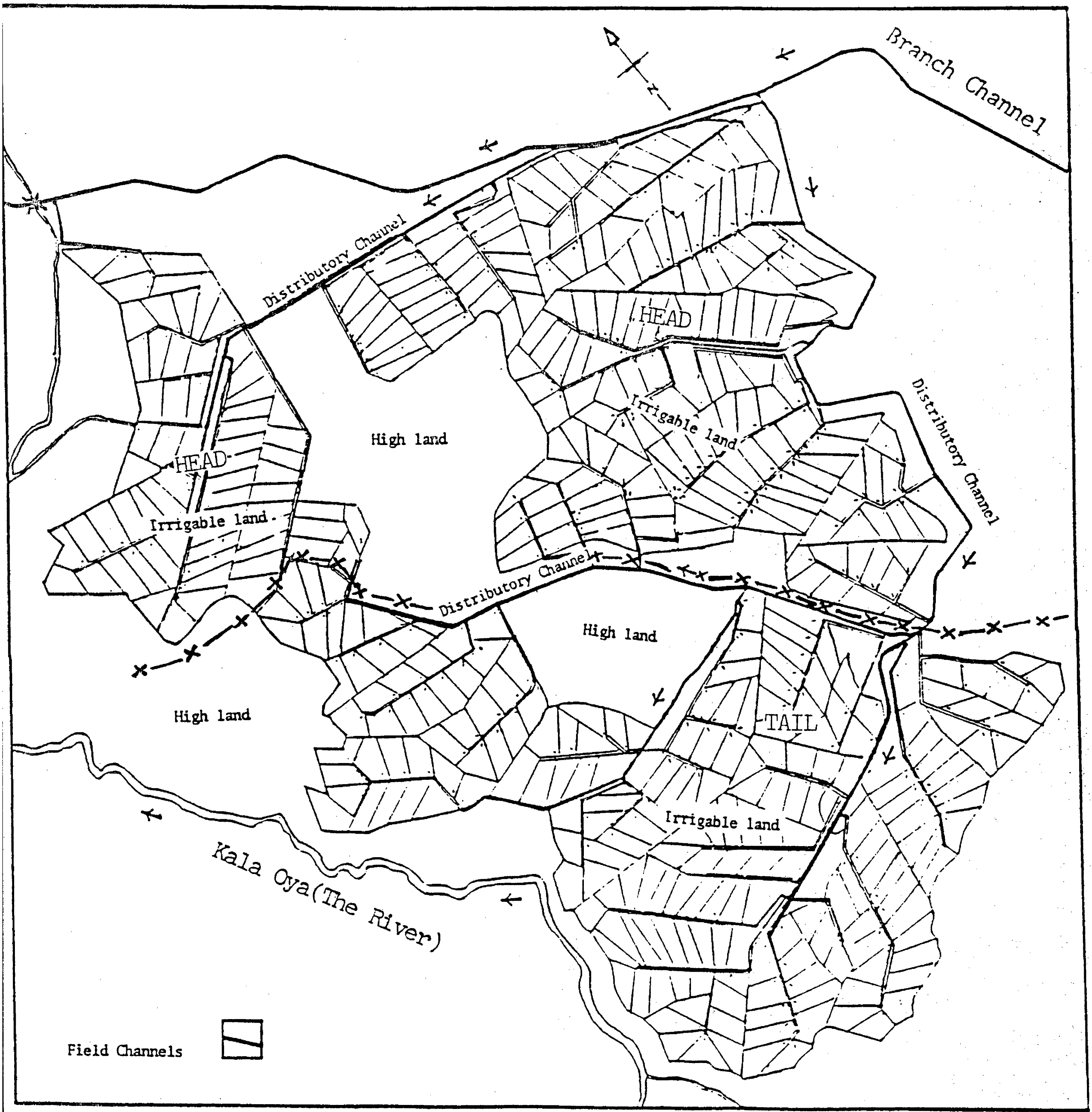


Figure 4-5: The Map of Block 313



Source: Mahaweli Development Board

As explained earlier, all the sample farmers cultivated rice in the Maha season. In the Yala season, 37 farmers cultivated only chillies, 22 only paddy and the others grew both crops. Thus 87 farmers cultivated rice while 102 cultivated chillies. The average variable costs and returns obtained by the sample farmers are given in Table 4-1.

Table 4-1: Average costs and returns obtained by sample farmers from alternative crops

	Maha Season		Yala season	
	Rice		Rice	chillies
	Head	Tail	All	All
The number of farmers	63	61	87	102
Land (Ac.)	1.96	2.13	0.85	0.70
Costs of Inputs (Rs./Ac.)				
Cost of seed	190.00	190.00	190.00	150.00
Pre Harvest Labour	940.56	796.81	923.43	2686.68
Harvest labour	725.99	749.38	878.52	1561.71
Draught power	448.30	428.50	211.71	53.00
Agro chemicals	108.33	131.91	164.72	509.62
Nitrogen	110.25	116.31	171.80	310.87
Other fertilizers	191.07	114.65	77.27	334.18
Total	2714.50	2527.56	2617.46	5602.01
Mean Output (Bu./Ac.)	70.55	45.63	47.70	430.40a/
Gross Revenue (Rs./Ac.)	4415.00	2855.52	2985.06	12279.31
Net Profit (Rs./Ac.)	1700.50	327.96	367.60	6677.30

a/ Kgs. of dried chillie per acre.

Note: The cost of family labour is valued at the market wage rate.

The costs of cultivation of rice in the three environments are similar. However, the mean yield and the net profit in Maha/head was significantly higher. Where water availability is similar across seasons (such as in experiment stations), dry season rice crops yield more than wet season crops (see Yoshida 1981). This is explained by the longer sunshine periods experienced in the dry season owing to the low cloud cover. The contradictory observation for System H is clearly the result of the difference in water availability.

Chillie was the most profitable crop. However, the average cost of production was more than double that for rice. Chillies can only be cultivated in the Yala season, and only in well drained soils of System H. All farmers in the sample who had well drained soils cultivated chillies in the Yala season.

4.2.1 Rice Cultivation - Recommendations and Practices

Practices recommended for the cultivation of rice in System H in the two seasons are identical except for the duration of the variety cultivated. Owing to the restricted availability of water, short duration varieties are recommended (3-3.5 months) in the Yala season. The recommended dosage of fertilizer for short aged varieties is lower than that for long aged varieties. Farmers are encouraged to transplant in both seasons, with basal and top dressings of fertilizer. Use of pesticides is encouraged only for the treatment of identified pest attacks and not as a preventive measure. Rather, the emphasis is on integrated pest management techniques with use of chemicals strictly need-based. Weed control by impounding water on paddy fields is discouraged in both seasons in order to conserve scarce water.

A comparison of the major practices followed in the area by location and season (Table 4-2) shows that, in the Maha/head, a majority of the farmers transplanted their rice crop, cultivated long and medium aged varieties and applied basal fertilizer. Fewer Maha/tail farmers followed these practices. In the Yala season, the proportion of farmers resorting to these practices was much lower again. Some practices such as the application of fertilizer top dressings were common in all three environments.

Long aged varieties, with adequate water, give higher yields owing to their longer vegetative growth phase which gives a longer time for recovery from various setbacks in the life cycle of the crop (De Datta 1981, Yoshida 1981). However, where water is scarce, short aged varieties may do better since their water requirements are lower and since they can be planted or sown later in the season when the rainfall pattern is better established. Transplanting is encouraged mainly for ease of weed control. However, where water is in short supply, transplanting may give adverse results if water stress occurs soon after transplanting. Basal fertilizer is recommended prior to the establishment of the crop, but it is commonly observed that farmers in risky situations often do not apply it. This may perhaps be a reflection of farmers' uncertainty about crop performance prior to the establishment of the crop (Binswanger, 1979). Another possible explanation is the belief among some farmers that basal fertilizer application leads to increased weed growth.

A smaller percentage of farmers in the Maha/head applied weedicides than in the Maha/tail and the Yala season which is probably due to the capacity to use impounded water for weed control in the Maha/head. The proportions of farmers applying pesticides differed little in the three environments. However, the degree of accuracy and detail regarding use of pesticides or herbicides which can be obtained from farm surveys is often low. Often farmers are unable to name the chemicals applied, and further, they rarely adhere to the dosage requirements.

4.2.2 Chillie cultivation - Recommendations and Practices

The cultivation of chillies under gravity irrigation is new to Sri Lankan farmers. Chillies have traditionally been cultivated under rainfed conditions in the Chenas (shifting cultivation) in the Dry Zone while in Jaffna peninsula they are traditionally cultivated with irrigation from deep wells. There are two high yielding varieties of chillies bred at Mahailluppallama, the regional agricultural research station located near System H, which are recommended for the Dry Zone. Recommendations regarding methods of establishment, fertilizing and pest disease control of irrigated chillie crops

Table 4-2: Incidence of alternative cultural practices in rice cultivation in Block 313 of System H: by season and by location in crop year 1984/85

The number of farmers

Practices	Maha Season		Yala Season
	Head (No) (%)	Tail (No) (%)	All (No) (%)
Method of Establishment			
Transplanting	44(70)	38(62)	15(17)
Broadcasting	19(30)	23(38)	72(83)
Variety			
Long aged	22(35)	17(28)	5(06)
Medium aged	20(32)	8(13)	33(38)
Short aged	21(33)	36(59)	49(56)
Basal fertilizer			
Applied	31(48)	9(1)	7(08)
Not applied	32(52)	52(85)	80(82)
Weedicides			
Applied	37(58)	54(88)	59(68)
Not applied	26(42)	7(12)	28(32)
Pesticides			
Applied	48(75)	44(72)	64(73)
Not applied	15(25)	17(28)	23(27)
Total no. of farmers	63	61	87

have not been developed to the same extent as for rice. Chillies are highly susceptible to pests and diseases, particularly leaf curl, and a wide variety of chemicals are being marketed for their treatment. Accordingly, agro chemicals account for a major part of the total variable costs.

Our field survey coincided with the first large scale chillie cultivation in Block 313. Accordingly, those farmers who grew chillies did so on an experimental basis. The Purana farmers in the sample had previous experience in growing traditional varieties of chillies under rainfed Chenas. However, the low input (only seed and labour) chena cultivation approach is very different to the intensive cultivation of crops under irrigation. Whether their previous experience was of any use in practising the new chillie technology emerged as an interesting issue.

All sample farmers cultivated new high yielding varieties of chillies and transplanted them. They all used topdressings of fertilizer, but in varying quantities. Only 18 per cent of them applied any basal fertilizer. They all practiced manual weeding and 3 per cent also used chemical weedicides. All the farmers used pesticides.

CHAPTER 5

The Results of Farmer Efficiency Analysis

5.1 Introduction

As discussed in the previous chapter, the sample area has three different environments for crop production, *viz.*, Maha/head, Maha/tail, and the Yala season. The only crop grown in the first two environments is rice. In the third, rice is grown on poorly drained soils and chillies are grown on well drained soils. There is no "head" and "tail" difference in the Yala season since all farmers cultivate land located in the "head" and therefore water is issued simultaneously to all field channels in that location. As the various inputs that comprise the new rice technology are expected to perform differently according to environments, three different frontier production functions [FPF] were estimated for rice, as well as a frontier production function for chillies. We will denote the FPFs Maha/head, Maha/tail, Yala/rice and Yala/chillie respectively. In this chapter, we present the estimates of the four FPFs. The technologies in the three rice growing environments, including returns to scale implied by the individual FPFs are compared and discussed. This is followed by an analysis of the differences in individual technical and allocative efficiency estimates for the four environments. Next, determinants of efficiency variation for each environment are examined. Finally, the overall economic efficiency of farmers is examined.

5.1.1 Algebraic Formulation of Production Frontiers

All choices in production and the relevant economic decision rules of agents are subject to the technological relationship of transforming inputs to outputs. It is often convenient in economic analysis to characterize (parameterize) such technologies in the form of algebraic expressions. The advantages and disadvantages of such parameterization were discussed at length in Chapter 3. For this study, the advantages outweigh the disadvantages. The most widely used parameterization for agricultural production functions is the Cobb-Douglas form which is written as follows:

$$Y=Ax_1^{b_1}x_1^{b_2} \tag{5.1}$$

where, Y is output, x_i inputs, b_i input coefficients and A is intercept. The properties of this production function are:

1. strict concavity, given by $0 < b_i < 1$, $0 < b_1 + b_2 < 1$ and $A > 0$;
2. strict quasi-concavity, given by $b_i > 0$ and $A > 0$;
3. homogeneity of degree $(b_1 + b_2)$;
4. elasticity of x_i given by b_i;
5. function coefficient $E = b_1 + b_2$ gives returns to scale;
6. elasticity of substitution $\sigma = 1$;
7. the function can be specified only with complementary factors;
8. isoquants have negative slopes, are convex to the origin; they converge when returns to scale are greater than one, they are equally spaced with constant returns to scale, and they diverge with decreasing returns to scale; and
9. the function exhibits only stage two of the production process for each individual factor and with respect to scale given strict concavity, while it exhibits only stages one or two with respect to scale given strict quasi-concavity.

The restrictions of constant unitary elasticity of substitution, and the inability to reflect all three stages of production have led to many alternative specifications of production technologies. The most commonly used alternatives are the Quadratic, Constant Elasticity of Substitution and Translog functions.

The Cobb-Douglas function can be shown to be a special case of CES and Translog functions. When the squared difference term in the CES is insignificant or when the quadratic term in the translog function is insignificant the technology is described by the Cobb-Douglas function.

Many empirical studies have employed the Cobb-Douglas form of production function in spite of its restrictiveness (Anderson and Jodha 1973, Upton 1979), because of its well known advantages. First, it represents many of the desired economic properties, being well behaved, i.e., positive monotonocity (positive marginal products for each input) and strict quasi-concavity.[1]. Second, it is computationally easy to handle. Third, it has achieved widespread empirical support in agriculture and in other industries. Heady and Dillon (1969) showed that this form has provided adequate fit for agricultural data more often than other functional forms. As shown above, the Cobb-Douglas form assumes that the elasticity of substitution between any pair of inputs is unity. Hayami (1970) used inter-country cross section data and found that his results were consistent with the assumption of unity elasticity of substitution. Lau and Yotopoulos (1971) and Sidhu (1974) fitted CES production functions to Indian agricultural data and found that the adequacy of the Cobb-Douglas functional form to represent the data cannot be rejected.[2][3] .

We also attempted to fit the translog function to the data but there were major problems with high multicollinearity among the independent variables (as often found when using this form (e.g., Mefford 1986)), and generally insignificant interaction terms. Therefore we decided to use the Cobb-Douglas form in our study.

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[1] The translog function does not satisfy strict quasi concavity globally. However, if wide enough regions of the input space (including the observed output and input levels) where these restrictions are satisfied, then the translog function is considered as well behaved. See Diewert and Wales (1987) for an attempt to develop methods for imposing global curvature conditions in the context of cost function estimation.

[2] A problem with this functional form is that risk increases with increased outputs as shown by Just and Pope (1979).

[3] Similar observations have been made for other industries as well. Corbo and Meller (1979) fitted translog production functions to 44 four-digit ISIC Chilean manufacturing industries and found that for 39 of these industries, the null hypothesis that their production function is the Cobb-Douglas cannot be rejected. This is consistent with the findings of Griliches (1967) and Zarembeka (1970) in relation to the CES function.

5.1.2 Variables

Cobb-Douglas production frontiers were specified for the three rice crops. Rice (unhusked) output in bushels was the dependent variable, and area cultivated in acres, the number of man-days of labour in pre-harvest operations and the quantity of nitrogen applied in kilograms were the independent variables. Harvest and post harvest labour were excluded as determinants of output since output is expected to be determined solely by inputs applied prior to harvest. Massell and Jhonson (1968) argued that, where the return to harvesting was sufficiently high so that nothing is left unharvested, harvesting will be perfectly complementary with, and will be determined by, the level of use of other inputs used in crop production. It would consequently be redundant to include harvesting in the production function as a separate input. Further, they show that the inclusion of harvesting in the production function will result in an identification problem in estimation.

In other specifications, inputs such as pesticides, weedicides, potassium and phosphorus were also included as independent variables but were found to be insignificant. A soil type dummy was also included (well drained = 1 and poorly drained = 0) in earlier specifications of the two FPFs for the Maha season, but was found to be insignificant. This is consistent with research findings reported earlier that, given adequate water, both types of soils have similar yield potential. The insignificance of the soil type in the determination of crop yield in the Maha season, therefore, suggests that there was in fact sufficient water for well drained soils to perform similarly to poorly drained soils. Both Maha/head and Maha/tail environments have the same proportion of well and poorly drained soils. Agronomic research has shown that given sufficient water, well drained soils can give similar rice yields to those obtained on poorly drained soils (Rasaiah 1980). The issue of soil type differences does not arise in the Yala season. Only rice is cultivated on poorly drained lands and only chillie is cultivated on well drained soils.

Interactive processes of this nature in regression analyses have been labled *data* *mining* or *specification searches*. As Johnston (1984) points out, at one extreme it is alleged that data mining invalidates all the conventional significance levels while at the other extreme it is suggested that if the set of models tried includes the "true" model, that model will have the smallest residual variance, so that specification search is a reasonable and sensible procedure. Although not taking any one of these extreme views we hold that the interaction between theory and data is both inevitable and, indeed desirable following Johnston's (1984) conclusion. The alternative specifications tried by us were based on the received knowledge in the estimation of agricultural production functions and were by no means an exhaustive mechanical search for "best" fit. Therefore, we report the significance levels and the standard errors in the conventional manner.

Another interesting point related to the finding that the soil type does not affect output in the Maha season is that this soil demarcation coincides with that for "head" and "tail" along field channels. Field channels run down the slope feeding well drained soils in the upper slope and then irrigating poorly drained soils in the lower slopes and bottom lands. Even if farmers in the head of a field channel use more of the water available from that channel, those in the "tail" do not suffer from inadequacy of water since they benefit from seepage from the "head" farms. However, farms in the "tail" of field channels have less control over water than those at the head. It should be noted that the "tail" of field channels represents an entirely different water availability regime than that in the distributories. Our Maha/head and Maha/tail demarcation was based on the distributory channels and not field channels.

The Yala/chillies FPF was specified with the dried chillie equivalent of total harvest (which may comprise both green and ripe chillies) as the dependent variable, and land area cultivated, nitrogen and pesticide costs were included as independent variables. Pesticides are an important input in the cultivation of chillies and were used by all the farmers. However, a variety of pesticides are being used which have different dosages, mixes etc. Hence, it was not feasible, in practice, to specify the FPF with separate continuous variables for each pesticide. Pre-harvest labour was not significant in a previous specification of the production frontier for chillies. This insignificance is the result of low variation in the use of pre-harvest labour per unit of land, and, of course, does not imply that this essential input is not important in chillie production. This problem in the estimation of of the contribution of certain inputs in explaining output occurs when farmers use similar quantities of inputs.

The available classification of soils in System H into well and poorly drained classes is a very broad categorization of their characteristics, and it is likely that there are wide and significant variations in soils among farms within this broad demarcation. These differences may relate to soil nutrients, drainage characteristics, salinity and iron toxicity etc., (Water Management Synthesis Project 1982). The identification of the soil characteristics of individual plots is a very highly resource intensive activity in terms of relevant professional skills and equipment and even then does not guarantee that all relevant factors can be identified (Tassic et al. 1987). Although some attempts have been made to identify particular soil problems in selected locations, e.g., salinity, detailed mapping of all the important variations of soils with productivity implications was precluded by resource constraints.

Irrigation water is an important variable factor in the production of rice. Where the quantity of water used can be measured this can be incorporated in the production function and the relationship between output and water use can be estimated (Hexem and Heady 1978). For example, Alaouze (1984) and Palanisamy and Easter (1983) have included water as an independent variable in a Cobb-Douglas production function. Although crop performance is heavily influenced by the timing and the volume of water used, the exact contribution of water to yield is determined by a complex relationship incorporating factors such as soil and atmospheric conditions (Small et al. 1981). Measurement of water applied by farmers to their crops was beyond the resources available for our field study. Therefore, we abstract from these problems by studying the performance of farmers within broadly identified water availability regimes.

The use of statistically estimated production functions to study farmer behaviour raises several problems as pointed out by Graff (1984) in a review of a recent study on the economy of an Indian village (Bliss and Stern 1982). Many of the problems encountered by Bliss and Stern (1982) in estimating production functions are similar to those we have described earlier and are common to much research based on farm survey data. For example, while there appeared to be eighteen different variables determining output only four are selected through step-wise selection and a good fit is obtained. These exclude some variables which clearly are likely to be important determinants of output in reality. However, multicollinearity and the problem of inadequate degrees of freedom given the small number of farms (47) forced such a selection of variables. The inclusion of non essential inputs in the production function is another problem they encountered. While such problems do not imply that research of this nature should never be undertaken it is vital that the researchers are aware of the limitations and are cautious in drawing inferences. The following extract from Graff (1984) is of great interest in this sense:

> A peasant farmer is an entrepreneur. The constraint a maximizing entrepreneur faces is a psychological one. It contains all the variables he believes to be relevant to his decision, not just those on which there is sufficient information available to an outsider trying to estimate regression coefficients. The outsider may succeed in producing a production function that is a pretty good predictor of output, but not much help when it comes to estimating costs. The reason lies close to the nature of peasant entrepreneurship. It is not a hired factor with a market wage the investigator can record. It is a variable input with which, quite possibly, high subjective costs may be associated at the margin. These are self evident to the entrepreneur, but concealed from the investigator, whose statistical production function can never include them, no matter how well it predicts output. (pp 333-4).

These considerations are particularly relevant to studies of efficiency and measures of technical efficiency obtained with estimated production frontiers should be cautiously interpreted. The estimated function may not incorporate major variables due to multicollinearity, due to lack of accuracy in the data or to lack of adequate variation in the sample. Such omisions distort both technical and allocative efficiency measures.

5.2 Frontier Production Function Estimates

The estimated FPFs given in the Table 5-1 show that the input elasticities for rice in the three environments vary substantially. Likelihood ratio tests of homogeneity (see Maddala 1977, p 180) of production functions were carried out for all the three environments together, for Maha/head and Maha/tail, for Maha/head and Yala and finally, Maha/tail and Yala. The relevant likelihood ratios (between fully restricted and completely unrestricted models) were 3814.3, 25.5, 5026.1 and 4458.8 respectively and were found to be highly significant at the appropriate degrees of freedom. The log likelihood function values for the fully restricted models were 3880, 37.8, 2553.6 and 2293.1 while those for the completely unresticted models were as reported in Table 5-1. Location specific agronomic research is not available to explain the exact causes of such variable input responses in detail, however, the following tentative hypotheses are presented as likely explanators. It is likely that these differences were caused by the variations in water availability which is the major difference between the three environments.

The coefficient for pre-harvest labour is similar in Maha/head and Yala/rice environments, but is substantially lower in magnitude for Maha/tail environment.

Agronomic research elsewhere has shown that water availability affects yield response to applications of nitrogen (De Datta 1981, Yoshida 1981). In general, when water control is optimal the yield response of high yielding varieties to nitrogen fertilizer is higher. This may explain the low output elasticity of nitrogen in the Yala season relative to the Maha season. A possible explanation of the lower output elasticity of nitrogen in the Maha/head than in the Maha/tail is that there is a higher rate of percolation in the former environment and the resulting nutrient losses through leaching are greater (Water Management Synthesis Project 1982), since well drained soils have a high rate of water loss through percolation.

Though farmers in the sample used potassium and phosphorus in addition to

Table 5-1: Maximum likelihood estimates of Cobb-Douglas stochastic frontier production functions for crop year 1984/85.

	Maha season		Yala season	
	Rice		Rice	Chillies
	Head Reach (n=63)	Tail Reach (n=61)	(n=87)	(n=102)
Variable	Coefficient	Coefficient	Coefficient	Coefficient
Intercept	+2.530 *** (0.3116)	+3.075 *** (0.3318)	+2.620*** (0.5061)	+4.035*** (0.6341)
Land	+0.624 *** (0.1176)	+0.760 *** (0.1863)	+0.252** (0.1315)	+0.403*** (0.1158)
Pre harvest labour	+0.408 *** (0.0888)	+0.145 * (0.1074)	+0.489*** (0.1414)	
Nitrogen	+0.120 *** (0.0391)	+0.262 *** (0.0677)	+0.083 (0.0806)	+0.164** (0.0921)
Pesticide cost (Rs.)				+0.3263*** (0.1176)
σ^2	0.1183	0.6732	0.6419	0.8113
γ	0.3575 (0.3228)	0.9753*** (0.0200)	0.9283*** (0.0021)	0.9584*** (0.0280)
Log likelihood function	-0.0115	-25.0235	-40.5824	-53.7626

Notes: figures within parentheses are standard errors of estimates.
*** significant at the 1 per cent level.
** significant at the 5 per cent level.
* significant at the 10 per cent level

nitrogen as well as pesticides and weedicides in rice cultivation their coefficients were not statistically significant. One possibility is that the responses of these inputs varied greatly across the farms so that variations in their levels did not correspond to their impact on yields. However, agronomic evidence on this point is insufficient to draw a firm conclusion. Similar arguments may explain why coefficients of pesticides and herbicides were also insignificant, but for these, it is also possible that inefficiency in their use may have been so widespread that the estimated best practice frontier may be well below the technologically feasible frontier. As noted earlier, the estimated frontier corresponds to the best practices prevailing in the community at the time and not necessarily the best practices which may be technically feasible. This point is particularly important in the case of chillies where this was the first season that it was grown on a significant scale by the sample farmers.

This is not the conventional yield gap study, i.e., the identification of farmer to researcher gap, but is rather an attempt to understand the inefficiencies related to, and the causes of, differential farmer performance. Given that the achievement of full efficiency under a new technology by small farmers through learning and adjustment takes time, the best practice performance of farmers is considered here as a realistic potential under farmer management at a given moment in time. There is an unavoidable period of adjustment for farmers from the time a technology becomes available, and an observed gap between researchers and best farmers will probably narrow because farmers' best practices are likely to improve over time.

5.2.1 Existence of Technical Inefficiency

In the Maha/head area, all variations in output from the frontier are due to purely random factors for it was found that, γ, the ratio of output variation due to technical inefficiency (U) relative to the total variation in output (U+V) was not statistically significant.* In contrast, in the Maha/tail, this ratio was statistically significant. To the extent that the FPF incorporated all relevant variables (including farm specific factors), this suggests that considerable technical inefficiency exists in the Maha/tail. The average technical efficiency there was 50 per cent and γ was .97 which was statistically significant at the 1 per cent level. In other words 97 per cent of the total variation in output from the frontier can be attributed to technical inefficiency.

The high level of technical inefficiency observed in the Maha/tail area is not surprising. The available new rice production technology was developed for areas with an adequate and timely supply of water. While these conditions prevail in the "head" of the irrigation channel, the "tail" experiences severe water problems both in terms of quantity

* Note that Lee and Chesher (1986) have shown that $\gamma = 0$ is a null hypothesis on the boundary of the parameter space and the test of it is non standard.

Lee, Lung-Fei, and Chesher, A, 1986, "Specification Testing when score Test Statistics are Identically Zero", <u>Journal of Econometrics</u>, 31, 129-149 and quality (timeliness of availability). Uncertainties with regard to water availability require farmers to exercise considerable skills in their management decisions regarding the timing of input application and in the selection of the most appropriate cultural practices. Farmers who are capable of adapting the available technology to their 'particular' conditions obtain higher output.

Some of these alternative outcomes were discussed in the previous chapter. The higher (average) productivity in the "head" compared with the "tail" is consistent with the situation often observed in irrigation systems (see, for example, Bromley et al. 1980; Moore et al. 1983; Skold et al 1984). While the complete absence of variation in technical efficiency among farmers in Maha/head (implied by the statistically insignificant γ) is somewhat unexpected, it is not implausible. A similar result has been reported by Huang and Bagi (1984) for Northwest India. This environment, which is homogenized to a large extent by water availability, is ideal for the practice of the available technology in the reccommended form and therefore does not impose heavy demands on management skills.

In the Yala season, substantial technical inefficiencies exist (Table 5-2). Average technical efficiency is 45 per cent for rice and 44 per cent for chillies. The γ ratios are .92 and .95 respectively and are significant at the 1 per cent level. The technologies of both Yala season rice cultivation and Yala season chillie cultivation under irrigation are not well defined. For instance, the existing recommendations for the cultivation of rice are identical for both seasons, which assumes that water availability would be similar in both seasons and is consistent with the pre-project expectations of the planners.

5.2.2 Returns to Scale

Another important difference between the estimated frontiers is the difference in returns to scale. Although the function coefficient E, gives the returns to scale of the Cobb-Douglas production frontiers, statistical tests were carried out to determine whether the implied returns to scale were significantly different from constant returns to scale

[4] (see Johnston 1984, pp 204-7).

The hypothesis that constant returns to scale exists in Maha/head is rejected at 5 per cent (F=4.67), while this cannot be rejected in Maha/tail (F=0.00). In the Yala season, the hypothesis of constant returns to scale is rejected (F=10.05) for rice but cannot be rejected for chillies (F=0.994). This suggests that in the Maha/head, increasing returns to scale exist, while in the Maha/tail, constant returns to scale prevail, while in Yala/rice returns to scale are decreasing. Chillie technology is characterized by constant returns to scale.

These findings have important implications for long term efficiency and equity. In the case of rice, as water availability decreases and therefore raises the importance of management (technical efficiency) in the achievement of best practice technology, returns to scale appear to decline. As the significance of technical efficiency in the production technology increases, fixed managerial ability of farmers may act as a constraint on the expansion of land and other inputs used in rice production. Management ability is determined by human capital endowments of farmers and therefore cannot be increased like other physical factors of production in the short run. It is thus a fixed factor.

Where all factors of production are variable, economic theory suggests constant returns to scale. However, where one or more factors are fixed in the short run, there will be an optimum scale of operation. In this case, where management is likely to be the relevant fixed factor, when the actual scale of operation is less than the optimum, and the farmers have idle management capabilities, increasing returns to scale will be observed. At the scale of operation consistent with the management abilities of farmers, returns to scale will be constant, and when the scale of operation is expanded beyond this optimum level decreasing returns will occur.

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[4] This test was carried out with the OLS regression since the available computer software does not allow this test to be done on the frontier. However, the use of OLS is appropriate as the slope coefficients of the OLS and the stochastic frontier are not expected to differ significantly. Note that the stochastic frontier production function model assumes shortfalls from the frontier to be the result of random error term U (technical inefficiency) and therefore, is a neutral transformation of the OLS production function (Schmidt 1985-86).

Accordingly, the optimum scale of operation consistent with farmers' management capabilities will vary with season and location. The optimum scale for an individual will also vary according to his stock of management. This latter point however, cannot be empirically established owing to our assumption that the farmer specific production function is a neutral transformation of the frontier function for the entire sample. In general, however, this implies that if management capacity is underutilized, farmers in a favourable environment will be able to expand their scale of operation profitably while those in less favourable environments will not be able to do so. In fact, those farmers in least favourable environments may already have exceeded their optimum scale. Given that individual endowments of skills are different and that technologies vary between locations, the prevailing trend towards a reallocation of land which is different from the original equal allotment size is not surprising. Furthermore, our findings on differences in technical inefficiency and the returns to scale are consistent with *a priori* expectations based on theoretical grounds.

5.3 Farm Specific Technical Efficiency

Estimates of firm specific technical efficiencies relative to the four frontiers reported in Table 5-1 are given in Table 5-2. These were obtained using the methodology outlined in the previous chapter. The average technical efficiency was, naturally, highest in Maha/head where there was no statistically significant technical inefficiency. Therefore, firm specific technical efficiency measures were not obtained for this location. In Maha/tail, the mean technical efficiency was 50 per cent with a standard deviation of 18.87 per cent. In the Yala/rice environment, mean technical efficiency was 45 per cent with a standard deviation of 19.7 per cent. In the Yala/chillie environment, the mean technical efficiency was 44 per cent with a standard deviation of 18.95 per cent.

Table 5-2: Frequency distributions of farm specific technical efficiency

Range	Maha/tail	Yala/rice	Yala/chillies
0-10	1(1.63)	1(1.14)	5(4.09)
11-20	3(4.91)	3(3.44)	3(2.94)
21-30	2(3.27)	15(17.24)	10(9.80)
31-40	10(16.39)	30(34.48)	31(30.39)
41-50	21(34.42)	9(10.34)	23(22.54)
51-60	8(13.11)	11(12.64)	12(11.76)
61-70	8(13.11)	7(8.04)	7(6.86)
71-80	2(3.27)	4(4.59)	5(4.90)
81-90	4(6.55)	6(6.89)	4(3.92)
91-100	2(3.27)	1(1.14)	2(1.96)
No. of cases	61	87	102

Note: figures within parentheses are percentages.

5.3.1 Factors Affecting Farm-Specific Technical Efficiency

Variations in TE arise from different practices/techniques employed in using given inputs. Farmers may vary their techniques/practices because of their individual perceptions about the technology and because of differences in their ability to implement or practice the perceived technology. If all component techniques and practices are known, and their effectiveness can be measured, then measured differences in technical efficiency variation may be fully explained.

In the absence of information on such finer points of technology, it is possible to relate variations in technical efficiency to known techniques and farmer attributes which are likely to determine technical efficiency, i.e., the effectiveness of input application. Here, these farmer attributes stand as proxies for unmeasured differences in practices.

Accordingly, various farmer attributes such as education, age, previous experience in growing HYV's (indicated by farmer background) and land specific experience of farmers were used as proxy variables in the following regression analyses of the determinants of technical efficiency variation. Direct measures of alternative techniques were also used as well as timing and quality differences in inputs where satisfactory measures and data were available. Thus, variables such as variety were included as explanatory variables at this stage of the analysis; the rationale for this procedure was that they are management variables that could be chosen by the farmer. A potential problem here is that of collinearity between farmer attributes and practices, and resulting inconsistency of OLS estimates in regression analysis. However, examination of the correlation matrices of the regressions reported below did not reveal correlations between explanatory variables exceeding .30. It should be noted that a similar potential for collinearity problems exists even if only practices were used to explain technical efficiency variations, i.e., good farmers may use all or most of the best practices. Indeed it is reasonable to expect good farmers to use most of the best practices together.

Technical efficiency (TE) variations have been explained in terms of explanatory variables using OLS estimates (Timmer, 1971; Page 1984). However, when TE is defined as the ratio of actual (adjusted for stochastic influences) to highest achievable output for a given level of inputs, it is bounded between zero and one and therefore is not normally distributed. As a result the OLS regression estimates with TE as the dependent variable are inefficient and the predicted values of TE may fall outside the bounded interval. In addition, a non-normally distributed dependent variable results in a non-normal error term and, therefore, prevents tests of significance and the making of confidence interval statements (Maddala 1977). Accordingly, we use a transformation of TE, where $T = \ln [TE / 1 - TE]$ which assumes values between $-\infty$ and $+\infty$, as the dependent variable in our regressions as reported in Tables 5-3 to 5-5.

There are two problems that can arise when attempting to analyse the determinants of technical efficiency. Firstly, "pure" TE can be confounded with farm specific environmental factors in the measured TE; this is likely to be higher when micro environmental differences across farms are high. Thus we could expect that this problem will be relatively less serious in the Maha/head. Secondly, the determinants of individual TE will be varied and complex. In a cross section study, the general factors influencing TE are likely to capture only a fraction of the multitude of factors operating on an individual.

Regression analysis of the determinants of TE variation in the Maha/tail with T as the dependent variable (Table 5-2) showed that Wet Zone (Kandy District) farmers had significantly higher efficiencies than others. Their previous exposure to HYV's (since the late 1960's) and their experience with practices such as transplanting, manual weed control and chemical fertilizer application (ARTI 1974) were clearly useful in this environment. In addition, they were competent at land levelling, terracing and the construction of field bunds which are essential components of good water management. This expertise in water management was developed over generations of rice cultivation on terraced hill slopes with water tapped from small natural waterways.

Literacy, defined as a minimum of three years of formal schooling was found to be positively and significantly related to TE. This was based on the proposition that literacy is more relevant in the determination of productivity in LDC agriculture than the total period of formal education (Jamison and Lau, 1982 and Lipton, 1985).

Farmers who have land specific experience (LSE) obtained by cultivating the same plot of land for a considerable period (at least five years) were found to be technically more efficient than others (see Rosenzweig and Wolpin, 1985; Ekanayake and Jayasuriya, 1986).

The TE of part time farmers (those who do not engage in farming as their sole economic activity), was significantly lower than full time farmers. The need to allocate time and managerial effort between on farm and off farm activities may have been an important factor here.

The second group of technical efficiency determinants comprised the following agronomic practices:

1. establishment date of the rice crop (early establishment would help to avoid water stress and the usual build up of pests towards the end of the season), and
2. weed and pest control (lower pest and weed damage levels[5] were taken as indicators of better management). We mentioned earlier that pesticides and weedicides did not affect output significantly when included as explanatory variables in the estimated production frontiers.

In addition, the farmers receiving bank loans were found to be more technically efficient. Access to capital can clearly affect allocative efficiency by enabling farmers to apply optimal quantity of inputs. However, the timely availability of capital may also affect technical efficiency, since delays in obtaining credit may affect the timing of input application. In system H bank loans for cultivation purposes are provided in kind, at the required time, i.e., fertilizer and agro chemicals, and therefore, farmers receiving bank loans do not encounter input supply bottlenecks. Accordingly, the availability of bank loans facilitates the timely application of inputs and may explain the higher technical efficiency of farmers receiving credit. It is interesting to note that the dummy for those farmers who were heavily indebted (in excess of Rs. 5000) and therefore had limited access to capital, had a negative (and significant) regression coefficient.

Regression analysis explaining variation in technical efficiency in the Yala/rice environment (Table 5-4) showed that Purana farmers were the most efficient of the three farmer categories in the area. This suggests that Purana farmers benefited from their greater experience and familiarity with the Yala season environment, i.e., their greater environment-specific experience. Technical efficiency decreased with age. On the one hand, age may be related to the efficiency of tasks performed, and on the other, to adoption of new practices/techniques. Old age may reduce the efficiency of performing

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[5] The farmers who manually weeded their fields appeared to have lower output for similar levels of other inputs as indicated by negative regression coefficients. This apparently surprising result may be explained by fact that the amount of weed control labour may actually be an indicator of the extent of weed infestation rather than that of an output increasing input.

Table 5-3: OLS Estimates of determinants of technical efficiency variation in Maha/tail environment

Variable	Coefficient
Intercept	-0.2304 (0.3128)
Wet Zone farmers a/	+0.9270*** (0.2160)
Literacy a/	+0.7171*** (0.1897)
Part-time farmers a/	-0.4656** (0.2245)
LSE farmers a/	+0.4954** (0.2476)
Farmers receiving bank loans a/	+0.7314** (0.3369)
Heavily indebted farmers a/	-0.4710 (0.3823)
Early established long aged varieties a/	+0.7671 (0.6383)
Early established short aged varieties a/	+0.4315*** (0.1640)
High pest damage a/	-0.8583*** (0.1800)
High weed damage a/	-0.3495* (0.1919)
Manual weeding a/	-0.4068** (0.1716)

$\bar{R}^2$= .60

F= 9.2395***

Notes: figures within parentheses are standard errors of estimates.

*** significant at the 1 per cent level.

** significant at the 5 per cent level.

* significant at the 10 per cent level

a/ dummy variable

certain tasks. Previous experience in cultivation with an old technology may make older farmers conservative in their adoption of new practices and therefore age may become a liability rather than an asset in learning and applying new practices, i.e., it may be hard to change traditional practices learned by experience.

As expected, farmers with land specific experience had higher technical efficiency. About half the farmers did not have such experience as they had moved from the tail to cultivate land in the head. Where land is heterogenous, the optimal set of management practices will vary between farms. Therefore, a farmer applying a known technology in a new farm (which has an unknown micro environment) is likely to be less efficient than another who applies it in a familiar environment.

In Yala, those who leased in land were more efficient. Surprisingly, farmers who received bank loans appeared to be less technically efficient. The literature on "X-efficiency and effort" (Corden 1976, Martin 1978) suggests that subsidized industries may be affected by a reduction in the managerial effort applied to the firm depending on the income effect of a subsidy. Thus the impact of subsidies such as cultivation credit on technical efficiency can be ambiguous. They may increase or decrease technical efficiency depending on the relative strengths of their income and substitution effects.

Those who cultivated long aged varieties had positive technical efficiency while those who cultivated short aged varieties had a negative coefficent. Long aged varieties are normally expected to have a higher yield potential under farmer management. However, under rainfed conditions short aged varieties are preferred to avoid moisture stress to the crop towards the end of the season. Under conditions of limited intermittent irrigation (as observed in Yala season), we would expect that long aged varieties would have higher yields because as Senadhira (1980) points out, they are able to recover from periodic water stresses.

Overall, the total variation in technical efficiency explained by the regression ($\bar{R}^2$) for the Yala/rice environment was lower than that for the Maha/tail. This does not mean that the regression carried out and the included variables were not important[6] . The regression was statistically significant as were some of the variables included (the relevant F and t statistics are given). It was pointed out at the beginning of this section that such low explanatory power of regressions of technical efficiency are to be expected.

Table 5-4: OLS Estimates of determinants of technical efficiency variation in Yala/rice environment

Variable	Coefficient
Intercept	1.2795*** (0.4879)
Purana farmers a/	+0.5172*** (0.2121)
Farmer age	-0.0136* (0.0078)
LSE farmers a/	+0.5172*** (0.2121)
Leasers a/	+0.6491* (0.3904)
Farmers receiving bank loans a/	-1.1569* (0.6495)
Water shortage	-0.2713** (0.1340)
Long aged varieties	0.8434**
Short aged varieties	-0.3495* (0.2055)

$\bar{R}^2$= .20

F = 3.7258***

Notes: figures within parentheses are standard errors of estimates.
*** significant at the 1 per cent level.
** significant at the 5 per cent level.
* significant at the 10 per cent level
a/dummy variable

The regression results for Yala/chillies was similar to Yala/rice in terms of the total variability explained. Again, omitted farm-specific environmental variables may have

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[6] For a further elaboration of this point, see Rahm and Huffman (1984, 1986).

Table 5-5: OLS Estimates of determinants of technical efficiency variation in Yala/chillies environment

Variable	Coefficient
Intercept	-1.0633 (0.6883)
Wet Zone farmers a/	+0.3265 (0.2322)
Purana farmers a/	+0.3901* (0.2357)
Part-time farmers a/	0.3070 (0.2326)
LSE farmers a/	-0.4220** (0.1874)
Farmers receiving bank loans a/	+0.8678** (0.4144)
Farmers reporting high pest damage a/	+0.6249*** (0.2011)
High weed damage a/	-0.3671*** (0.1242)
Water shortage a/	-0.3580** (0.3125)

$\bar{R}^2$= .18

F=3.8374***

Notes: figures within parentheses are standard errors of estimates.
*** significant at the 1 per cent level.
** significant at the 5 per cent level.
* significant at the 10 per cent level
a/ dummy variable

been partly responsible for this. As in the Yala/rice situation, Purana farmers were found to be the most efficient. In the case of chillies, they appear to have benefitted from their previous experience in chillie cultivation and from their familiarity with the environment, although the technology they used previously was substantially different, being based on traditional varieties and under rainfed conditions. Farmers receiving bank loans had high technical efficiency. In the case of chillies, which is more capital intensive than rice, bank loans raises TE. The average cost of production of chillies in the sample area was double that of rice (Table 4-1).

Further, and as expected, farmers reporting high weed damage and high water stress were technically inefficient. However, farmers who reported high pest damage were technically efficient. One reasonable explanation for this surprising result is that good farmers may have been able to identify pest damage. Certain types of pest attacks are known to be difficult to identify (Godell et al. 1982). Another unexpected result is the negative coefficient for land specific experience, which does not seem to have a reasonable explanation. However, as we have noted earlier most of these farmers were cultivating chillies on a significant scale on irrigable land for the first time. Their previous experience was with cultivating rice, a crop which is differs greatly in management requirements from chillies. That experience, in fact, may have acted to prevent them from learning the very different set of practices required for chillie cultivation on that land. Field observations indicated that most of these farmers who had been used to the very high water requirements for rice on well drained soils tended to over-irrigate chillies.

Land specific experience should be distinguished from environment specific experience associated with Purana farmers. A Purana farmer may not necessarily have the latter since he may be located in the tail and is required to move to a farm located in the head during the Yala season.

5.4 Farm Specific Allocative Efficiency

In the previous section, it was argued that the accuracy of a farmer's perception of a given technology and his ability and capability to practice it determines his technical efficiency. The correct perception of the parameters of a technology (i.e., the marginal productivities of various inputs when combined with alternative practices) and the ability to implement that technology effectively are prerequisites for allocative efficiency. However, a profit maximizing farmer also needs ability to seek and decode market information so that he can equate marginal value products of inputs with their marginal costs. Thus education, experience and access to market information may determine allocative efficiency too, apart from their influence on technical efficiency. The role of education in seeking market information and decoding them in the determination of allocative efficiency is obvious and needs no elaboration. Long experience in operating in particular markets, e.g., the market for rice or chillies, may provide additional insights. Similarly, those who have general experience in operating within a market economy may have an advantage in efficient allocation of resources over those who have had little previous exposure to markets. Finally, some farmers may experience particular constraints in their access to resources which may prevent them applying an allocatively efficient level of inputs.

Table 5-6: Frequency distributions of farm specific allocative efficiencies

Range	Maha/head	Maha/Tail	Yala/rice	Yala/chillies
< 0	0	6(9.83)	3(3.44)	1(0.98)
0-10	1(1.58)	0	0	1(0.98)
11-20	0	0	0	18(17.64)
21-30	0	1(1.63)	0	33(32.35)
31-40	1(1.58)	2(3.27)	2(2.29)	26(25.49)
41-50	2(3.17)	11(18.03)	10(11.49)	16(15.68)
51-60	2(3.17)	19(31.14)	7(8.04)	4(3.92)
61-70	8(12.69)	14(22.95)	8(9.19)	1(0.98)
71-80	12(19.04)	7(11.47)	14(16.09)	1(0.98)
81-90	25(39.68)	1(1.63)	12(13.79)	0
91-100	12(19.04)	0	31(35.63)	1(0.98)
No. of cases	63	61	87	102

Note: figures within parentheses are percentages.

The calculation of allocative efficiency (AE) of individual farmers at farm gate prices is difficult owing to the problems in identifying farm specific opportunity costs as discussed in Chapter 3. We thus derive farm specific measures based on market prices which we will call "*apparent* allocative efficiency". Unlike technical efficiency, allocative efficiency (as defined in Chapter 3) may take negative values if farmers overallocate inputs and therefore a comparison of mean values for each location cannot be meaningful. However, the distributions of firm specific efficiency given in Table 5-5 provide an understanding of the nature of distributions.

In the Maha/head, 75 per cent of the farmers were more than 80 per cent allocatively efficient, whereas in the Maha/tail, 75 per cent of the farmers were less than 40 per cent allocatively efficient. In the Yala season/rice 75 per cent were above 70 per cent allocatively efficient while for Yala season/chillies 75 per cent of the farmers were less than 40 per cent allocatively efficient.

5.4.1 Technical Efficiency as a Determinant of Allocative Efficiency

The preceding discussion showed that a farmer's perception of a technology is an important determinant of both his technical and allocative efficiency. If individual farmers know the parameters of their production functions and markets with certainty, and aim to maximize profits, they can achieve both technical and allocative efficiency. To the extent that their knowledge of the technology is imperfect there is likely to be both technical and allocative inefficiency, i.e., the efficiencies are likely to be positively correlated.

Given that inefficiency is related to the dynamics of technological change, such a positive correlation between efficiencies may be expected to prevail over time, i.e., with increasing familiarity with a new technology, technically efficient farmers will be allocatively efficient. However, such a correlation need not necessarily exist in static measures of firm specific efficiency within a dynamic situation, i.e., where farmers are in the process of adjusting to various disequilibria. For example, those farmers who adopt new practices immediately after their introduction will appear to be technically more efficient than others. The former group however, may be allocatively inefficient since they may be uncertain about the performance of these practices and thus are unable to judge appropriate input levels and thus maximize profits. Further, they may not attempt to maximize profits if they are aware of this imperfection in their perception of the technology with these new practices. The latter group, on the other hand, may achieve allocative efficiency since they are applying familiar practices.

For decades economists have been aware of this positive correlation between technical and allocative efficiencies, and were concerned about the resulting simultaneity bias in single equation estimates of production functions (Hoch 1958). One way of avoiding this bias and the resulting inconsistency of production function estimates is to assume that farmers maximize the mathematical expectation of profits given the stochastic nature of output in agriculture (Zellner et al. 1966). The other method is to follow the duality approach by estimating profit or cost functions.

Schmidt and Lovell (1980) introduced a method of testing for significant positive correlation between technical and allocative efficiencies of a sample of firms and also a method to allow for this correlation in obtaining consistent production frontier estimates. Their estimates of the frontier function under the standard assumption of uncorrelated efficiencies and under their "generalized" model, which allows for positive correlation of efficiencies, were found to be strongly similar, in spite of the presence of a statistically significant positive correlation between the efficiencies. Thus they conclude that...

> This strong similarity in the two sets of estimates of frontier technology is comforting. It suggests that the way in which we model inefficiency relative to a stochastic frontier, and the nature of efficiency we find, has no appreciable effect on our inferences concerning the shape and the placement of that frontier. (p 91).

At the time the Schmidt and Lovell (1980) paper appeared there was no means of obtaining firm specific technical efficiency estimates relative to a stochastic frontier function. Hence a special test to determine the existence of correlation between efficiencies was required. However, a method of obtaining firm specific technical efficiency measures is now available and therefore, the relationship between the two efficiencies can be identified through regression analysis.

Despite the long standing awareness of correlated efficiencies, surprisingly little attention has been given to this in the empirical literature on firm efficiency. A notable exception is Page (1980). He estimated a deterministic production frontier and obtained Farrell-type measures of technical and price (allocative) efficiency for three industries in Ghana and found a significant positive correlation between the two efficiencies of firms in the logging industry. However, he, too, recognized that the relationship between these may be more complex and that such positive correlations may not necessarily be observed empirically. He stated that:

> Correlation analysis of the indices of technical and price efficiency supports such an interpretation for logging where the two indices are significantly and positively correlated, suggesting that managers who are technically inefficient may also be unaware of opportunity costs and alternative techniques [input output combinations]. But the relationship between the choice of technique and technical efficiency may be more complex. Variations in capital intensity may reflect different relative factor prices faced by individual firms. Capital intensive firms should be those with access to the most highly subsidized segments of the capital market. Such subsidies may have an income effect tending to reduce the amount of managerial effort supplied to the firm, and may, therefore, lower the level of technical efficiency. (p 337).

The nature of the relationship between technical and allocative efficiencies is examined here by regression analysis with the former as the independent variable[7] . Our AAE is not normally distributed. Therefore, as in the case of TE, we obtain 'A' a measure of AAE, where A = ln [1 / 1 - AE], which can assume values ranging from $-\infty$ to $+\infty$ (A=0 when no profits are made). Tables 5-9 to 5-12 present regressions for each environment in the study area.

1. Maha/head farmers were both technically and allocatively highly efficient. The available technology was developed for such a favourable environment where conditions are quite homogeneous. Here, farmers are able to implement the technological package with minimum demands on their human capital. The new technology needs minimal

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[7] Note that Schmidt and Lovell (1980) and Page (1980) used Farrell's (1957) definition of allocative efficiency. Our approach differs from this as outlined in Chapter 3. A problem with the former definition is that technically inefficient farmers are allocatively inefficient as well by definition. An empirical illustration of this point is given in section 5.5. Also see Ekanayake (1987) and Ekanayake and Shand (1987)

adjustment to farm conditions. Regression analysis of the efficiency relationship is not feasible due to the invariance in technical efficiency among farmers in this location.

2. On the average, Maha/tail farmers are both technically and allocatively less efficient. There is, however, a strong positive correlation between the two efficiencies as seen in Regression 1 for the tail (Table 5-11). Another regression specifying a quadratic relationship between technical and allocative efficiencies (Regression 2, Table 5-11) gave a better fit, but the magnitude of the coefficient of the squared term was negligible. This suggests that both technical and allocative inefficiencies are related to the existing levels of understanding of the technology.

3. There was a generally high degree of technical and allocative inefficiency in the Yala/rice environment, but no significant linear relationship was found between these efficiencies. The relationship, in fact, varied among different farmer groups (Table 5-7). First, there was a small group of farmers who were technically highly efficient but were only moderately efficient allocatively. Second, a large majority of farmers were only moderately efficient technically, but were highly allocatively efficient. Third, a few farmers had both very low technical and allocative efficiencies.

Here, a regression specifying a quadratic relationship between technical efficiency and allocative efficiency showed that the intercept and the two independent variables TE (technical efficiency) and TE^2 (technical efficiency squared) were significant at the 1 per cent level with the expected signs, i.e., TE positive and TE^2 negative (Regression 1 Table 5-12).

The observed quadratic relationship between technical and allocative efficiencies suggests that technically highly efficient farmers were allocatively inefficient. This may be explained either by a lack of adequate knowledge or perception of the parameters of the technology for maximizing profits or by specific constraints on the application of correct input levels, e.g. capital. The latter explanation, however, lacks credibility in this crop year, for the Yala season followed a good Maha season with high yields and the capital requirements in the Yala season were relatively low owing to the smaller area cultivated by each farmer. Further, it is hard to find specific resource constraints which only affect technically efficient farmers.

The former explanation seems to be the more realistic. Detailed recommendations do not exist to guide farmers in cultivating rice in the Yala season. The lack of special recommendations and therefore of a specific set of practices for the Yala season follows from the project planning expectations of similar water availability for both Maha and Yala seasons. In practice, however, the two seasons represent very different environments for rice cultivation. Therefore, farmers are left to experiment and learn the appropriate technology by experience. In this context, a majority of farmers chose to apply a low levels of inputs although all the farmers cultivated modern rice varieties (Table 4-2). For example, 72 percent of the farmers broadcast seeded instead of transplanting, while only 7 percent applied basal fertilizer. Only 5 percent of the farmers cultivated long aged varieties. We used discriminant function analysis to explore the characteristics of the farmers grouped by the two attributes TE and AE. The farmers were grouped into two. The first group comprised farmers with TE > 65 percent and moderate AE and the remainder were allocated into the second group. The estimated discriminant function, using the SPSS (1975) package, is presented in Table 5-8. The major discriminating variables in order of their relative contribution to the discriminant function were choice of variety, establishment method and the use of basal fertilizer. The discriminant function was able to correctly classify 84 per cent of the cases between the two groups. As shown in Table 4-2, the cultivation of long and medium aged rice varieties, transplanting and the use of basal fertilizer are more typical of Maha season practices.

Discriminant function analysis was again used to explore the difference in characteristics of farmers who transplant long and medium aged varieties of rice in the Yala season and others. The standardised discriminant function showed that the most

Table 5-7: Relationships between allocative efficiency and technical efficiency in the Yala/rice environment

TE Range	No.of farmers	Tech. Efficiency		Allo. Efficiency	
		mean	std. dev	mean	std.dev
> 65%	16	78.6	10.2	50.4	10.1
< 65% <	68	38.5	10.8	84.1	14.7

Note: Three farmers in the sample had negative allocative efficiencies and were omitted from this analysis.

Table 5-8: Standardized canonical discriminant function coefficients for Yala/rice farmers with TE > 65 per cent and others

Variable	Coefficient
Long aged varieties	1.1160
Medium aged varieties	0.4511
Use of basal fertilizer	-0.4952
Transplanting	0.3455

important variable influencing group membership was being a Wet Zone farmer (Table 5-9). This finding that Wet Zone farmers were closely associated with those practices found to be efficient in the Yala season suggests that their previous experience in the use of such practices may have influenced their choice of transplanting as the appropriate establishment method. On the other hand, the more cautious approach of the Purana villagers in their selection of practices, i.e., broadcast seeding and the use of short aged rice varieties to avoid potential damage from water stress, may be due to their long experience of the variability in the Dry Zone rainfall pattern and their relatively short exposure to the new rice technology.

Table 5-9: Standardized canonical discriminant function coefficients for Yala/rice farmers transplanting long or medium aged varieties and other farmers

Variable	Coefficient
Wet Zone farmers	0.9723
Purana farmers	0.1161
Farmer age	0.1396
Literacy	0.1836
Off farm income	-0.1242

Farmers here, even after eight years of settlement, were still experimenting with practices based on their previous experience in similar activities or environments and their familiarity with certain techniques. They were, therefore, unlikely to have fully perceived the true input output relationships resulting from their actions in the new environments. As their perceptions more closely reflect actual outcomes of their practices with greater experience, the magnitude of resulting allocative errors would decrease.

Treating technical efficiency as a neutral transformer of the FPF, farmer specific production functions are derived. Then allocative efficiency for a technically efficient farmer requires higher input levels than for a relatively inefficient farmer. During a process of experimentation and learning by doing, farmers may not expect high technical efficiencies and are likely to to err more in their allocative decisions by under-using inputs.

It is tempting to attribute the apparent allocative inefficiency of technically efficient farmers to a higher perceived risk and a resulting risk minimization strategy. However, it should be noted that even in the absence of such perceived risk and an associated allocative strategy, farmers who experiment with new technologies and achieve good results and therefore become relatively technically efficient can be allocatively inefficient if their ex-ante perception of the technology deviates from its "true" ex-post outcome. As such, the observed divergence may be attributed to human error in resource allocation. Greater experience will tend to reduce divergences from allocative efficiency due to such errors.

4. In the Yala/chillie environment the relationship between technical and allocative efficiencies was negative and significant (Regression 1 Table 5-13). As mentioned earlier, this was the first season when farmers in the study area cultivated chillies on this scale and under irrigation. This crop too suffered from a lack of detailed recommendations even more than in the case of the Yala/rice crop. Here, too, farmers were experimenting and it is unlikely that they correctly perceived the outcomes of their practices. Probably, the same reasons given above for Yala/rice environment explain the allocative inefficiency of these technically efficient farmers.

As farmers gain more experience, the differences between their perceptions and actual outcomes may converge over time and allocative efficiencies of farmers for the two Yala season crops is likely to improve.

5.4.2 Other Factors Affecting Farm-Specific Allocative Efficiency

Farmers in the Maha/head had high AAE. More than three fourths of these farmers had AAE greater than 70 per cent . Regression analysis showed that older farmers had higher AAE (Table 5-10) in this environment. This suggests that greater farming experience raises allocative efficiency. Second, AAE was positively related to the quantity of family labour used per unit of land, which could suggest factor market imperfections and/or quality differences between types of labour.

AAEs varied more among Maha/tail farmers than among Maha/head farmers (Table 5-6). Regression of A on a series of hypothesized determinants (Table 5-11) showed farmer age to have a positive relationship with AAE in the "tail", too. However,

Table 5-10: OLS Estimates of the determinants of variation in allocative efficiency in Maha/head environment

Variable	Maha/head coefficient
Intercept	0.9265*** (0.2916)
Technical efficiency	
Literacy a/	-0.2181 (0.1988)
Age a/	0.0111** (0.0052)
Leasers	0.3274 (0.2681)
Use of family labour (Man days/Acre)	0.0215*** (0.0080)
$\bar{R}^2$=	.21
F =	5.0479***

Notes: figures within parentheses are standard errors of estimates.
*** significant at the 1 per cent level.
** significant at the 5 per cent level.
* significant at the 10 per cent level
a/ dummy variable

the coefficient for the quantity of family labour used per acre was negative and was thus different from that in the "head". Such a negative relationship may occur due to "overuse" of family labour owing to a lower opportunity cost of family labour or to a perceived higher productivity of family labour. Technical efficiency was positively and significantly correlated with AAE; therefore, it was expected that some of the determinants of TE had a similar relationship with AAE, too (regression 2 in Table 5-11).

In the Yala/rice environment (Table 5-12) apart from technical efficiency, other significant variables explaining AAE variation were use of bank loans which had a positive coefficient and the rate of interest paid for loans which had the expected negative coefficient.

Table 5-11: OLS Estimates of the determinants of variation in allocative efficiency Maha/tail environment

Variable	Regression 1	Regression 2	Regression 3	Regression 4
	coefficient			
Intercept	0.2681* (0.1581)	-0.5524*** (0.2030)	0.2225 (0.1870)	-0.0689 (0.1934)
Technical efficiency	0.0100*** (0.0032)	0.0523*** (0.0082)		0.0042* (0.0025)
Technical efficiency squared		-0.0004*** (0.00007)		
Literacy a/	0.2997* (0.1590)		-0.0791 (0.1057)	
Age	0.0093 (0.0060)		0.0248*** (0.0040)	0.0230*** (0.0034)
Farmers from Wet Zone a/			0.0218 (0.1394)	
Purana farmers a/			-0.0126 (0.1213)	
LSE farmers a/			0.0772 (0.1585)	
Bank loans a/			0.3876** (0.1971)	
Part time farmers a/			-0.2749** (0.1425)	
Use of family labour (Man days/Acre)			-0.0262*** (0.0063)	-0.0161*** (0.0056)
$\bar{R}^2$=	.13	.41	.52	.50
F =	9.724***	21.909***	9.062***	20.672***

Notes: figures within parentheses are standard errors of estimates.
*** significant at the 1 per cent level.
** significant at the 5 per cent level.
* significant at the 10 per cent level
a/ dummy variable

In the Yala/chillie environment (Table 5-13) Wet Zone farmers were found to be allocatively inefficient. This is consistent with their lack of experience in chillie cultivation as well as their lack of familiarity with the Yala season environment. Surprisingly, literacy had a negative relationship with AAE.

Table 5-12: OLS Estimates of the determinants of variation in allocative efficiency in Yala/rice environment

Variable	Regression 1	Regression 2	Regression 3
	coefficient		
Intercept	0.6175	2.4287***	2.5534**
	(0.8744)	(0.8744)	(1.1976)
Technical efficiency	0.0918***		0.0447
	(0.0363)		(0.0403)
Technical efficiency Squared	-0.0011***		0.0007**
	(0.0003)		(0.0003)
Age		-0.0126	0.0187
		(0.0138)	(0.0123)
Purana farmers a/		0.2489	0.3018
		(0.3528)	(0.3240)
Part time farmers a/		0.5465	0.4524
		(0.3837)	(0.3389)
LSE farmers a/		-0.5558	0.2971
		(0.3455)	(0.3108)
Bank loans a/		2.3338**	1.7920*
		(1.1777)	(1.0454)
Rate of interest		-0.0454**	-0.0517**
		(0.0229)	(0.0233)
Amount borrowed		0.0003	0.0002
		(0.0002)	(0.0002)
$\bar{R}^2=$	.22	.09	.29
F=	13.3989***	2.1630**	4.9405***

Notes: figures within parentheses are standard errors of estimates.
*** significant at the 1 per cent level.
** significant at the 5 per cent level.
* significant at the 10 per cent level
a/ dummy variable

5.5 Farm Specific Economic Efficiency

The distributions of farm specific economic efficiencies for each environment are given in Table 5-14. As explained in Chapter 3, economic and allocative efficiency measures were identical for the Maha/head, since firms are technically efficient here. In the other three environments, economic efficiencies are well below their respective

Table 5-13: OLS Estimates of the determinants of variation in allocative efficiency in Yala/chillies environment

Variable	Regression 1	Regression 2	Regression 3
	coefficient		
Intercept	0.7869*** (0.0633)	0.5637*** (0.0636)	0.9350*** (0.0773)
Technical efficiency	-0.0086*** (0.0013)		-0.0085*** (0.0012)
Literacy d/		-0.1441** (0.0683)	-0.1647*** (0.0572)
Farmers from Wet Zone d/		-0.1342** (0.0597)	-0.0757 (0.0507)
$\bar{R}^2$ =	.29	.07	.35
F=	43.0570***	4.7728***	19.1471***

Notes: figures within parentheses are standard errors of estimates.

*** significant at the 1 per cent level.
** significant at the 5 per cent level.
* significant at the 10 per cent level
a/ dummy variable

allocative efficiencies in percentage terms. This is expected as economic efficiency is a combination of both technical and allocative efficiencies of firms. There was a high correlation between these economic efficiency measures and the technical efficiency measures for each farm (Table 5-15). As our economic efficiency concept is similar to the allocative efficiency concept used by Farrell (1957) as shown in Chapter 3, the two efficiencies are positively correlated. These results also suggest that once farmers attain full technical efficiency most of their economic inefficiency will tend to disappear.

5.6 Conclusions

Our results are, by and large, consistent with the hypothesis that farmers vary in their ability to adjust succesfully to new technology and different environments and that human capital accumulated over their life time is a major determinant of such ability. From their first season in the project, Mahaweli farmers all adopted the new high yielding rice varieties. In the Yala season, they chose the appropriate cropping pattern, i.e.,

Table 5-14: Frequency distributions of farm specific economic efficiencies

Range	Maha/head	Maha/tail	Yala/rice	Yala/chillies
0 <	0	6(9.83)	3(3.44)	1(0.98)
0-10	1(1.58)	8(13.11)	47(54.02)	101(99.02)
11-20	0	27(44.26)	22(25.28)	0
21-30	0	14(22.95)	10(11.49)	0
31-40	1(1.58)	3(4.92)	5(5.74)	0
41-50	2(3.17)	3(4.92)	0	0
51-60	2(3.17)	0	0	0
61-70	8(12.69)	0	0	0
71-80	12(19.04)	0	0	0
81-90	25(39.68)	0	0	0
91-100	12(19.04)	0	0	0
No. of cases	63	61	87	102

Note: figures within parentheses are percentages.
a/ There is no significant technical inefficiency here.

Table 5-15: The Relationship Between Firm Specific Economic Efficiencies and Technical Efficiencies

Coefficients	Maha/head	Maha/Tail	Yala/rice	Yala/chillies
Constant		-0.1138***	0.1592***	0.0666***
		(0.0212)	(0.0029)	(0.0016)
TE		0.0065***	0.1141***	0.0248***
		(0.0004)	(0.0029)	(0.0016)
$\bar{R}^2$ =		.80	.94	.70
F=		249.6333***	1457.7797***	239.2523***

chillies in well drained soils and rice in poorly drained soils which demonstrated their sensitivity to costs and returns from alternative cropping patterns. This showed that even traditional farmers respond to new opportunities for improving their economic status and that they will rapidly adopt new technology and new crops when they perceive substantial increases in profits.

Estimated differences in the levels of technical inefficiency in the three rice environments were consistent with the relative favourability of each for the available technology in terms of the availability of water. In the most favourable environment (Maha/head) technical inefficiency was not significant. The levels of the significance of technical inefficiency were consistent with the estimates of returns to scale for each location.

In a dynamic setting where farmers are involved in a process of adjustment, full (100 per cent) technical and allocative efficiencies are not expected in the short run even when they are profit maximizers operating in a competitive market environment. Full efficiency is a characteristic of static environments. Where the environment for rice cultivation was most favourable and the technology needed no significant farm specific adjustment, farmers were technically and allocatively highly efficient. By the time our study was undertaken some eight years after settlement, the farmers in this most favourable environment were already well adjusted to the new environment. This suggests that adjustment is likely to be rapid under such favourable conditions and variation among farmers diminishes rapidly. The rate of adjustment may have varied here in the initial stages, although at present there is relatively little variation. In less favourable environments, as expected, farmer efficiencies were much lower. The available technology needed farm specific adjustments and therefore the performance of individual farmers were influenced by their personal capacities as influenced by literacy, age, environment-specific experience, land specific-experience, access to capital and certain cultural practices.

In the Yala season, when variations in micro environment across farms are expected to be most pronounced, attempts to relate inefficiencies to human capital and other determinants were less successful than in the Maha season. Estimates of efficiencies in this situation were probably confounded with the effects of omitted farm-specific variables whose impact was greater in this water scarce environment. Such deviations from the frontier caused by environmental factors cannot be explained by human capital endowments. Estimates of firm specific allocative efficiency are also affected if the relevant frontier production function suffers from an omitted variable bias.

The most important variable explaining allocative efficiency variation was technical efficiency. Where farmers are price takers, and future prices are known with certainty, allocative efficiency is dependent on the farmer's knowledge of his technology, i.e., the production elasticities of inputs. In a relatively favourable environment, with a well defined technology, farmers who have a good perception of the technology will be technically efficient and are likely to be allocatively efficient as well. This is illustrated in the two Maha season environments by the positive relation between the two efficiencies.

In the Yala season, the technology is not well defined. There are no detailed recommendations to guide farmers in rice or chillie cultivation, so each farmer has to learn the best optimal package of practices through experience. Therefore, it would be difficult for farmers to be able to assess accurately the outcomes of their actions in terms of various practices and inputs in this season which in turn makes it difficult for them (even if they wanted) to maximize profits. In this situation, they are forced to experiment with alternative techniques and practices and they do so with varying levels of success. The lack of an accurate perception of the output response of inputs and practices at this stage of experimentation prevents them from achieving allocative efficiency. Farmers who "accidently" achieve high technical efficiency are likely to err in the determination of allocatively efficient input levels than others, since at higher levels of technical efficiency, allocative efficiency requires higher levels of conventional inputs. Therefore the two efficiencies are likely to be negatively related. This was actually observed in the Yala season.

CHAPTER 6

Social Efficiency Analysis

The foregoing analysis revealed substantial inefficiencies in current resource allocation by individual farmers within Mahaweli project at prevailing market prices. These prevailing prices reflect the influence of government interventions in markets as well as other imperfections in markets. In a recent theoretical work Stiglitz (1987) describes government intervention in agricultural markets as follows:

> They [governments] subsidize farmers (mostly in developed countries); they tax farmers (mostly in developing countries); they try to stabilize prices; they impose import tariffs and quotas; they restrict production; they provide food subsidies for urban areas; they support the use of fertilizer; they build irrigation systems; they offer extension services; they try to control marketing; and they provide credit often below market rates.

He lists the following "legitimate reasons" for such government intervention.

1. *Incomplete markets in insurance futures and credit* which may require government sponsored insurance and credit programmes,
2. *Public goods and increasing returns* which may justify investment in irrigation,
3. *Imperfect information* and therefore extension services,
4. *Externalities* (e.g., the successful adoption of a new technology by one farmer may convey valuable information to his neighbours, thus subsidies may be justified), and
5. *Income distribution* i.e., the concern with the distribution of income generated by free markets.

However, he cautions that such market failures do not justify government intervention, rather they identify potential areas for intervention since the causes of market failure may affect government remedies in the same way they affect markets, e.g.,

imperfect information in relation to credit markets. There is a subsidized credit scheme for rice and other crops operating through commercial banks in Sri Lanka. This scheme is also tied to a compulsory crop insurance scheme, i.e., all those who obtain cultivation loans from commercial banks are insured. However, in practice these schemes affect very few of the farmers in the island. In the sample only 5 per cent of the farmers obtained bank loans in the wet season while only 2.4 percent obtained bank loans in the dry season. In 1977, when the present agricultural credit system was created by writing off all the debts of farmers to previous schemes, the majority of the farmers in System H obtained bank credit which was given at an interest rate of 9 per cent per annum. In 1984/85 crop year the total number of farmers receiving this subsidized credit was estimated to be less than 10 per cent in the whole of System H (Panditharatna 1984). This failure of the government subsidized credit scheme is related to the familiar problem of loan recovery. Accordingly, non-institutional sources of credit dominate rural lending at apparently exorbitant rates of interest. However, the failure of the subsidized credit schemes seems to suggest the high open market interest rates are related to information costs and to high lender risks. Given the insignificance of subsidized credit in the sample, it is ignored in our social efficiency analysis.

The important subsidies are those for fertilizer and irrigation water. In Sri Lanka, irrigation water from government built schemes is supplied almost free of charge[1]. As such the loss or gain to the society owing to firm level inefficiencies may not be reflected accurately in efficiency calculations reported in previous chapters. which are based on actual market prices. In addition, distorted markets may result in social inefficiencies in production even if individual farmers are privately allocatively efficient. Policy guidelines designed to increase efficiency at farm level which do not take such distortions into account may be inappropriate and may decrease efficiency from a social viewpoint. For example, measures leading to increased allocative efficiency at farm level by encouraging farmers to increase the use of inputs may lead to overuse of subsidized inputs and thus incur social losses.

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[1] There is a water charge based on the area cultivated, but, in practice, this is not strictly enforced.

Therefore, we introduce shadow prices to the private efficiency analysis of previous chapters and obtain measures of the social benefits and costs of private farmer inefficiencies and market imperfections.

6.1 Sources of Social Inefficiency in Production

We define three types of social inefficiency based on the model of farmer private efficiency and his social efficiency introduced in Chapter 3.

1. Social cost of technical inefficiency (STIE)- This is defined as the value of output loss to the society due to technical inefficiency at shadow prices.
2. Social cost of allocative inefficiency (SAIE)- this is defined as the the loss of profit to the society owing to allocative inefficiency at farm level. This is calculated as the difference between profits (calculated at shadow prices) obtained at the actual input/output combination and those at the private profit maximizing input/output combination at market prices.
3. Social cost of price distortions (SPD)- this is defined as the difference in profits (calculated at shadow prices) to the society obtained at input/output combinations corresponding to 100 per cent technical and allocative efficiency (=economic efficiency) at shadow prices and at market prices. To the extent that market prices diverge from shadow prices, resource allocation even at 100 per cent private efficiency will deviate from the optimum resulting in a loss to the society, i.e., the inputs used and outputs obtained will differ from the situation with prices at the scarcity values of goods and services. Therefore SPD may be taken as a measure of loss to the society in crop production under a distorted price regime.

We may write these three measures as follows:

$$STIE=(Q_f - Q_1)P_q^* \tag{6.1}$$

where, Q_f is the frontier output at a given level of inputs; Q_1 is the technically inefficient output for that level of inputs; and P_q^* the shadow price of the product (say, rice). This measures the social loss due to technical inefficiency at any given level of inputs, and not necessarily at the allocatively efficient level of inputs. The most meaningful application of this measure is to the current mean level of inputs in the sample which may or may not be allocatively efficient.

$$SAIE=(P_q^* Q_{opt} - \Sigma P^* X_{opt}) - (P_q^* Q_{act} - \Sigma P^* X_{act}) \tag{6.2}$$

where, Q_{opt} is the optimum (profit maximizing) output and X_{opt} the corresponding inputs at market prices; Q_{act} the actual output and X_{act} the actual inputs. The optimum input/output combination at market prices is obtained by simultaneously solving the first order conditions at market prices as shown in Appendix II. P_q^* and P^* are shadow output and input prices.

$$SPD=(P_q^* Q_{shad}-\Sigma P^* X_{shad})-(P_q^* Q_{opt}-\Sigma P^* X_{opt}) \qquad (6.3)$$

where, Q_{shad} and X_{shad} are optimum output and input levels at shadow prices; Q_{opt}, X_{opt}, P_q^* and P^* are as defined above.

These measures can provide useful directions for government policy. This is important because policy measures to reduce these individual sources of inefficiency may be different. For example, where farmers are economically efficient as private individuals, efficiency gains are possible only through reductions in market distortions. This requires policy intervention at national level and thus affects the entire economy. Governments are not often free to remove distortions when they have been introduced to achieve several, often conflicting, objectives. For example, the removal of a fertilizer subsidy may have an adverse impact on national food production goals and income distribution goals.

On the other hand, distortions caused by market failures are not easily corrected. Distribution of irrigation water is a good example (Bromley 1980). Irrigation water has certain public good characteristics which could result in a market outcome which is socially inefficient even if a market can function effectively. Generally it is difficult to develop an efficiently functioning market in irrigation water as the measurement of water used by an individual is difficult: measuring devices are expensive and are unreliable. There are externalities, i.e., one individual's production (or utility) function is affected by another's use of water. Enforcement of water use guidelines is also difficult and the free rider problem can be serious. Distortions resulting from such market failures cannot be corrected as easily as changing market prices through taxes and subsidies.

On the other hand, the reduction in firm level technical inefficiency requires specific measures at farm or project level rather than at national level, directed towards better farmer education, extension and information services for improved efficiency in the use of available resources. Such measures may also result in improved allocative efficiency since farmers need to know the parameters of their technology to be able to equate marginal cost of inputs with their marginal returns. Allocative inefficiency among profit maximizing farmers may be caused by imperfect knowledge of their technology and markets, as well as by resource constraints. Allocative inefficiency caused by resource constraints may be corrected through interventions and measures which improve access to resources. These may be in the form of credit facilities, improved access to water, cooperative tractor services, better transport etc.

We can also perform Benefit-Cost calculations to assist choice between alternative means of improving technical or allocative efficiency at firm level. The importance of such Benefit Cost analysis in the provision of better access to resources needs no elaboration. However, measures for improving technical efficiency will incur social costs even though increased technical efficiency at farm level requires no additional inputs. For example, the training of more efficient farmers has social costs even if the farmer himself receives the training free of charge[2]. We do not attempt to make such benefit-cost calculations in this thesis due to lack of cost data on particular measures for increasing farmer efficiency.

6.2 Shadow Pricing

The process of shadow pricing presupposes a well defined social welfare function and a precise description of the economy (a general equilibrium model). Given these, shadow prices which reflect the change in welfare resulting from any marginal change in the availability of commodities and factors of production may be derived by the solution of the relevant constrained optimization problem.

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[2] It is possible that increased technical efficiency even at farm level can be achieved only by some investment in knowledge by the farmer: the technical inefficiency as defined in this study does not include this cost.

Given the social welfare function which describes the preferences of a planner or a government, shadow prices can be obtained with a model which describes the impact of a project on the entire economy by a with and without project comparison. This allows the identification of welfare improving projects and/or alternative forms of government intervention. However, various simplifying assumptions are often used to provide rules of thumb in shadow pricing since it is generally difficult to describe fully or simulate the working of the entire economy.

The theoretical literature on project appraisal and shadow pricing has evolved considerably since the early landmarks of the OECD Manual (Little and Mirlees 1968), UNIDO guidelines (Dasgupta, Marglin and Sen 1972) and the highly influential work for developing countries by Little and Mirrlees (1974). Despite the many subsequent contributions to the field of shadow pricing the Little and Mirrlees approach dominates practical applications of shadow pricing for project appraisal in developing countries. In particular, the World Bank and other international agencies as well as national planning agencies such as those in Sri Lanka use this approach.

Shadow prices can also be employed for the evaluation of welfare implications of government activities in the areas of trade, taxation, public good provision etc.,. (e.g. Timmer, 1975; Pearson et al. 1981; Timmer, et al 1983). When considered in a welfare context, shadow prices need to take into account all the repercussions of a project/government policy in an economy[3].

The Little and Mirrlees (1974) [L-M] approach derives shadow prices by relating goods and services to their internationally traded prices. This approach is also applied to tradeable but not actually traded goods as well. Goods and services which cannot be traded are shadow priced by their marginal costs. These costs are estimated by breaking

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[3] An example of the magnitude of the tasks involved in identifying the direct and indirect impact of a project on an economy is illustrated by Bell et al. (1982) in their study of the Muda Irrigation Scheme in Northwest Malaysia.

down the physical components of the goods into unskilled labour, skilled labour, tradeables and residuals. These components are then valued in terms of uncommited foreign exchange in the hands of the government, the numeraire in this approach. The skilled labour component is multiplied by a standard conversion factor which is an average tariff value to obtain its tradeable value. The unskilled labour is converted into a tradeable value using an accounting ratio. The residuals are excluded from the shadow value by treating these as representing taxes etc. Thus Little and Mirrlees disaggregate all non traded goods into their foreign exchange equivalents.

The principle of shadow pricing traded goods at their border price is generally accepted irrespective of the approach taken to define shadow prices. However, there is much controversy over the derivation of shadow prices for non traded tradeables as well as non tradeables[4]. In this study, while recognizing the various criticisms, we follow the L-M approach as elaborated by Squire and van der Tak (1975) and use shadow prices estimated by others using this approach. As is well known, shadow pricing can be very demanding in informational requirements. Further, the use of shadow price definitions which are widely used in the appraisal of various components of the Mahaweli Project has the added attraction of being consistent with other studies and would facilitate easy comparison. The numeraire of the L-M approach (uncommitted foreign exchange in the hands of the government) is especially relevant to the Mahaweli Project since the major objective of the project was import substitution of food and energy.

Traded goods were priced at their border values and the prices of non traded goods were adjusted to border values using a standard conversion factor and a shadow wage rate. We also estimated a shadow price for irrigation water based on the principle of opportunity cost.

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[4] Warr (1982) discusses the informational constraints for estimating shadow prices for non traded commodities and demonstrates, using a general equilibrium model, that potential welfare gains from correct shadow prices can be eroded by quite small errors in the estimated shadow prices.

6.2.1 The Standard Conversion Factor

In actual project appraisal it is not usually feasible to obtain shadow prices for all commodities. In such cases a general conversion factor[5] is obtained for the conversion of domestic market prices into their border price equivalents for all those commodities for which individual shadow prices cannot be obtained. The simplest way of calculating such a standard conversion factor is to use the "trade data approach". The formula used is:

$$SCF = \frac{M+X}{M(1+t_m)+X(1-t_x)} \tag{6.4}$$

where,

M = c.i.f. value of imports

X = f.o.b. value of exports

t_m = average tax on imports

t_x = average tax on exports

The practical advantages of this approach are: (a) it mainly requires readily available aggregate trade data, and (b) it is computationally not highly demanding. Simplicity in this formulation is obtained as a result of several assumptions. They are: (a) the country does not have monopoly power in trade, (b) marginal changes in expenditure on non tradeables can be neglected, (c) income effects can be ignored or that all income elasticities on spending are roughly equal to one, (d) the proportion of imports and exports adequately represent the importance of traded goods in non traded production and consumption, and (e) quantitative restrictions on trade can be ignored as being relatively small.

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[5] The SCF is closely related to the concept of Shadow Exchange Rate in UNIDO (1972) methodology as suggested by Little and Mirrlees (1974), Dasgupta (1972) and Lal (1974). The relationship between the two is given by: SCF=Official exchange rate/shadow exchange rate.

These assumptions are quite reasonable for Sri Lanka, for it is a fairly open economy with few quantitative trade restrictions and it is a small country with no monopoly power in trade in any commodity. In 1977, the Sri Lankan government adopted a policy committed to trade liberalization and it replaced most quantitative trade restrictions by tariffs (Cuthbertson and Athukorala 1986). By 1985 it maintained an exchange system virtually free of restrictions on transactions (G.G.Johnson et.al., 1985). Agrawala (1983) showed that, amongst 31 developing nations Sri Lanka had a relatively low trade distortion level. The standard conversion factor used by the World Bank in the most recent project appraisals in Sri lanka was 0.85 (World Bank 1984).

6.2.2 Shadow Wage Rate

Herath (1983) calculated a shadow wage rate for agricultural labour using the L-M procedure[6]. The formula used was:

$$SWR=c\text{-}1/s(c\text{-}m) \qquad (6.5)$$

where, c=market wage rate; m=marginal product in subsistence agriculture; s=value of savings relative to consumption;

and,

$$s=[1+1/2(r\text{-}i)]^T \qquad (6.6)$$

where, r=social return to investment; i=consumption rate of interest; and T=the time period after which savings and consumption are equally valuable.

Herath's estimation yielded a conversion factor for agricultural labour of 0.77. The most recent estimate by the World Bank for Sri Lanka is a factor of 0.8 for the conversion of the market wage rate into the shadow price (World Bank 1984).

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[6] Warr (1985) criticised this approach on the grounds that if intergenerational savings is a public good, the incorporation of a "premium on saving" into the calculation of the shadow price of labour in an effort to raise aggregate savings is self defeating.

6.2.3 Shadow Price of Irrigation Water

Ex-ante appraisals of irrigation projects typically do not usually estimate shadow prices for irrigation water. Rather, such studies estimate the rate of return for investments in irrigation. Our analysis is neither an ex-ante appraisal nor an ex-post evaluation. We are interested in the social costs of various types of inefficiencies (defined earlier) in the use of resources in current production. Thus the investment costs are "sunk" and are irrelevant as far as the efficiency of current resource use is concerned. The current issue is the optimal allocation of scarce irrigation water among competing uses.

The absence of a market for irrigation water makes the efficient allocation of this scarce resource dependent on various bureaucratic and institutional means (Bromley 1980). At the time of the field study in System H the emphasis was on regulatory means of water allocation by determining cropping patterns and areas to be cultivated together with the enforcement of a water rotation system with little or no farmer involvement. Research on efficient irrigation water allocation among small farmers elsewhere has shown that farmer organisations can play an important role (Mass and Anderson 1980). The absence of such organizations in System H may be partly explained by its relatively recent origin as a settlement and the diversity of the backgrounds of the settlers. Traditional settlements in Sri Lanka and in other countries have well defined systems of water rights and institutions to handle the allocation of water (Leach, 1980). Official attempts to promote these have not met with notable success in System H.

The absence of a market does not mean that water is a free good to society. The supply of water for agriculture has an opportunity cost where it can be used productively in alternative enterprises and where the operation and management of irrigation systems are costly.

Irrigation water is supplied to System H by means of a diversion weir built across a major river (Mahaweli River) and a storage reservoir built at the head of System H. In the wet season the local catchment of the reservoir gets substantial rainfall, and diversion water is required only for supplementing water from the local catchment of the reservoir. In the dry season, however, the reservoir is almost entirely dependent on diversions from the river.

There are two alternative uses for water at the point of diversion. One is to divert it to the reservoir for irrigation, while the other is to send it down the river to generate hydro-power. In the wet season, water is abundant and these two uses do not compete. In the dry season when water is scarce, there is competition between these two alternatives. The water diverted to the reservoir in the wet season can either be used in the wet season or may be saved for use in the dry season.

Ideally, if information on the the alternative uses of water, and their marginal productivities and other information regarding storage costs etc., are available the shadow price of water may be derived by solving an optimization problem subject to constraints imposed by factors such as reservoir capacity, suitability of available land for different crops. As mentioned earlier due to data inadequacy it was not possible to estimate the marginal productivity of irrigation water in System H. We assume that in the wet season it is possible to use as much water as is desired for both irrigation and hydro power and still have a full reservoir at the end of the season for dry season cultivation. Therefore, the cost of irrigation water is its marginal supply cost. This is derived by dividing the total cost incurred in the project for supplying the total quantity of water by the area irrigated, which implies that the marginal cost of supplying water to individual farms from the reservoir is constant.

The operations and maintenence (O&M) cost in System H was Rs 2516 per hectare per year at 1983 financial prices according to the records of the project manager, which is equivalent to Rs. 2755 at 1984 prices when adjusted for inflation by the consumer price index. Despite certain weaknesses the cost of living index is considered appropriate here as more than 90 per cent of the O&M costs comprise wages. These wages are paid for skilled labour and thus reflect the economic values, since skilled labour is assumed to be priced correctly.

Thus the O&M cost of supplying irrigation water per acre of land in the Maha season is Rs.557.00. However, the cost per acre in the Yala season is double this, since only half the area is irrigated, while the overheads of maintaining the canal system are similar. In addition, the shadow price of water in the Yala season should include the opportunity cost of not using the water for hydro power generation.

In the Yala season, since water has to be diverted from the river even if the reservoir is full at the beginning of the season (the reservoir capacity is limited to one third of the water required in System H), the marginal cost of diverted water is the value of electricity generation forgone by the diversion plus the cost of supplying water from the reservoir to the farmers.

A recent study commissioned by the government of Sri Lanka (ACRES 1984) estimated the 1984 economic price of hydro electric energy to be Rs. 1.13 per Kilo Watt hour at the official exchange rate, based on data from the latest addition to the Mahaweli power grid (Rantembe Project). This study also estimated the energy equivalent of 1 million cubic meters (mcm) of water diverted to System H to be 0.55 Giga watt hours. Assuming constant marginal costs, the shadow price of 1 mcm of water diverted to System H in the dry season works out to be Rs. 622,000 or Rs.0.62 per cubic meter of water.

6.2.4 Other Shadow Prices

The derivation of other shadow prices used in the analysis were based on their border prices and are given in Tables 6-1 to 6-3. Table 6-1 compares market prices of the relevant commodities in 1984 against their shadow prices. It is interesting to note that market prices of rice and chillies do not vary much from their shadow prices while nitrogen and irrigation water have the greatest price divergences. These latter represent substantial subsidies in favour of Mahaweli farmers. The subsidy for nitrogen is a national subsidy while that for water is specific for the project. The prices of draught power and agro-chemicals are assumed to be undistorted.

Table 6-1: Shadow price of rice

Average import price of rice to Sri Lanka in 1984 according to the Central Bank (Rs./metric ton)	=	4876.00
Shore handling and harbour dues according to Nedeco 1984 was (Rs./metric ton)	=	160.00
Converted from husked to unhusked rice equivalent at 0.7 (Rs./metric ton)	=	3525.20
Less, milling, storing, fumigation and transport costs as per Nedeco 1984 (Rs./metric ton)	=	633.00
Shadow price of rice at farm gate (Rs/metric ton)	=	2892.00
" " " " " (Rs/bushel)	=	60.35

Table 6-2: Shadow price of dried chillies

The import price of dried chillies to Sri Lanka in 1984 as reported by ARTI, 1985 (Rs/metric ton)	=	29370.92
Therefore, the import price per Kg.	=	29.37
Less, packaging and transport to project area at the rate of Rs. 0.80 per Kg (Ministry of Finance and Planning 1984), the shadow farm gate price (Rs./Kg.)	=	28.53

6.3 Analysis

A comparison of private and social profits under four different scenarios are given in Tables 6-5 to 6-8. These were computed on the basis of the production frontier estimates given in Chapter 5 and the shadow prices discussed earlier. The production functions for rice had land, pre-harvest labour and nitrogen as variable inputs while the frontier for

Table 6-3: Shadow price of nitrogen

Market price of Urea in 1984 in the project area (Rs./metric ton)	= 3000.00
The subsidy (Rs./metric ton) according to Nedeco (1984)	= 2050.00
The actual domestic cost (Rs./metric ton)	= 5050.00
Nitrogen content of urea fertilizer by weight	= .46
The shadow price of nitrogen (Rs./Kg)	= 5050/(.46x1000)
,, ,, ,,	= 10.97

Table 6-4: Comparison of market prices in 1984 with shadow prices

Commodity	Market Price	Shadow Price
Rice (Rs./bushel) a/	62.58	60.35
Dried chillies (Rs./Kg.)	29.88	28.53
Nitrogen (Rs./Kg.)	6.52	10.97
Agricultural labour (Rs./man day) in the wet season	28.58	22.86
Agricultural labour in the dry season (Rs./man day)	29.55	23.64
Irrigation water wet season (Rs./Ac.)	50.00	557.69
Irrigation water dry season (a) cost of supply (Rs./Ac.)	100.00	1115.38
(b) cost of diverted water (Rs./Cu. m.)	-	0.62

All other costs are converted to shadow values using a standard conversion factor of 0.85.
a/ Unhusked rice or paddy.

chillies had land, nitrogen and pesticide cost as variable inputs. Farmers in reality use many other inputs such as draught power, other fertilizers, agro chemicals and harvesting labour in crop production. Although these are often left out of estimated statistical production functions for reasons mentioned earlier (see Chapter 4) these inputs influence the profits to the farmers and to the society. The profits of farmers are determined by the gross revenue and actual costs incurred in production and not only by those inputs which are specified in the production function (Graff 1984). Therefore, we have allowed for these inputs in our calculations, as shown in Table 6-5.

There was no variation in technical efficiency and relatively low variation in allocative efficiency among farmers cultivating rice in the Head in Maha season. However, a wide range of technical and allocative efficiencies was observed among farmers in the Tail in Maha season and among all farmers growing rice and chillies in the Yala season.

Table 6-7 shows that at the current levels of technical efficiency and the mean levels of input use, the crop with the highest private profit was chillies in the Yala season followed by rice in the head in the Maha season, rice in the Yala season and rice in the tail in the Maha season. However, social profits diverged from private profits and socially the most profitable was chillies in the Yala season followed by rice in Maha/head. The Yala/rice crop resulted in a net loss to the society which was larger than the profit per acre from Maha season rice and Yala season chillies together. Rice in Maha/tail was near the break-even point in social terms, i.e., near zero profit.

Increasing farm level technical efficiency to 100 per cent at current input levels could substantially increase private and social profits. However, the Yala/rice crop continues to make negative profits at shadow prices (Table 6-8). Similarly, private and social profits will increase if farm level allocative efficiencies was increased to 100 per cent while technical efficiency remained at the current level (Table 6-9). Even here, Yala/rice yields negative social profits.

The fact that water is scarce and has a high social opportunity cost in the Yala season makes rice cultivation in this season socially undesirable. However, only about half the extent of the land in the project area is technically suitable for the cultivation of chillies. As such, farmers who have land suitable only for rice continue to cultivate it since water is available free of charge and therefore they can make private profits. The fact that farmers share land in the dry season points to the possibility of sharing well drained lands among the farmers leaving poorly drained lands out of cultivation. Although this will reduce the extent cultivated by each farmer, the profits will be comparable to those obtained in the wet season owing to the higher profits from chillies.

As explained in our description of the project area, the well and poorly drained lands are distributed at a more or less constant ratio along distributory channels from head to tail. Accordingly, if all the farmers served by a distributory channel are to cultivate well drained lands then, even if they share such land, the entire distributory channel should be in operation. Under the present arrangement only the head area is given water. Therefore, the economics of such an approach will depend on the associated water losses and other technical parameters. The longer the channel length, the greater are the conveyance losses involved. In the wet season, only rice can be cultivated under farm conditions in the area. This is both privately and socially profitable.

The following table summarizes the findings of the social efficiency analysis conducted using the model discussed earlier. While social costs of farm level inefficiencies are substantial, the cost to the society due to price distortions and the resulting misallocation of resources are relatively low. In fact, if farmers were 100 per cent efficient both technically and allocatively (privately) the average loss in social profit due to resource misallocation resulting from price distortions is only 12 per cent of the potential social profit.

Table 6-5: Social costs of farm level inefficiencies and price distortions in Rs./Ac.

The Type of inefficiency	Wet Season rice		Dry season rice	Dry season Chillies
	Head	Tail	All	All
STIE	0	2720	3509	15628
SAIE	3477	98	150	19045
SPD (%)	440 (8)	201 (17)	765 (12)	14138 (11)

The relatively high social cost of farm level inefficiencies in comparison with those due to price distortions has important implications. It indicates a potential for improved performance at farm and project level even if the policy framework related to markets is unchanged. The difficulty of removing policy induced distortions and the potential costs of such corrective action was pointed out earlier. Controversies related to rural credit, insurance and irrigation water are good examples.

Further, this suggests that the ex-post appraisal of agricultural projects should look into firm level inefficiencies in addition to market imperfections and their influence on resource allocation within such projects. This is especially important in the case of projects which involve settlement in new lands and technology transfer, where human capital has a major role in the determination of farmer adjustment to these disequilibria, and significant farm level inefficiencies can be present. In such instances, project planning needs to addressing the potential need for assistance to the farmers for rapid and successful adjustment to the changes. Such measures are likely to increase project costs unless a reallocation of existing resources with efficiency gains is feasible. In the absence of such measures the inevitable delays in farmer adjustment will lower project returns in the early stages which will therefore lower overall project benefits.

Table 6-6: Mean levels of inputs used and outputs achieved per crop per location and per season

	Wet Season		Dry season	
	Rice		Rice	chillies
	Head	Tail	All	All
Land (Ac.)	1.96	2.18	0.85	0.70
Pre Harvest Labour Md.s	64.52	60.80	26.57	63.65
Nitrogen (Kgs.)	33.15	38.90	22.40	33.38
Other costs (Rs./Ac.)				
Cost of seed	190.00	190.00	190.00	150.00
Harvest labour	725.99	749.38	878.52	1561.71
Draught power	448.30	428.50	211.71	53.00
Agro chemicals	108.33	131.91	164.72	509.62
Other fertilizers	191.07	114.65	77.27	334.18
Total	1663.69	1614.44	1305.78	2608.51
Mean water requirement Ex-sluice (meters)**	1.43	1.43	2.10	1.90
Mean Output (Bu./Ac.)	70.55	45.63	47.70	430.40a/

a/ Kgs. of dried chillies per acre.

** Estimate is based on Nedeco 1983 and 1984 and is not the actual.

Table 6-7: Comparison of private and social profits obtained for crops at current input and output levels by location and by season (in Rs./Ac)

	Maha season				Yala season			
	Rice				Rice		Chillies	
	Head		Tail		all		all	
	P	S	P	S	P	S	P	S
Gross Revenue	4415	4257	2855	2753	2985	2878	12860	12279
Variable Costs								
Pre harvest labour	960	768	797	637	878	703	2687	2150
Nitrogen	110	185	116	195	172	289	311	533
Fixed Costs								
Other costs	1664	1415	1614	1372	1306	1099	2609	2218
Water	50	557	50	557	100	6386	100	5882
Total cost	2784	2925	2577	2761	2456	8477	5707	10783
Profit	1631	1332	278	-8	529	-5596	7153	1496

Note: P denotes private costs at market prices while S denotes social costs at shadow prices given in Table 6-4.

Table 6-8: Comparison of potential private and social profits with current input levels at 100 per cent technical efficiency, by location and by season (in Rs./Ac)

	Maha season				Yala season			
	Rice				Rice		Chillies	
	Head		Tail		all		all	
	P	S	P	S	P	S	P	S
Gross Revenue	4415	4257	5675	5473	6627	6390	29227	27907
Total cost a/	2784	2925	2577	2761	2456	8477	5707	10783
Profit	1631	1332	3098	2712	4171	-2087	23520	17124

Note: P denotes private costs at market prices while S denotes social costs at shadow prices given in Table 6-4.

a/ these are the same as in Table 7.

Table 6-9: Comparison of potential private and social profits of crops at current level of firm specific technical efficiency and 100% allocative efficiency by location and by season (in Rs./Ac)

	Maha season				Yala season			
	Rice				Rice		Chillies	
	Head		Tail		all		all	
	P	S	P	S	P	S	P	S
Gross Revenue	15549	14995	4954	4778	4703	4536	68815	65455
Variable cost	8210	8214	2016	2759	2690	2497	33676	36814
Other costs	1664	1415	1614	1372	1306	1099	2609	2218
Water	50	557	50	557	100	6386	100	5882
Profit	5625	4809	1274	90	607	-5446	32430	20541

Note: P denotes private costs at market prices while S denotes social costs at shadow prices given in Table 6-4.

Table 6-10: Comparison of potential social profits of crops at 100% technical and allocative efficiency at farm level at market prices and at shadow prices by location and by season (in Rs./Ac)

	Maha season				Yala season			
	Rice				Rice		Chillies	
	Head		Tail		all		all	
	1	2	1	2	1	2	1	2
Gross Revenue	14995	15300	15245	12480	29270	32530	328005	265417
Variable cost	8214	8079	8802	5079	16112	18607	206780	130054
Other costs	1415	1415	1372	1372	1099	1099	2218	2218
Water	557	557	557	557	6386	6386	5882	5882
Profit	4809	5249	4514	5472	5673	6438	113125	127263
1/2	.92		.82		.88		.89	

Note: 1 denotes shadow costs and revenue at optimum input output levels at at market prices while 2 denotes shadow costs and revenue at optimum input output levels at shadow prices. Note also that the social cost of water and other costs do not vary since their use is considered fixed.

CHAPTER 7

Farm incomes and equity

In this chapter we examine the performance of System H in achieving its objectives of (a) providing an adequate standard of living for the settlers through high farm incomes, and (b) ensuring equity. This is followed by an analysis of the causes of low average farm incomes and high inequality. Finally, implications for System H as well as for other future land settlements are discussed.

The Mahaweli Development Project was initiated as a means of achieving broad goals of increasing agricultural production and hydro-power generation, of increasing employment and income levels and of achieving a more equitable income distribution. According to the "Five Year Plan" for national development in operation when System H was planned, 40 per cent of the households in Sri Lanka were earning less than Rs. 200.00 per month and another 40 per cent were earning between Rs. 200 - 400. One of the stated objectives of the plan was to increase incomes while ensuring equity (Ministry of Planning and Employment 1971).

The design of the Mahaweli Project with small equal sized farms reflected these joint goals of increasing incomes and equity. This was strengthened by the tradition of allocating equal sized allotments in state sponsored land settlements in Sri Lanka. The development of land for irrigation and the supply of irrigation water was thought to provide a "more or less equal opportunity" for income generation. The plan recognized the fact that the different soil types in the project area were suited to different crops, but the possibility that their profits may be different was apparently not considered.

7.1 Farm Incomes

The mean annual income of pre-project households in System H was Rs.1200.00. (Table 7-1). The final feasibility report for System H (Sogreah 1972) considered an annual income of Rs.3600.00 per farm family as an adequate level. The feasibility studies showed this income was attainable with the planned cropping patterns, cropping intensities and estimated costs and returns of these enterprises. The project documents, however, do not explain why this income level was accepted as the desired goal. Income data in the Five Year Plan (Ministry of Planning and Employment 1971) suggest that this figure was around the mean household income in Sri Lanka at the time of project appraisal. It corresponds closely to the mean income per income receiver in Sri Lanka in 1973 (Central Bank), which was Rs. 311.00 per month (Table 7-2).

Table 7-1: Distribution of agricultural income per farm prior to the project (in 1971)

Range	Percentage of families
Less than 1000 Rs.	45.5
1000 - 1500	26.4
1500 - 2000	10.1
2000 - 3000	11.0
3000 - 5000	5.6
More than 5000	1.4
Average Rs.	1210.00

Farm household income for the sample was calculated using survey data on area cultivated under each crop, crop yields and inputs used, together with the off farm incomes reported by each farm household. Net farm income in crop production was calculated allowing only for hired labour amongst other items in the cost of production. Thus net farm income reported consists of profits and wages earned both on and off farm by family labour (Table 7-3)[1] .

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[1] All farmers obtained positive profits when the cost of family labour was ignored. However, we costed family labour at market wage rates in our allocative efficiency calculations. Thus some farmers were found to earn negative profits.

Table 7-2: Gini coefficients based on one month income of income receivers in Sri Lanka

Sector	Gini Coefficient 1973	 1978/79	 1981/82
BY SECTOR:			
Urban	0.40	0.51	0.54
Rural	0.37	0.49	0.49
Estate	0.37	0.32	0.52
BY ZONE:			
Zone 1	0.43	0.46	0.47
Zone 2	0.35	0.54	0.51
Zone 3	0.33	0.51	0.48
Zone 4	0.39	0.48	0.54
Zone 5	0.39	0.59	0.59
All Island	0.41	0.49	0.52
Mean income Rs./month	311.00	921.00	1635.00

The performance of the project in 1984/85 crop year in terms of average incomes cannot be directly compared with the target set in 1972 owing to inflation. There are three available indicators of inflation for Sri Lanka(Table7-4). Official inflation indices are often thought to underestimate true inflation and therefore should be used with caution. The implicit GNP deflator of the Central Bank was used here to adjust the target income of Rs. 3600 per farm to 1984/85 prices. The wholesale price index is not available for the entire period while the Colombo Consumers Price Index may be even less appropriate for small farmers living in the Dry Zone of Sri Lanka.

An income of Rs. 3600 in 1972 is equal to a nominal income of Rs.21,876 in 1984/85 prices. The observed average farm income was Rs. 17763 in 1984/85 crop year. Therefore, the mean total income of sample farmers was only 81 per cent of the target

Table 7-3: Distribution of household income among sample farmers arranged in deciles of total income

Decile	Average Total Income	Average Wet/rice Income	Average Dry/rice Income	Average Chillie Income	Average Off-farm Income
1	2395.18	801.85	320.50	538.96	733.87
2	6613.03	2460.08	1175.64	1824.09	1153.22
3	11203.69	4096.20	2328.25	3513.12	1266.12
4	12576.73	5982.82	1448.26	3476.30	1669.35
5	16628.86	4591.53	1602.28	6749.57	3685.48
6	17558.05	5826.53	1851.27	8255.29	1625.00
7	22756.44	4365.16	1728.25	11166.26	5496.77
8	24026.79	6848.06	1731.29	11350.67	4096.77
9	30016.42	8013.38	2795.62	11021.94	8185.48
10	33858.45	5377.98	1749.13	15570.05	11161.29
Mean	17763.36	4836.35	1673.04	7346.62	3907.33
Gini Coefficient	.3058	.2279	.1961	.3289	.4444

income while the mean income excluding off farm income was only 63 per cent. It should be noted that the estimated target farm income did not allow for any off-farm income.

The official poverty line of the government (Ministry of Plan Implementation 1982) is a monthly income of Rs 400 per household. Households below this poverty line are eligible for a food subsidy scheme made available through food stamps. The definition of poverty and identification of a poverty line are controversial issues. The literature on income distribution and poverty offers many different measures of poverty which often yield varying rankings for the same data (Mellor and Desai 1985). The official poverty line is based on the adequacy of income for sufficient household food and nutrition. In 1984/85 prices, the official poverty line amounts to Rs. 580.00 per month or Rs. 6960 per year. About 20 per cent of sample farmers were below this level of income in 1984/85.

Table 7-4: Measures of inflation in Sri Lanka.

Year	Colombo consumers Price Index 1952=100	Implicit GNP deflator 1970=100	Wholesale Price Index of Central Bank 1974=100
1971	2.6	3.0	n.a
1972	6.3	4.8	n.a
1973	9.7	16.7	n.a
1974	12.3	26.2	n.a
1975	6.7	7.5	3.4
1976	1.2	6.4	8.2
1977	1.2	18.1	20.9
1978	12.1	7.9	15.8
1979	10.8	15.9	9.5
1980	26.1	18.2	33.7
1981	18.0	20.4	17.0
1982	10.8	10.2	5.5
1983	14.0	16.1	25.0
1984		13.15 a/	

a/ The average of the previous two years. The official estimates are not yet available.

The mean monthly income per income receiver on the island in 1981/82 (when the latest consumer finance survey was carried out) was Rs. 1635.00[2], which was four times the poverty line income. The equivalent of the 1981/82 average income per income earner in 1984/85 prices is Rs. 2368 per month and Rs. 28,416 per year. This is substantially higher than the 1984/85 value of the original target farm income of Rs. 3600 per month and reflects a real increase in mean incomes in Sri Lanka since 1972. The project

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[2] Income distribution data are available in the form of income per income earner and consumption expenditure per spending unit. Lee (1977) argued that consumption expenditure data are more indicative of income distribution while Laxman (1980) preferred the former. Following Laxman (1980) we use income data for our analysis, so an income earner is considered to be comparable to a farm household in System H.

performance appears to be even more disappointing by this standard. The mean sample farm income is only 62 per cent of the mean income of income receivers in Sri Lanka in 1981/82. If off farm incomes are ignored, this ratio falls to 49 per cent. However, the real agricultural income per farm has approximately doubled under the project. The income from chillies is responsible for this increase. Without chillies project farm income from agriculture is marginally lower than the pre-project situation.

7.1.1 Determinants of Low Farm Incomes

This low average farm income in terms of project objectives is caused by three major factors.

1. low average productive efficiency
2. low cropping intensity
3. a decreasing profit margin from rice cultivation, since the time of project appraisal.

The magnitudes and the determinants of low average technical and allocative efficiency among farmers in System H were discussed at length in Chapter 5 and therefore are not repeated here. Potential private and social gains in increasing technical and allocative efficiencies were given in Tables 6-7 to 6-10 in Chapter 6. These show that substantial increases in profits are obtained by increasing efficiency at farm level.

It was noted that the actual cropping intensity in System H was about 150 per cent against a target of 200 per cent. Thus water management at a higher level of efficiency may result in increased cropping intensity and therefore in increased farm incomes. Studies of irrigation system efficiency have indicated a potential for improved efficiency at system level through channel lining, better structures as well as synchronized planting (Nedeco 1985). Similarly efficient on-farm water management can contribute substantially to the overall efficiency in water use (Water Management Synthesis Project 1984, 1985).

The third point was discussed in Chapter 1. Many researchers have noted that the profit margin from rice cultivation to farmers in Sri Lanka has dropped during the last decade (Ekanayake 1982, Wickremesekara 1984). Falling real prices of rice and the increasing costs are partly responsible for this. The commodity price forecasts of the World Bank (1986) indicate that this may be a continuing trend.

7.2 Equity

Various measures taken in the planning of the project to ensure equality were discussed earlier in this thesis. The most important among them was the allotment of equal sized farms to the settlers.

The Tables 7-1 and 7-5 show the pre-project pattern of income distribution and the distribution of land holdings. These indicate a wide disparity in the distribution of both land holdings and household incomes prior to the project. The mean income per family was one third of the target income under the project.

The allocation of equal sized holdings, settler selection criteria, water distribution pattern etc. in System H were designed to achieve equity. However, the observed pattern of income distribution is far from equal (Table 7-3). The pattern of operational land holdings has also changed from the original equal size at the commencement of settlement (Table 7-6).

A comparison of income distribution observed in our sample with national data on income distribution provides an indication of the success in attaining equity through planned settlement in System H. The comparisons are between the level of inequality in the sample and those for the nation as a whole, the rural sector and the Zone in which System H is located, using the Gini index. This index is obtained as one minus twice the area under the Lorenz curve which relates the cumulative proportion of income received when units are arranged in ascending order of their income. Although the use of Gini index has been criticised[3] for various reasons, it is used here for the convenience in facilitating comparisons with published data for Sri Lanka.

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[3] Kuznets (1976) states that the standard Gini coefficient is a summary that can conceal as much as it reveals.

The Gini index* for the total household income in the sample is .30. This is lower than the figure of .49 for the entire rural sector of Sri Lanka in 1981/82 (Table 7-2). Thus income distribution within the project area appears to be relatively more egalitarian than in the wider rural sector though it showed greater inequality than was probably anticipated at the time of project design. The Central Bank of Ceylon stratified the whole of Sri Lanka into 5 Zones, and Zone 2 covers the districts of Hambantota, Moneragala, Amparai, Polonnaruwa, Anuradhapura and Puttlam. Our sample area is located in Anuradhapura district. These districts are in the Dry Zone of Sri Lanka and cover the major rice growing areas in the country and therefore may be taken to be representative of the without project scenario for System H. The Gini index for the same peiod in Zone 2 of Sri Lanka was .51. Again, the project area appears relatively more egalitarian.

Available pre-project income distribution data given in Table 7-1 do not permit the calculation of exact Gini coefficients owing to the lack of an upper limit for the highest income group. However, assuming that an upper limit of those earning more than 5000 Rs. to be Rs. 6000 to 10000, Gini indexes range between .39 to .40. Thus post project income distribution appears to be more equitable than that prior to the project.

The distribution of farm size in the sample (Table 7-6) was highly egalitarian with a Gini index of .16 compared to the wide disparity shown in Table 7-5 prior to the project. However, since the commencement of the project, the operational holding size has diverged from the fully egalitarian situation which existed immediately after land allocation when each farmer had 2.5 acres, therefore resulting in a Gini Index of zero. Although the existing distribution suggests that the project has been somewhat successful in achieving a more equitable distribution of income one cannot assume that the process of land reallocation has stopped. In a following section the potential for an increasing trend in income disparity is discussed.

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* Consider the numbers x_i as a sample drawn from a distribution function $F(x)$. Assume that $F(x)$ increases on its support (the values of x for which $0 < F(x) < 1$) and the mean μ of $F(x)$ exists. The first assumption implies that $F^{-1}(p)$ is well defined and is the population p^{th} quantile. Given any degree of freedom (d.f.) $F(x)$, the theoretical Lorenz curve corresponding to it is defined by $L(p) = \mu^{-1} \int_0^p F^{-1}(t)\,dt$. The Gini index of the curve $L(p)$ generatedby a d.f. $F(x)$ is $\Delta/(2\mu)$, where

$$\Delta = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} |x-y|\,dF(x)\,dF(y) = 4 \int x[F(x)-1/2]\,dF(x).$$

Table 7-5: Pre-project land ownership pattern

	Percentage of Farmers		
Size	rice land	upland	chena land
Less than 0.5 Ac.	71.5	98.1	56.3
More than 0.5 Ac.	51.6	65.0	51.6
More than 2 Ac.	25.2	14.0	13.4
More than 4 Ac.	10.3	1.9	2.3
More than 8 Ac.	1.8	0.2	0.3

Source: Sogreah 1972

Table 7-6: Farm size distribution in the sample in 1984/85

decile	mean size (Ac.)
1	.92
2	1.45
3	1.89
4	2.44
5	2.5
6	2.5
7	2.5
8	2.5
9	2.5
10	3.94
Mean	2.31
Gini index	.1629

7.2.1 Sources of Inefficiency

It is interesting to observe that the inequality in total household income distribution is greater than that of farm size. The respective Gini coefficients are .30 and .16. This suggests that farm size is not an adequate explanator of farm income distribution. Therefore, we analyze the contribution to total income inequality from different sources using the concentration coefficient following the approach of Kakwani (1980)[4].

Total family income is equal to the sum of all factor incomes. Suppose there is a total of n factor incomes x_1, $x_2,\ldots,x_n$ and g_i (x) is equal to the mean of the i^{th} factor income of the units having the same total income x. Then,

$$x = \sum_{i=1}^{n} g_1(x) \tag{7.1}$$

Kakwani (1980) showed that if families are arranged according to their total income, the Gini index [G] of total family income is given by the following:

$$G = 1/U \sum_{i=1}^{n} u_i C g_i \tag{7.2}$$

where Cg_i is the concentration index of the i^{th} factor income g_1 (x), u_i the mean of the i^{th} factor income for all families and U the mean of the total family income.

This useful identity is based on the fact that the concentration index of x (total household income) is equal to its Gini index. The decomposition of the contribution of factor incomes to overall inequality in income distribution was obtained from this relationship.

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[4] See Shand (forthcoming) for an application of the concentration coefficient to income distribution data in a Malaysian irrigation scheme.

The concentration curve is defined as follows. Suppose income X is a random variable with probability density function f(X) and distribution function F(X), the proportion of units having an income less than or equal to x being F(x). Let g(X) be a continuous function of X so that its first derivative exists, and g(X) $\geq$ 0 for all X $\geq$ 0. If E[g(X)] exists, it follows that

$$F_1[g(x)]=1/E[g(X)]\int_0^x g(X)f(X)dX$$

which can be defined where

$$E[g(X)]=\int_0^\infty g(X)f(X)dX,$$

so that,

$$\lim_{x\to 0} F_1[g(x)]=0 \tag{7.3}$$

and

$$\lim_{x\to\infty} F_1[g(x)]=1 \tag{7.4}$$

The relationship between F_1[g(x)] and F(x) will be called the concentration curve of the function g(x). The curve is obtained by inverting the functions F_1 [g(x)] and F(x) and eliminating x if the functions are invertible. Alternatively, the curve can be plotted by generating the values of F(x) and F_1 [g(x)] by giving some arbitrary values to x. Like the Lorenz curve, this curve is represented in a unit square and, as implied by the equations (7.3) and (7.4), passes through (0,0) and (1,1).

The concentration index is one minus twice the area under the concentration curve for g(x), while the Gini coefficient is one minus twice the area under the Lorenz curve.

Such a decomposition cannot be obtained with the Gini index for each factor. Rao (1969) has shown that,

$$G \leq 1/U\sum_{i=1}^{n} u_i G_i \tag{7.5}$$

where G_i is the Gini index for each factor.

According to Table 7-6 the greatest contribution to income inequality among sample farmers is made by the income from chillies. The next highest contribution is made by off-farm income. These are the two main sources of income inequality. A relatively minor contribution was made by wet/rice and dry/rice. This underlines, incidentally, the need to take all sources of income into account to gain a proper perspective of income disparities both for within farm and for total household income (Shand, forthcoming).

Table 7-7: Income inequality by factor components

Sources of income	Mean income (%)	Concentration index	Contribution of each factor income to total income inequality	Percentage Contribution
Wet/rice	4836.35 (27.22)	.1871	.0509	16.64
Dry/rice	1673.04 (9.42)	.1340	.0126	4.12
Chillies	7346.62 (41.36)	.3589	.1484	48.53
Off-farm	3907.33 (22.00)	.4269	.0939	30.71
Total	17763.68 (100.00)	.3058	.3058	100.00

The variation in income for each crop is explained partly by differences in levels of inputs used including land, and partly by variations in technical and allocative efficiency among farmers. However, off-farm income and chillie income are dependent on specific factors which are unrelated to holding size which are discussed separately.

7.3 Policy Implications

It was mentioned earlier that the selection criteria for non Purana settlers permitted only unemployed people with experience in agriculture to be settled in the project lands. However, this was not enforced in the case of Purana settlers. Purana settlers were given project land irrespective of their off-farm employment status. Accordingly, those Purana villagers who were employed in government service (such as teachers), and those who were engaged in other occupations such as trading activities were also given project land. This introduced a source of income inequality among the settlers from the very beginning of the settlement. Excluding people with off-farm employment from receiving land in their native areas was not politically feasible and cannot be easily justified. Off-farm income has been thought of as being capable of reducing inequality in situations where smaller farmers can supplement their income thus (Kada 1983). Indeed, Shand (forthcoming) has shown that off-farm income had an inverse relationship to land holding size and therefore helped reduce inequality in the Kemubu irrigation scheme of Malaysia. Similarly, increased opportunities for off-farm employment could help to counter various factors contributing to inequality in the the particular circumstances in System H described above, even though at the time of the study it was itself a source of inequality.

Apart from differences in formal education among settlers which determine types of off-farm employment, e.g., in the public sector, inequality also stems from the differences in pre-project capital endowments. Farmers who start off in the project with relatively more resources than others are likely to be advantaged in adjusting to the new project environment.

Chillies can only be cultivated on the well drained soils in the Yala season. Only about 50 per cent of the project lands are in this category. Therefore only those farmers who have suitable land can cultivate this crop. We noted earlier that all farmers who were allocated well drained lands under the share arrangement in the Yala season cultivated chillies. Only the Head area, covering 50 per cent of the total land area, was irrigated in the dry season and farmers located in the Tail shared land with those in the head. However, all farmers did not get land suitable for chillies owing to the fact that the ratio of well and poorly drained lands is the same in the Head as in the Tail. Accordingly approximately 50 percent of the land cultivated in the dry season was under chillies (71 acres) while the balance was under rice (74 acres). Since chillies is a highly profitable crop with ten times the net profit per acre from rice on the average in the dry season (Chapter 6) it would be both socially and privately gainful to devise a pattern of land and water use for the dry season which would allow all the farmers to grow chillies, particularly since it was shown in Chapter 6 that rice cultivation in the dry season results in a net loss to society.

A feasible measure is to allocate each farmer 1.25 ac. of well drained land for the dry season along the distributory channel (in the head as well as in the tail) instead of the current practice of simply allocating 1.25 ac. from the head of the distributories. While this may involve some detailed soil mapping and blocking out into equal allotments and may initially require substantial effort on the part of the project management to persuade the farmers it would be highly profitable for both farmers and for society. This would require the conveyance of water along the entire length of distributory channels and increase conveyance losses of water as there is insufficient well drained land in the head to be allocated to all the farmers served by a distributory channel. However, the lower requirement of water for chillie-only cultivation as compared to a chillie and rice cultivation, may compensate for those increased conveyance losses. Otherwise the size of the individual allotment can be appropriately adjusted.

Apart from improving income distribution, average farm incomes would also rise by increasing the area cultivated in chillies. This would mean a doubling of the chillie area from the present level. An increase in the quantity of chillies produced is unlikely to lower the market price of chillies to any significant extent as the quantity supplied would still be a small fraction of total national demand. However, if this strategy is to be more widely accepted througout the Mahaweli System, a more detailed market analysis would be required. If market demand is highly inelastic, then most of the benefit of the increased supply will be reaped by the consumers.

According to the calculations presented in Chapter 6 the average profit per acre for a chillie-only cropping pattern would be Rs.10432, as against a profit of Rs. 5639 for a chillie and rice (50/50) cropping pattern [in financial terms at the prevailing level of average input use and average technical efficiency]. In economic terms (using shadow prices) the former would yield a profit of Rs. 2720 per acre while latter results in a loss of Rs 4072 per acre. This substantial difference in profits in both financial and economic values are mainly due to the supply of irrigation water free of charge. But even if the issue of water along the entire length of distributory channels increases the conveyance lossess to the extent of reducing the cultivable area under chillies by 45 per cent (which is highly unlikely) a chillie only cropping pattern will yield the same level of financial profit as the current chillie and rice cropping pattern.

The observed differences in productive efficiency between farmers, and the increasing returns and constant returns to scale in wet/head rice and chillie technologies have important implications for future trends in income distribution. Farmers who successfully adjust to the new environment and technology, and thus are highly efficient, will accumulate more wealth than the less efficient farmers, and will be in a position to expand their scale of operations. Where increasing or constant returns to scale exist in a technology, expansion in the scale of operations is profitable. Thus a continuing trend of increasing inequality in land distribution and in income distribution can be expected. However, measures designed and implemented to facilitate rapid adjustment by all farmers could help to counter this trend.

CHAPTER 8

Summary and Conclusions

The provision of new technologies to small farmers in developing countries invariably requires major investments in physical and social infrastructure such as land and irrigation development, agricultural research, extension services and marketing services. Micro-level development plans for the provision of these facilities - usually formulated as specific projects - typically ignore the productivity and equity implications of differences in farmer ability to adjust to the disequilibria which accompany technological change and of differences in micro environments between farms. The fact is that high variability in performance among farmers adopting new agricultural technologies under such plans/or projects, is a common phenomenon which has important efficiency and equity implications. In this thesis the theoretical and empirical issues raised by such differences were addressed in an analysis of farmer performance in a new irrigation and land settlement project in Sri Lanka, the Mahaweli Project.

8.1 Summary

First, the broad dimensions of the efficiency and equity issues raised by differential farmer performance in the context of new technology and different environments were discussed and illustrated with special reference to the Pilot Phase of the Mahaweli Project of Sri Lanka.

Then, alternative theoretical explanations of inter-farm variability in performance were reviewed, and in the process, received neo-classical theory was found to be unsatisfactory in this context. In particular, the emphasis on comparative statics ignores the dynamic path of adjustment to economic disequilibria, since neo-classical theory assumes (often implicitly) that profit maximizing firms adjust instantaneously to conditions of disequilibria. Moreover. the pre-occupation with the states of equilibrium (comparative statics) results in a discounting of the useful economic role of entrepreneurship in innovation and in the adoption and application of innovations. Alternative theories were found to be useful in understanding the economic role of entrepreneurship and helped to provide a theoretical explanation for the existence of differential performance. Among these, Schultz's concept of the ability to adjust to disequilibria was found to be particularly useful for our purposes as it specifically refers to agriculture and to the dynamics of technological change. However, other theories, including X-efficiency theory, contribute important insights into the behaviour of the firm. The literature on human capital provided a basis for the identification of various types of human capital relevant to the ability to adjust to disequilibria. Thus, measured differences in farmer performances were hypothesized to be due to differences among farmers in terms of factor endowments, differences in their ability to adjust, in non-maximizing behaviour, in market imperfections and in various risks and uncertainties.

The concepts of technical and allocative efficiency of the firm were utilized in the empirical analysis for the measurement of technical and allocative abilities of individual farmers. The degree of success in performance in a dynamic environment was therefore considered to be a reflection of individual ability to adjust to disequilibria. Thus, differences among farmers in their ability to adjust to a new technological package and to changes in the natural and socio-economic environments were hypothesized to result in inter-farm variations in measured efficiencies.

The farm specific measures of ex-post performance used in this study (technical and allocative efficiencies) were actually based on the neo-classical model of profit maximizing farmer behaviour in a competitive market environment. But, these provided only a bench mark for the analysis. Their use did not constrain the study by imposing prior assumptions about the motives of farmers or the nature of the markets. The focus of the study was on explaining observed departures from this bench mark situation with various factors mentioned earlier.

These farmer specific efficiency measures were developed to be consistent with an adjustment process. Thus the Farrell measure of firm specific technical efficiency was accepted for the analysis of technical ability. But, for the analysis of allocative ability an alternative measure was defined following Herdt and Mandac (1981). The latter approach was chosen because it was consistent with a dynamic scenario where farmers are involved in a process of adjustment. In an environment characterized by changing technology and by farmers with varying ability to adjust, it was more appropriate to expect that individual farmers would attempt to maximize profits with respect to the particular components of the technology that they had adopted rather than with respect to the best practice frontier. We reviewed the literature which shows that farmers adopt new technology in a step wise manner and that the rate of adoption varies between individuals. Further, we demonstrated both theoretically and empirically that the use of the Farrell measure of allocative efficiency would have *imposed* allocative inefficiency on technically inefficient farmers, purely because they are technically inefficient. Finally, measures of social efficiency of farmer performance were defined to enable comparisons of relative losses to the society due to farm level inefficiencies and to price distortions.

In our review of the state-of-the-art in the estimation of frontier production functions and the measurement of firm level efficiency on which our empirical model is based, attention was drawn to the major associated theoretical and empirical problems. The current controversies on frontier production function approach relate to issues such as the choice between deterministic and stochastic approaches, specification of the error structure, and the parameterization of the production function. These issues were addressed in the body of the thesis and the limitations inherent in each approach were made explicit. In formulating the model used in this thesis, alternative approaches for the estimation of frontier production functions were tested. In particular, we discussed the theoretical problems and empirically demonstrated the drawbacks of deterministic methods often used in such estimations. Since efficiency of the firm measured relative to a frontier function is essentially a residual, the accuracy of measured efficiency critically depends on the inclusion of all variables which influence output. Omitted variables thus adversely affect the efficiency measures. The accuracy of the firm level efficiency measures derived and the success of the regression analysis in explaining the variation in efficiencies can be improved with better specification and measurement of environmental variables which should be included in the production functions. An interdisciplinary approach is likely to be particularly useful for this task.

The major findings of the farmer efficiency analysis were:

1. The estimates of frontier production functions and the levels of technical inefficiency obtained were consistent with our hypothesis that the greater the adjustment required by individual farmers (e.g., due to the lack of location specific recommendations) the greater was the average inefficiency. However, individual farmers who were endowed with particular forms of human capital such as technology, environment and land specific experience achieved high levels of efficiency even in adverse environments.

2. The greater the importance of technical efficiency in a given location lower was the returns to scale for that environment. Thus, the estimates of the returns to scale for each rice growing environment were consistent with the implications of the observed technical efficiency levels in each location.

3. Technical efficiency variations were found to be significantly related to alternative forms of human capital such as different types of farming experience, literacy and age as well as to particular component practices of the new technology used by individual farmers. Thus different forms of human capital hypothesized to be important under different circumstances were found to be statistically significant in the determination of observed technical efficiency variations. However, the proportion of variability in technical efficiency explained by these factors was lower in environments where the heterogeneity in physical micro-environments was high.

4. Allocative efficiency was closely related to technical efficiency. This was consistent with our hypothesis that in a dynamic environment such as the study area, ex-post allocative efficiency (among other factors) depends on close correspondence between ex-ante expectations and actual yields associated with the various inputs and practices. Such familiarity with the technology is likely to be positively associated with high technical efficiency. The importance of the relationship technical and allocative efficiencies has been generally ignored in the literature of firm behaviour. Other important variables explainning variations in measured allocative efficiency were farmer specific rate of interest, literacy and farmer age.

5. Most of the overall economic efficieny variation among farmers was explained by technical efficiency variations. This suggests that technical efficiency was relatively more important in the determination of economic efficiency in an environment of technological change, and should therefore be the principal focus of policy.

A social efficiency analysis carried out utilizing our measures of social efficiency showed that firm level inefficiencies referred to above lead to substantial losess in social terms. In fact, the prevailing market distortions were found to result in only a 12 per cent loss in social profits if farmers were privately fully efficient. Thus, increased private efficieny in Maha/head, Maha/tail and Yala/chillie environments, if achieved were found to be capable of generating substantial social gains. Notably however, the cultivation of rice in the Yala season was found to be socially inefficient even if farmers were fully efficient privately.

Comparison of pre and post-project farm income distributions showed that post-project mean farm family incomes (in real terms) were higher and that inequalities were lower. However, post-project incomes (in real terms) were lower and income inequality was higher than project targets. Observed inequality in income distribution far exceeded the inequality in operational holding size. Analysis of the contributions to overall income inequality from various income sources showed that the income from chillie cultivation and that from off-farm income were the most important to this result. Thus land quality (which determined to a large extent the cropping pattern and potential productivity) and human capital endowments (which determined on-farm economic efficiency as well as off-farm employment) were the major factors which influenced farm family incomes and income distribution. Crop diversification in the Yala season by expanding chillie cultivation emerged as a measure which offers potential efficiency and equity gains.

8.2 Conclusions and Implications for Future Research

In a dynamic situation where farmers are at an early stage of adjustment to new technology in an unfamiliar natural environment, high individual technical and allocative efficiencies cannot be expected even if they are profit maximizers in a competitive market environment. Variation among individuals in their levels of efficiency, however, are to be expected to the extent their human capital and other resource endowments differ at this stage. High efficiency on the average is more likely to be a characteristic of static environments.

The levels of farmer efficiency in the different environmental complexes in the study area showed that where the available technology is well adapted to the environment, farmers will achieve high levels of both technical and allocative efficiency rapidly. In a less favourable environment for the technology, farmers who attain technical efficiency with successful farm specific adjustments are likely to be allocatively efficient as well. Thus, in general, with a well defined set of optimal practices, the two efficiencies are likely to be positively correlated as observed in the two wet season environments. Where such a well defined set of optimal practices does not exist and appropriate recommendations are not available to guide the farmers, a relatively longer period will be needed for farmers to evolve a suitable package by their own experimentation (i.e., learning by doing). In the initial stages, farmers are likely to try out familiar practices and inputs in such situations. But they are unlikely to perceive correctly the ex-post technical efficiency of their actions at the time of input applications and therefore technically highly efficient farmers are likely to make substantial allocative errors. Under such circumstances, the relationship between efficiencies is hard to predict on an *a priori* basis.

Policy options emerging from this analysis fall into three categories: investment in environmental modifications, in human capital improvement and in adaptive research. First, improved water availability in the tail and in the dry season through better water management at farm and system level can improve farmer performance. This has implications for irrigation systems management and related benefits and costs. Second, selection of farmers with appropriate forms of human capital and/or improving the stock of such human capital of farmers without such initial advantages with education and extension can increase efficiencies. Third, adaptive research directed towards determining best practices under less favourable environments and the dissemination of this information can lead to more rapid adjustment by individual farmers and thus, to higher technical and allocative efficiency.

While social costs of farm level inefficiencies are substantial, the social costs due to price distortions and the resulting misallocation of resources were found to be relatively low in this particular situation. In fact, if farmers were fully efficient both technically and allocatively, the average loss in social profit due to resource misallocation resulting from price distortions was only 12 per cent of the potential profit.

The relatively high social cost of farm level inefficiencies in comparison with those due to price distortions has important policy implications. It indicates a potential for improved performance at farm and project level even if policies affecting the markets remain unchanged. It is our view that it is probably easier to capture such potential gains at farm and project level than to change broader national pricing policies.

The findings of this study strongly suggest that both ex-ante and ex-post appraisal of agricultural projects should investigate farm level inefficiencies in addition to price distortions and their effects on resource allocation within such projects. This is especially important in the case of projects which involve new and diverse environments and technology transfer, where human capital factors can create inefficiency. In such instances, projects need to be planned with a carefully projected analysis of the benefits and costs of assistance to the farmers for rapid and successful adjustment. In the absence of such measures there will be inevitable delays in farmer adjustment which will lower project benefits in the early stages and therefore depress economic rates of return.

Given the wide variation among farmers in their human capital endowments and the heterogeneity in the quality of land, the concept of "differential ability to adjust to disequilibria" suggests that inequalities in income distribution are inevitable. The notion that the provision of equal allotments of land will lead to equality in income distribution is, both simplistic, and unrealistic as was empirically confirmed for this study area. Policy measures suggested above for increasing efficiency may also reduce inequality in some circumstances.

Important areas for future theoretical and empirical work include, the desirability of developing the stochastic frontier function methodology in ways which will relax the current restrictive assumption that the frontier function is a neutral transformation of the average function. This may also enable researchers to relax the assumption that firm specific functions are neutral transformations of the best practice frontier for the entire group. Wider empirical application of our approach for analysing farmer adjustment to changes and that for comparing the relative importance of social losses due to farm level inefficiencies and price distortions in other environments are likely to yield important policy insights on the factors affecting farmer/firm adjustment to changes in their decision making environment. Another important area of research is to analyse the dynamics of firm level efficiency and farmer ability over time using the approach outlined in Chapter 3. In this connection, we were constrained by the lack of necessary panel data and were confined to use cross section data. Nevertheless we were able to demonstrate the usefulness of this approach in a study of the dynamics of adjustment.

Appendix 1

Derivation of Indices of Allocative Economic and Social Efficiency

Our true Cobb-Douglas production frontier is given by,

$$Q_f = A\prod_{i=1}^{m} X_i^{b_i} \prod_{j=m+1}^{n} X_j^{b_j} e^{U+V} \tag{1}$$

Where, X_1 to X_m are variable inputs and X_{m+1} to X_n are fixed inputs. Technical efficiency is given by U and random deviations in output by V.

Given our assumptions of half normal (negative) distribution of U and normality of V, and the maximum likelihood estimation, the estimated coefficients A and b_i are relevant at 100 per cent technical efficiency. Using these coefficients and the U_i estimated for each farm, farm specific production functions may be derived by substituting estimated U_i in the above production frontier. This assumes that technical efficiency neutrally transforms the farmer specific production function and that the technology reflected by the estimated frontier coefficients other than the constant are identical to all the farmers in the sample. In the Cobb-Douglas case this amounts to a rotation of the frontier to the left as technical efficiency decreases from the 100 per cent level representing the frontier. Accordingly, the production function of a farmer who is 50 percent technically efficient will lie below that of a farmer who is 60 percent efficient. The frontiers of both these will lie below the estimated frontier for the sample.

For simplicity, the above general model may be written as follows in logarithms.

$$\ln Q_f = \ln A + b_1 \ln X_1 + b_2 \ln X_2 + b_3 \ln X_3 + U + V \tag{2}$$

Where,

Q=output (rice)

X_1=land (fixed input)

X_2=pre harvest labour

X_3=nitrogen

U=technical efficiency

Given perfect markets and profit maximizing farmers the maximum profit can be obtained by solving the following maximization problem to determine the output level and inputs which maximize profits.

$$\pi=TR\text{-}TVC \tag{3}$$

Short run profit is the difference between total revenue and total variable cost. This can be written as follows:

$$Maximize \Pi = P_q Q\text{-}(P_2X_2+P_3X_3) \tag{4}$$

subject to production function given in (2). The Lagrangian function is

$$L = P_qQ\text{-}P_2X_2\text{-}P_3X_3\text{-}\lambda\left\{Y\text{-}F(X_1,X_2,X_3)\right\} \tag{5}$$

The first order conditions are

$$\frac{\partial L}{\partial Q}=P_q\text{-}\lambda=0$$

$$\frac{\partial L}{\partial X_2}=\text{-}P_2\lambda F_{X2} \tag{6}$$

$$\frac{\partial L}{\partial X_3}=\text{-}P_3\lambda F_{X3} \tag{7}$$

In the Cobb-Douglas case, these turn out to be

$$P_2=P_q\frac{b_2Q}{X_2} \quad and \quad P_3=P_q\frac{b_3Q}{X_3}.$$

Given the prices P_q (expected price of rice), P_1 (rent), P_2 (wage) and P_3 (price of nitrogen) the simultaneous solution of the production function together with first order conditions for a profit maximum (MPP=Price Ratio) yields the profit maximizing Y, X_1, X_2 and X_3, for each farmer at his level of technical efficiency U. The relevant system of equations can be written in logarithms as follows:

$$lnQ=lnA+b_1lnX_1+b_2lnX_2+b_3lnX_3+U+V \tag{8}$$

$$\ln Q+\ln b_2=\ln X_2+\ln (P_2/P_q) \tag{9}$$

$$\ln Q+\ln b_3=\ln X_3+\ln (P_3/P_q) \tag{10}$$

Where X_1 is a fixed input the system reduces to 3 equations as follows: where

$$lnA^*=lnA+U+b_jln \sum_{j=m+1}^{n} b_jX_j \tag{11}$$

Written in matrix form,

$$Y=(X^TX)^{-1}X^TC \tag{12}$$

Where,

$$\begin{bmatrix} 1 & -b_2 & -b_3 \\ 1 & -1 & 0 \\ 1 & 0 & -1 \end{bmatrix} = X$$

$$\begin{bmatrix} lnA^* \\ lnP_2/P_q-lnb_2 \\ lnP_3/P_q-lnb_3 \end{bmatrix} = C$$

and

$$\begin{bmatrix} Y \\ X_2 \\ X_3 \end{bmatrix} = Y$$

Name the resulting Y.X_2 and X_3 $\hat{Y}$, $\hat{X}_2$ and $\hat{X}_3$ respectively to denote profit maximizing input levels and output for each farmer[1]. A unique solution to this system exists provided

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[1] Often researchers have been satisfied with the calculation of partial average allocative efficiency measures for each input holding the use of other inputs at their geometric mean level. The extension of this approach to our firm specific allocative efficiency measure will result in the calculation of partial allocative efficiencies for each input while holding the others at their actual level. We prefer the simultaneous solution approach since the former approach yields ambiguous results when farmers overuse one input when other inputs are underutilised. The latter approach provides an overall allocative efficiency measure instead of input specific measures with the former.

that the determinant ($\mathbf{X}$) of the coefficient matrix is between zero and one in value. This determinant is in fact,

$$1-(\sum_{i=1}^{n} b_i),$$

where,

$$\mathbf{X}=(\sum_{i=1}^{n} b_i),$$

gives returns to scale from the technology. When returns to scale are constant $\mathbf{X}=0$, yielding a singular matrix with no unique solution. It can be shown that a determinate solution exists only when $0 < X < 1$, i.e., when returns to scale are decreasing (Beattie and Taylor 1985). Increasing returns to scale describe a situation where increasing input application yields output increases at an even greater rate. Hence, a profit maximum cannot exist. Even when returns to scale are constant or increasing for fixed and variable inputs together, it is likely that a unique short run allocative efficiency may exist since only variable inputs are taken into consideration.

The maximum profit for each farmer given his technical efficiency and the fixed input of land is obtained by the following.

$$Maximum\ \Pi = P_y\hat{Y}-\sum_{i=1}^{n} P_i\hat{X}_i \tag{13}$$

The expected output Y^* for each farmer at his actual input level is obtained by substituting the actual input levels used by him denoted as X^*_i in equation (1) above. This gives the expected output at the level of inputs applied. This in fact, may vary from the actual output due to random variations in output. Thus we adjust for such random variation in output in our calculation of allocative efficiency since they have no relationship with allocative decisions of the farmer.

The expected profit at his actual input level is obtained from the following.

$$Expected\ \Pi = P_qQ^* - \sum_{i=1}^{n} P_iX^*_i \tag{14}$$

Finally, the success of each farmer in maximizing expected profits is obtained as follows:

$$(Expected\Pi/Maximum\Pi)x100 \tag{15}$$

This ratio for individuals may vary from a maximum of 100 where the expected profit is equal to maximum profit, to a negative real number where

$$P_qQ^* < \sum_{i=1}^{n} P_iX_i^*$$

Calculation of Economic Efficiency

The potential maximum profit at 100 per cent technical eficiency is calculated by assuming U = 1, the natural logarithm of which is zero. Accordingly, the equation [11] is changed as follows while the rest of the system remains unaltered.

$$\ln A^{**} = lnA + b_j ln \sum_{j=m+1}^{n} b_jX_j$$

However, the predicted output at actual input use is identical to that derived for the calculation of allocative efficiency.

Appendix 2

A Comparison of Alternative Approaches to Measure Firm Specific Technical Efficiency

Alternative procedures for the measurement of firm-specific technical efficiency using cross section data were discussed in Chapter 3. All these methods can be grouped into two major types: deterministic approaches and stochastic approaches. Deterministic methods, whether they are statistical or programming approaches, do not allow for purely random variations in output and therefore are likely to yield biased estimates of technical efficiency. The selection of a suitable approach to estimating a frontier functions for this thesis was based on a comparison of the two approaches by estimating frontier production functions from both methods.

The deterministic method selected for this comparison was the Corrected Least Squares (COLS) method of Greene (1980). A major advantage of this method compared to other deterministic approaches (programming) is that production coefficients of inputs have standard errors and thus statistical properties, except for the intercept. Greene (1980) showed that COLS estimates are efficient and consistent although biased. Programming methods, on the other hand have no statistical properties, and are dependent on a few observations (one per dependent variable) and thus are highly sensitive to the influence of outliers. Accordingly, the estimates of intercept as well as the other coefficients are suspect, whereas in the COLS the input coefficients are OLS estimates. As shown by Schmidt (1985/86) these should not be significantly different from those obtained from the stochastic frontier (SF) model. Technical inefficiency is assumed to be a neutral transformation of the intercept in the SF model. Therefore, the only differences between COLS and SF frontier estimates are in the intercept. The SF model is presented in detail in Chapter 3 and thus is not repeated here.

The COLS method of estimating a frontier production function is to first obtain OLS estimates of a production function and then increase the value of the estimated intercept until all the farmer specific residuals become negative in value except for one which will be zero. Thus the OLS residual with the highest positive value, i.e., the residual of the farmer who is placed at the greatest positive distance from the average production function, will be assigned the value zero and will be taken to be the most efficienct firm (100 per cent technically efficient). Obviously this method ignores the stochastic element in crop production. Further, like any other deterministic approach a statistical test of the significance of inefficiency is not provided. The SF model provides such a statistical test.

The data for the study was collected from a farm record book survey carried out in two locations in Block 313 of the System H of Mahaweli Development Project in Sri Lanka in the Wet season in the 1984/85 crop year. Although the operational plan of water distribution was designed to enable farmers in both "head" and "tail" of the channel to have equal access to water on a rotational basis, in practice farmers located at the "head" have access to water throughout the season while access to water for those at the "tail" is more limited. The randomly selected sample had 63 farmers in the head and 61 farmers in the tail. The total farmer population in the Block was 436 (see Chapter 4 for details).

Cobb-Douglas production frontiers[1] (deterministic and stochastic) were fitted separately for "head" and "tail" with rice (unhusked) output in bushels as the dependent variable. The explanatory variables were: area cultivated (in acres), the number of man days of labour in pre-harvest operations, and quantity of nitrogen applied (in kilograms)[2]. The estimates of the SF and COLS frontier production functions for the head and the tail are given in Table 1. Firm specific technical efficiency measures derived from both deterministic and stochastic methods are reported in Table 2.

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[1] Despite the well known limitations of the Cobb-Douglas specification we have used it for the usual reasons.

[2] In other specifications inputs such as pesticides, weedicides, potassium and phosphorus were also included as independent variables but were found to be not significant.

Results

The SF and COLS methods yield sharply contrasting TE levels for the "head" while the results from both methods are similar for the "tail". These illustrate two extreme situations.

In the "head", the SF approach suggests that all variations in output from the frontier are due to purely random factors; the ratio γ was not statistically significant. However, the COLS measures show substantial technical inefficiency in the "head" with a mean sample TE of only 53 per cent.

In the "tail", both procedures suggest the existence of considerable technical inefficiency and give a sample mean TE of 50 per cent . With the SF model, the ratio γ is .97 which is statistically significant at a 1 per cent level; in other words 97 per cent of the total variation in output from the frontier is attributable to the technical inefficiency in the SF approach.

The differences between these two sets of results arise from the relative importance of the "U" and "V" terms in total error (E). When the symmetric random error "V" dominates "E" - as is the case in the "head" - the SF and COLS results diverge. When "U" is unimportant, the SF procedure suggests that all variation from the frontier is due to random error rather than any technical inefficiency, while such variation is attributed to technical inefficiency by COLS.

However, the results from the "tail" show that when "V" is relatively small - as indicated by the high value of γ - the two procedures yield almost identical results. Further, the rankings obtained with the two approaches are strongly correlated (Kendall's tau coefficient is .96 and significant at 1 per cent level) and are consistent with Waldman's (1984) conclusions[3].

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[3] If we ignore the statistical significance and compute rankings for TE from SF method for the "head", a similar high correlation is obtained between those and TE rankings from COLS. However, the mean TE from the SF method for the "head" is 81 per cent as against 53 per cent from COLS.

The high level of technical inefficiency in the "tail" revealed by both approaches is not surprising. The available "new" rice production technology was developed for areas with adequate and timely suply of water. While these conditions prevail in the "head" of the irrigation channel, the "tail" experiences severe water supply problems. These uncertainties with regard to water availability require farmers to excercise considerable skills in their management decisions regarding the timing and methods of various cultural practices and farmers who are capable of adapting the available technology to their particular conditions obtain higher output.

Higher (average) productivity in the "head" compared with the "tail" is consistent with the situation often observed in irrigation systems (see, for example, Skold et al., 1984 and Godell, 1984). While the complete absence of variation in technical efficiency among farmers in the "head" (implied by the SF results) is somewhat unexpected, it is not implausible[4]. This environment is ideal for the practice of the available technology in the recommended form and does not impose great demands on management skills. In such a situation random variations can be more important in explaining observed productivity differences between firms than differences in TE, hence, a deterministic procedure such as COLS tends to overestimate the average level of inefficiency.

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[4] A similar result has been reported by Huang and Bagi (1984) for Northwest India.

Table 1: Comparison of Stochastic and Deterministic (COLS) Estimates of Frontier Production Functions for Block 313 in System H in the Wet Season 1984/85.

Head Reach (63 sample farmers)

Variable	Stochastic Estimate	Deterministic Estimate
Intercept	2.530 (0.3116) ***	3.019
Land	0.624 (0.1176) ***	0.601 (0.1263) ***
Labour	0.408 (0.0888) ***	0.409 (0.0940) ***
Nitrogen	0.120 (0.0391) ***	0.127 (0.0408) ***
σ^2	0.1183	
γ	0.3575 (0.3228)	
log likelihood function	-0.01157	

Tail Reach (61 sample farmers)

Variable	Stochastic Estimate	Deterministic Estimate
Intercept	3.075 (0.3318) ***	2.752
Land	0.760 (0.1863) ***	0.739 (0.2577) ***
Labour	0.145 (0.1074) *	0.274 (0.1948) *
Nitrogen	0.262 (0.0677) ***	0.260 (0.1358) ***
σ^2	0.6732	
γ	0.9753*** (0.0200)	
log likelihood function	-25.0235	

Notes: Standard Errors are given in parentheses.
COLS intercept has no standard errors.
*** stands for significance at 1 per cent level.
** " " " 5 per cent "
* " " " 10 per cent "

Table 2: Frequency distributions of farm specific technical efficiency from stochastic and deterministic frontier production functions

	Head		Tail	
Range	Stochastic a/	Deterministic	Stochastic	Deterministic
01 - 10	0	0	1(1.6)	4(6.5)
11 - 20	0	1(1.6)	3(4.9)	1(1.6)
21 - 30	0	3(4.7)	2(3.3)	8(13.1)
31 - 40	0	8(12.7)	10(16.4)	9(14.7)
41 - 50	0	14(22.3)	22(36.0)	7(11.5)
51 - 60	0	21(33.3)	7(11.5)	14(22.9)
61 - 70	0	11(17.4)	8(13.1)	9(14.7)
71 - 80	0	3(4.7)	2(3.3)	4(6.5)
81 - 90	0	0	4(6.5)	3(4.9)
91 -100	63	2(3.2)	2(3.3)	2(3.3)
No. of cases	63	63	61	61

Note: figures within parentheses are percentages.
a/ There is no significant technical inefficiency here.

Appendix 3

Maximum Likelihood Estimation of a Frontier Function

The statistical model of our production frontier may be written as follows:

$$Y_i = x_i B_i + E_i, \quad i = 1,2,3,\ldots,N \tag{1}$$

where

$$E_i = u_i + v_i, \quad i = 1,2,3,\ldots,N$$

Y_i are observable random variables that are output values. x_i are inputs and B_i are coefficients.

Assuming that U and V are independent, U is normally distributed but truncated at the mean, and V is normally distributed, the corresponding density functions for the two random errors can be written as follows (Aigner et. al 1977, Battese and Corra 1977, Kalirajan 1981).

$$f_u(u_i) = 1/\sqrt{1/2\pi}.1/\sigma_u.exp(-u_1^2/2\sigma_u^2), \tag{2}$$

if $u_i < 0$

$f_u(u_i) = 0$, otherwise

and

$$f_v(v_i) = 1/\sqrt{1/2\pi}.1/\sigma_v.exp(-v_1^2/2\sigma_v^2). \tag{3}$$

where: $-\infty < v < +\infty$

The negative error u_i is interpreted as technical inefficiency in production while v_i accounts for the usual statistical noise. However, these two random errors are not observable. The observable error E_i is composed of u_1+v_i. The observable random variable Y (output) in our production function has the following density function.

$$f_{Yi}(Y_i)=f_{Ei}(Y_i-x_jB_j) \tag{4}$$

where f_{Ei} denotes the density function for E_i. This is obtained from the joint probability density function for u_i and v_i. Note that the value of the random variable E_i never exceeds that of v_i since $E_i=u_i+v_i$ and u_i is a negative random variable.

$$f_E(E_i)=1/\sigma\sqrt{1/2\pi}exp\left\{-1/2(u_i+v_i)^2/\sigma^2\right\}\left\{1-F(u_i+v_i).\sigma_u/\sigma.\sigma_v\right\} \tag{5}$$

where F(.) is the cumulative distribution function of the standard normal random variable. The above expression can be written as

$$f(E_i)=1/\sigma\sqrt{1/2\pi}exp\left\{-1/2E_i^2/\sigma^2\right\}\ \left\{1-F(E_i.\gamma/1-\gamma)\right\} \tag{6}$$

where $\sigma^2=\sigma_u{}^2+\sigma_v{}^2$

and $\gamma=\sigma_u{}^2/\sigma^2$

Now the density function for $f(Y_i)$ is obtained by substituting $(Y_i-x_jB_j)$ for E_i in the above equation, resulting in the following:

$$f(Y)=1/\sigma\sqrt{1/2\pi}exp\left\{-1/2(Y_i-x_jB_j)^2\right\}\ \left\{1-F((Y_i-x_jB_j).\gamma/1-\gamma)\right\} \tag{7}$$

Given the sample observations, $y_1,y_2,y_3,\ldots,y_n$, on the random variables, Y_i, the likelihood function is given by

$$L^*(Y;\theta) \tag{8}$$
$$=\prod_{i=1}^{n}\left\{1/\sigma\sqrt{1/2\pi}[1-F((Y_i-x_jB_j)/\sigma)\sqrt{\gamma/(1-\gamma)}].exp^{-1/2}(Y_i-x_jB_j)^2/\sigma^2\right\}$$

where θ, the parameter to be estimated, is equal to $(B,\sigma^2$, and $\gamma)$. The maximum likelihood method can be employed to find the values for parameter θ which maximizes the above likelihood function. It is convenient to write the logarithm of the above function since the natural logarithm of a function has a maximum value at the identical position to that of the original function.

$$L(Y;\theta)=-n/2.ln\pi/2-n/2.ln\sigma^2+\sum ln[1-F(W_i)-1/2\left\{(1-\gamma/\gamma)\right\}\sum W_i^2 \tag{9}$$

$$where W_i=(Y_i-x_jB_j)((1-\gamma/\gamma).1/\sigma^2)^{1/2}$$

Maximum likelihood estimates of θ, can be obtained by first taking following partial derivatives

$$\frac{\partial L}{\partial B}, \frac{\partial L}{\partial \sigma}, and \frac{\partial L}{\partial \gamma}$$

with respect to elements of θ and setting them equal to zero and solving simultaneously. Numerical methods are used to find a covergence solution to the maximum likelihood parameters owing to the difficulty in expressing them in closed form from the simultaneous solution of the above. We use the Newton-Raphson technique following Battese and Corra 1977. The advantage of this method is that it locates a convergence solution more quickly than other techniques since it uses second order partial derivatives. Rapid convergence is obtained if the initial estimates are in close vicinity of the maximum likelihood estimates (Bard 1974). This technique is unable to converge to a solution if the likelihood function is not well behaved and has the drawback that it may get trapped in local maxima most other techniques (Harville 1977; Taha 1976). A pre-determined specified proportion of change was allowed at every iteration as suggested by Kale (1962) to restrain the possibility of successive estimates overshooting the true solution.

As such the modified estimator is

$$\theta=\theta_o-\alpha\left\{\partial L^2(Y;\theta_o)/\partial\theta\partial\theta'\right\}^{-1}\partial L(Y;\theta_o)/\partial\theta \tag{10}$$

where α is the pre determined proportion of change and varies from 0 - 1.

$$\partial L/\partial\theta and \partial L^2/\partial\theta\partial\theta'$$

are first and second order partial derivatives of the likelihood function evaluated at the initial estimator θ_0. A Number of researchers have used this modified estimator (Battese and Corra 1977, Kalirajan 1979). Initial estimate of θ_0 was obtained by estimating our production function specification through OLS since it is reasonable to expect the frontier technology to be at least as high as the average technology. Therefore, the initial θ_o is assumed to be B_i and σ^2 obtained from OLS. Since OLS does not provide an estimate for γ, different values of γ ranging from 0 - 1 are tried in the iterations. Iterations are carried out till the likelihood function achieves its maximum value and the estimator associated with that maximum value of the likelihood function is the maximum likelihood estimator, i.e., the parameters of the frontier function.

Appendix 4

The Questionnaire

1. Background Information

1.1 Farmer Background

Sample Identification Number:

Enumerator's Name:

Farmer's Name:

Sex:

Age(No. of Years):

Marital Status:

Residence prior to settlement in System-H:

District:

Village:

Occupation prioir to settlement in System-H:

Whether compensation received for land and property losses due to Mahaweli Project:

If yes, How much?: Rs.

1.2 The Farm

Irrigable allotment No.:

1.2.1 Location

within the distributory channel:

within the field channel:

soil type:

1.2.2 Tenure

Extent under own cultivation:

Extent under other tenure:

Type of other tenure:

Tenure period:

Crop share: Bu. of Paddy

Land rent: Rs.

1.3 Homestead, house and the household

1.3.1 Homestead identification

Village name:

Village no.:

Allotment no:

1.3.2 Other members of the household

	Relationship to the farmer	Sex	Age	Education	Occupation	Nature of participatio in farm work
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

1.3.3 The House

Walls:

Roof:

No. of rooms:

Toilet:

1.3.4 Ownership of Durable Household Goods

Radios:

Sewing mechines:

Pressure lanterns:

Bicycles:

Motor Cycles:

1.3.5 Ownership of farm implements/mechnery and draught animals

4 wheel tractors:

2 wheel tractors:

trailors:

Tractor ploughs:

Animal ploughs:

Levelling boards:

Water pumps:

Power sprayers:

Hand sprayers:

Weeders:

Seeders:

Threshers:

Buffaloes:

Cattle:

1.3.6 Homestead utilization

Crop	Extent	No.of trees	Animals

	type	Number
1		
2		
3		
4		
5		
6		
7		
8		

1.4 Other land cultivated in 1984/85 crop year in addition to the legal allotment

	Location	Extent	Type of land	tenure	Rent	Share	Utilization
1							
2							
3							
4							
5							
6							

1.5 Cultivation details of 1983/84 crop year

1.5.1 1983/84 Maha season

Parcel	Crop	Extent	Yield
1			
2			
3			
4			

1.5.2 1983/84 Yala season

Parcel	Crop	Extent	Yield
1			
2			
3			
4			

2 Maha season 1984/85

2.1 Crops cultivated

Date	Extent	Crop	Variety	reason for the selection	Source of seed	Nature of payment	Rs.	Bu. /paddy

2.2 Land preparation, nursery and crop establishment

2.2.1 Labour

Date	Activity	Family labour		Exchange labour		Hired labour		Wage	
		male	female	male	female	male	female	male	female

2.2.2 Draught power

Date	Activity	Power source	Nature of Payment	Rs.	Bu./paddy

2.2.3 Basal fertilizer application

Date	Mixture	Amount	Nature of payment	Rs.	Bu./paddy

2.2.4 Chemicals applied to the nursery

Date	Activity	chemical	Nature of payment	Rs.	Bu./paddy

2.3 Details of credit obtained

Date	The need	Input	Form of repayment	Rs.	Bu./paddy	Annual rate of interest

2.3.1 Details of outstanding debts

Amount	source

2.4 Application of fertilizer top dressings, pesticides and weedicides and other forms of weed control

2.4.1 Labour

Date	Activity	Family labour		Exchange labour		Hired labour		Wage	
		male	female	male	female	male	female	male	female

2.4.2 Fertiliser

Date	Mixture	Amount	form of Payment	Rs.	Bu./paddy

2.4.3 Pesticides and weedicides

Date	Mixture	Amount	form of Payment	Rs.	Bu./paddy

2.5 Weed, pest and disease incidence

The level of weed infestation as reported by the farmer:

The relevant weeds:

The level pest damage as reported by the farmer:

The relevant pests:

The incidence of diseases as reported by the farmer:

The relevant diseases:

2.6 Harvesting, processing and transport

2.6.1 Labour

Date	Activity	Family labour		Exchange labour		Hired labour		Wage	
		male	female	male	female	male	female	male	female

2.6.2 Draught power

Date	Activity	Power source	Nature of Payment	Rs.	Bu./paddy

2.6.3 Yield

Crop	Variety	Extent harvested	Amount harvested

2.6.4 The sale of produce

Crop	Variety	Date	Outlet	Price/kg.	Amount

2.7 Repayment of loans

Date	Creditor	Amount Rs.	Amount in kind

2.8 Agicultural extention

Does the farmer know the extension worker for the area?

If yes, does he know his name?

How many times did the farmer meet the extention worker during the last season?

How did the farmer obtain information on the seed variety, fertilizer, pesticide and weedicide types quantities and times of application during the last season?

What is the correct dosage of basal fertlizer for an acre of rice according to the farmer?

What is the correct dosage of top dressing for an acre of rice according to the farmer?

a/ Ureah

b/ T.D.M

Does the farmer transplant rice?

If not, why?

Does the farmer practice manual weeding?

If not, why?

Does the farmer apply weedicides?

If not, why?

Does the farmer apply pesticides?

If not, why?

Does the farmer obtain bank loans for cultivation?

If not, why?

Does the farmer experience labour shortages?

If yes, when?

What are the reasons for labour shortages?

Does the farmer recieve irrigation water on time?

Does the farmer recieve sufficient irrigation water?

Did the farmer experience crop losses due to elephants?

If yes, about how many bushels of rice?

3 Yala Season

3.1 Farm and Farmer Identification

Irrigable allotment No.:

Location within the distributory channel:

Location within the field channel:

Soil type:

Farmer's name:

Crop share ("Bethma") farmer's name:

Type of other tenure:

Crop Share:

Background of tenant:

Major occupation of tenant:

3.2 Land preperation, nursery and crop establishment

3.2.1 Labour

Date	crop	Activity	Family labour		Exchange labour		Hired labour		Wage	
			male	female	male	female	male	female	male	female

3.2.2 Draught power

Date	crop	Activity	Power source	Nature of Payment	Rs.	Bu./paddy

3.2.3 Basal fertilizer application

Date	Crop	Mixture	Amount	Nature of payment	Rs.	Bu./paddy

3.2.4 Chemicals applied to the nursery

Date	Crop	Activity	chemical	Nature of payment	Rs.	Bu./paddy

3.3 Details of credit obtained

Date	The need	Input	Form of repayment	Rs.	Bu./paddy	Annual rate of interest

3.4 Application of fertilizer top dressings, pesticides and weedicides and other forms of weed control

3.4.1 Labour

Date	Crop	Activity	Family labour		Exchange labour		Hired labour		Wage	
			male	female	male	female	male	female	male	female

3.4.2 Fertiliser

Date	Crop	Mixture	Amount	form of Payment	Rs.	Bu./paddy

3.4.3 Pesticides and weedicides

Date	Crop	Mixture	Amount	form of Payment	Rs.	Bu./paddy

3.5 Weed, pest and disease incidence

The level of weed infestation as reported by the farmer:

The relevant weeds:

The level of pest damage as reported by the farmer:

The relevant pests:

The incidence of diseases as reported by the farmer:

The relevant diseases:

3.6 Water availability for Crops

Crop	Adequacy of the amount recieved per issue	Adequacy of the number of issues	Whether water is available on schedule

3.7 Harvesting, processing and transport

3.7.1 Labour

Date	Crop	Activity	Family labour		Exchange labour		Hired labour		Wage	
			male	female	male	female	male	female	male	female

3.7.2 Draught power

Date	Crop	Activity	Power source	Nature of Payment	Rs.	Bu./paddy

3.7.3 Yield

Crop	Variety	Extent harvested	Amount harvested

3.7.4 The sale of produce

Crop	Variety	Date	Outlet	Price/kg.	Amount

3.8 Repayment of loans

Date	Creditor	Amount Rs.	Amount in kind

3.9 Agicultural extention

How did the farmer obtain information on the seed variety, fertilizer, pesticide and weedicide types quantities and times of application during the last season?

What is the correct dosage of basal fertlizer for an acre of chillies according to the farmer?

What is the correct dosage of top dressing for an acre of chillies according to the farmer?

Does the farmer transplant chillies?

If not, why?

Does the farmer practice manual weeding?

If not, why?

Does the farmer apply weedicides?

If not, why?

Does the farmer apply pesticides?

If not, why?

Does the farmer obtain bank loans for cultivation?

If not, why?

3.10 Farm family income from off-farm sources (October 1984 to September 1985)

Salaries from permenent employment:

Wages from casual emlployment :

Profits :

Rents :

Other :

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